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EFFECTS OF URBANIZATION ON VEGETATION PATTERNS:

THE CASE OF DETROIT, MICHIGAN

by
Napier Shelton

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Geography)
in The University of Michigan
1974

Doctoral Committee:

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CHAPTER I

VEGETATION AND URBANIZATION: ELEMENTS OF THE PROBLEM

A. Introduction

To judge from the care lavished on plants at home and in the office, and the outrage at the wholesale destruction of plant cover that occurs in many new developments, most urbanites appreciate trees and other vegetation in the city. Many are aware of some valuable roles plants play in regulating the physical environment of the city. If the effects of urban processes on vegetation patterns can be clearly seen and understood, there is a greater chance that they will be controlled in favorable ways. Toward that end, this study measures changes in vegetation in urban and urbanizing areas, explores how and why these changes have come about, and provides a conceptual framework for understanding the processes of vegetation change.

Urbanization--a process of major scope and importance throughout the world--involves social, demographic, and economic change. Social organization and patterns of behavior of individuals change. Population becomes more concentrated. And economic activities become more diversified and spatially clustered to serve customers beyond and in the city. The present study is most concerned with the last aspect of urbanization; specifically, with changes in land use. For present purposes, therefore,

urbanization is defined as the conversion of rural land to urban uses. Rural land includes areas devoted to agriculture and forestry. Urban uses are primarily residential, commercial, and industrial. Undeveloped open space--land not put to any economic use and not set aside for recreation--is considered intermediate between rural and urban because most of it is spatially intermediate between the agricultural hinterland and the city proper, and most is owned by speculators or by people who live on it and expect eventually to sell some or all of it for urban purposes. Recreational land may be considered either urban or rural, depending on the predominant types of land use around it.

Since the majority of us in the United States live in cities (55 percent in urban places of 10,000 or more in 1970; Bureau of the Census, 1970), the quality of urban environments is a matter of increasing concern. On the physical side of it, air and water pollution have received the most attention. On the aesthetic side, design of buildings and areas has been emphasized. Vegetation--an important physical and aesthetic aspect of urban environments--has been unduly neglected.

The values and functions of plants in urban areas are numerous. Among their chief physical roles are control of soil erosion, retention of water for city supplies, trapping of airborne particulate matter, modification of city climates, and buffering against noise. Perhaps even more important are the psychological values of vegetation. It softens the impact of stone, concrete, and glass and makes a pleasant setting for recreational activities. Furthermore, it provides habitat for wildlife enjoyed by urban dwellers. Loss of trees and other

vegetation during the urbanization process thus can mean impairment of the quality of the city.

Vegetation in and around cities consists of a mixture of wild and planted plants. Outside the city, the two types are fairly evenly mixed, with agricultural crops, pastures, and gardens accounting for most of the planted vegetation, and forests, weeds, and brush accounting for most of the wild vegetation. Within the city, some wild vegetation may survive, prominently as forest patches in parks and trees on individual lots, but most urban vegetation is planted.

Urbanization affects vegetation both directly and indirectly. As new areas are built up, much of the existing vegetation is destroyed, to be replaced by roads, buildings, or new plantings. But city influence extends far beyond the built-up areas, since the dispersion of rural residences and the expectation of urbanization affect the ways land is used for miles beyond the city edge. These land-use effects in turn have a pronounced influence on vegetation patterns--that is, the distribution of vegetation types and characteristics. Pollution, soil erosion, and other environmental by-products of city growth have an impact on vegetation, but not usually to the extent of destroying large patches of vegetation or drastically changing their structure, as land-use change does; these other agents are not considered in the present study.

The central question of the study, then, is: how does land-use change affect vegetation patterns? An underlying question, treated qualitatively in this study, is: how do motivations and attitudes of landowners affect vegetation patterns? These problems can be put under the

umbrella of a general question: how does the vegetation of the city evolve from the vegetation of the countryside?

The general plan of the study is to examine land-use and vegetational changes at various levels in a hierarchy of regions, with the assumption that many vegetational characteristics of urbanizing areas are inherited from earlier, rural conditions. First, forest trends in eastern United States since the time of European settlement are traced. U.S. Forest Service statistics by states and groups of states are the primary data used. Then, forest trends in and around six midwestern cities during the 1950s and 1960s are considered, in order to determine whether similar kinds of vegetation change are occurring in all these urban areas, and to look for the major influences. Samples from U.S. Geological Survey topographic maps provide the basic data. Next, in more detail, vegetational changes are investigated in relation to land-use changes northwest of Detroit for the period 1937 to 1964. These processes are analyzed and interpreted within a framework of land-use zones representing stages of urbanization. A sample of quarter-sections from 1937 and 1964 air photos provides the vegetation data for this analysis. Finally, some implications of the findings for the quality of urban environments (especially with respect to recreation, wildlife, and aesthetics) are explored. Throughout, forests receive the major attention, since this is a highly valued type of wild vegetation, takes a long time to develop, and is relatively easy to measure.

B. A General Hypothesis

The general hypothesis of this study is that vegetation patterns around cities are determined primarily by land use, and that individual

types of land use have characteristic vegetation patterns.

In areas where human activity is slight or lacking, vegetation patterns are primarily the result of climate, topography, soils, fire, evolutionary history, and to some extent the chance distribution of seeds. In settled areas, man replaces the wild vegetation with non-native species or structures or sets back the stage of plant succession by cutting and other activities. In some places within these regions, however, such as where uncut forest patches grow and on idle land, the forces of nature continue or begin again to exert the primary control.

Around and in cities, then, within the limits of the natural potential of the environment, vegetation patterns are the result of past and present decisions about use of the land. These decisions may be influenced by any of a number of factors, including: location (with respect to cities, roads, neighboring land uses, etc.), size of land-holding, nature of ownership (public or private), land values, taxes, zoning, physical character of the land, cultural traditions, and owner/manager characteristics, such as occupation, income, physical abilities, and personal interests.

Present decisions about land use, and thus the existing vegetation patterns, are also partly dependent on past decisions. Each owner of a piece of land inherits a vegetation pattern from the previous owner; aside from changes due to plant succession on idle areas, it takes positive action on the part of the new owner to change the pattern, and this usually involves expense. For instance, the first owner's choice of area to clear for crops may determine the location and extent of trees and woodlots on a property for decades to come. Since removal of trees

is expensive, subsequent owners are likely to cut them only if there is a compelling reason, such as appreciable income to be gained from some other use of the land.

Though the owner of a piece of land theoretically has many options as to its use, he is in fact constrained by many factors, including those listed above. Several important influences on land use, such as land values, property taxes, and zoning, have a close relationship with distance from the city center: land values and taxes decrease, and zoning becomes less restrictive. Thus most forms of agriculture are more feasible farther away than close to a city. On the other hand, some types of land use, such as residential, are located largely near or in the city, because people want quick access to workplaces and city goods and services; they are willing to pay the higher prices to obtain this access. At intermediate distances, a number of uses are possible, though many are not ideally suited to the situation. Agriculture can be carried on with some difficulty, and people who work in the city can live here if they are willing to make long commuting trips. Thus a zonation of land uses based on distance from the city center develops, with residential use predominating close in, a mixture of uses farther out, and agriculture predominating at the greatest distances, if the region is physically and economically suited for it. As will be shown in the course of this paper, this zonation of land uses produces some zonation of vegetation.

The predictability and degree of zonation of vegetation depend to a large extent on the particular associated land uses, for the variability of vegetation differs from one type of land use to the next.

For instance, the percentage of forest varies less on farmland than on open space land, since the farmer is under economic pressure to put most of his land into crops that give high returns, while open space land is mostly in the hands of speculators and rural non-farmers, who do not depend on products of the land for income, and so have wider choice as to the kind of plant cover to allow. (For instance, on predominantly agricultural plots in the Detroit study area the percentage of deciduous forest ranged from 0 to 55.8, with few cases above 30 percent, while on predominantly open space plots, deciduous forest ranged from 0 to 77.3 percent, with many cases above 30 percent.) On residential land, variability of vegetation is small because of the force of cultural tradition to have certain kinds of plant cover. Vegetation patterns and their variability within any given kind of land use could change drastically through changes in technology or human preferences and attitudes. For instance, if a large proportion of our food were grown hydroponically, the forest area on agricultural land might shrink considerably. If lawns went out of fashion, many residential lots might look more like forest, with more shrubs and trees.

C. Previous Studies

Considering the values of vegetation and the large areas affected by urbanization, it should be useful to understand how urbanization is affecting vegetation patterns. But there seems to have been little study of the subject. Probably the most significant work appears in the chapter on woodlands in Jean Gottmann's Megalopolis: The Urbanized Northeastern Seaboard of the United States (1961). The contribution of Gottmann's study will be discussed in Chapter III.

Land-use and forest surveys contain useful information, though most of them do not attempt to relate vegetation change to the urbanization process. Since the 1930s, the U.S. Forest Service has conducted inventories of timber resources, detailing by states and their subdivisions the amount of forest area and many characteristics of the forests. Nationwide appraisals by states appeared in 1958, 1965, and 1973. Land-use surveys sometimes contain relevant data. For instance, a report by Anderson (1956) on land use and development on the southeastern coastal plain showed that forest had increased in an area where agricultural space had declined and population was growing. Similar kinds of change were revealed in a survey comparing land use in Ohio in 1940 and 1960 (Ohio, State Regional Planning Staff, 1967).

Open space studies usually deal with urban areas and sometimes contain data on vegetation. For instance, the chapter by Touland on open land in Philadelphia (in Wallace, 1970) presented tables and graphs showing the percentage of open land in forests and marshes, by distance from the downtown. A survey of open land in metropolitan Chicago (Miller, 1962) contained data on forest area by distance from the Loop.

An analysis of the pollen rain in Yonkers, New York, in 1932, 1953, 1954, and 1967 (Solomon & Buell, 1969) suggested changes in vegetation brought about by suburbanization. Between 1932 and 1967, numbers of herb pollen decreased by almost one-half. Upward change in individual genus rank among trees was greatest in the street plantings, Platanus and Acer, while decreases in rank were greatest in two native hardwoods, Carya and Juglans. These results were thought to be due primarily to a change from very weedy farmland to subdivisions in

Bergen County, New Jersey, directly windward from the pollen collection site.

The sizeable literature on urban planning and beautification and on nature in the city provides background for the consideration of urbanization-vegetation relationships. In recent years the burgeoning interest in preserving natural elements in cities has provoked a number of conferences, studies, and blueprints for action. For example, Man and Nature in the City presents the discussions of a conference called by the Bureau of Sport Fisheries and Wildlife (1969) to explore the values of urban nature. A series of booklets currently being published by the National Park Service deals with the same topic and suggests ways of keeping and augmenting nature in the city. Urbanization and Environment (Detwyler & Marcus, 1972), a broader kind of work, views man-environment interactions in the city within a systems framework, and presents some of the current knowledge about urban geology, climate, soils, vegetation, wildlife, noise, and risk from nature.

Foreign situations have not been investigated because most of these differ greatly from those in eastern United States. In Great Britain and Europe, for instance, stronger public control of land use and the careful husbanding of arable land bring about a much sharper demarcation between urban and agricultural areas than in the United States. Similarly, literature dealing with cities in western United States has been largely ignored because vegetation patterns are very different there. For example, many western cities lie in naturally treeless regions, and trees planted in these cities form man-created oases. It would have been interesting to compare urbanization-vegetation

relationships in eastern and western United States and Europe, but such a scope was considered too time-consuming.

While testing the general hypothesis and specific expressions of it, it will be useful to have a generalized mental map of metropolitan land use. Such a model is presented in the next chapter.

CHAPTER II

A REGIONAL LAND-USE MODEL

A. Bases of the Model

In Chapter I a zonation of land uses around cities was sketchily described. In this chapter a model of land use in a metropolitan region is presented verbally and diagrammatically (Figure 1). This will serve as a framework for later analysis of empirical data.

The model describes a metropolitan region with a major city and two lesser urban centers, all located within an agricultural part of the country. Assumptions are: (1) the initial physical environment was homogeneous; (2) urban growth occurs more rapidly along major transportation routes; and (3) the width of each non-agricultural zone is proportional to the size of the city to which it is related. The model is intended to represent in a general way the current land-use pattern of many North American metropolises.

B. Description of Land-use Zones

Land use in and around cities can be classified and mapped as occurring in four roughly concentric zones: a commercial core, then residential, transitional, and agricultural zones (Figure 1). More detailed, complex models have been postulated, but the present simple one seems best suited to the study of metropolitan vegetation. It most

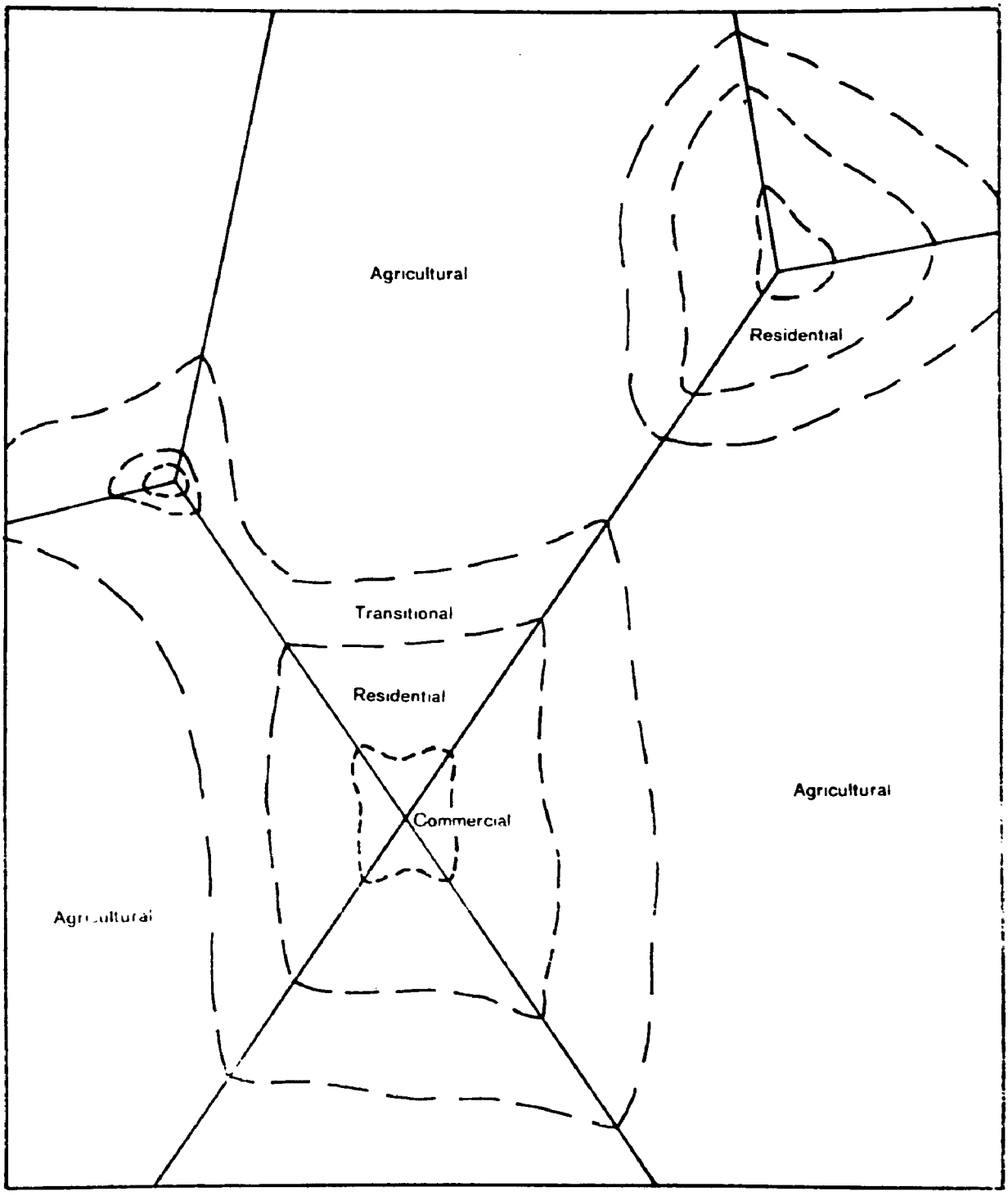


Fig. 1.--Diagrammatic model of land use in a metropolitan region.

closely resembles the models of Thünen (1875) and Burgess (1927), which treated, respectively, land use outside and within the city. Thünen's concentric zones of agricultural production, which were derived largely from empirical data collected in northern Germany in the early nineteenth century, consisted of narrow rings of intensive farming and forest (for building material and firewood) nearest the city, and then broad bands of extensive agriculture and ranching with unused wasteland beyond. Burgess postulated the existence of five concentric zones in a city: first, the central business district; next, a business-residential zone; and then, a zone of independent workingmen's homes, a zone of better residences, and a commuter's zone, including satellite urban centers. The model used in the present study can be considered a generalization of the zones described by Burgess and Thünen, with the addition of a transitional zone between the urban and agricultural areas, and with allowance made for the influence of major roads and additional urban centers. The outer boundary of the residential zone can be considered the limit or edge of the city, but as with the other boundaries, this one is not self-evident and must be defined. The zones shift outward and widen as the city grows. The present study is concerned only peripherally with the commercial core. It focuses on vegetation changes that occur in the shift from rural to urban conditions rather than changes within continuously urban areas.

The boundaries between zones become less distinct with distance from the city center. In most cities, the change from commercial to residential areas is distinct, commercial use of land being confined largely to the central business district and strips along major arteries,

with occasional expansions at shopping centers. The change from residential areas to what I have called the transition zone (often referred to as the rural-urban fringe) is less distinct, though at some distance from the city center along any given line there is usually a rapid drop in the density of houses. A definition of this "city edge" is presented in Chapter IV. The change from the transition to the agricultural zone is usually even more gradual; this boundary is thus more arbitrary, and may be defined in terms of some percentage of land devoted to agriculture.

1. The Residential Zone

The residential zone is characterized, of course, by predominantly residential use, but commercial, industrial, recreational, and other uses may occur within it. Many vacant lots are present, their number and proportion of the total area generally increasing with distance from the city center. Residential lots tend to increase in size with distance from the city center.

2. The Transition Zone

The transition zone contains a rather chaotic mixture of land uses, none of which is predominant. With distance outward in the zone, residential use usually decreases, while agricultural use increases. Many other uses also occur, including some more typically associated with the city proper. Industrial plants, for instance, are often located here to take advantage of more abundant, cheaper land.

Many of the characteristics of this zone are related to improvements in transportation, particularly roads. Improved road systems have

meant that people can live farther from their workplaces in the city. The result has been a great rise in recent decades of new subdivisions in the countryside and of rural non-farm residences, most of which are scattered along pre-existing roads. The parcels of rural non-farmers, which range from small lots to great spreads of 100 acres or more, may be used for gardens, hunting, horse pastures, or any of a number of other purposes, not the least of which is simple enjoyment.

Easier automobile access to the city has also meant that urbanization of the countryside proceeds at a faster pace, which has encouraged much more land speculation in the transition zone, the urban land of tomorrow (assuming continued city growth). Such landholdings range from small plots held by individuals to large acreages owned by investment companies, banks, and other institutions. This kind of land may be leased entirely or in part to farmers, but more usually it remains idle, because the owner wants to be free to sell it when he gets a good offer and because (at least until very recently) rent from agriculture usually has been small.

Agriculture in the transition zone is a mixture of highly intensive farming and low-input types. Most farmers here have only two choices: raise high-priced products on small acreages or raise lower-income products on larger acreages and take an off-farm job as well. Thus around cities we see market gardens, nurseries, a few dairy farms, and many fields of alfalfa, soy beans, corn, and small grains. Agriculture is difficult in this zone, however. Conflicting neighboring land uses and high taxes, as well as high land values, put pressure on the farmer to sell and move to a more hospitable area farther out.

Anticipating such a move, many farmers see no point in putting much effort and money into their land.

If any use is dominant in the transition zone, it is "non-use"; "non-used" areas are sometimes described as undeveloped open space, as in this study. Idle land held by speculators and rural non-farmers may amount to more than half of the fringe area around a city. This fact has considerable import for vegetation, as will be shown later.

Because of the mixed nature of land ownership in this zone, parcel sizes here usually average larger than in the residential zone, but smaller than in the agricultural zone.[1] Lot size, too, has implications for vegetation patterns.

The width of the transition zone is a reflection of the quality of the road system and the size and anticipated rate of growth of the city. Quick access to the city and a rapid growth rate increase the distance at which there is likely to be new development, and thus enhance land values at greater distances.

3. The Agricultural Zone

In the agricultural zone, taxes, land values, and residential density are favorable enough to allow agriculture to be the dominant land use. Some of this may be dairy or truck farming to supply the

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[1]For example, for 1970 in the Detroit study area, a 28 percent random sample of sections in the easternmost column of townships, going north from the built-up area through a rural-urban transition zone into agricultural land, gave average parcel sizes, excluding subdivisions and "small tracts," of 12, 28, 29, 27, 35, 60, and 46 acres. Inclusion of subdivisions and small tracts would have magnified the increase with distance, because the number of these small lots fell off rapidly north of the built-up area. A 1956 sample gave similar results, though with generally larger parcel sizes. The data were taken from plat books for Oakland and Lapeer counties.

metropolitan area, but much may be of the predominant regional type, such as livestock-grain farming in the Corn Belt, which is related to national rather than local markets. In an agricultural part of the country, this zone may be considered to extend to the area of influence of another city.

To some extent, the above-described zonation of land uses produces a zonation of vegetation, although vegetation changes between land-use zones are gradual rather than abrupt, since boundaries between the zones also are gradual. This influence on vegetational zonation is an underlying theme of the following chapters.

CHAPTER III

LAND USE-VEGETATION TRENDS IN EASTERN UNITED STATES

A. Long-term Trends

Before proceeding to an examination of vegetation changes around specific cities, it is helpful to have an overview of the vegetational history of the larger regions in which these cities lie. The vegetation trends of eastern United States are largely the result of developments and changes in agriculture, which directly affect the area and location of forests, the natural (as opposed to man-created) plant cover in most of the East. In many areas, such as New England, the Appalachians, and much of the South, clearing for agriculture has reached a peak and now abandonment of farmland exceeds clearing of new land, with the result that forest area is increasing. In a few parts of the East clearing of additional land or intensification of agriculture on existing farmland continues to reduce the forest acreage. In recent decades, urbanization has had an important secondary effect on forest acreage, causing decreases where building occurs, and in many places bringing about increases beyond the built-up areas by promoting a shift from farming to speculation or other non-use of the land.

In the United States as a whole, forest acreage reached its lowest point in the early 1900s (estimated as 614 million acres in 1920; Forest Service, 1958), and then slowly increased into the 1960s

(estimated as 639 million acres in 1963; Forest Service, 1965). But there has been great regional variation in this pattern. From Virginia to New England, forest area began to increase about the time of the Civil War (Waggoner & Stephens, 1973). By 1940, Virginia was about 58 percent forested (Lotti & Evans, 1942), and by 1966, 64 percent (Knight & McClure, 1967). A century ago, Connecticut was one-third wooded; today, two-thirds is in forest (Waggoner & Stephens, 1973). Soil exhaustion in Virginia, natural infertility in New England, and competition from more productive farmland farther west were largely responsible for these changes. In New York the reversal occurred about 1880. In that year, more than three-fourths of the state was farmland. Thereafter, the rate of farm abandonment exceeded clearing (Stout, undated). Forest increase began in the Southern Appalachians around the turn of the century, as many families found they could no longer make a living from steep, eroded hillsides. In much of the upland South, pine has been planted or allowed to regenerate naturally on thousands of acreas of cropland abandoned because of erosion, loss of fertility, and the boll weevil invasion, which occurred around the turn of the century. In Georgia, for instance, forest covered 57 percent of the land area by 1936 (Larson & Spada, 1963), and 68 percent by 1972 (Forest Service, 1971-73). Even in Ohio, much of which is high-class farmland, the forest area has been increasing since about 1930, due largely to land abandonment in the hilly southern and southeastern parts of the state. Forest area was about 12 percent in 1940 (Writer & Redett, 1971), and 24 percent in 1968 (Kingsley & Mayer, 1970). Only a few eastern states have not experienced this reversal from decrease to increase of forest

area. In Indiana and Illinois, for instance, the high productivity of the land encourages farmers to intensify their efforts; this intensification of farming, plus growth of towns and cities, continues to reduce the forest area.

Now, in the 1970s, the East may be experiencing the beginning of a new decline in forest area. With most of the marginal farmland already reverted to brush and forest, and urbanization and new clearing in some areas for agriculture taking large chunks of existing forest, it appears that a gradual decrease in forest area will be the prevailing trend. For the southern half of the East (Virginia to Texas), U.S. Forest Service data show a decline in forest area between 1962 and 1970; clearing of forest for crops and pasture, particularly in the coastal plain from Georgia to Louisiana, more than offset reversion of abandoned land to forest in the uplands. In the northern half of the East, during the same period, forest area continued to increase (Forest Service, 1973), but it is difficult to see how this trend can continue, given the growth of world food needs and the spread of cities.

It has been stated (p. 18) that urbanization causes both increases and decreases in forest area. We will begin to explore the mechanisms of these changes by looking at what has happened along the heavily populated Northeast seaboard.

B. Urbanization and Forest Trends in the Northeast

Paradoxically, the general forest increase in the East has occurred in heavily populated, as well as sparsely populated, areas. So pronounced has this phenomenon been that a conference of prominent

foresters and ecologists was called in Connecticut to discuss the management of the "suburban forest" (Waggoner & Ovington, 1962). Natural History magazine devoted a special supplement of its November 1973 issue to "The Metro Forest."

The section of the Northeast extending from Richmond, Virginia, to Boston is the most densely populated large region in North America. In his monumental study of this region (about 48 percent of which was forested in the mid-1950s) Jean Gottmann found that between 1946 and 1956, the total area of forest increased somewhat, and substantial increase occurred in most of Connecticut, the counties in New York north of New York City, parts of eastern Pennsylvania and central New Jersey, and much of Maryland and eastern Virginia (Gottman, 1961). "Oddly enough," he says, "there seems to have been more wooded area added in the outer suburbs of the larger cities (except around Boston and Providence, where the land was already heavily wooded, and on Long Island) than in the more rural outlying sections of Megalopolis."

Gottmann concluded that the forest trend in any particular part of the region depended on the relative rates of cropland abandonment and urban expansion. If urban expansion proceeded more slowly than cropland abandonment, forest increased. Table 1 documents the continued increase of forest in the Megalopolitan states since the period of Gottmann's study. Parts of Virginia, Pennsylvania, and New York are outside Megalopolis as Gottmann defined it, but the excluded parts of Virginia and Pennsylvania are not greatly different in general character from the included parts. Upstate New York may have contained a larger proportion of abandoned farmland than did the Megalopolitan section of the state.

TABLE 1

FOREST AREA IN MEGALOPOLITAN STATES,
1953-1970

	1953 (1,000 acres)	1963 (1,000 acres)	Percent change 1953-63	1970 (1,000 acres)	Percent change 1963-70	Percent change 1953-70
Virginia	15,832	16,492	+ 4.2	16,389	- 0.6	+ 3.5
Maryland	2,920	2,920	0.0	2,960	+ 1.4	+ 1.4
Delaware	454	392	-13.7	391	- 0.3	-13.9
New Jersey	1,958	2,229	+13.8	2,463	+10.5	+25.8
Pennsylvania	15,205	15,186	- 0.1	17,832	+17.4	+17.3
New York	14,450	14,450	0.0	17,377	+20.3	+20.3
Connecticut	1,990	1,990	0.0	2,186	+ 9.8	+ 9.8
Rhode Island	434	434	0.0	433	- 0.2	- 0.2
Massachusetts	3,288	3,288	0.0	3,520	+ 7.1	+ 7.1
Total	56,531	57,381	+ 1.5	63,551	+10.8	+12.4

Source: Forest Service, U.S.D.A., 1958, 1965, 1973.

Among other developing megalopolises in the United States, the chain of cities from Pittsburgh to Chicago (sometimes referred to as "Chipitts," and also including Cleveland and Detroit) stands first in size of population. South of "Chipitts," Cincinnati, Louisville, Indianapolis, and other urban areas spangle the lower Ohio River basin. We will inquire now whether forest has also increased in this midwestern region and, in particular, what are the trends near some of its largest cities.

C. Forest Trends in the Midwest

The cities of "Chipitts" and the lower Ohio River basin lie within regional matrices with widely varying topography and land use, from the very hilly strip-mine country around Pittsburgh to the fairly level farmland around Indianapolis and Chicago. We will look first at the extent of forested land in these states, and then will focus on the forest situation around Pittsburgh, Cleveland, Cincinnati, Detroit, Indianapolis, and Chicago.

1. Forest Trends in Five Midwestern States

Much of the land in the area under consideration lies within the Corn Belt, a region where level land, fertile soils, and adequate rainfall have allowed development of one of the world's richest farming zones. Grains, particularly corn, and livestock are the chief agricultural products. Western Ohio, the northern two-thirds of Indiana, the southernmost two tiers of counties in Michigan, and the northern half of Illinois usually are included in the Corn Belt region, which also extends through southern Wisconsin, southern Minnesota and most of Iowa. Eastern Ohio and western Pennsylvania have hilly land on which dairy farming is the predominant type of agriculture; and large areas have been strip-mined.

Table 2 shows forest acreages in the Pennsylvania-Illinois area in recent decades, as reported by the U.S. Forest Service. These data indicate a rise in Pennsylvania, Ohio, and southern Michigan and a decline in Indiana and Illinois. They suggest that areas within the Corn Belt have experienced a loss of forest area, while those outside it

have experienced a gain. In Ohio, forest increase in the hilly southeast has outweighed forest loss in the corn-growing northwest. In the southern half of Michigan's lower peninsula, the Corn-Belt strip along the south boundary is outweighed in area and influence on forest extent by the non-Corn-Belt portion, which is dominated by other types of farming and by urban centers.

TABLE 2

FOREST AREA, PENNSYLVANIA TO ILLINOIS, 1935-1970
(thousand acres)

	1935, 1942, 1948	1953[a]	1963[b]	Percent change 1953-63	1970[c]	Percent change 1963-70	Percent change 1953-70
Pennsylvania	--	15,205	15,186	- 0.1	17,832	+17.4	+17.3
Ohio	3,708 (1942)[d]	5,446	5,171	- 5.0	6,498	+25.7	+19.3
Indiana	--	4,103	4,018	- 2.1	3,908	- 2.7	- 4.8
Illinois	3,996 (1948)[e]	3,993	3,871	- 3.1	3,789	- 2.1	- 5.1
Michigan (southern half, lower peninsula)	2,296 (1935)[f]	2,639 (1955)[g]	2,857 (1966)[h]		--		+ 8.3 (1955-66)

Source: (a) Forest Service, U.S.D.A., 1958; (b) Forest Service, U.S.D.A., 1965; (c) Forest Service, U.S.D.A., 1973; (d) Ohio Agric. Exp. Sta., 1944; (e) King and Winters, 1952; (f) Forest Service, U.S.D.A., Lake States For. Exp. Sta., 1936; (g) Findell et al., 1960; (h) Chase et al., 1970.

2. Forest Trends around Six Cities

Do the forest changes around midwestern cities parallel statewide changes, and do the important factors appear to be the same as those along the Northeast seaboard? To begin to answer these questions I resorted to the information on U.S. Geological Survey topographic maps --particularly the extent of forests, indicated by green overprint.

I am not aware of any studies of the consistency of photo-interpretation of forest areas for Survey maps, but the instructions for this work seem precise enough. "Woods-brushwood," the type under consideration here, is defined as:

> . . . areas containing tree cover or brush that is potential tree cover. The growth must be at least 6 feet tall and dense enough to afford cover for troops. . . . This condition is considered to exist where density of the vegetative cover is 20 percent or more. By visual inspection of the aerial photographs, growth that meets the minimum density requirement may be estimated as follows: where the average open-space distance between the crowns is equal to the average crown diameter, the density of the vegetative cover is 20 percent. However, this criterion is not a hard-and-fast rule because 20 percent crown density cannot be determined accurately where there are irregularly scattered trees and gradual transitions from wooded to cleared areas. Therefore, where such growth occurs, the minimum density requirement is flexible between 20 and 35 percent, and the woodland boundary should be drawn where there is a noticeable change in density. A crown density of 35 percent exists where the average open space between the crowns is equal to one half the average crown diameter. . . . Woodland areas covering 40,000 square feet (about 1 acre) or more are shown regardless of shape. [Geological Survey, 1967.]

Compilers have both the current and previous set of air photos from which to determine whether changes have occurred in woodland boundaries. In using U.S. Geological Survey topographic maps to measure woodland area, I had no cause to question consistency of photointerpretation except occasionally in parks and cemeteries within cities. Such questionable cases constituted only a very small fraction of the total woodland.

My procedure was as follows: For each city, within a radius of about 50 miles of the central business district, 7 1/2-minute quadrangles mapped in the 1950s and 1960s were identified and listed from the state index map, working from north to south along rows. Then every second, third, or fourth quadrangle, depending on the total number available from the desired periods, was selected from the list. Emphasis was

placed on securing a large sample for the 1960s, for which the number of selected quadrangles per city ranged from 24 to 67. Only about two-thirds of these quadrangles were also mapped in the 1950s; the number per city ranged from 15 to 48. Therefore the sample for the 1950s was smaller and less evenly distributed in space than that for the 1960s. For this reason, the percentage of forest by distance from city centers was plotted for the 1960s only.

On each quadrangle selected, the area of solid green overprint was sampled by recording the percentage of green under each of 13 square plots, randomly located on a transparent sheet and gridded into 100 cells. This gave a sample of 24 percent of the area on each quadrangle. By city, the samples represented the following percentages of total land area within a 50-mile radius: Pittsburgh, 2 percent of total area measured for both 1950s and 1960s (providing data for Table 3), 6 percent for 1960s only (providing data for Figure 2); Cleveland, 6 and 11 percent; Cincinnati, 4 and 5 percent; Detroit, 6 and 10 percent; Indianapolis, 3 and 4 percent; Chicago, 3 and 8 percent. Notes were made on the size of settlements, apparent land use, and degree of hilliness and other prominent physical features. The distance of the center of each quadrangle from the CBD (central business district) was recorded and each plot from that quadrangle was considered to be equidistant from the CBD. The plot data were grouped by 4-mile-wide distance bands from the CBD and the average percentage of area in woods and brushwood was obtained for each distance band and for the total area around each city.

Table 3 shows the amount of change in forest area in each of the metropolitan regions, and also the size and rate of growth of each of

TABLE 3

FOREST AND POPULATION CHANGE OF SIX MIDWESTERN METROPOLITAN REGIONS

City	Percent forest and brush[a]		Percent change	Number of plots	1950 pop.[b]	1970 pop.[b]	Percent pop. increase 1950-1970
	1950s[c]	1960s[c]					
Pittsburgh	22.9	25.8	+12.7	182	2,213,236	2,401,245	8.5
Cleveland	23.5	22.7	- 3.4	288	1,532,574	2,064,194	25.8
Cincinnati	15.5	18.8	+21.3	333	1,023,245	1,384,851	26.1
Indianapolis	14.2	13.4	- 5.6	221	675,370	1,109,882	39.1
Detroit	9.5	10.1	+ 6.3	272	3,016,197	4,199,931	28.2
Chicago-Gary	8.8	8.8	0.0	265	5,586,096	7,612,314	26.2

[a]Using only quadrangles mapped in both periods.

[b]Standard Metropolitan Statistical Areas. Source: Bureau of the Census, 1950, 1970.

[c]Years for individual cities varied: Pittsburgh, 1951-54 and 1960-64; Cleveland, 1953 and 1960-63; Cincinnati, 1950-55 and 1960-65; Detroit, 1952-54 and 1965-69; Indianapolis, 1948-56 and 1966-70; Chicago, 1953-58 and 1962-69.

the corresponding Standard Metropolitan Statistical Areas (in the case of Chicago-Gary, a Standard Consolidated Area). SMSA's for 1950 were made to conform in area with those for 1970.

An inspection of Table 3 suggests that there might be some relationship between the growth rate of a city and the change in forest area. The fastest growing urban region, Indianapolis, has the greatest decrease of forest, and the slowest growing, Pittsburgh, has the second highest increase of forest. But among the other four cities, with about equal growth rates, forest change ranges from -3.4 percent to +21.3 percent. A Spearman rank correlation test, comparing growth rate of cities and forest increase gives a correlation coefficient of -0.49, indicating a rather weak relationship.

It seems reasonable that there might be a relationship between degree of hilliness and forest change. Therefore, the six cities were ranked in order of hilliness, by inspection of the quadrangles. This was not difficult, since the degree of hilliness varies widely among the cities. The two cities with the largest increase of forest are both in hilly terrain, especially Pittsburgh. But the Cleveland region, which ranks third among the six cities in hilliness, experienced a decrease of forest. A rank correlation test comparing hilliness and forest increase in the six urban regions gave a correlation coefficient of 0.51, again indicating a rather weak relationship.

When the data from all six cities are aggregated, hilliness appears to have a stronger influence. Table 4 groups quadrangles by population density class and degree of hilliness. (Each quadrangle was classed by inspection as hilly or not hilly, depending on the density of

TABLE 4

DEGREE OF HILLINESS, POPULATION DENSITY, AND FOREST CHANGE, 1950s TO 1960s, IN SIX URBAN REGIONS

	Hilly						Not hilly					
	Medium to high pop. density			Low pop. density			Med. to high pop. density			Low pop. density		
	Change in % forest			Change in % forest			Change in % forest			Change in % forest		
	Up	Down	Unch.*	Up	Down	Unch.*	Up	Down	Unch.*	Up	Down	Unch.*
No. of quads	6	5	1	11	4	2	18	24	4	17	16	3
Total=111												

*Two percent or less change.

contour lines and taking into account differences between quadrangles in contour intervals. Quadrangles with red overprint, signifying built-up areas, or with subdivisions were considered to have medium to high population density; all others were assigned to the low-density group.) In areas of both high and low population density, hilliness produced a much higher proportion of quadrangles in which forest increased between the 1950s and 1960s than did non-hilliness.

In the Detroit region, which was studied more intensively than the others, the forest area decreased north of the city, where the land is level, good soils for crops are extensive, and urban growth is rapid. The other sectors of the region all experienced an increase in forest area. These include level, slow-growing areas with moderate farming intensity and hilly, fast-growing areas with moderate to low farming intensity.

Let us now return to the questions posed at the beginning of this section: Do the forest changes around midwestern cities parallel statewide changes, and do the important factors appear to be the same as those on the Northeast seaboard? We can conclude that forest trends around the six cities do parallel those of the states in which they lie, with the exception of Cleveland. Here rapid urbanization in the hilly sections south and east of the city and a fairly successful persistence of agriculture to the southwest seem to have more than offset new growth of brush and trees on idle land.

As Gottman stated, the relative rates of cropland and pasture abandonment versus urban growth do seem to be the dominant influences on change of forest area. The role of hilliness may be that farmers in such areas are ready to quit farming or sell out sooner than farmers in more level, productive areas, where the income from the land may justify paying high taxes and resisting high-priced offers from speculators and developers. Hilly land may therefore remain in the transition stage between agriculture and residential building longer than the better farming areas do, thus allowing time for open land to revert to forest.

Figure 2, which shows percentage of forest and brush area by distance from the central business districts of the six cities, further supports the foregoing comments. For each city except Indianapolis, the percentage of forest increases outward from the city to some intermediate distance, then declines. (In the Indianapolis region, hilly forested areas occur in the outer parts of the measured 50-mile zone.) I interpret the prevailing pattern to mean that forest usually increases in the transition zone (see Chapter II) between agriculture and the

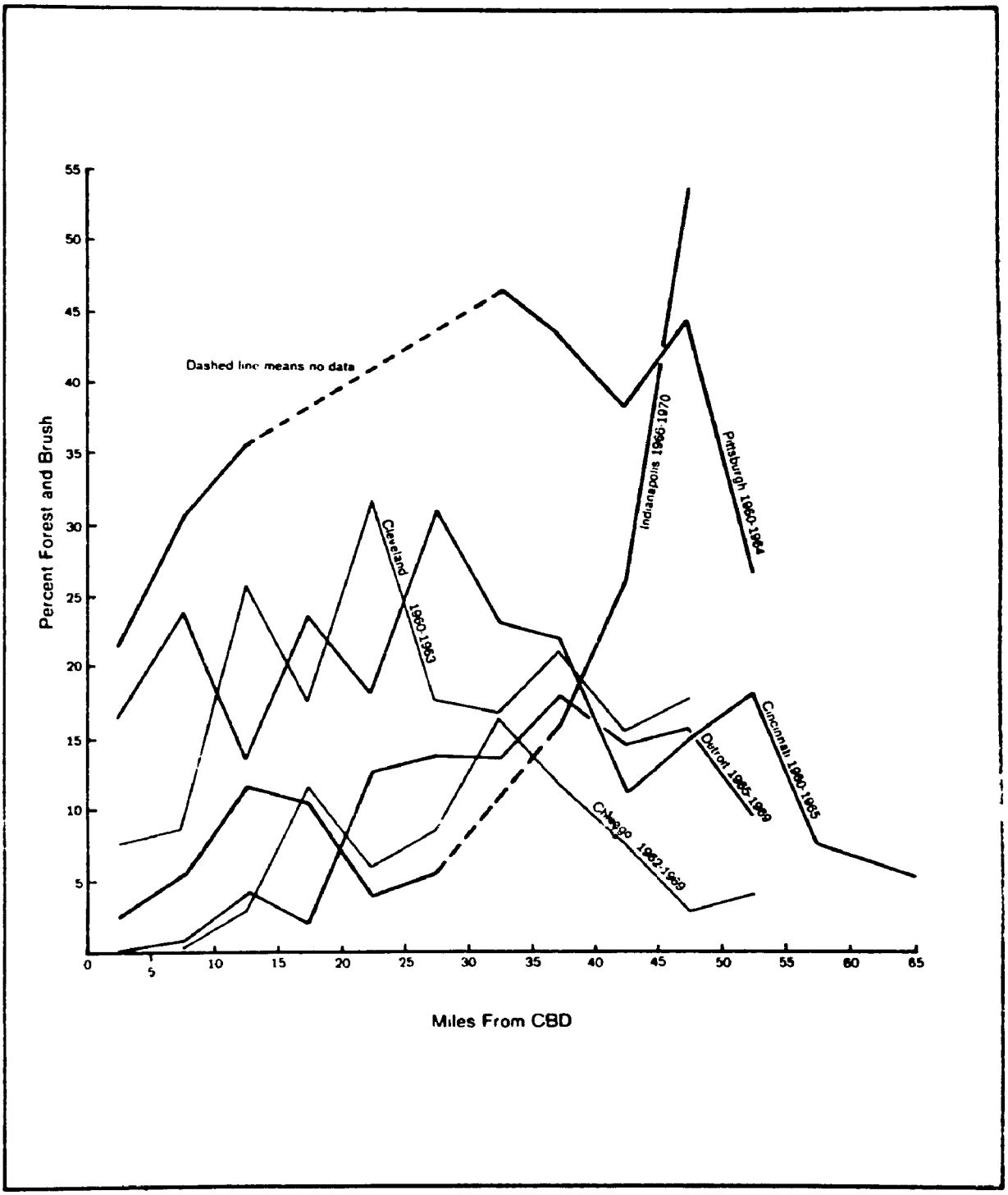


Fig. 2.--Forest and brush area by distance from the central business districts of six midwestern cities. Total number of plots, by city: Pittsburgh, 520; Cleveland, 517; Cincinnati, 455; Detroit, 411; Indianapolis, 312; Chicago, 419. The number by distance bands for each city varies, but in most cases is over 20.

outer built-up parts of a city. This I believe is largely due to passive use or non-use of privately held land, but some may be attributed to expansion of forests in public parkland, much of which typically lies beyond the city edge. Around Chicago, for instance, where much of the land is naturally treeless, a number of forest preserves have been established to maintain existing stands. And outside of Cleveland a number of "reservations" along incised streams protect large tracts of forest. The boundaries of such areas often include within them open areas on which new forest in time develops.

The curves in Figure 2 support the idea of forest increase in an intermediate, transition zone in another way: the distance at which the peak area of forest occurs is to some extent correlated with the size of the metropolitan population. A Spearman rank correlation test applied to the data for these cities gives a high correlation (.771) between the two variables. Outside the three largest cities--Chicago, Detroit, and Pittsburgh--the peak forest area occurs between 30 and 40 miles from the CBD. Around Cleveland and Cincinnati, this occurs between 20 and 30 miles. Indianapolis, within the zone of relative topographic uniformity, shows a secondary peak between 10 and 15 miles. These results suggest a wave effect, with the growing city pushing before it a ring of area on which forest and brush constitute a higher proportion than elsewhere. The magnitude of the peak, at least in the cases studied, is related to the degree of hilliness of the land.

It can be tentatively concluded from the foregoing discussion that land use change does have a pronounced effect on the amount of forest and brush around midwestern cities, and that usually a peak zone

of forest and brush area occurs somewhere between the city and the dominantly agricultural land. This effect, related to land-use zonation, is modified to the degree that the topography is not uniform; that is, uniformly level or uniformly hilly. The less topographically uniform an area is, the more irregular land-use zonation and its effects on vegetation tend to be.

Having outlined forest trends at various regional scales, particularly in urban areas, and having suggested some of the mechanisms of forest change, the study now focuses on one metropolitan area, Detroit, to further test these ideas and to examine the effects of urbanization on vegetation patterns, including aspects other than forest area, in more detail. Detroit was selected for this purpose because air photos were available back to 1937, good vegetation and land-use maps of an adjacent county had been made, and for personal convenience.

CHAPTER IV

LAND USE-VEGETATION TRENDS IN THE DETROIT REGION

A. Original Vegetation and Regional Development

Present patterns of vegetation around Detroit are the result of 175 years of settlement and development, acting upon the prior pattern created by nature and Indians. Before considering the recent situation, therefore, we will briefly trace the history of man's shaping of the landscape in southeastern Michigan.

1. Physical Setting

To understand vegetation patterns, it is necessary first to know the environmental influences that have helped shape them, for these act not only directly upon vegetation, but also influence human activity, which in turn superimposes its own effects. Therefore we will briefly consider the topography, soils, and climate of southeastern Michigan.

Southeastern Michigan consists essentially of two basic physiographic sections--flat, former lake bed and a rolling to hilly morainal belt (Figure 3). The city of Detroit lies in the lake bed section, with its eastern side against the Detroit River and Lake St. Clair. This section has virtually no natural lakes. The soils are predominantly loamy, with sands and clays in some areas. Drainage is poor in parts of the section. The northwestern suburbs of Detroit extend into the

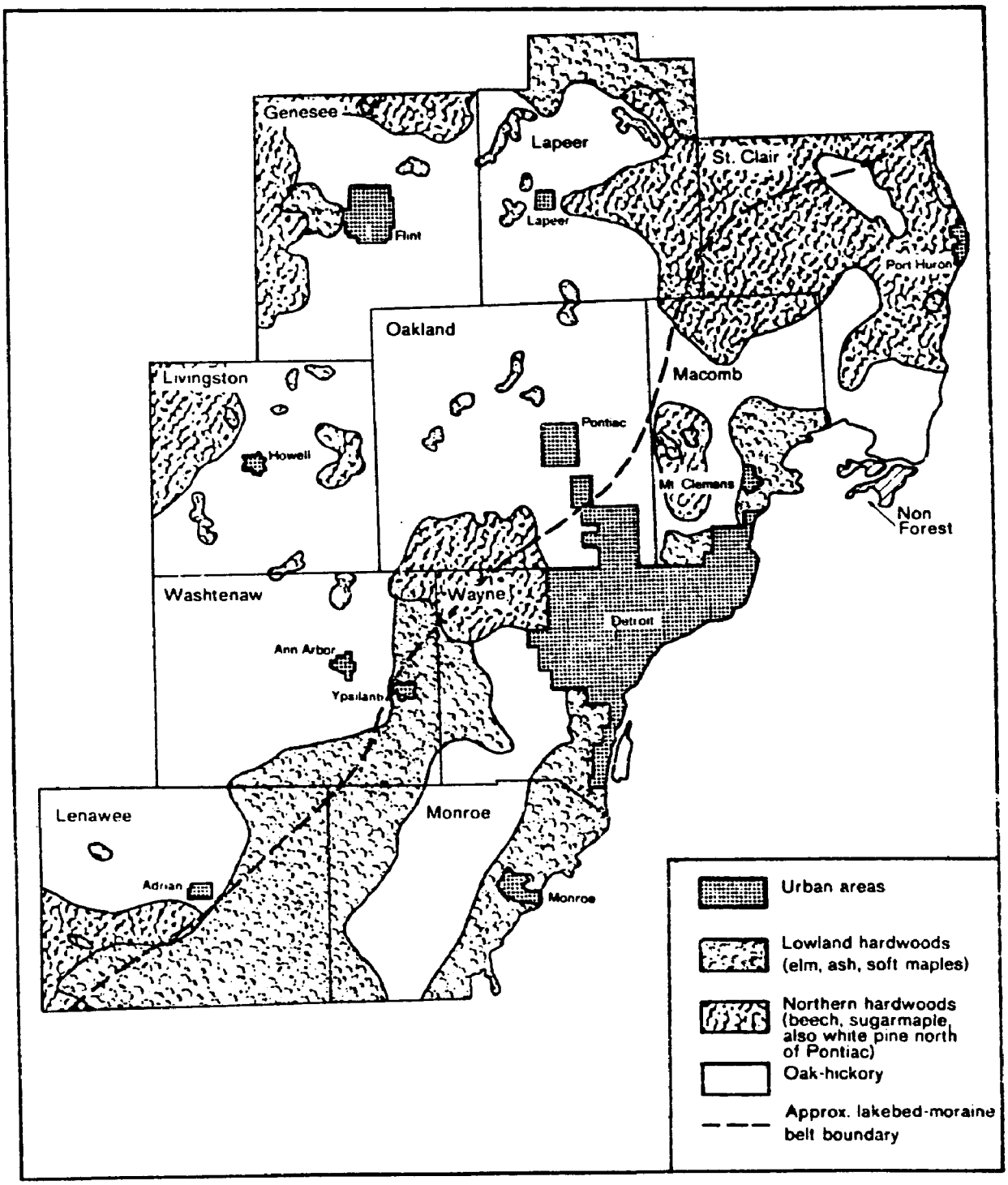


Fig. 3.--Map of suggested distribution of presettlement forest types in southeastern Michigan, based on observation of remnant stands in 1956. (Adapted from Essex et al., 1956.)

moraine belt, which runs northeast-southwest and contains numerous lakes, till plains, and outwash areas. Sandy loams predominate on the moraines and loams on the lower-elevation areas in the moraine belt. Bogs, marshes, and swamps mark the sites of many former lakes.

Bedrock lies near the surface in parts of Monroe County, but over most of the Detroit area it is deeply covered with glacial drift. Clay drift averaging 100 feet thick underlies most of the lake bed soils, and about equal areas of clay drift and sandy drift, 200 to 300 feet thick, underlie the soils of the moraine belt (Veatch, 1953).

According to the Koppen classification, Detroit lies on the border between two climatic zones--humid continential warm-summer and humid continental cool-summer. Precipitation, which averages about 30 inches a year, is distributed fairly evenly through the year, with a slight peak in summer. Rainfall and soil moisture are generally adequate for forest growth, although areas of dry prairie did exist in southwestern Michigan before settlement (Veatch, 1928). Table 5 presents climatic data from three stations in southeastern Michigan.

2. Pre-settlement Vegetation

Aside from fires set by Indians, human influence on the vegetation of southeastern Michigan was negligible before the 1800s, when American settlement of the region began. What, then, was the nature of the vegetative cover that settlers and their successors were to alter?

Our knowledge of pre-settlement vegetation in southeastern Michigan, as in most of the Midwest, is based mostly on reports of early explorers and, especially, the notes of Government land surveyors, who

TABLE 5

CLIMATIC DATA FOR THREE STATIONS IN SOUTHEASTERN MICHIGAN

	Mean annual temp. (°F)	Mean Jan. temp. (°F)	Mean July temp. (°F)	Growing season (days)	Mean annual precip. (in.)	Mean annual snow, sleet (in.)
Monroe	50.2	27.2	73.9	176	30.8	--
Detroit City Airport	50.1	26.9	74.4	181	31.0	31.8[a]
Flint	47.5	24.5	71.2	151	30.1	40.5[b]

All data average for 1931-60 except: (a) 32-year record; (b) 25-year record.

Source: Weather Bureau, 1964.

recorded the species of witness trees at section corners and along section lines and made more general notes on the terrain and vegetation they passed through. The following description of pre-settlement vegetation is based on literature which in turn was based on the above types of sources (Dick, 1937; Bald, 1961; Fuller, 1916; Blois, 1839; Merk, 1951; Bingham, 1945).

Taken together, pre-settlement vegetation in southeastern Michigan was largely forest, though broken in many places by lakes, marshes, and "prairies." Because of fire it presented a much more open prospect than that in the popular imagination. Figure 3 shows the suggested distribution of presettlement forest types, based on observation of remnant stands in 1956.

The region's plant cover roughly coincided with major soil types and topographic features, which trend northeast-southwest. Lowland hardwoods (elm, ash, red and silver maple, swamp white oak, cottonwood, and others; see Appendix I for scientific names) were predominant on loam and clay areas of the lake bed section, and on swampy areas in the moraine belt. These generally were dense, dark, wet forests.

Oak-hickory forest (white, red, and black oaks and shagbark hickory being the most common species) occurred principally on the sandy uplands of the moraine belt, although stands also occurred on sandy parts of the lake bed section. Much of this type was an open forest with little undergrowth referred to as "oak openings." Such stands often were likened to orchards or cultivated parks. The openness of the understory was generally attributed to the frequent fires set by Indians to clear land and promote vegetation conducive to game.

Beech-maple forest (dominated by American beech and sugar maple) covered less area than either of the above two types. It occurred primarily on areas of well-drained clays and sandy loams in a belt between the lake bed and the hilliest moraine land.

Though much less extensive than the deciduous forests, several types of coniferous forest occurred. There were notable stands of white pine in northern Oakland County, along the Flint River in Genesee and Lapeer counties, and in the northern and western parts of St. Clair County. Around many lakes and in bogs in the moraine belt grew tamarack, white cedar, and some spruce.

Small areas of "prairie" occurred, mostly in St. Clair, Macomb, Washtenaw, Wayne, and Monroe counties. Most dry prairies probably were

maintained by fire. Wet prairies, the more common type, were found in periodically flooded places.

Shrub swamps, with such species as buttonbush and red-osier and grey dogwood, undoubtedly occurred in many places, as they do today. Marshes covered many old lake sites and fringed much of the shore of Lake Erie, Lake St. Clair, and the Detroit River.

3. Regional Development

a. Nineteenth Century

Although a succession of forts existed at the site of Detroit throughout the eighteenth century, the settlement there remained quite small. In 1796 the Americans took over control of Fort Lernoult from the British, and in the next quarter century settlement began in earnest in Michigan. During these 25 years a number of towns were established in southeastern Michigan, including Monroe, Ann Arbor, Pontiac, and Mount Clemens. With completion of the Erie Canal in 1825 and development of steam navigation on the Great Lakes, a flood of immigrants poured into Michigan through Detroit.

Earliest settlement was concentrated along the Detroit, Raisin, Rouge, and Clinton rivers for access to water transportation and water power. As we have seen, much of the land near the Detroit River and Lake Erie was covered with dense, wet forests of elm and ash. These lands were difficult to clear and drain, so the subsequent stream of settlement largely bypassed them and moved inland to the oak openings and prairies of Oakland, Washtenaw, and northern Lenawee counties. Here

settlers had only to break the tough sod to get a first crop; the widely spaced trees could be removed later.

In 1816, the Government Land Survey was begun in Michigan to allow more orderly occupation of land and to clarify ownership. After establishment of base and meridian lines, the land was surveyed into townships six miles square, and each of these was divided into 36 sections, each one mile square. This method of land division, applied to most of midwestern United States, put a permanent stamp on the landscape. Typical land purchases for farms were square quarter-sections (160 acres) or rectangular halves of quarter-sections (80 acres--the minimum purchase allowed). Quarter-section lines thus became field and property boundaries, many of which remain today.

As land was taken up, roads were built along section lines. Gradually a grid of these local roads developed, further strengthening the pattern of squares. Only in wet or especially hilly areas does this road pattern break down. These roads supplemented the major roads, mostly built earlier, which radiated from Detroit to other important centers, such as St. Joseph, Kalamazoo, Grand Rapids, Saginaw, Port Huron, Monroe, Chicago, and towns in Ohio.

The first half of the nineteenth century was the main period of settlement in the counties around Detroit. The second half saw continued clearing of forests and rapid growth of towns and industry.

b. Twentieth Century

The period 1900-1910 was an important economic watershed in southeastern Michigan. It marked both the peak of agriculture as a

space-using activity and the beginning of a population explosion in Detroit.

Although 1931 was the peak year for acreage of cropland in the United States as a whole (Clawson et al., 1960), the crest came earlier in southeastern Michigan. For most of the counties around Detroit, the total area in farms as well as area of cropland peaked about 1900 to 1910. In Oakland County, farm land constituted 95 percent of the total area in 1900; in Macomb County, 93 percent in 1910 (Bureau of the Census, 1870-1964). Apparently, the proportion of forest in rural parts of these counties was lowest at this time. In 1870, woodland still averaged about 25 to 40 percent of farm area in the counties of southeastern Michigan (Bureau of the Census, 1870). By 1920, these percentages were down to about 10 to 12 percent, levels that have remained to the present (Bureau of the Census, 1920-1964). It seems probable that this level of stabilization was reached about 1900 to 1910, when the cropland acreage peaked. (The Census of Agriculture did not regularly report woodland acreage on farms before 1910.)

The advent of the automobile industry, accompanied by other industrial development, brought about a phenomenal spurt in the growth of Detroit's population. Between 1900 and 1930, Detroit's population almost doubled each decade, going from 285,000 to 1,525,000 (Bureau of the Census, 1900-1930). The City of Detroit expanded in area from 29 to 138 square miles (New York World Telegram, 1900, 1936).

Since 1930, urbanization of southeastern Michigan has continued at a rapid pace. Between 1930 and 1960, the population of a ten-county area around Detroit (Genesee, Lapeer, St. Clair, Livingston, Oakland,

Macomb, Washtenaw, Wayne, Lenawee, and Monroe) grew from about 2,672,000 to 4,675,000, a 75 percent increase. The fastest growing counties were Wayne (1,888,946 to 2,666,297), Oakland (211,251 to 690,259), Macomb (77,146 to 405,804), and Washtenaw (65,530 to 172,440). (Figure 4 shows the 10 counties and major urban areas and roads in 1969.)

The growth of the Detroit market led to an emphasis on dairying and truck gardening in the agriculture of the surrounding counties. In recent decades, truck gardening (mostly in Macomb and Wayne counties) has maintained a steady level of income if not area, but dairying has declined. Monroe County, south of Detroit, specializes in field crops such as corn and soy beans. Northwest of the city, the chief area of this study, dairying, though not as important as formerly, remains the chief type of farming (Honzatko, 1960).

While area in farms has steadily decreased since the early 1900s (from 3,949,892 acres in 1900 to 2,299,824 acres in 1964 in the 10-county area), average size of farms (except in Wayne County, which includes Detroit) has steadily increased, in keeping with the national trend. In 1964, the average size of farms was 116 acres in Monroe County, 68 acres in Wayne, 84 acres in Macomb, 132 acres in Oakland, 141 acres in Lapeer, and 115 acres in Genesee (Bureau of the Census, 1964). Large numbers of part-time farms help to keep these averages well below those of counties farther from the major cities, where there are more full-time farms.

During the 1950s and 1960s, interstate highways were built (Figure 4). These generally parallel older major routes out of Detroit. Interstate 94 goes west past Ann Arbor and north to Port Huron; I-75

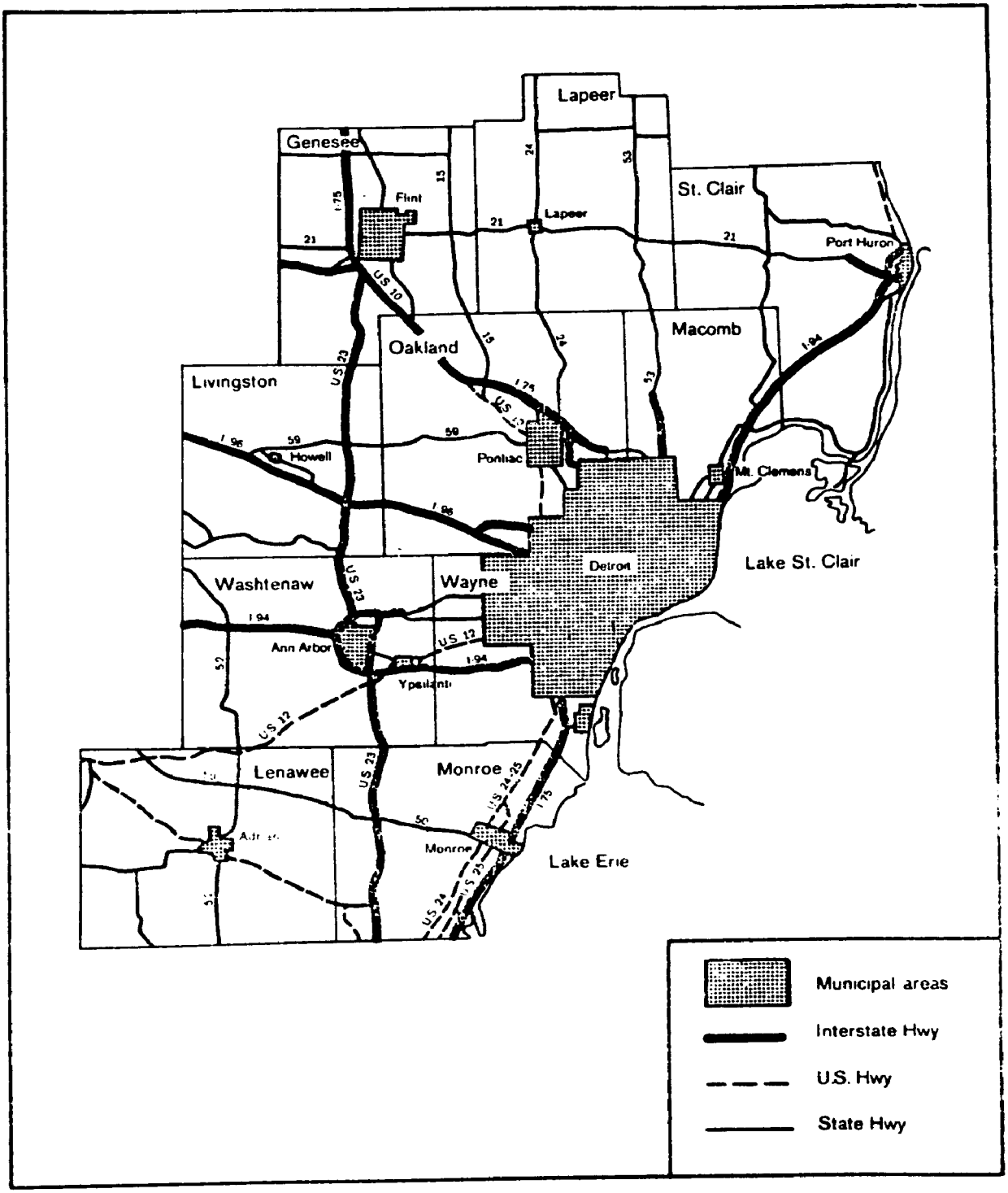


Fig. 4.--Map of urban areas and major highways, southeastern Michigan, 1969. (All four-lane, limited-access highways are shown here with the same width of line.)

goes northwest through Flint and south through Toledo; I-96 runs west-northwest through Lansing. The locations of these highways indicate and help to perpetuate the major directions of growth--north and west--in the metropolitan region. The interstate highways also encourage continued urban sprawl, since they allow quicker travel to and from the city.

For several decades, the number of rural non-farmers around Detroit, as around other American cities, has risen steeply, in response to improved automobile transportation, the shift of much industry to extra-urban locations, and the flight of farmers from the urban fringe. Since rural non-farmers have a very different impact on vegetation from that of farmers, their increase has considerable significance for the present study. The U.S. Soil Conservation Service, which now expends a large part of its energy in suburban areas, predicted a rise in woodland acreage between 1958 and 1975 in the interior, morainal counties (Oakland, Genesee, Lapeer, Livingston, and Washtenaw), and a decrease in woodland acreage in the lake-bed counties flanking Detroit (St. Clair, Macomb, Wayne, and Monroe) (U.S.D.A., Economic Research Service, 1960). This contrast may be at least in part attributed to the great increase of rural non-farm and small-town settlement in the more attractive morainal counties, which have numerous hills and lakes. It may also be due to the greater combined pressure of agriculture and urbanization in the lake-bed counties.

To sum up, since 1900 the differentiation between city and countryside has become much less distinct. Full-time farmers have tended to move farther from the city, while more and more former

city-dwellers have moved to small pieces of land or subdivisions beyond the limits of cities, a trend encouraged by the great increase in automobile ownership and the tremendous improvements in highway systems.

How these and other aspects of urbanization have affected vegetation patterns northwest of Detroit is the subject of the next section. Vegetation characteristics will be described by land-use categories, over space, and through time, each mode of description adding understanding of urbanization-vegetation relationships.

B. Land Use-Vegetation Trends, 1937-1964, Northwest Sector

1. Land Use, Vegetation, and Distance

The present study is concerned chiefly with what happens to vegetation as rural land is converted to urban uses, particularly residential use. In this section we narrow the geographic focus still further, to a sector northwest of Detroit proper, and investigate vegetation characteristics associated with specific land uses that represent stages in the urbanization process.

a. Hypothesis Concerning Land Use-Vegetation Relationships

We now return to the general hypothesis stated in Chapter I: Vegetation patterns around cities are determined primarily by land use, and individual types of land use have characteristic vegetation patterns. The first part of the general hypothesis was addressed in Chapter III (pp. 24-33), and will be again, in Chapter IV, when physical factors are considered more specifically. In this section we will test the

second part, stated somewhat more precisely: Areas with different land uses have significantly different vegetation characteristics.

b. Test of Hypothesis

To test this hypothesis certain vegetation characteristics and land uses were measured for an area northwest of Detroit. As will be explained later, only a few of these vegetation and land-use variables were extensively used in the test.

The Study Area

The study area is a pie-shaped sector extending from two miles inside the 1937 edge of Detroit[1] to a distance 20 miles beyond the 1964 edge of Detroit (Figures 5-8). The area is roughly bisected by U.S. 10, and its eastern boundary coincides with the eastern boundary of Oakland County. The area includes about two-thirds of Oakland County, six townships in southern Lapeer County, and six townships in southeastern Genesee County. It also includes the city of Pontiac and a number of smaller urban places and extends to the edge of Flint.

This area was chosen for study for several reasons. During the 1937-64 period it was the most rapidly growing sector of the Detroit metropolitan region. It contains a diversity of landforms and a

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[1]Location of the city edge was determined by (1) mapping from air photos the urbanized areas in 1937 and 1964 (subdivisions with at least curbs and gutters visible, named settlements, commercial and industrial property adjacent to settled or subdivided areas); and (2) use of the "epsilon measure" (Nystuen, 1967) for determining what areas should be considered part of "mainland" Detroit and what areas as "islands" separated from it. The boundary was established by rolling the edge of a circle with one-half mile radius along the outer edge of the mapped urbanized areas.

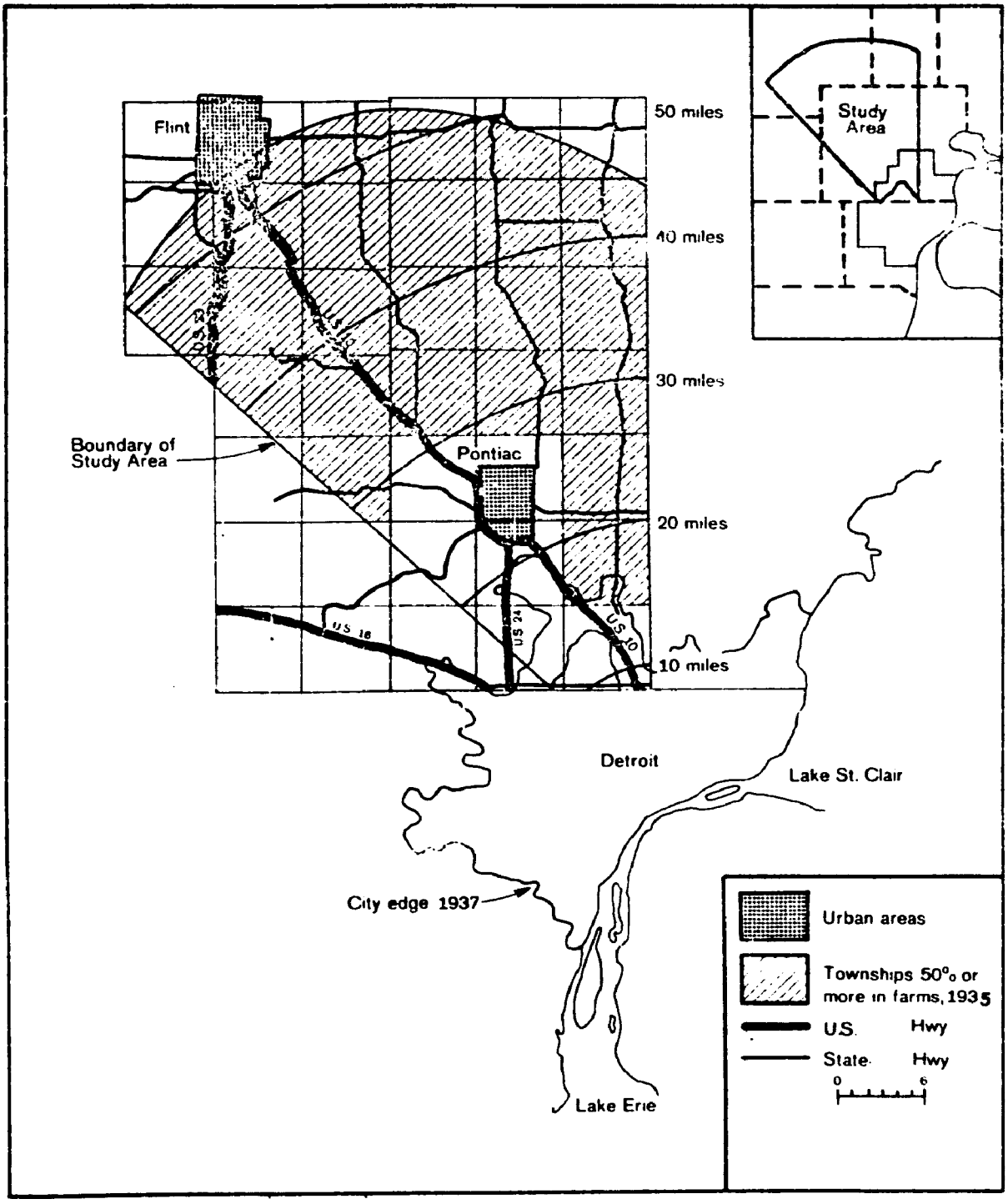


Fig. 5.--Map of Detroit study area, 1937, showing Detroit city edge, major highways, and townships 50 percent or more in farms in 1935. (Scale is in miles.)

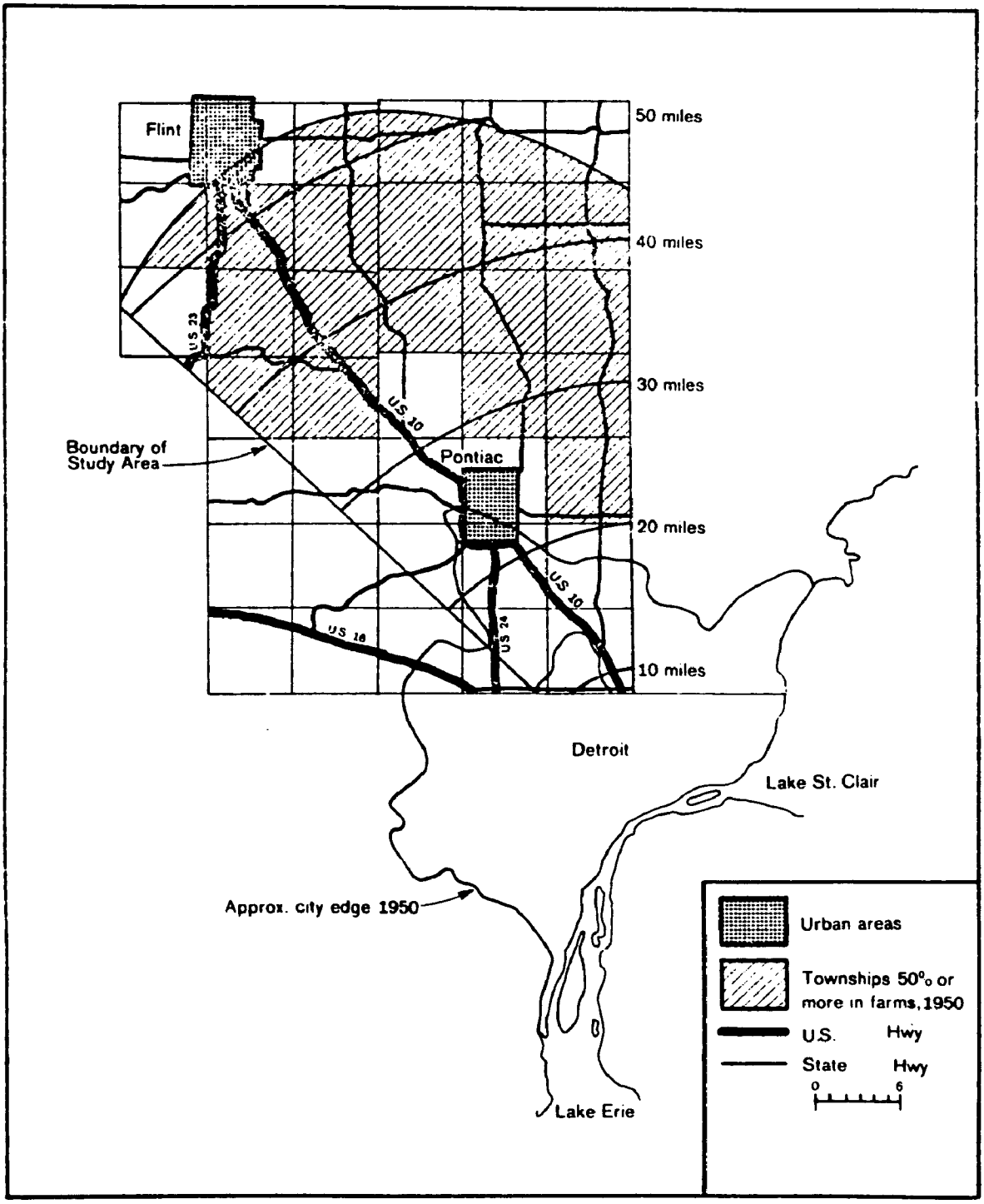


Fig. 6.--Map of Detroit study area, 1950, showing approximate Detroit city edge, major highways, and townships 50 percent or more in farms. (Scale is in miles.)

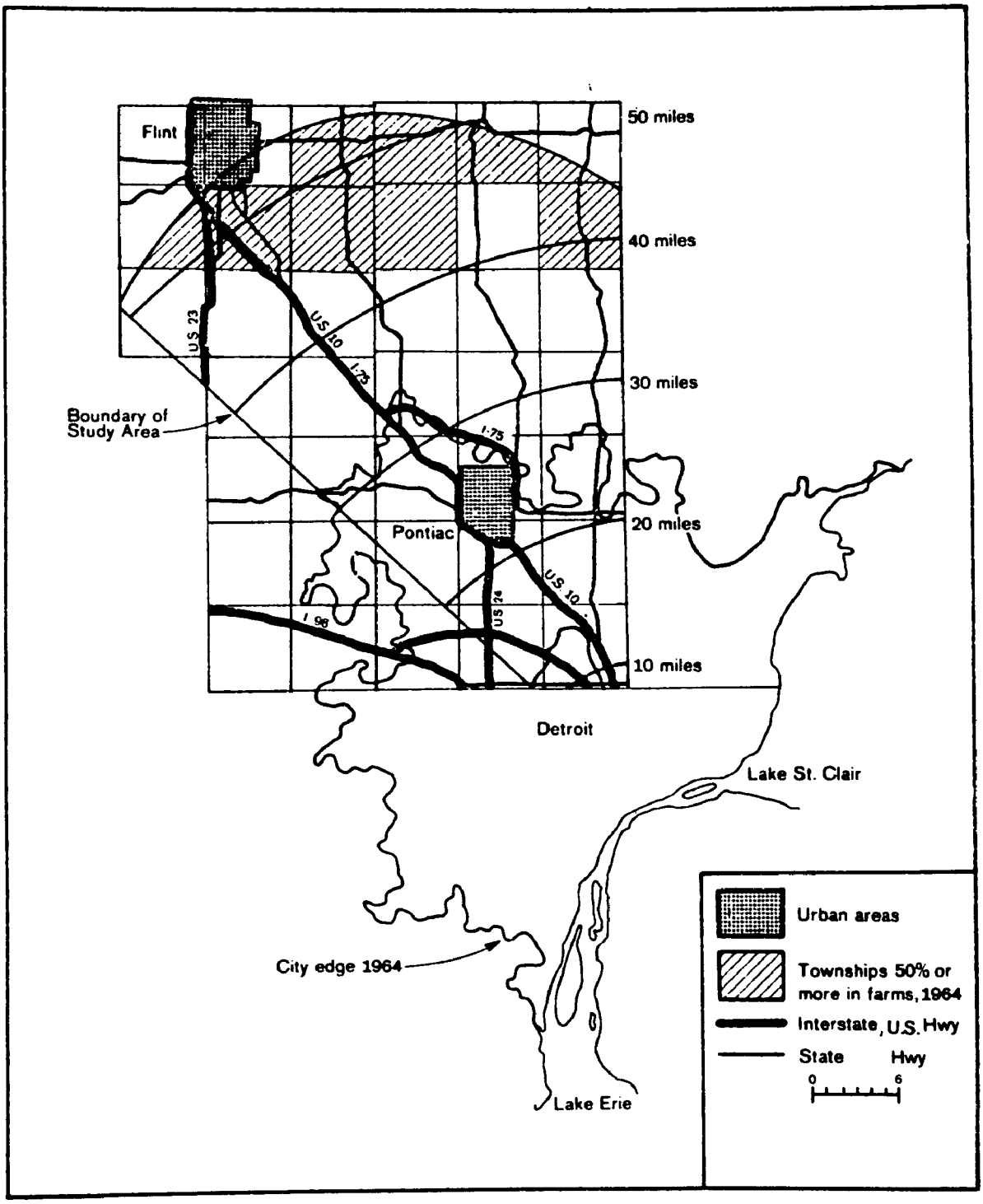


Fig. 7.--Map of Detroit study area, 1964, showing Detroit city edge, major highways, and townships 50 percent or more in farms. (Scale is in miles.)

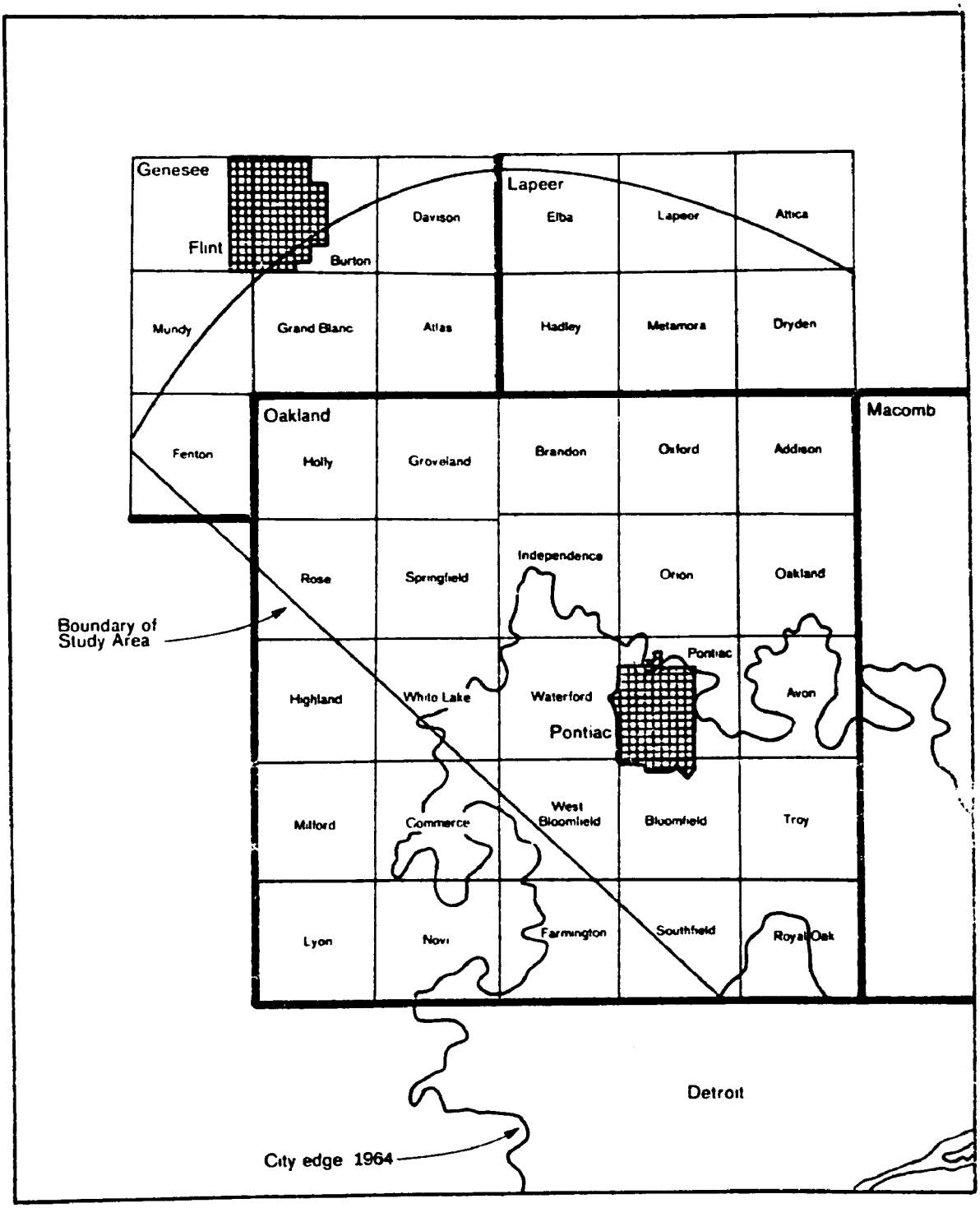


Fig. 8.--Enlarged map of study area showing township names and 1964 Detroit city edge.

spectrum of land uses ranging from commercial-residential to agricultural and recreational. And suitable data were available, notably air photos and land use and vegetation maps of Oakland County.

The study area lies mostly in the moraine belt, although the southeastern corner is on former lake bed. Elevations rise gradually from about 600 feet in the southeast to about 1200 feet in northern Oakland County and then decrease somewhat to the northwest. Lakes are particularly numerous in the middle part of the study area where elevations and relief are greatest. The vegetation includes all the regional types described earlier, with the possible exception of prairie, and white pine now occurs only in small stands. Planted vegetation includes orchards (mostly apple), row and hay crops, pastures, stands of red, jack, and Scots pine, nursery trees and shrubs, and the plantings around homes and other structures.

Population densities are highest in the Royal Oak-Pontiac urbanized salient; they decline to the north and northwest, and then rise slightly in Genesee County as Flint is approached. As is generally the case, land values and median incomes vary roughly with population density. Residential land use (with single- and/or multiple-family dwellings) follows a similar curve. Agricultural land use (land in farms) is most prevalent in the northern part of the study area. Undeveloped open space tends to predominate at intermediate distances from Detroit and Flint. Recreational areas (public parks) are scattered.

Methods

Vegetation characteristics, land use, and other data were recorded for a random 7 percent sample of quarter-sections (10 per township), giving a total of 270 quarter-sections. The quarter-section was found by testing to be a better plot size than the section; that is, twenty quarter-sections, for example, gave a more accurate estimate of vegetation characteristics in an area than did five sections.

Vegetation types on the sample plots were mapped from U.S. Department of Agriculture air photos taken in 1937 and 1964 (scale 1:20,000). The classification of types was based more on structure than composition of vegetation, and was considerably influenced by ease of identification of types on air photos. Thus marshes, field crops, pasture, and weedy fields were lumped in a herbaceous category, whereas forests were separated into deciduous and coniferous. The categories are as follows: deciduous forest (tree crown closure at least 20%), coniferous forest (tree crown closure at least 20%), brush (woody species cover at least 30% of the area and average less than 20 feet high), orchard, herbaceous (wild or cultivated), planted residential (lawns, trees, and shrubs around homes; for part of the sample separated into areas with at least 20 percent tree and shrub cover and areas with less than 20 percent tree and shrub cover), planted other (as in preceding, but larger areas, such as cemeteries, institutions, "manicured" parks), non-vegetated (at least 75 percent of the area bare of plants and not normally supporting vegetation; e.g., gravel pits, parking lots, large buildings), and water. All types except residential, non-vegetated, and water were required to be at least five acres to be mapped. Residential

vegetation was mapped if at least one acre. Water and non-vegetated areas were mapped if at least two acres. Areas were required to be at least 132 feet wide at all points (except for acute corners). Roads, railroads, and streams at least 100 feet wide were considered boundaries between typed areas, except in the case of residential vegetation, where roads were included if the type existed on both sides of a road.

The areas of the quarter-sections and vegetation patches within them were measured by planimeter or dot grid overlay (the latter method was found to be quicker and as accurate as the first and was adopted part way through the data-collection stage of the study). Planimeter measurements were made to the nearest one-hundredth square inch. The dot grid density was 121 per square inch. All measurements were made twice (three times if the second was 10 percent or more different from the first, which didn't occur often) and averaged. The areas of the patches of each type were summed and expressed as a percent of the plot area. Acreages were used very little in the study because the interest was mainly in trends rather than absolute areas, and also because there was some variation in the actual scale of air photos between 1937 and 1964.

Total tree cover was measured on 1964 air photos (scale, 1:7,920 or 8 inches=1 mile) with a dot grid overlay with a density of 25 per square inch. As with the vegetation patches, measurements were made twice, sometimes three times, and averaged. Total tree cover was not obtained for 1937 because large-scale air photos were not available.

Distribution of tree cover was recorded for both years. An estimate was made of the degree to which the total tree cover in a plot was

concentrated in the mapped forest patches and recorded as follows: 1 - 75% or more of tree cover in forest patches; 2 - 25% to 74% of tree cover in forest patches; 3 - 0% to 24% of tree cover in forest patches; 4 - no trees in quarter-section.

Number of vegetation types and total number of patches were recorded for each plot, in order to get some measure of diversity.

All forest patches were mapped in their entirety, which often extended beyond the plot boundaries, so that size of these patches could be determined. Change in size of individual forest patches between 1937 and 1964 could not be measured easily in absolute terms because of variable differences in air-photo scale between the two years, but it was possible to determine for each forest patch whether it increased, decreased, or remained about the same size.

Type, density, and diameter class of forest patches were obtained from a vegetation map of Oakland County (data for which were collected in 1963 and revised in 1966) published by the Oakland County Planning Commission (1970). Diameter class was recorded as follows: 1 - saplings, more than one-half of the trees less than 5 inches d.b.h. (diameter, 4 1/2 feet above the ground); 2 - pole timber,more than one-half of the cubic-foot volume in trees between 5 and 10 inches d.b.h.; 3 - saw timber, more than one-half of the cubic-foot volume in trees larger than 10 inches d.b.h. Density classes were recorded similarly: 1 - crown closure essentially 20% fo 45%; 2 - 45% to 70%; 3 - over 70%. Where a forest patch was divided into areas with more than one density or diameter class, the largest two in area were recorded and a summary code used; e.g., 1,2=1.3; 2,1=1.7; 1,3=1.7; 3,1=2.3. Type, density, and

diameter class were not recorded for the plots in Lapeer and Genesee counties.

The selection of vegetation variables indicates a predominant interest in forests. This is the type of vegetation which people most desire to preserve in urbanizing areas and the type that takes the longest to grow; therefore it has received more attention in this study.

Land use data were obtained for 1964 from a land use map of Oakland County published by the Oakland County Planning Commission (1966b), and from U.S.D.A. air photos and U.S. Geological Survey 7 1/2-minute quadrangles of Lapeer and Genesee counties. The land-use categories were: residential, commercial, public and quasi-public, manufacturing, industrial non-manufacturing, recreation and conservation, transportation and utilities, extraction, agriculture, and undeveloped open space (land not on farms and not used for any of the above purposes). The land use occupying the largest area was recorded for each plot; thus, for example, a plot two-thirds residential and one-third open space was recorded as residential.

The distance (to the nearest 1/10 mile) of each plot from the Detroit central business district (intersection of Woodward and Jefferson avenues) and from the city edge was also measured, as were several other variables to be discussed in later sections.

The data were recorded on punch cards and analyzed by computer at the University of Michigan.

After the data were collected, it was found that certain vegetation and land use types occurred too infrequently to provide an adequate

sample. Therefore, of the vegetation types mapped, only deciduous forest, brush, and herbaceous area were used in testing the hypothesis, although all types were used in determining number of types and number of patches; planted residential, though frequent, coincided so closely with residential land use that it seemed pointless to use it, either. Among the land uses recorded, only agriculture, undeveloped open space, residential, and recreation occurred often enough to give a sample that could be used in the test. But together these four land uses accounted for over 95 percent of the study area (Table 7).

Data for each vegetation characteristic were averaged for all the plots on which a given land use was dominant, so that land uses could be compared for each vegetation variable. Significance levels were obtained for differences between each pair of land uses with respect to each vegetation variable. The four land uses listed above were compared with respect to percent deciduous forest, percent brush, percent herbaceous, number of types, number of patches, percent total tree cover, tree distribution, size of forest patches, density of forest patches, and diameter class of forest patches. Only vegetation data for 1964 were used, since the land use data were for 1964 only.

Results

Since there are six pairs of land uses to be compared for each of ten vegetation variables, there is a total of 60 tests of the hypothesis. Using the .95 significance level as a minimum, the hypothesis is supported in 30 of the 60 cases. In five other cases the significance level is between .90 and .95. A larger number of plots on which

recreation was dominant (only 12 occurred in the sample) might have increased the number of successful tests of the hypothesis. Appendix II lists significance levels for all combinations.

The four land uses differed most significantly with respect to percent deciduous forest (6 pairs out of the 6 possible combinations had a significance level .95 or higher). Percent brush and percent herbaceous followed with five pairs. Next came average number of vegetation types (4 pairs), tree distribution (3 pairs), and average number of vegetation patches (2 pairs). There were no pairs of land uses that differed at the .95 level or higher with respect to average size, density, and diameter class of forest patches.

Three of the four land uses can be considered stages in the process of urbanization. Typically, agriculture gives way to undeveloped open space as the dominant land use type in the transition zone, and undeveloped open space gives way to residential use as the city expands. Recreational land is scattered through the three zones and cannot be considered typical of any one. In the discussion of the ten vegetation characteristics that follows, the differences in vegetation between land use types will be interpreted and related to the urbanization process. Table 6 presents means for the ten vegetation variables by land use type.

Percent Deciduous Forest. The four land uses are ranked in terms of this variable, in descending order, as follows: recreation, open space, agriculture, residential. Interpretation: Forested areas are usually selected for parks, if not playgrounds. Farmland usually has woodlots, but not extensive forests. Open space, much of it owned

TABLE 6

VEGETATION CHARACTERISTICS BY LAND USE TYPE, 1964

	Agri-culture (n=31)	Rank	Open space (n=98)	Rank	Resi-dential (n=34)	Rank	Recreation (n=12)	Rank
Percent deciduous forest	12.7	3	17.9	2	1.7	4	29.1	1
Percent brush	6.4	3	14.7	2	2.6	4	28.0	1
Percent herbaceous	77.1	1	48.6	2	15.3	4	27.6	3
Number of types	2.6	3	3.1	1	2.0	4	2.9	2
Number of patches	3.7	4	5.7	2	4.8	3	6.1	1
Percent total tree cover	18.9	3	25.7	2	16.1	4	36.6	1
Tree distribution[a]	1.6	2	1.7	3	2.9	4	1.4	1
Size, forest patches (acres)	46.7	3	61.5	2	23.7	4	83.7	1
Density, forest patches[b]	2.00	3	1.98	4	2.08	2	2.12	1
Diameter class, forest patches[b]	2.74	1	2.61	2	2.43	4	2.57	3

[a]See page 51 for explanation of code.

[b]See page 52 for explanation of code.

by rural non-farmers and speculators, is a post-farm land use on which the woodlots often have time to spread, and sometimes land remains as open space long enough for herbaceous or brush land to develop into forest. In residential areas most of the previous forest area is occupied by home lots on which trees may remain but lower layers of the pre-existing forest have been removed and replaced by lawns and other planted vegetation.

Percent Brush. The land use ranking is: recreation, open space, agriculture, residential--the same as for percent deciduous forest. Recreation land may have more brush than open space land because of a longer period since it was farmed, or because it was marginal farmland to begin with. Much of the recreation land in the study area is on hilly or swampy land that reverted to the state through tax delinquency in the 1930s and 1940s. On agricultural land, brush is held down by cultivation or grazing. In residential areas, brush remains only on a few vacant lots.

Percent Herbaceous. The ranking is: agriculture, open space, recreation, residential. This order reflects the replacement of much herbaceous plant cover by brush and forest as agricultural land becomes open space land, and the further elimination of herbaceous areas on home sites in residential areas. Recreation land may have less herbaceous area than open space land because forested areas are favored for parks and because recreation land in the study area may have had longer to develop brush and trees on former herbaceous areas.

Number of Types. The ranking is: open space, recreation, agriculture, residential. Open space land often has some brush, and

occasionally conifer stands planted by its owners, as well as deciduous forest and herbaceous areas. Recreational lands have a similar diversity, and their difference from open space was only significant at the .57 level. Agricultural land has less diversity because of intensive management for a few purposes; though most farms have deciduous woodlots, they are apt to lack brush and stands of planted or swamp conifers (rural non-farmers may be more interested in planting conifers than are farmers, and there are more of them). Residential areas have the least diversity, with an almost unanimous choice on occupied lots of lawns, shrubs, and trees; what diversity of types there is generally comes from vacant lots with herbaceous vegetation, brush, or forest. Of course, the lack of diversity of residential areas is partly due to the vegetation classification used, in which lawns, shrubs, and trees around houses were lumped as one type. If the plots had been mapped at a much larger scale, perhaps lawns could have been mapped as herbaceous areas, and shrubs as brush areas, thus raising the average number of types on residential land. But at the scale used, residential vegetation dissolves into one type, almost ubiquitous around homes.

Number of Patches. The ranking is: recreation, open space, residential, agriculture. The difference between recreation and open space may not be real, since the significance level is only .39. The larger number of vegetation types on these two land uses almost insures that they will have the largest number of patches also, although it is possible, but not usual, to have a large number of patches where only two vegetation types are present. Residential land comes ahead of agricultural land possibly because of the number of blocks of five acres or

more in subdivisions which have not been built upon and remain as herbaceous, brush, or forest area.

Percent Total Tree Cover. The ranking is: recreation, open space, agriculture, residential. This order is the same as for percent deciduous forest, probably for some of the same reasons. Apparently, the growth of shade trees in older residential areas is offset enough by their lack in new subdivisions to keep residential land as a whole below agricultural land in amount of tree cover. The significance level for this pair is only .73 however.

Tree Distribution. The ranking, beginning with the land use on which tree cover is most concentrated in forest patches, is recreation, agriculture, open space, residential. Residential is significantly different from all the other land uses at the .99 level, but the other pairs are below .85. Assuming, however, that real differences exist between all these land use types, the first place of recreation may be explained by the large size of forests on such land, even though many scattered trees occur in the open areas. Open space probably comes after agriculture because, although it has somewhat larger patches of forest, it also has many more scattered trees in the open areas. Residential areas have little forest but large numbers of scattered trees, either retained from earlier land uses or planted along streets and in yards.

Size of Forest Patches. The ranking, beginning with the largest, is: recreation, open space, agriculture, residential. Significance levels for all of these pairs are under .95, although recreation-residential is .91, and recreation-agriculture is .93. The suggestion

is that forest patches on agricultural land tend to expand when that land becomes open space, and that new patches that may spring up on open land do not hold down the average size appreciably. Most forest patches in residential areas are in small parks or on small, as-yet-unbuilt-upon parcels.

Density of Forest Patches. The ranking of land uses is: recreation, residential, agriculture, open space, but significance levels range from .71 to .11, indicating little difference between the four land uses.

Diameter Class of Forest Patches. The ranking of land uses is: agriculture, open space, recreation, residential, but significance levels range from .88 to .31. The data on density and diameter class, which together indicate degree of maturity and disturbance of forests, suggest that in the study area quality of forests does not change much as a rural area becomes residential. This possibility seems interesting and important, and will be examined further in later sections.

c. Land Use-Distance Relationships

Though land use is the best indicator of degree of urbanization, there are several reasons why it might be useful to substitute distance for land use and look at distance-vegetation relationships, provided, as our regional model assumed, that there is a correlation between distance from the CBD and type of land use. Among these reasons are some that are general and some that are specific to this study. Specific reasons include: (1) Land use data comparable to those for 1964 were not available for 1937. (2) The determinations of land use types on the map used

were in part based on vegetation. For instance, undeveloped open space was interpreted partly by the presence of brush, forest, or weedy fields. More general reasons for substituting distance for land use include: (3) It provides comparisons of vegetation with other variables that change in a regular way with distance from the CBD, such as population density. (4) Variations of vegetation over distance, as well as over two-dimensional space, give more detail than variations with land use and suggest additional urban and other influences on the distribution of vegetation.

To see if distance could be substituted for land use, the land use-distance relationship was measured by obtaining the proportions of various land uses by distance bands from the Detroit CBD. Table 7 shows proportions of 5-mile bands represented by plots on which a given land-use type is dominant. The table indicates that in 1964, residential use was dominant from 10 to 20 miles, open space from 20 to 45 miles, and agriculture from 45 to 55 miles.

These results indicate that distance is correlated with various degrees of urbanization, substantiating the kind of land use zonation described in Chapter II.

2. Vegetation and Distance

It has been shown that distance from the CBD is correlated with type of land use, in a continuum from urban ro rural. Changes in vegetation over distance may also be affected by factors other than land use, and some of these will be discussed in a later section. But land use has been assumed to be the dominant influence. The results interpreted in this section will help test that assumption.

TABLE 7

LAND USE BY DISTANCE FROM DETROIT CBD, 1964

Distance (miles)	Percent of Plots						
	Residential	Open space	Agriculture	Recreation	Public & quasi-public	Transportation	Extraction
10-15	88.9	11.1	--	--	--	--	--
15-20	55.6	27.8	--	5.6	11.1	--	--
20-25	42.1	52.6	5.3	--	--	--	--
25-30	17.6	67.6	11.8	2.9	--	--	--
30-35	6.3	53.1	15.6	12.5	9.4	3.1	--
35-40	--	64.7	29.4	2.9	--	--	2.9
40-45	--	50.0	39.6	8.3	2.1	--	--
45-50	--	26.8	68.3	4.9	--	--	--
50-55	11.8	26.5	58.8	--	--	--	2.9
Total area	14.1	45.4	32.3	4.8	2.2	0.4	0.7

a. Hypothesis

Since distance is correlated with type of land use, distance-vegetation relationships should be described in the following hypothesis: Vegetation changes over distance parallel changes of vegetation between land use types. For example, the percentage of deciduous forest has been shown to be greater on open space land than on agricultural land, and to be less than either on residential land. It has also been shown that agricultural land occurs farthest out, open space at intermediate distances, and residential land closest to the CBD. Therefore, the change over distance, going toward the city from 50 or 60 miles out, should be first a rise, then a sharp drop in percentage of deciduous forest.

b. Test of the Hypothesis

The hypothesis was tested by grouping the plots in the study area into 5-mile bands by distance from the Detroit CBD and, for each vegetation variable, obtaining the mean for each band, for 1937 and for 1964. Figures 9-11 show the results on graphs.

In comparing changes in vegetation with land use and distance, it should be borne in mind that distance correlates only roughly with land use, since each band has more than one land use. Table 7 shows that the highest percentage of residential use in a band is 89 percent (10-15 miles), highest open space use is 68 percent (25-30 miles), and highest agricultural use is 68 percent (45-50 miles). Nevertheless, in most cases, vegetation changes over distance do seem to parallel changes with land use, as is shown in the following analysis.

Percent Deciduous Forest

Moving cityward from the 50-55 mile band, in both 1937 and 1964, percentage values increase, then decrease sharply, as in moving from agriculture to open space to residential uses (Figure 9A). But the curves for the two periods are similar. If the proportion of deciduous forest really is higher on open space land than on agricultural land, the 1937 curve should peak closer to the city than the 1964 curve. Possibly residential growth around the city of Pontiac held down the amount of forest in the 1937 25-30 mile band.

Percent Brush

The curve for 1964 does parallel the vegetation change with land use, peaking in the middle distances where open space prevails (Figure 9B). The 1937 curve is quite different, trending downward from the city edge outwards. This may be explained by a zone of land speculation near the city, where land is allowed to lie idle, and by a large amount of subdivision in 1924-26, much of which was still not built upon in the late 1930s (Michigan Planning Commission, 1939).

Percent Herbaceous

The curve for 1964 shows a steady drop toward the city, thus being similar to the change with land use (Figure 9C). The 1937 curve is less steep, indicating more open land near the city at that time, but generally parallels the 1964 trend. A small peak in the 15-20 mile band corresponds with the gap at that time between the Detroit city edge and Pontiac.

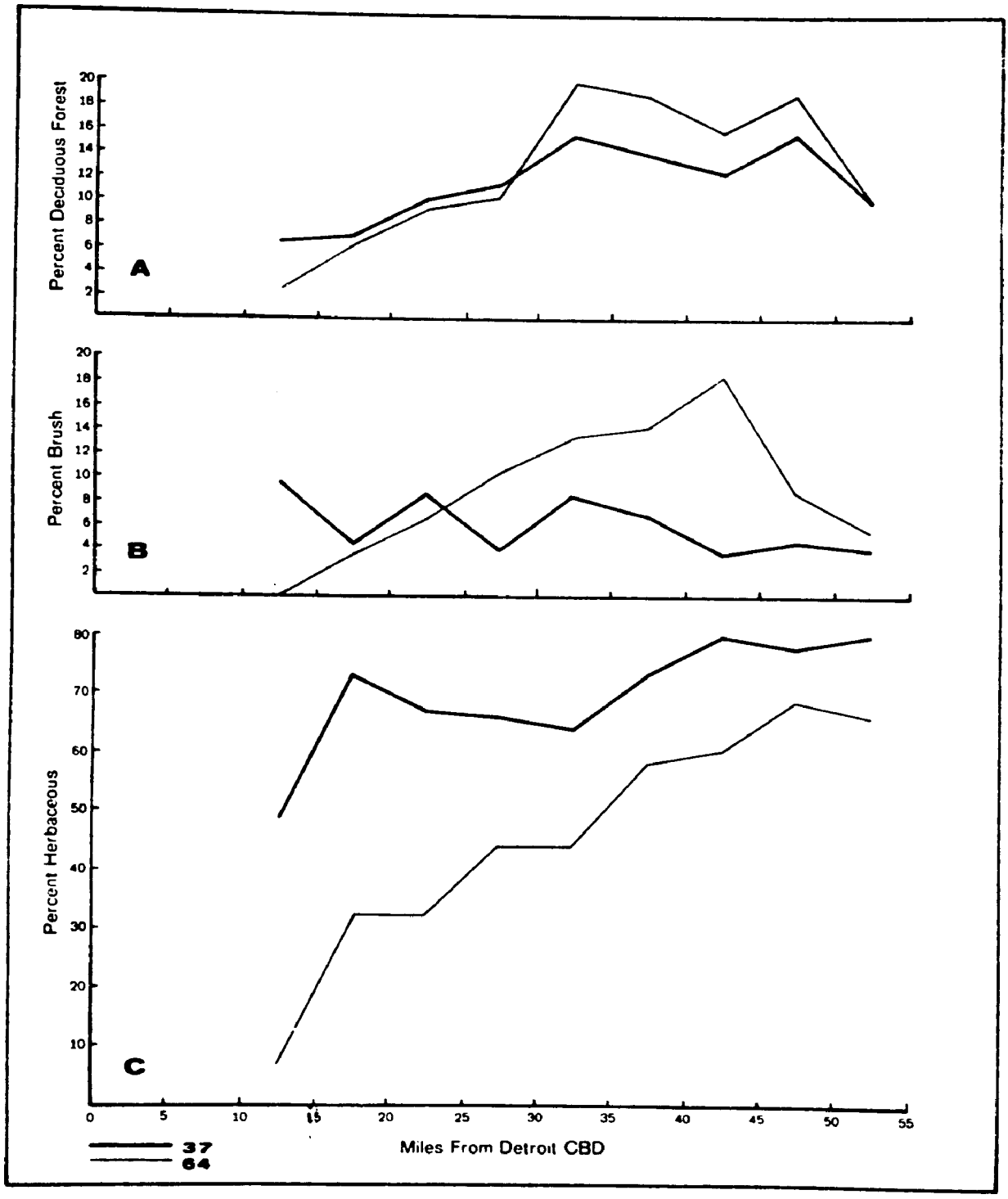


Fig. 9.--Percent deciduous forest (A), percent brush (B), and percent herbaceous cover (C) by distance from Detroit central business district, northwest sector, 1937 and 1964.

Number of Types

The curve for 1964 seems to show a slight peak in the middle distances, which correspond with the open space zone (Figure 10B). The 1937 curve shows a gradual decrease from the city outwards. Again, this might be explained by a speculative (open space) zone near the city, in which zone the number of types has been shown to be greater.

Number of Patches

The 1964 curve peaks in the middle (open space) distances, again supporting the hypothesis (Figure 10C). A lesser peak in the 15-20 mile band corresponds with an area of extensive subdivision, many blocks of which had not been built upon. The 1937 curve trends steadily downward from the city outwards, again perhaps because of a speculative zone and unbuilt-upon lots near the city.

Percent Total Tree Cover

The curve (1964) again parallels the change with land use, peaking in the middle (open space) distances, and dropping off in the far distances and those near the city (Figure 10A). However, the percentage is lower in the farthest (agricultural) band than in the bands (residential) near the city, opposite from what is expected according to land use. The very open land near Flint seems to be responsible.

Tree Distribution

The 1964 curve again supports the findings with respect to land use, decreasing steadily from the city outwards, which indicates an increasing concentration of trees in forest patches (Figure 10D). The 1937 curve is similar, but shows a consistently higher degree of

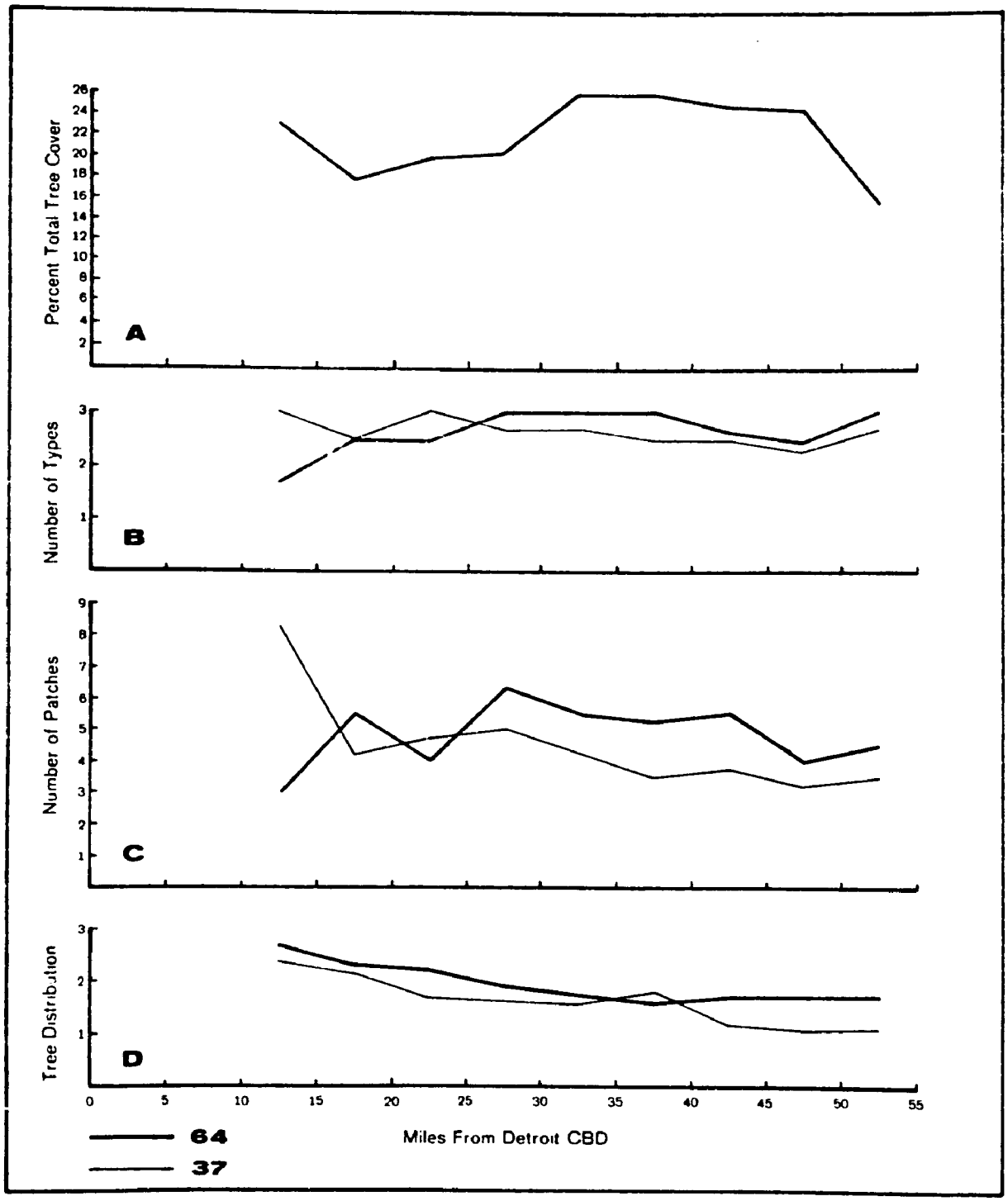


Fig. 10.--Percent total tree cover (A), number of vegetation types (B), number of vegetation patches (C), and tree distribution (D) by distance from Detroit central business district, northwest sector, 1917 and 1964. (See p. 51 for explanation of tree distribution code.)

concentration of trees. This might be attributed to the higher percentage of farmland in all distance bands in 1937.

Size of Forest Patches

The curve for 1964, though quite irregular, shows a peak in the middle distances, corresponding with the situation according to land use (Figure 11C). The 1937 curve, however, shows a steady rise outwards from the city. To support the hypothesis it should show a peak cityward from the 1964 peak. The curves for size of forest patches are roughly similar to those for percent deciduous forest. Perhaps residential growth around Pontiac also holds down average size of woodlands.

Density of Forest Patches

The 1964 curve is flat for most of its length, thus paralleling the lack of significant differences between land uses with respect to this variable (Figure 11B). The samples for the bands at either end, which seem to show differences, were very small and may not reflect the actual situation.

Diameter Class of Forest Patches

Here again the curve shows no clear trend, as with the land use data, indicating that size of trees in forests does not vary significantly over distance from the CBD (Figure 11A).

The apparent lack of change in density and diameter class of forests with distance from the CBD is difficult to understand, in light of the relationships between forest type and density and diameter, and between degree of urbanization and forest types. While density and

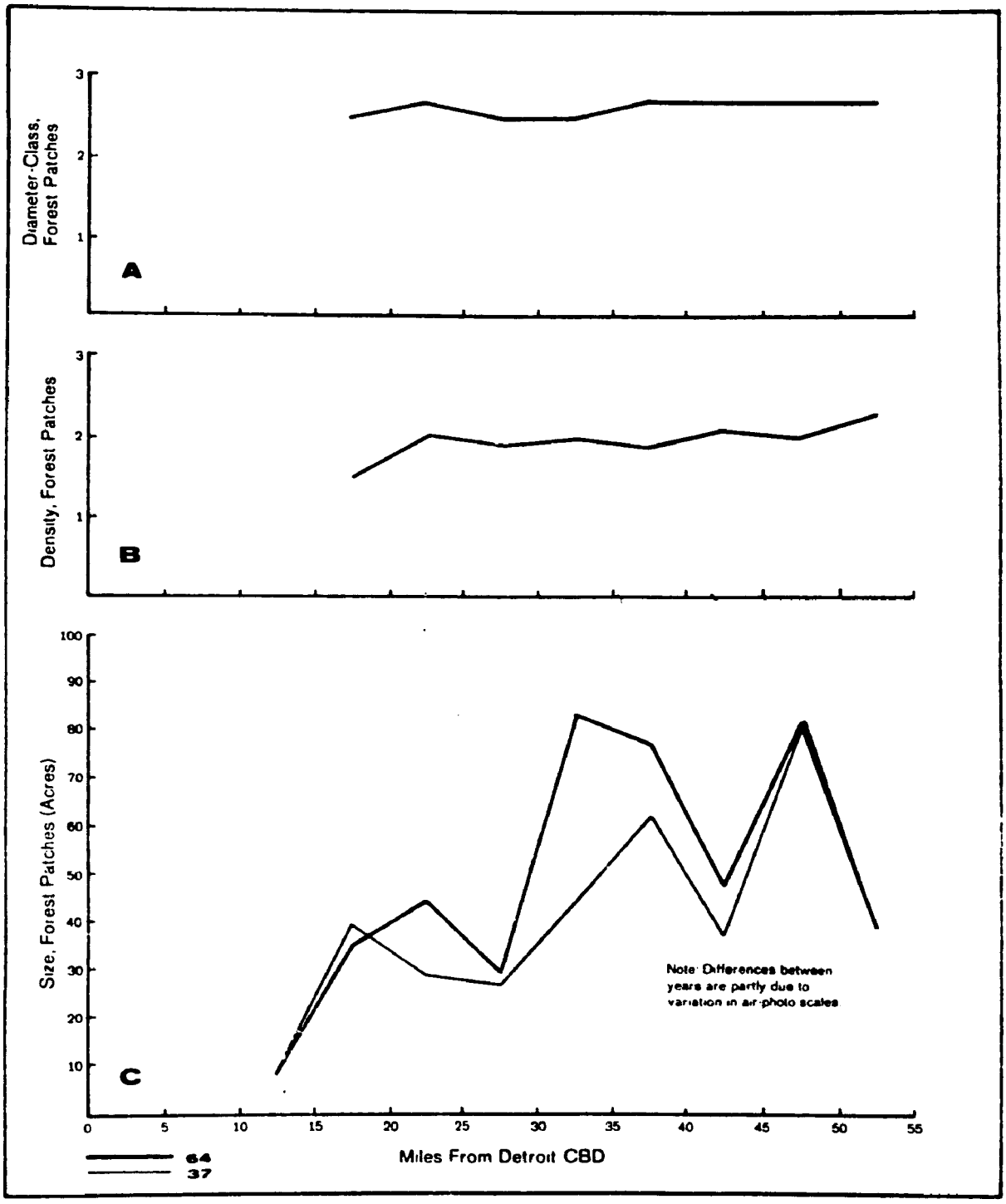


Fig. 11.--Characteristics of forest patches by distance from Detroit central business district, northwest sector, 1937 and 1964: diameter class (A), density (B), size (C). (See p. 52 for explanation of diameter-class and density codes.)

diameter class of forests seem to have little relationship to distance from the CBD, they appear to have a stronger relationship to type of forest. As Table 8 shows, oak-hickory forests have a higher average density and diameter class than do lowland hardwoods (elm-ash-maple) or mixed hardwoods.

TABLE 8

DENSITY AND DIAMETER CLASS BY TYPE OF FOREST, OAKLAND COUNTY, 1964

Type of forest	N	Mean density	Mean diameter class
Oak-hickory	68	2.26	2.90
Mixed hardwoods	133	1.98	2.59
Lowland hardwoods	81	1.74	2.51

Urbanized townships have a higher percentage of lowland hardwoods than do rural townships (Table 9). This conclusion, based on the data from the 7 percent sample in Oakland County, was further tested by taking a 100 percent sample of seven townships from the vegetation map of the county. In five townships in the urbanized southeast part of the county (Bloomfield, Southfield, Pontiac, Waterford, and Royal Oak), lowland hardwoods accounted for 43 to 100 percent of the forest patches. In Avon Township, just outside the urbanized area, lowland hardwoods accounted for 20 percent; and in Brandon Township, 10 to

TABLE 9

DEGREE OF URBANIZATION AND FOREST CHARACTERISTICS, OAKLAND COUNTY, 1964

	Percent oak-hickory	Percent mixed hardwoods	Percent lowland hardwoods	Number of patches	Mean density	Mean diameter
Townships 1-5% residential and other urban uses	41	42	17	115	2.02	2.69
Townships 6-29% urban	15	41	44	39	1.90	2.74
Townships more than 29% urban	0	22	78	23	2.00	2.65

15 miles beyond the city edge, they accounted for 19 percent. The difference seems related more to the urbanization process than to topographical differences, since some of the urbanized townships are in the moraine belt, where lowland hardwoods normally would be less frequent than on lake bed areas, and Avon Township is partly in the lake bed section. Apparently, lowland hardwood stands, occurring on wet ground, survive longer than types occurring on land that is more suitable for

building. It is still not clear why the forests in urbanized areas do not have significantly lower densities and diameter classes (as Table 9 confirms), since lowland hardwoods were shown to have lower values in these respects than the other deciduous types (Table 8). One possible explanation might be that lowland hardwoods in urban areas do have fairly high values as to density and diameter class, but that lowland hardwoods in rural areas are frequently cut over and therefore have low values, thus producing low average values for the whole study area, much more of which is rural than urban.

Distribution of "First-class" Forests

All forest patches of both the highest density and highest diameter classes (designated "9" in a scale from 1 to 9 on the Oakland County vegetation map) in the Oakland County part of the study area were classified by type, distance from the Detroit CBD, and land use. As Table 10 shows, these forests were preponderantly oak-hickory, about twice as many as would be expected according to the proportion of this type among all forest patches in the sample. By distance, first-class forests were underrepresented at distances up to 39 miles, and overrepresented from 40 to 49 miles. By land use, a disproportionate number of first-class forests were on farms or recreational land (Table 11). These results are attributed to the relative concentration of first-class forests on sandy moraines in the northwest part of the county, where oak-hickory forests are especially prevalent.

TABLE 10

FIRST-CLASS FORESTS BY DISTANCE FROM THE DETROIT CBD, OAKLAND COUNTY, 1964

Distance from CBD (miles)	Number of patches	Number by type			Percent of Total							
					All forest		K		W		E	
		K	W	E	Sample	1st-class forests	Sample	1st-class forests	Sample	1st-class forests	Sample	1st-class forests
10-19	0	--	--	--	3	0	0	--	0	--	100	--
20-29	30	12	9	9	20	15	11	40	41	30	78	30
30-39	91	60	27	4	53	45	30	66	46	30	22	4
40-49	80	55	9	16	23	40	50	69	31	11	17	20
Total area	201	127	45	29	99*	100	29	63	38	22	30	14

*Not 100 due to rounding.

TABLE 11

FIRST-CLASS FORESTS BY LAND USE, OAKLAND COUNTY, 1964

Land use	Number of patches	Percent by type			Percent of 1st-class forests on land-use type	Percent of sample plots in this land use
		K	W	E		
Open space	109	68	21	20	54	54
Agriculture	48	30	13	5	24	17
Recreation & conservation	38	25	9	4	19	7
Extraction	3	3	0	0	1	1
Public & quasi-public	3	1	2	0	1	1
Total	201	127	45	29	99*	80

K = oak-hickory; W = mixed hardwoods; E = lowland hardwoods
*Not 100 due to rounding

c. Size of City and Distribution of Forests

In the investigation of six midwestern cities it was noted that a peak in forest and brush percentage occurred at some intermediate distance outside most of the cities and that the distance of the peak from the CBD was related to the size of the city, the peak occurring farther out around the larger cities. Data from the Detroit region suggest that these phenomena occur similarly around smaller cities.

Figure 12 shows that such peaks occurred northwest of Detroit, southeast of Flint, and around Ann Arbor, in both 1937 and 1963-64. The data for Detroit and Flint come from the Detroit study area. The data for Ann Arbor consist of a random sample of four sections per township (an 11 percent sample), within Washtenaw County, to a distance of 15 miles from the CBD. The approximate populations of the metropolitan areas (not SMSAs) in the two years were: Detroit, 2,500,000 and 3,500,000; Flint, 148,000 and 200,000; and Ann Arbor, 27,000 and 80,000.

It is interesting to speculate about how small an urban place can generate this forest ring effect. Probably it partly depends on how far the town lies from a larger city, which could amplify the ring effect either by encouraging forest increase near the smaller place or by decreasing the amount of forest near the larger city. Such an effect probably occurs in the case of the cities above. Land values and uses around Ann Arbor are probably affected somewhat by the influence of Detroit, whose CBD is only about 30 miles away. And the drop in percentage of forest beyond 35 miles from Flint probably can be attributed to the building around Pontiac and Detroit.

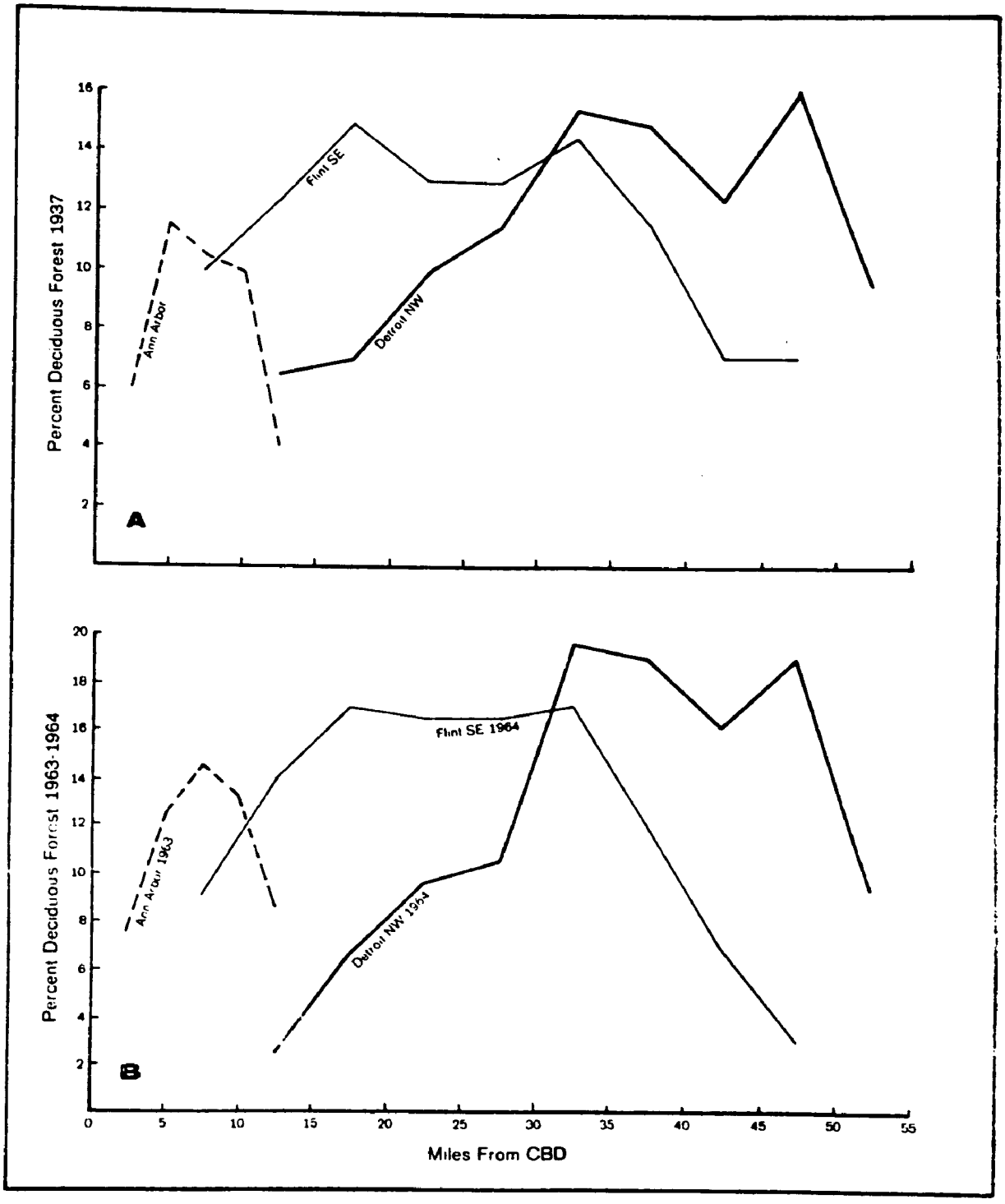


Fig. 12.--Percent deciduous forest by distance from the central business district, Ann Arbor, Flint, and Detroit, Michigan, 1937 and 1963-64.

3. Vegetation and Time

a. Hypothesis

If changes in vegetation over distance resemble changes in vegetation from more rural to more urban land uses, changes over time should be similar to both. At a given location, as the city grows, land use should become more urban and, at locations outside the city, distance to the city edge should decrease. The relationship can be hypothesized as follows: Vegetation changes over time parallel changes between land use zones and changes over distance.

b. Test of the Hypothesis

To test this hypothesis, mean values for various vegetation characteristics in the northwest study sector for 1937 and 1964 were compared, as were means within 5-mile distance bands. Table 12 presents the results for the study area as a whole. The predominant land use in 1937 was agriculture, in 1964 undeveloped open space. Vegetation changes between 1937 and 1964 should resemble the differences associated with agriculture and open space, according to the hypothesis. Comparison of Tables 12 and 6 indicates that this holds true for each vegetation characteristic measured for both years.

The city edge advanced an average of about eight miles during the 1937-64 period. Since the mean distance of plots from the CBD is about 38 miles, the change in vegetation between 1937 and 1964 should be similar to the change from 38 miles to 30 miles in 1937. This can be tested fairly well by comparing Table 12 and Figures 9-11. This comparison affirms the expectation except in the case of tree distribution, which has an anomalous peak on the graph for 1937.

TABLE 12

VEGETATION CHANGES, 1937-1964, DETROIT STUDY AREA

Vegetation characteristic	1937 (avg. per plot)	1964 (avg. per plot)	Percent change	Significance level, difference between means
Percent deciduous forest	12.3	14.3	+16.3	.91
Percent brush	5.5	10.8	+96.4	.99
Percent herbaceous	72.9	52.3	-28.3	.99
Number of types	2.57	2.76	+ 7.4	.99
Number of patches	4.08	4.88	+19.6	.99
Tree distribution	1.50	1.82	+21.3	.99

c. Interpretation of Results

Vegetational Changes in the Total Study Area

As noted earlier, the changes in vegetation for the total study area can be attributed largely to a shift from predominance of agriculture to predominance of undeveloped open space. By 1964 residential use still occupied only 15 percent of the area. The large herbaceous area lost shifted mainly to residential vegetation and brush. The greater increase of brush than of deciduous forest reflects a difference in speed of development of the two types. After abandonment of cropland or pasture, brush may take over in as few as five years; young forest usually doesn't develop for 20 or more years (Beckwith, 1950). Diversity, as measured by number of vegetation types and number of patches,

increased significantly. In large part this can be attributed to the more frequent occurrence of brush. On most plots where farming predominated, brush was absent. With the shift from farming to undeveloped open space, brush commonly developed. This land-use shift also helps to explain the more scattered distribution of trees in 1964, though increase of residential area is also an important factor.

Orchards and coniferous stands have not been discussed previously because they occurred so infrequently in the sample. But these types are of some interest for their aesthetic and wildlife value, not to mention their economic value. Between 1937 and 1964, the proportion of the study area in orchards dropped from 0.8 percent to 0.2 percent. The primary fruit-growing area in 1937 was the townships immediately south and west of Pontiac. Most of this activity ended during the next three decades, but numerous fruit trees remain here in subdivisions today. Only in the northwest part of the study area did orchards maintain their 1937 significance.

Coniferous forest, on the other hand, increased from less than 0.1 percent of the area in 1937 to 0.2 percent in 1964. This can be attributed largely to plantings of red, Scots, and jack pine, encouraged by programs of the U.S. Soil Conservation Service and the Michigan Department of Natural Resources. The area of swamp conifers (white cedar, tamarack, and spruce) probably did not change much, and no wild stand of white pine large enough to be mapped occurred in the sample plots. The actual area of conifers in 1964 might have been as high as 1 percent, since many of the pine plantations are less than 5 acres in extent (and hence escaped my sampling procedure).

Planted residential vegetation increased over the period from 3.0 percent to 15.0 percent, in accordance with the spread of urban growth. The non-vegetated area rose from 0.1 percent to 0.7 percent, mostly because of new roads and buildings. And, interestingly, water area increased from 4.1 percent of the total area to 4.3 percent; assuming this is real and not just a measurement error, it probably indicates that dredging and enlarging of ponds and creation of boat channels along lake edges exceeded draining of ponds.

Vegetational Changes Within Distance Bands

On Figures 9-11, which show vegetation characteristics by 5-mile bands for 1937 and 1964, it can be seen that deciduous forest decreased slightly up to 30 miles, and increased considerably beyond 30 miles. Brush has a similar pattern, except that it increased beyond 25 miles. The 25-30 mile band was largely agricultural in 1937; in 1964 it was a transitional zone between city and countryside. Between the two years forest destruction in this band exceeded forest spread, while spread of the faster-developing brush exceeded its destruction. Herbaceous area decreased at all distances, but the amount of decrease was greater near and in the urbanized area, where the change in land use was greater. The decrease at the farthest distances, where agriculture still prevailed in 1964, indicates a drop in area devoted to farming, reduced intensity of farming, or both. Number of types and number of patches increase over the period beyond 25 miles, the approximate location of the 1964 city edge. Tree distribution becomes more scattered at almost all distances, indicating increased residential area, some loss of

distinction between the vegetation types, and, in much of the area, a move toward the nearly solid forest that would occur if all the land were left idle.

Changes in Number and Size of Forest Patches

Of the 297 forest patches (including a few coniferous) present on the sample plots in 1937, 150 increased in size, 42 stayed about the same, 57 decreased, and 48 had disappeared by 1964. In addition, 60 new forest patches had developed. The total in 1964 was 299 patches (the number was not 309 because of splitting and joining of patches). The slight net gain in total number of forest patches resulted from greater increases in the middle distances than decreases near Detroit and Flint. New patches of forest generally developed from former brush areas, though some are due to spread of forest patches too small to map in 1937. Decrease in number of forest patches occurred through cutting and the joining together of two or more patches.

Average size of forest patches in the sample in 1937 was about 48 acres; in 1964, 57 acres. In 1937, the largest single forest, located in Metamora Township in Lapeer County, covered about 620 acres. By 1964 it had expanded to about 740 acres. The largest forest in 1964, located in Orion Township, Oakland County, covered about 850 acres, and it extended across roads to well over 1,000 acres. The average size of forest patches lost was about 16 acres, though one was about 90 acres. This indicates that small patches of forest are much more likely to be removed than are large patches. New patches averaged about 25 acres.

Table 13 presents data on distribution, type, and replacement vegetation for forest patches. Nearly two-thirds of the forest patches lost were replaced by subdivisions. Brush and herbaceous vegetation replaced the rest. Forests were not typed for 1937 (except for the deciduous-coniferous division), but the types of forest remaining in 1964 give a clue to the types most frequently removed. In the 10-to-29 mile zone, where most of the building and loss of forests occurred, lowland hardwoods (elm-ash-soft maple) in 1964 accounted for two-thirds of the stands. Oak-hickory, however, is considered the predominant natural forest in this area (Bingham, 1945; Findell, et al., 1960). This supports the contention made earlier that development between 1937 and 1964 took mostly oak and mixed hardwood forests and avoided the wetter lowland forests.

Vegetation changes in the study area over distance and time thus parallel differences in vegetation between land use areas, and show that there are regularities in vegetation patterns that parallel regularities in land use zonation around cities. We will now look at some factors other than distance and time that can have an important influence on land use and thus on vegetation distribution.

4. Influence of Physical and Economic Factors

Among the factors mentioned in Chapter I that apparently influence a landowner's use of his land are its physical character, its monetary value, and the owner's income and occupation. In this section the relationship of these variables to vegetation characteristics are measured directly, and the ways they may affect land use are discussed in the interpretations.

TABLE 13

NUMBER, TYPE, AND REPLACEMENT TYPE FOR FOREST PATCHES,
BY DISTANCE FROM DETROIT CBD

Distance from Detroit CBD (miles)	Number of town-ships	Number of patches		Percent change	Major replacement type (no.)*			Number by type, 1964, Oakland Co.*				
		1937	1964		PR	B	H	K	W	E	Pine	Swamp conifer
10-19	3	19	12	-37	10	--	--	--	--	6	--	--
20-29	5	54	46	-15	17	1	3	3	11	21	2	--
30-39	8	96	108	+13	1	3	1	29	44	21	--	2
40-49	9	90	97	+ 8	--	4	2	21	13	7	1	--
50-57	6	38	36	- 5	2	2	1	--	--	--	--	--
Total area	31	297	299	+0.7	30	10	7	53	68	55	3	2

*PR = planted residential; B = brush; H = herbaceous; K = oak-hickory; W = mixed hardwoods; E = lowland hardwoods.

a. Physical Factors

The physical variables tested were percent wetland, predominant soil texture, relief, and predominant land form, most of which were recorded for all plots. Relationships between vegetation variables and percent wetland and relief were measured by obtaining correlation coefficients. Relationships between vegetation and soil texture and landforms were measured by testing the difference between means for each soil texture type and landform class with respect tc each of the vegetation variables. Percent wetland and landform type appeared to have a closer relationship to vegetation than did relief and soil texture.

Wetland and Relief

Table 14 presents correlations between vegetation variables and percent wetland and amount of relief. These data indicate that on the wetter plots tree cover is much greater, density and diameter class (and therefore height) of forest patches is greater, and percentage of brush and deciduous forest is somewhat higher than on drier plots. The results for density and diameter class appear to contradict earlier findings (pp. 70, 72). Amount of relief appears to have only slight influence on any of the vegetation characteristics. Apparently, the steepness of most of the land in the study area does not reach the magnitude it does in the Pittsburgh, Cleveland, and Cincinnati regions, where this variable appeared to have a strong influence on the percentage of forest and brush.

The relationship between percent wetland and amount of relief and occurrence of forest patches was tested by classifying forest

TABLE 14

CORRELATIONS BETWEEN VEGETATION, WETLAND, AND RELIEF

Vegetation characteristic	Percent wetland (correlation coefficient)	Relief (correlation coefficient)
Percent deciduous forest	.22	.17
Percent brush	.29	.18
Percent herbaceous	-.31	.11
Number of types	.17	-.04
Number of patches	.17	.01
Total tree cover	.78	.11
Tree distribution (from less to more scattered)	.05	-.15
Size, first forest patch in plot	.21	.10
Density, first forest patch in plot	.55	.13
Diameter class, first forest patch in plot	.55	.16

patches by wetland and relief categories. The data were obtained from U.S.G.S. 7 1/2-minute quadrangles, 1968 and 1969. "Wetland" was the area covered by the marsh-swamp symbol. Here again wetland had much the greater significance. Forty-four percent of forest patches were 30 percent or more wetland, while only 16 percent of all the sample plots consisted of more than 25 percent wetland. Sixty-six percent of the forest patches contained some wetland. The amount of relief within forest

patches was distributed about the same as relief on all the sample plots, after adjusting for the greater size of the plots, thus indicating little tendency for forests to be concentrated on the hillier ground.

The obvious interpretation concerning wetland is that wet areas are often left alone by farmers, developers, and other landowners, and therefore support wild vegetation. In many cases this is some type of brush or forest.

Landform

Table 15 presents data on selected vegetation characteristics by type of landform. These data can be interpreted best in terms of land use-landform relationships. Moraines ranked second in percent deciduous forest and percent brush, and last in degree of scatteredness of trees. These results may be attributed to the somewhat marginal character of agriculture and the high proportion of recreation land that occurs on moraines. Outwash ranks first in percent brush, number of types, and number of patches. Outwash tends to have sandy and/or wet soils, and these lands would likely be among the first to shift out of farming under the pressure of urban influence. About two-thirds of the outwash area was undeveloped open space in 1964, the kind of situation in which "patchiness" is likely to develop. Till plains ranked second in percent herbaceous and were intermediate in other categories. These facts seem attributable largely to the tendency of agriculture (45 percent of the till plain area) to favor this type of landform. Lake bed (ponded water) had the anomalous attributes of being first in both percent deciduous forest and percent herbaceous, these two categories accounting for 91

TABLE 15

VEGETATION AND LANDFORM*

	Moraine (n=204)	Rank	Outwash (n=118)	Rank	Till plain (n=114)	Rank	Lake bed (ponded waters) (n=30)	Rank	Lake bed (sand) (n=48)	Rank	Lake bed (clay) (n=6)	Rank	Waterlaid moraine (n=20)	Rank	Significance level, all means not equal	No. of pairs significance level .95 or more (21 total pairs)
Percent deciduous	15.6	2	15.1	3	10.2	4	17.4	1	9.1	5	0	7	5.5	6	.99	12
Percent brush	8.9	2	9.9	1	6.7	3	5.0	4	8.9	2	3.6	5	2.9	6	.94	4
Percent herbaceous	65.9	3	52.8	4	72.4	2	73.9	1	49.4	6	40.9	7	50.7	5	.99	13
Number of types	2.6	3	2.9	1	2.6	3	2.6	3	2.8	2	2.2	5	2.3	4	.99	5
Number of patches	4.3	3	5.3	1	4.1	4	3.6	5	5.0	2	3.0	6	5.0	2	.99	6
Tree distribution	1.5	6	1.8	4	1.6	5	1.5	6	2.0	3	3.0	1	2.5	2	.99	13

*Entire sample, both years combined.

percent of the area. This landform type is used mostly for agriculture (80 percent), but perhaps has a number of wet areas where forest remains. The vegetation characteristics of lake bed (sand), lake bed (clay), and waterlaid moraine seem related to their use primarily as residential areas (southeastern Oakland County).

Soils

The relationship between soils and vegetation was examined on the plots in Lapeer and Genesee counties only, since a soil survey of Oakland County had not yet been made. The part of the study area in Lapeer and Genesee counties was about 66 percent agricultural and 27 percent open space in 1964, with a sprinkling of other uses. Sandy loam ranked first in percent herbaceous, reflecting a preference of agriculture for this soil type (Table 16). Loamy sand and muck took first place in the other vegetation categories, indicating abandonment or avoidance of these types by agriculture. The loam areas, which have more wetland than sandy loams do, were somewhat less favored for agriculture than the sandy loams, and consequently had intermediate rankings for all the vegetation characteristics.

b. Economic Factors

Land Values

Within the study area, as in urban regions generally, land values decline with distance from the city. This is demonstrated by correlation coefficients between land value and distance from the Detroit CBD (-.29) and land value and distance from the Detroit edge (-.50). Therefore land values might be expected to have the same kinds

TABLE 16

VEGETATION AND SOIL TEXTURE[a]

	Loam (n=106)	Rank	Sandy loam (n=30)	Rank	Loamy sand (n=14)	Rank	Muck (n=14)	Rank	Significance level, difference among means[b]
Percent deciduous	12.4	3	10.3	4	14.3	2	19.9	1	.88
Percent brush	4.9	4	5.7	3	16.7	1	9.7	2	.99
Percent herbaceous	76.3	2	79.6	1	64.1	3	58.5	4	.99
Number of types	2.5	2	2.5	2	2.6	1	2.6	1	.14
Number of patches	3.6	2	3.3	4	3.7	1	3.5	3	.70

[a]Means are for 1937 and 1964 combined, Lapeer and Genesee counties.

[b]Includes clay loam (n=4) and silt loam (n=6) as separate categories. Not listed above because of small sample sizes.

of relationships with vegetation that distance does. As Table 17 indicates, this is generally true; where correlations between a vegetation characteristic and distance are high, the correlation with land value is usually also fairly high; where the correlations with distance are low, the correlation with land value also tends to be low. But the relationships between vegetation and land value in most cases are not as strong as those between vegetation and distance, particularly distance from the city edge.

The rather high correlations for density and diameter class of forests (which indicate these have higher values near the city) agree

with the finding(on p. 85) that wetness is correlated with density and diameter class, since forests near the city were shown (Table 9, page 74) to be primarily lowland hardwoods; but they contradict the density and diameter data in Table 9, which indicate that these variables do not have higher values near the city.

TABLE 17

CORRELATIONS BETWEEN VEGETATION AND AVERAGE PRICE OF FARMLAND, DISTANCE FROM THE DETROIT CBD, AND DISTANCE FROM THE DETROIT EDGE

Vegetation characteristic	Average price of farmland, 1964-66*	Distance from Detroit CBD	Distance from Detroit edge
Percent deciduous forest	.01	.12	.06
Percent brush	.10	.02	-.12
Percent herbaceous	-.29	.36	.50
Number of types	.11	-.05	-.12
Number of patches	.17	-.19	-.27
Total tree cover	.36	0	-.37
Size, first forest patch in plot	0	.12	.07
Density, first forest patch in plot	.43	-.09	-.34
Diameter class, first forest patch in plot	.48	-.11	-.36
Tree distribution	.12	-.29	-.34

*Source: Oakland County Planning Commission, map of isovalues, 1966a. Data for Oakland County only.

Income and Occupation

It was suspected that some relationship might exist between the affluence and occupations of people in an area and the total amount of tree cover. One tends to think of the more expensive residential areas, for example, as consisting of large lots with many trees. The township data did not support this picture, however. Within townships 35 percent or more urbanized (5 townships), Bloomfield, with the highest median income in 1960 did have the largest value for tree cover (23.0 percent) (Bureau of the Census, 1960). But Southfield, with the second highest median income, had the lowest amount of tree cover (17.7 percent). Between these narrow limits, the order of the other townships was equally scrambled. In the non-urban townships, tree cover ranged from 5.6 percent to 37.6 percent, but again bore no apparent relationship to income. Similarly, percentages of various occupation groups correlated very poorly with percentage of tree cover. Perhaps within smaller units of measurement a significant correlation between income, occupation, and tree cover could be detected, but it did not show up at the township scale.

5. Summary

The distribution of vegetation characteristics in the Detroit study area depended largely on the distribution of land uses, which in turn was closely related to distance from the central business district, and secondarily to local topography. Outward from the city, the character of the vegetation thus reflected the diminishing influence of urbanization, and the increasing influence of agriculture.

In most of the Detroit area, as in most of eastern United States, forest is the potential wild vegetation. The major agents retarding or eliminating forest are agriculture and urban growth. In the transition zone between the city and predominantly agricultural land, forest and its predecessor, brush, get a temporary reprieve from the twin pressures. The extent to which the wild vegetation increases depends on the length of time it takes urban expansion to occupy former agricultural land.

In the shift from agriculture to the transition (or open space) stage in the study area, specific changes were: a decrease in herbaceous area and increases in brush and forest area, total tree cover, dispersion of tree cover, average size of forest patches, and diversity of vegetation (number of types and number of patches). In the residential stage, herbaceous area declined further; sharp drops occurred in brush and forest area, total tree cover, average size of forest patches, and number of vegetation types; and dispersion of trees increased.

The influence of local topography seemed to occur primarily in the 1964 transition, or open space, zone, where numerous wet areas boosted the percentage of forest and brush. These wet areas of the moraine belt appear to have been responsible for keeping the peak of forest percentage in that distance zone in both 1937 and 1964, instead of allowing the peak to move farther out, as would be expected. Apparently, physical aspects of the land have a much greater effect on the distribution of forest than on the distribution of faster-developing types of vegetation such as brush. One can conclude that vegetation changes over time at a given distance from the city are more predictable

than changes over distance, which may be strongly affected by topography. Appendix III presents the basic vegetation data, by quarter-sections.

In the next chapter, the ways in which land use is related to vegetation will be explored in more detail, and an outline of urbanization-vegetation relationships will be presented.

CHAPTER V

TOWARD AN EXPLANATORY MODEL OF URBANIZATION-VEGETATION RELATIONSHIPS

A. Introduction

Having described vegetation patterns over space, time, and by associated land uses, and having shown that all three methods of description are interrelated and roughly interchangeable, I will attempt to use these findings, along with data from maps, published literature, and interviews, to produce a coherent description of the ways that urbanization changes vegetation patterns. Because of the many factors involved and the many possibilities in any given area, this account will necessarily be generalized and somewhat speculative. For the sake of simplicity, we will assume a fairly homogeneous terrain.

Some of the insight into ways land use affects vegetation was gained through interviews with landowners and personal inspection of their properties in the summer of 1971. Twenty-six properties or quarter-sections were visited, and 23 landowners or managers were interviewed.

The following kinds of information were sought in the interviews: (1) how various parts of the property were being used, and why; (2) species of wildlife observed on the property and their abundance; (3) former owners and their use of the land; (4) characteristics of the

present owner: occupation, age, proportion of income from the property; (5) occupants of the property; (6) future plans for the property; and (7) owners and uses of adjacent land. During inspection of properties, notes were taken on vegetation, especially trees and forests, and on wildlife. In some cases, forest stands were sampled to determine the dominant species and wildlife counts were made.

In addition, questionnaires about policies and practices concerning removal of trees and other natural vegetation were sent to 25 of the most-active developers in the Detroit-Flint area. These were selected by a person familiar with homebuilders in the Detroit area from a list of members of the National Association of Homebuilders. Twelve of the 25 responded. The questionnaire asked about (1) how decisions were made to keep or remove trees; (2) how these decisions were related to the type or cost of housing; (3) existing regulations in the Detroit-Flint area concerning removal of trees; (4) whether the company ever preserved part of a development in a natural state; and (5) any changes in recent years in the company's practices with regard to the above questions.

Our exploration of the relationships between the urbanization process and vegetation change will be channeled through the three major land-use zones defined in Chapter II: agricultural, transitional, and residential. Within each zone a number of sub-classes could be identified; for our purposes, only the transitional zone will be "subdivided" --into several types of land, among which rural residential and land in speculation are the most important.

B. The Agricultural Zone

Many American metropolitan regions, and especially those in the Midwest, have developed within agricultural country. The vegetation such cities inherit, to shape or destroy as they will, is essentially that of the agricultural zone, because, as will be argued later, vegetation patterns usually are not changed radically in the transitional stage between farming and city development.

The agricultural zone, defined in Chapter II as the area in which farming is the dominant land use, may begin almost at the city's edge or many miles out, depending on the size of the city, zoning, and a number of other factors. Many types and degrees of farming, as well as sizes of farms, may occur; and other land uses will be scattered through the zone. We will consider here the vegetation of a typical farm of about 200 acres, on which livestock and crops are raised, and whose owner gets most of his income from farming. Other types of farming more common in the transition zone will be considered in the appropriate place.

The vegetation of this typical farm is clearly defined and distinctly separated into different kinds of patches. Row crops, hayfields, pastures, and woodlots each have their distinctive character and an internal homogeneity. Weedy or brush areas are few and small, generally occupying rough or wet ground or field borders. In most parts of the farm, weeds and woody plants are kept in check by plowing, competition from planted vegetation, or grazing. (On the Detroit sample plots it was noted that many wet areas that had herbaceous vegetation in 1937 had developed brush by 1964. This change was interpreted by one farmer as

resulting from the removal of livestock.) Trees are confined largely to woodlots, the farmyard, and some fencerows.

The woodlots are a legacy from the past, remaining where earlier farmers decided they should be. For the most part, they are on wet or hilly ground unsuited for crops, or else in a far corner of the farm, where they do not hinder wagons coming from the fields, leaving land nearer the farmhouse for the uses which require more frequent visits. The canopy of most woodlots is about 60 to 80 feet above the ground, and many of the trees are a foot or more in diameter. The farmer cuts occasional trees for lumber or firewood, and if he feels financially pressed he may allow a timber company to cut all the trees over a certain size. He is apt to have a fondness for his woodlots--for their beauty, wildlife, and history--but he does not allow this to override his essentially economic attitude toward them, an attitude which extends to all his land except possibly the part of the farmstead around his house.

A study of woodlot owners in Washtenaw County, Michigan (Clark, 1970) emphasizes the farmer's essentially economic attitude toward his woodlots. The 54 people interviewed were divided into two groups: those who got little or no income (less than 25 percent) from farming and those who got most or all of their income (90 percent or more) from farming. The sample was also divided according to whether or not the owner gave liking for trees as a primary or secondary reason for keeping his woodlots. Those who gave this reason were called the aesthetic group; the rest were called the practical group. Among the "practical" reasons for keeping woodlots rather than clearing them were: the expense or trouble of clearing land, land not good for farming, farm

labor shortage, saving for future real estate value, and satisfactory current cash return on trees. Eighty-two percent of the farmers were in the practical group, as opposed to only 52 percent of the non-farmers.

On balance, the farmer is an agent working against diversity of vegetation. Although he may add something by planting conifers in a corner or two, his net effect is to hold down the number of types of vegetation. Brush seldom is allowed to develop on farmland, and marshes are likely to be drained. The farmer also holds down diversity of species. His fields are usually each planted to one species, his pastures to one or two. Cultivation and herbicide application also reduce the number of species present. The farmer works against diversity of species in his woodlots by selective cutting of trees and sometimes by allowing livestock to graze there.

The landscapes of the agricultural zone are generally open and rather neat, though seldom as neat as the older agricultural landscapes of Europe or Asia. To the farmer, weeds and brush are a sign that nature is getting the upper hand over man, and that the land is not being made to produce what it could.

The agricultural zone thus has a certain uniformity of uses and characteristic vegetation patterns consisting mostly of herbaceous fields and sharply distinct woodlots. This uniformity and distinctness becomes blurred in the chaos of the transition zone.

C. The Transition Zone

If uniformity characterizes the vegetation and landscapes of the agricultural zone, diversity is the key word of the transition zone. For here there is a multiplicity of land uses and types of landowners,

an increase in the number of types of vegetation and perhaps of plant species, and a greatly increased patchiness of the landscape.

The vegetation of this zone is characterized by an increase in brush, a decrease in herbaceous area, and an increased number of vegetation types and patches. Whether the forest area increases or decreases depends on the balance of land uses and the speed of urban development in the zone. The increase in brush is due primarily to the large amount of idle land, the decrease of herbaceous vegetation to the encroachment of buildings and brush, and the increased number of vegetation types and patches largely to the greater frequency of brush and to new residential areas.

The diversity of vegetation may also be attributed in part to the increased number of people in this zone, occupying smaller pieces of land, on the average, than exist in the agricultural zone. With so many decision-makers, most of whom derive most of their income from sources other than their land, many kinds of land uses become possible, and thus a variety of vegetation is likely to develop. Many residents of this zone stress aesthetic values more than strictly economic ones, and thus tolerate--or in some cases even promote--the growth of weeds and brush. Many plant conifers for their appearance, usefulness to wildlife, or for timber or Christmas trees. (Properties on which conifers planted for timber or Christmas trees bring in only incidental income are not considered farms in this study.) So the basic vegetation pattern of agricultural days is kept, and new types are intentionally added or allowed to develop.

Landscapes of the transition zone are thus more broken and patchy than those of the agricultural zone. They are also more "closed in" by the growth of weeds, brush, and many scattered trees. But the essential vegetation structure of the agricultural zone remains. Most of its woodlots survive, and much of the herbaceous area remains, though now in goldenrod and queen-anne's-lace instead of corn and alfalfa.

We will now consider specifically some of the types of land use in this zone and how they affect vegetation.

1. Rural Residential Use

Much of the land of the transition zone is owned by people who live on their property but work elsewhere. Many have gardens and keep a field or two in crops, either through their own efforts or some local farmer's, to help pay the property taxes, and some support a cow or pigs, but for the most part these people simply enjoy their land rather than work it. Many such properties qualify as farms under the inclusive Census of Agriculture definition, but here they are not considered farms.

The effect of this type of use on vegetation is intermediate between the effects of agriculture and complete idleness. Typically, such properties are pieces of former farms. As mentioned, a field or two may be continued in crops, but some of the former cropland will probably be left idle. Here weeds, later brush, and perhaps, eventually, trees develop. Stephen Beckwith (1950) investigated plant succession on abandoned cropland in northern Washtenaw County, just west of the study area, and found that if undisturbed it went through five stages in the first 25 years or so. Annuals and biennials, such as black bindweed,

common ragweed, and prickly lettuce, were the dominants 1 to 4 years after abandonment. Perennial grasses, such as Canada bluegrass, Kentucky bluegrass, and quackgrass, dominated from 2 to 10 years. Mixed herbaceous perennials, such as asters, goldenrods, and common yarrow, predominated 4 to 20 years after abandonment. The shrub stage, in which staghorn sumac, smooth sumac, blackberries, and gray dogwood occurred most commonly, dominated 5 to 25 years after abandonment. And an intolerant (to shade) tree stage, typically with American elm, black cherry, and hawthorn, developed in 20 or more years. Of course, succession varied from one place to another depending in part on the last crop planted, soil conditions, and available seed sources.

The tendency of rural non-farmers to leave their woodlots alone is revealed in the study by Clark (1970) as well as my own. The study did not detail the ways non-farmers used their woodlots, but there was a clear implication in the data that these uses were less consumptive than those of farmers. Of 22 non-farmers interviewed, 55 percent kept their woodlots for non-economic reasons, chief among which was simply that they liked trees. Several others kept them for their future value as residential sites. Only 22 percent of the farmers kept theirs for non-economic reasons. Fourteen percent of the non-farmers, versus 59 percent of the farmers, had plans to clear part or all of their woods. The less-intensive use of woodlots by non-farmers suggests that these stands are more apt to spread and become taller and denser, with more dead trees, than those on farms. If the former owners had allowed grazing in the woods, the ground cover and shrubs could now recover. My field work suggested that the number of owners of an individual forest

patch tended to be greater in the transition than in the agricultural zone, and the fragmentation of land would also imply this. But there was no apparent tendency toward fragmentation of forests, but rather a tendency toward increased size. This fact, too, seems to reflect the preservationist attitude of rural residential people toward their woodlots.

Pond-building and conifer-planting are popular activities with rural non-farmers. The net effect of pond-building is probably to reduce the area of marsh, since drainageways and wet places are selected for pond sites. Conifer-planting usually increases vegetative diversity, since wild conifer stands are scarce or lacking in some urban regions (such as around Detroit).

2. Speculation

Much of the land held by speculators is left idle, and if held long its vegetation can change markedly. The outskirts of many large cities are marked by old fields springing up in brush, whether it be sumac and gray dogwood around Detroit or red cedar around Washington.

Woodlots on speculatively held land may be even more likely than those on rural residential property to increase in density, height, shrub and ground cover, and number of dead trees. Not knowing the wishes of potential developers with regard to trees and forests, and perhaps because of the expense involved in tree removal, speculators generally let them stand.

3. Other Uses

Though rural residential and speculation are the predominant land uses, the transition zone is replete with other uses. The effects of some of these will be briefly discussed.

Creation of parks usually preserves woods and sometimes allows them to spread. Herbaceous and brushy areas may be converted to grassy play areas. The latter possibility is more likely in parks near or in the city. Creation of ponds or lakes on parkland of course wipes out large areas of wild vegetation. In some parkland, vegetation is managed to enhance aesthetic appeal of the landscape and to benefit wildlife. For example, in the Holly State Recreation Area, in northwest Oakland County, about 20 areas of open meadow are maintained to provide visual variety and for wildlife. Strips of corn, barley, buckwheat, and other grains are planted for wildlife food.

Establishment of country clubs generally includes the building of golf courses. The vegetation of golf courses is quite similar to that of parks near or in the city. Fields and brush give way to fairway grass and "rough" grass. Some trees are removed to give the golfer a better chance. But forest stands usually remain.

The vegetation of cemeteries ranges from lawn grass to wild forest. Most smaller cemeteries are a mixture of grass, shrubs, and scattered trees, like typical residential yards, but some large cemeteries preserve considerable forest. Holy Sepulchre Cemetery, in Southfield Township, Oakland County, in some ways resembles a miniature national park. Among members of the large staff are administrative people, a maintenance crew, and a landscape foreman, who is also something

of a wildlife manager. The cemetery's 373 acres consists not only of grassy grave areas, but also of fields held in reserve, a tree nursery, ponds, and extensive woods. An astonishing variety of wildlife (including deer and foxes), lives on or uses the property. Within the 160-acre piece of the cemetery investigated, one part was lawn-type grass with graves; another was former cropland now mostly wild grasses; another was a former hayfield now largely covered with sumac, black cherry, sassafras, aspen, and cottonwood; and the rest was a 50-acre mixed hardwood forest with some trees two feet in diameter and with well-developed understory and shrub layers. Some saplings were removed from these woods for use as plantings, but otherwise the forest was not disturbed, and the plans were to keep it that way.

The relatively small amount of agriculture that occurs in the transition zone is mostly either low-intensity part-time farming or very high intensity farming such as truck gardening or sod-growing. The part-time farms can be expected to have vegetation rather similar to that of rural residential properties, but with more cropland. Most of the high-intensity farms, such as sod farms, have little wild vegetation; with the high taxes in this zone they can't afford to.

One especially interesting sort of situation, more frequent near eastern cities, is the deliberate attempt of the residents of an area to maintain rural conditions. An example of this in the Detroit region occurs in southern Lapeer County, about 40 miles north of the Detroit CBD. Here, in much of Metamora and Dryden townships, members and friends of members of the Metamora Hunt do their utmost to discourage development, encourage conditions favorable for foxes, and generally

preserve a rural, slightly unkempt atmosphere. They fiercely resist the paving of roads, some of which, in fact, are little more than lanes. Within an area of about 30 square miles, some 80 percent of the land is owned by members of the hunt club or their friends. Farmers in the area raise primarily corn, wheat, and oats. Members of the club raise some hay but few field crops. They let brush grow and cut very few trees from their woods. There are some conifer plantations. Such preservation efforts may be successful for a long time, keeping a pleasant landscape and safeguarding forests as the city approaches.

Scattered subdivisions occur also in this zone, but this type of use will be considered in the next section.

D. The Residential Zone and Commercial Core

The residential zone is defined as the area in which residential use occupies the greatest amount of land. Somewhere along the inner edge of the transition zone, building density increases rapidly, and over a rather short distance the patchiness and apparent confusion of the landscape give way to the uniformity of subdivisions. We have entered the outskirts of "the city."

The vegetation of the residential zone is characterized by a lack of variety (as defined in the study), a sharp decrease of all types of wild vegetation, some decrease of total tree cover, and greatly increased dispersion of tree cover. Toward the CBD, residential land use increases and then decreases as the commercial core is approached. Forest, brush, and herbaceous areas decrease toward the CBD, as the

proportion of land in vacant lots declines, although the proportions of forest land may vary widely from one city to another, depending on the distribution of parkland. Diversity of vegetation decreases along with the reduction in number of vacant lots. The total tree cover may decrease or increase, depending on the relative effects of smaller lots, increased building and road density, and increased age and cover of individual trees.

The vegetation of the city is the result of planting; nature working on neglected places such as vacant lots, railroad rights-of-way, and streambanks; and decisions by developers, homeowners, and public and private agencies and institutions about the vegetation that is inherited from the transition zone. Developers play the most critical role in the absorption of urban fringe vegetation into the city. To gain some understanding of developers' effects on vegetation patterns I sent a questionnaire to 25 developers and builders in the Detroit-Flint area. The following discussion is based on 12 replies, as well as personal observation and some literature.

The developer's major choice with respect to vegetation on his land is whether to save trees, and if so, which ones. The decision on individual sites is largely based on three interrelated factors: legal requirements for drainage grading; the location of underground services, streets, walks, driveways, home sites, and utility easements; and cost-benefit ratios. The required grading often results in the removal or death of trees by disturbance, suffocation, or reduction of moisture available to the roots. The development plan usually takes into account the location of trees, and an effort is made to minimize the number of

trees that must be removed. The decision about trees, where there is a choice, is ultimately based on costs and benefits. One developer stated that one tree in front of a house could be worth $500 in sale price of the home. A United States Forest Service study in Amherst, Massachusetts, found that on one-half acre lots with homes, the first tree 6 inches or more in diameter added an average of $300 to the value of the property, the tenth tree added $200, the twentieth added $100, and the thirtieth, nothing. Adding more than thirty trees reduced the total property value. These values did not vary with the value of the properties or homes (Payne, 1973). The costs of keeping trees include protection during and after construction and sometimes added costs of avoiding trees in site plans. On the other hand, removal of trees also costs money. Most of my respondents stated that they and other developers try to save as many trees as possible, because they have found that the benefits of trees outweigh their costs. Furthermore, several said that lot size and price of home had nothing to do with the effort to save trees, although smaller lots necessarily meant that fewer trees could be saved.

Most of my respondents said they did not try to preserve areas of wild vegetation, other than some forest on individual lots occasionally, unless, as one put it, "it is impossible to do anything else with the land." Two or three felt that cluster development could profitably allow for such preservation, but that most local communities either prohibited or were not receptive to this kind of plan. Many said, however, that communities and homebuyers had become much more exacting about environmental aspects of development in the last few years.

If the sample is representative, most developers around Detroit try to minimize the removal of trees, though shrub and ground level vegetation usually are removed. This would mean a moderate reduction of tree cover on developed sites, but a nearly total elimination of forest, brush, and herbaceous patches as defined in this study. Commercial or industrial development, though not carefully investigated, probably takes a much larger proportion of the trees on a site. One parcel of about 40 acres, which had been first-class oak-hickory forest in 1964, was entirely bulldozed to sell the land for commercial uses.

What the homeowner plants in his yard seems to depend on the pre-existing trees, the size of the yard, personal tastes and knowledge about plants, and cultural and local traditions. Given a bare lot, most people plant grass on it, with shrubs and flower gardens around the house and lot edges, and add a few trees. The proportions of each are almost predictable, and the net effect in a new subdivision is one of uniformity. Even where many trees remain from a forest stand, the homeowner usually attempts to grow grass, shrubs, and flowers. The ideas about what is proper in yard vegetation is so narrow that neighbors are likely to become quite morally indignant when someone tries something unusual. The eventual tree cover from yard and street plantings usually reaches a fairly high percentage.

"Natural" forest, with a shrub and ground layer, survives in most cities only in parks, arboretums, and sometimes cemeteries. I surveyed such areas within the city limits of Detroit by examining all areas shaded green on U.S. Geological Survey topographic maps. There were only nine shaded areas, and only two of these proved to contain

"natural" forest: part of Belle Isle, a park in the Detroit River; and part of Palmer Park, in the northwest section of the city. One reason Detroit proper is lacking in natural parkland probably is because it does not have incised stream valleys where building would have been difficult.

CHAPTER VI

SOME IMPLICATIONS OF THE FINDINGS

What is the significance of the foregoing findings for the welfare of metropolitan man? In this chapter I would like to present a few of my thoughts, particularly on the subjects of recreation, wildlife, and aesthetics. These are the avenues through which the vegetation of urban areas touches the human spirit, and that, I am convinced, is its chief value.

A. Recreation

Recreation, of course, includes a gamut of activities from active sports and hunting through camping, picnicking, and hiking to the study and simple enjoyment of nature. I will discuss a few of these activities as they relate to the distribution of metropolitan vegetation.

Most athletic activities require grassy playing fields, preferably located very near the people they are expected to serve. Such locations generally are high-priced, but the amount of land needed for such activities is comparatively small. To minimize development expenses and to preserve trees, herbaceous or brush areas should be taken for this kind of recreation, although the presence of some trees is very desirable. Fortunately, herbaceous and brush land with scattered trees is generally abundant in the fringes of eastern cities.

As will be brought out in the next section, there is no dearth of animals to hunt around cities. Pheasants, quail, and rabbits abound on the many acres of idle land in weeds, brush, and young trees, and squirrels chatter from every woodlot. But there is a problem of safety in this zone of fairly high population density. For this reason, many local jurisdictions in the urban fringe have ordinances against hunting. However, where the vegetation is open and visibility good, bow hunting might fall within the margins of reasonable safety.

For most people, camping and hiking is best where the surroundings are wild over a fairly extensive area, and much of this should be wooded (nature's ultimate expression of wildness in much of the East). Water in the form of streams or lakes is also desired. The evidence from Chapter IV suggests that forest patches are largest where the proportion of land in forest is highest, and in agricultural regions this usually occurs in the transition zone between farm country and the city edge. Thus it appears that the right kind of vegetation for a fairly good camping experience is usually present in urban regions. Expense, however, is a problem. Probably good camping and hiking areas should be identified before the growing city puts them in the transition zone, raising the price by proximity.

Enjoyment of nature is involved in the preceding forms of recreation, but this may also be the primary goal. Enjoyment of nature can be a purely aesthetic experience, but often it includes observation of specific plants and animals. The aesthetics of vegetation, the plants of which it is composed, and the animal life it supports vary greatly from one type of vegetation to another. Wildlife and aesthetics will be

discussed in the succeeding sections. But here we might briefly consider the distribution and preservation of vegetation types and plant species.

Diversity of plant species is a function of diversity of environments; that is, of substrates, moisture conditions, microclimates, and general types of surrounding vegetation. Substrates and to a large extent moisture conditions are distributed independently of urban activities, but the distribution of vegetation types (and the microclimates within them), as we have seen, are strongly affected by the land uses generated by urban centers. In the Detroit study area, diversity of vegetation per unit area (number of types and number of patches) was greatest in the transition zone. Therefore it is likely that diversity of plant species is also greatest here. The number of patches is important for the following reason. Within a given type of vegetation, the number of species at first rises rapidly as area is increased, but then the number of new species added per unit area falls off, until the curve becomes nearly flat (Cain, 1938). For this reason, as Stanley Cain suggests, a large number of rather small patches of a vegetation type usually will contain more plant species than a small number of large patches (Cain, 1966). This may be true also partly because of the larger amount of "edge" in the first situation.

Vegetation and plant species of wet places seem to stand the best chances for survival in an urbanizing area. These kinds of places are unsuitable for agriculture, so many of them remain in the transition zone. Here urban development occurs first on upland sites near the city edge, moving farther afield as the city expands. Wet places, flood

plains, and very steep land are the last to go. It would therefore seem easiest, and cheapest, to preserve marshes, swamps, and bogs, as opposed to upland types. Again, however, it is probably best to identify and purchase them before the urban shadow of the transition zone falls on them.

While upland patches of vegetation are more subject to development pressure, they may also be more numerous than lowland patches. In the Oakland County portion of the study area there were, for instance, 201 patches of first-class forest (Table 10). But the abundance of this class of forest fell off rapidly as the city was approached, and none occurred within 20 miles of the CBD. I visited eight (of 25) first-class forests within the 1964 city edge (some outside the study area) to observe their condition and find out how they had survived. Six of the eight were oak-hickory stands, one was beech-sugar maple, and one was nearly pure red maple. Several of the stands were quite impressive, with trees up to 3 or 4 feet in diameter and over ninety feet tall. The beech-maple stand harbored rare green and white hybrid trilliums. All the stands showed some evidence of selective cutting in the past and at least one had suffered a light burn. Four of the stands were owned by private individuals, two by development companies, and two by institutions. Most had been on farms one or two owners previously. Only the two stands owned by institutions (a community college and a scientific institute) seemed safely preserved. Two of the private owners expressed a desire that their woods be preserved in the future, but no means was then on the horizon. The two owned by development companies probably will be subdivided, but local residents were fighting to preserve one of

these. It was at least heartening that five of these stands had champions, and that such forests could survive this long. Apparently, some farmers as well as many non-farmers preserve woodlots in a nearly untouched condition.

Many idle properties serve as unofficial recreation areas, for a diversity of purposes. In my field work I saw youngsters on foot, horseback, and motorbikes in such places, most of which were laced with trails indicating the "desire-lines" of local users. A middle-aged man who lived beside one such piece of land detailed to me his pleasure in watching the wildlife there. In total, the usage of idle land for "recreation" probably rivals that of public parks.

B. Wildlife

Many city and suburban people derive great pleasure from observing wildlife near their homes. Much of the residential zone and most of the transition zone harbor considerable numbers of animals and with management could be made to support many more. In this section I will explore the relative size of wildlife populations in relation to the vegetation characteristics of the three zones.

To a large degree, wildlife populations vary with type, size, and arrangement of patches of vegetation (Leopold, 1933). In eastern United States, the diversity and biomass of vertebrates per unit area of a given vegetation type probably is roughly proportional to the biomass of the vegetation, and increases from one stage of plant succession to the next. Thus herbaceous vegetation can be expected to harbor fewer kinds and numbers of animals than brushy areas do, and forests more than

brush. The size of a patch of vegetation of a given type is important because animals have varying spatial requirements--for defended territories or simply for enough area to provide them sufficient food and cover. A mouse might be satisfied with a quarter-acre patch of trees, but a black bear needs extensive forests. Finally, the way in which types of vegetation are interspersed has a great deal to do with the kinds and numbers of animals present, because many species have needs for more than one type. Pheasants, for instance, like to nest in alfalfa fields, but find better feeding and cover in weedy areas and along fencerows. Putting all these principles together, we can probably say that diversity and abundance of vertebrates per unit area is greatest where there is a variety of sizes and types of vegetation patches, a majority of which are in the later stages of plant succession. Other factors of course come into play--for instance, the availability of water and food (including man's garbage), the mineral nutrients in the vegetation, and the amount of human activity and pollution, but types and distribution of vegetation remain the basic factor.

Applying these ideas to the patterns of vegetation in and around cities, we should be able to predict the relative diversity and abundance of animal populations in various parts of a metropolitan region. Per unit area, the transition zone, with the greatest variety and number of vegetation patches, many of which are brush or forest, should have more animals than the agricultural zone, in spite of the increased human activity. The residential zone, with the least variety of types, very little forest, and tree cover equal to or less than that of the agricultural zone, should have fewer animals than that zone, and the commercial core should have fewest.

Data I collected in the Ann Arbor, Michigan area (for other purposes) seem to support this prediction, at least with respect to birds. A grid with intersections 1/4 mile apart was established for Ann Arbor and its periphery. The nearest road location to each grid intersection was used as a sampling point, at each of which all birds seen or heard within 200 yards during a three-minute period were counted. The study was conducted between May 30 and June 10, between 7:00 and 11:00 a.m., on days without rain or strong wind. Thus, most of the birds recorded were local breeding species, and the best hours and weather for observation were selected. At each of the 202 sampling points, the main land uses within 200 yards were recorded, in order of spatial dominance. For purposes of the present study, each point was classified, according to land use and location, as falling into one of four zones: agricultural, transition, residential, or commercial. Table 18 shows the average number of species and individuals per sampling point for each of the four zones. The results agree with the prediction except in the case of number of individuals in the residential

TABLE 18

DIVERSITY AND ABUNDANCE OF BIRDS, BY LAND-USE ZONES, ANN ARBOR, MICHIGAN, JUNE 1968

Zone	Number of sampling points	Mean number of species per sampling point	Mean number individuals per sampling point
Agriculture	12	8.4	16.3
Transition	84	8.9	18.2
Residential	95	7.0	16.5
Commercial	11	4.6	11.6

zone, which slightly exceeded that for the agricultural zone. Significance levels with respect to difference between means for number of species are .95 or higher for agriculture-commercial, transition-commerical, residential-commercial, and transition-residential. The same pairs of zones differed significantly at the .95 level with respect to number of individuals.

C. Aesthetics

Beauty is difficult to assess, although people can easily label individual objects, people, or scenes as beautiful, ugly, or indifferent. The aesthetics of vegetation might be considered in two ways: by analyzing vegetation as the sole component of landscapes, and by thinking about typical reactions of certain groups of people to various kinds of vegetation.

A recent attempt to identify and define the elements of beauty in landscapes listed three aesthetic criteria:

> (1) Unity. Affected by proportions among parts and whole. Absence of unity is fragmentation. (2) Vividness--that quality in the landscape which gives distinction and makes it visually striking. Similarity can achieve vividness by re-enforcement. Contrast produces vividness through conflict of dissimilarity. Indifferent difference occupies a middle point. (3) Variety--an index to how many different objects and relationships are found present in a landscape. Variety does not add to quality unless given order, by repetition, segregation, or gradation" [Litton, 1972].

We might now imagine landscapes on flat terrain composed entirely of the types of vegetation used in the present study, and try to apply the above criteria to the vegetation of the three land-use zones discussed. In terms of unity, which I interpret to mean the degree to which the parts of a landscape "hang together" or harmonize,

I would rank the agricultural zone first, residential second, and transitional third. This reaction may be related to the fact that the first two zones have a unity of purpose, imposed by man. But most landscapes of the transitional zone have been won over neither by man nor nature, and convey a feeling of irresolution. In vividness, I would rank the three zones in the same order. The agricultural zone achieves vividness by contrast--between woodlots and cropland--the residential by repetition, of landscaped lots with similar vegetation. In the transition zone, the vividness of agricultural vegetation has been blurred by growth of weeds, brush, and trees, and the scattered residential vegetation provides neither real contrast nor repetition. In variety, however, I would rank the transition zone first, agriculture second, and residential third. As we have seen, the transition zone has the greatest variety of vegetation types and number of patches, each of which can be considered an "object" in terms of Litton's description of variety. In this respect, agriculture ranked second and residential third. The variety of the transition zone does not add much to its quality, however, because it does not give order through "repetition, segregation, or gradation"; rather, its variety seems orderless.

Another way to approach the aesthetics of vegetation is to consider some typical human responses to it, to gain some consensus according to the motivations of certain groups. The concept of beauty in landscapes, or vegetation alone, cannot, I think, be restricted merely to the visual questions of form, arrangement, color, and texture, but is also linked with function of the land and connotations to the individual observer. Thus, the row crops, pastures, and woodlots of the

agricultural zone are beautiful to the farmer because they have been structured by him and because in his terms they are productive. Weeds and brush, on the other hand, may be ugly to the farmer because they represent loss of control by man and are in his view unproductive. To the naturalist, however, the weeds and brush of the transition zone might appear beautiful, because they represent natural production and a certain sense of wildness, have great species diversity, and support considerably more animal life than fields of corn or alfalfa. I suspect, however, that the majority view is that of the farmer. I would hypothesize that man in general likes vegetative landscapes that are dominated completely either by nature or by man--forest and marsh or lawns and gardens.

D. Effects of Roads on Vegetation Patterns

Although the effects of roads on the distribution of vegetation was not investigated directly, one can make some reasonable inferences from the information at hand. As assumed in the regional model in Chapter II, major roads extend the city into the countryside by encouraging urban uses near them. Thus, along such roads, each of the land-use zones begins and ends farther from the CBD than in the interstices between major roads. In the vicinity of such roads, vegetation patterns should be affected in accordance with the way land uses are affected.

Limited-access highways, most of which parallel earlier main roads, at least around Detroit, probably have the effect of encouraging urban-type land uses near interchanges, which might be extensive enough to have a significant effect on the metropolitan vegetation pattern.

Between interchanges there might well be an opposite effect. Because these sections of limited-access highways act as barriers to travel across them, they make the adjacent land less accessible. There might be a tendency for wild vegetation, perhaps even forests, to develop along such stretches. Adding to the access factor is the tendency for planners to route such highways through the middle of sections, which are poles of inaccessibility anyway, since the pre-existing roads often follow section lines. In section centers, as will be discussed below, woodlots often occur. Many of these are split by the new highways, but the surviving fragments may, for a time at least, be protected by their location next to the highway, though noise and air pollution reduce their value as de facto nature preserves.

Minor roads, and the types of land survey systems to which they are related, might have an effect on vegetation patterns through the degree of density and pattern of the network. Thrower (1966) compared two areas in Ohio, one that was surveyed unsystematically, producing an irregular road system that was related primarily to settlements and the terrain, and another that was subdivided under the systematic Government Land Survey, which led to a denser grid pattern of roads, similar to the one in southeastern Michigan. He found that in the area surveyed unsystematically, the average landholding was about twice as large, and average field sizes were larger than, those in the systematically surveyed area, both in 1875 and in 1955. The dense grid road network that developed along section lines appears to have effectively held down the size of landholdings and fields. Perhaps woodlots, too, were smaller here. At any rate, the number of vegetation patches must have been

greater in the systematically surveyed area, and with a larger number of landowners per unit area, there may also have been a greater variety of vegetation types.

In country that is, or recently was, farmland, there is a tendency for woodlots to be located at the greatest possible distances from roads, because farmers often establish woodlots on the "back forty," as described earlier. This tendency is especially pronounced on level terrain, where most of the land is suitable for crops. On maps of level areas where a grid road system prevails, the regularity of occurrence of woods in the centers of sections can be quite striking.

Thus, roads affect vegetation patterns through their influence on adjacent land uses and by the way they divide the land.

E. Future Settlement Patterns and Their Effects on Vegetation

Crystal-ball gazers predict a variety of future patterns of metropolitan settlement in America, depending on their expectations about advances in transportation technology, costs of commuting, public decisions about land use, and other factors. Doxiades (1970) foresees the concentration of most of our population in a few giant megalopolises of from 10 to 50 million people. Friedmann expects a greatly increased spreading of the homes of urban workers over the countryside beyond metropolitan centers, a much more dispersed pattern of settlement than Doxiades' forecast (Friedmann & Miller, 1965). The resulting "urban fields" would be "a fusion of metropolitan spaces and non-metropolitan peripheral spaces centered upon core areas (SMSAs) of at least 300,000 people and extending outwards for a distance equivalent to two hours'

driving over modern throughway systems (approximately 100 miles with present technology)." Based upon current SMSAs of this size, such urban fields would take up most of the east coast and an Ohio to Illinois segment of the Midwest, as well as other large chunks of the country. An intermediate view is held by Richard Morrill (1973): "in the absence of a radical public intervention, the future pattern of settlement may be remarkably unchanged from the present." If that radical public intervention does occur, a fourth possibility exists: increased densities in urban centers, with restrictions on urban spread and a consequent narrowing of the transition zone between the city and agricultural land.

In terms of the present study, the question involves the width of the transition zone and the distribution of land uses within it. Vegetation of the agricultural and residential zones would not be expected to change much in the event of any of the future developments outlined above. If urban growth is restricted and the transition zones of cities narrow to virtually nothing, vegetation patterns would jump almost directly from those of agriculture to those of residential areas (as one sees in much of Europe), with only the influence of recreational and other public or institutional land to confuse the picture. But if present trends continue or accelerate, the transition zones of cities will expand to include very large portions of the East. The result will be networks of large and small cities, between which most of the land will be owned by "rural" non-farmers and speculators. Brush and forest will cover much of this interstitial space.

There are several reasons why this might not happen. The financial and governmental strains of such sprawl might become intolerable. People might no longer be able to afford, or obtain fuel for, long commuting trips. And shortage of agricultural land might force a restriction on urban growth. But in the long run, unless population stops growing or remarkable advances in agricultural technology drastically reduce the area needed to grow food, the squeeze of urbanization and agriculture on forests, brush, marshes, and other wild vegetation will continue to reduce their total extent. The increase of brush and forest we see around some eastern cities probably is only a small and local advance in a general pattern, now resuming, of long-term retreat.

APPENDIX I

COMMON AND SCIENTIFIC NAMES OF PLANTS

Authority: Fernald, M. L., Gray's Manual of Botany, 8th ed., 1950.

American beech	Fagus grandifolia Ehrh.
Ash	Fraxinus spp., esp. F. nigra Marsh.
Aspen	Populus tremuloides Michx.
Aster	Aster spp.
Black bindweed	Polygonum convolvulus L.
Black cherry	Prunus serotina Ehrh.
Bluegrass, Canada	Poa compressa L.
Bluegrass, Kentucky	Poa pratensis L.
Buttonbush	Cephalanthus occidentalis L.
Cedar, red	Juniperus virginiana L.
Cedar, white	Thuja occidentalis L.
Common ragweed	Ambrosia artemisiifolia L.
Common yarrow	Achillea millefolium L.
Cottonwood	Populus deltoides Marsh.
Dogwood, gray	Cornus racemosa Lam.
Dogwood, red-osier	Cornus stolonifera Michx.
Elm, American	Ulmus americana L.

Goldenrod	*Solidago* spp.
Hawthorn	*Crataegus* spp.
Hickory, shagbark	*Carya ovata* (Mill.) K. Koch
Maple, red	*Acer rubrum* L.
Maple, silver	*Acer saccharinum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, black	*Quercus velutina* Lam.
Oak, red	*Quercus rubra* L.
Oak, swamp white	*Quercus bicolor* Willd.
Oak, white	*Quercus alba* L.
Pine, jack	*Pinus banksiana* Lamb.
Pine, red	*Pinus resinosa* Ait.
Pine, Scots	*Pinus sylvestris* L.
Pine, white	*Pinus strobus* L.
Prickly lettuce	*Lactuca scariola* L.
Quackgrass	*Agropyron repens* (L.) Beauv.
Queen-anne's-lace	*Daucus carota* L.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Spruce	*Picea* spp., mostly *P. mariana* (Mill.) BSP.
Sumac, smooth	*Rhus glabra* L.
Sumac, staghorn	*Rhus typhina* L.
Tamarack	*Larix laricina* (DuRoi) K. Koch

APPENDIX II

SIGNIFICANCE LEVELS FOR DIFFERENCES BETWEEN LAND-USE PAIRS WITH RESPECT TO VEGETATION CHARACTERISTICS

	Residential-recreation	Residential-agriculture	Residential-open space	Recreational-agriculture	Recreational-open space	Agricultural-open space
Percent deciduous	.99	.99	.99	.99	.99	.99
Percent brush	.99	.86	.99	.99	.99	.99
Percent herbaceous	.93	.99	.99	.99	.99	.99
Number of types	.99	.99	.99	.87	.57	.99
Number of patches	.86	.95	.92	.99	.39	.99
Tree distribution	.99	.99	.99	.72	.83	.41
Percent total tree cover	.99	.73	.99	.99	.99	.99
Average size, forest patches	.91	.53	.77	.93	.74	.79
Average density, forest patches	.11	.20	.25	.59	.71	.13
Average diameter class, forest patches	.46	.83	.59	.86	.31	.88

APPENDIX III

VEGETATION DATA BY QUARTER-SECTION, DETROIT STUDY AREA, 1937 AND 1964

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[e]
OAKLAND COUNTY														
Holly														
33-3[a]	2.4							97.6			2	2	n.d.[d]	7
34-4			9.0		5.6			83.1			3	3	3	
5-2	9.4							90.0		0.6	2	2	1	109
4-2	18.5		2.7					72.6	6.3		3	3	1	129
27-4	22.8		15.8					11.6	49.0	0.9	3	7	1	28 119
1-3	29.2							64.0			2	6	1	42 118 31
36-1			11.4					87.1		1.5	2	4	3	
17-1	19.6							80.4			2	4	1	15 8 37
35-1	8.0		6.4	1.7				82.5	1.4		4	6	1	14 12 9
31-3	11.9		33.2					57.3	0.8		3	4	n.d.	55
Rose														
11-3	9.1		4.5					86.4			3	3	2	79
22-2		2.0	4.3					91.9		1.8	3	6	2	
7-3			4.0	5.5				91.5			3	3	n.d.	
10-3	10.3			2.4				82.8	2.6	1.9	3	5	1	73 24
12-1	9.2							89.0		1.8	2	5	2	69
5-4	12.1			4.3				83.6			3	4	1	33 5
3-2	7.9			5.0	0.6			76.7	8.6	1.2	4	8	n.d.	80
1-1	11.9							88.1			2	2	1	287

APPENDIX III—(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[a]
Groveland														
6-2	9.0							91.0			2	2	n.d.	69
8-2	41.8		20.7					37.6			3	8	1	87 228
4-2	38.8		4.6					56.6			3	4	1	174
28-4	22.7							51.7	25.7		2	6	1	161 19 97
1-1	11.7		23.0					63.7		1.6	3	6	n.d.	43 23
24-1	7.6				0.7			90.3		1.4	3	4	n.d.	23
29-4	4.7			4.7				86.3	0.7	3.6	3	5	1	33
27-2	7.6							90.7		1.7	2	3	1	92
33-4	22.7							74.1		3.2	2	3	1	310
16-2	32.3		19.2					48.6			3	7	1	49 66 53
Springfield														
3-1	31.2							68.8			2	4	1	157
22-1	7.1							78.2	12.8	2.0	2	6	2	22
26-2			5.1					92.8			2	3	3	
31-1	10.9		15.7					68.9	2.1	2.4	3	5	2	45 11
19-4	9.0							89.9		1.1	2	3	1	25
20-3	12.4							87.6			2	3	1	20 65
27-2			25.9					74.1			2	4	3	
16-1	17.9		7.2					73.5			3	6	1	67 22
25-1	34.7							65.3			2	4	n.d.	173 27 16
15-3	19.5							80.5			2	3		19 320

APPENDIX III--(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[e]
White Lake														
16-1	26.9							73.1			2	3	1	95 8
26-3	13.2		17.2		12.5			8.5	48.7		4	7	2	77
15-1	7.8		7.8					81.0		3.4	3	8	2	12 11
14-1			4.0			2.3		38.3	54.0	1.3	3	5	3	
22-1	31.2		6.2					46.6	13.7	2.4	3	6	1	120 13
11-3	18.1		17.1					52.0	11.4	1.3	3	6	n.d.	324
9-4	20.8		8.7					68.5		2.1	3	9	1	38 9 18 9
28-1	47.2		8.4					14.7	30.8		3	6	1	131 241
Brandon														
21-1	13.5		6.4					68.4	11.7		3	4	n.d.	20 35
15-3	6.5			4.1				89.4			3	3	2	19
12-3	39.5							60.5			2	2	1	123
36-1	8.4		9.7					81.9			3	3	1	25
26-1			14.1	7.7				78.2			3	3	3	
11-2	21.9		6.9					71.2			3	3	1	99
5-2	21.0							79.0			2	3	n.d.	45 12
8-1	39.1							60.0		1.0	2	3	n.d.	123
35-1			3.7					96.3			2	2	3	
4-4								100.0			1	1	3	

APPENDIX III—(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[e]
Independence														
21-4	16.0							84.0			2	3	1	29 17
13-3	15.4							83.3		1.4	2	3	1	45
12-1								99.0	1.0		1	1	3	
1-1	61.3							38.7			2	4	1	326
20-3			7.8	6.7	33.3			45.9	5.6	0.7	4	5	3	
7-4	12.3							87.7			2	2	1	34
3-4	11.3		14.0					43.0	31.0	0.7	3	5	2	336 16
4-4	14.6		4.5					65.5	15.3		3	3	1	72
17-3								100.0			1	1	3	
28-4								96.4	3.6		1	1	3	
Waterford														
28-1	16.7		8.5	19.6	3.8			13.3	36.6	1.6	5	9	1	171
17-4			10.3					89.7			2	2	3	
9-4	11.8		10.4					77.9			3	4	1	115
30-4	17.4							82.6			2	3	1	12 162
32-4			14.7					81.8		3.5	2	4	3	
5-4	12.0							88.0			2	4	1	39
11-3	5.6		5.9			6.9		23.9	51.3	6.5	4	6	2	17
24-3	5.7		5.7		1.7	19.8		66.8		0.3	4	6	1	7 51
23-4	3.7		3.4			0.7		90.3		2.0	4	5	2	11
33-1	12.1		12.8	4.4	11.7			33.7	20.9	2.6	5	11	2	30 26

APPENDIX III--(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[e]
West Bloomfield														
24-4	3.4		7.2		9.2	4.1		6.8	67.9	1.4	4	7	n.d.	10
5-3	45.1		3.8					38.2	10.8	1.7	3	4	1	30 132
4-2	7.3							90.7		2.0	2	3	1	76
17-1	14.3			23.1				62.6			3	3	2	64
10-2	44.4			12.7				10.8	30.5	1.9	3	5	n.d.	169 24
14-2	11.3							55.5	27.1	6.2	2	6	1	55 26
7-1				12.0		5.1		80.0	1.8	1.1	3	4	3	
1-4	6.1							67.2	23.7	3.0	2	3	2	20
3-4									98.8	1.2	0	0	4	
Oxford														
18-1	19.8		4.2					76.0			3	3	2	56
33-3	7.8		12.3					66.5	11.5	2.2	3	8	1	15 23
26-1			6.1					28.5	43.1	22.4	2	3	3	
8-2	25.2							74.8			2	3	1	29 33
3-1	10.4	5.0	8.5					76.1			4	5	1	384 78
2-4								100.0			1	1	3	
32-4	66.7							33.3			2	2	1	592
19-4	4.3							92.9		2.8	2	2	2	71
35-2			9.4	12.4				75.9	0.8	1.5	3	4	3	
25-3	3.6		5.8					76.7	13.5	0.4	3	3	3	29

APPENDIX III—(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[e]
Orion														
34-2	21.1							78.9			2	2	1	203
13-1	4.5		2.4					87.8		5.2	3	4	2	13
9-1					11.4	2.5		68.5	15.1	2.5	2	5	3	
24-1	46.0		7.6					46.4			3	4	1	488
19-4	7.5		26.8					65.8			3	4	2	113
36-2	14.8							83.8		1.4	2	5	1	9 8 31 13
20-1	17.8		6.5					32.2	43.5		3	3	1	171
28-4	28.7		19.9					48.9		1.8	3	6	1	76 38 15
16-3			17.8					36.8	45.4		2	5	3	
5-2	14.6		29.3					56.1			3	4	2	133
Pontiac														
25-1			23.9					73.8		2.3	2	5	3	
13-2	18.2				1.1			77.2		3.6	3	8	1	20 21 210
22-2	2.5				7.1	65.5		23.8		1.1	3	4	2	7
16-1						19.9		80.2			2	3	3	
15-1	5.2		4.0					87.1		3.7	3	4	2	14
21-4	14.9		27.3		1.7	2.1		52.6		1.4	4	5	1	54
9-1					2.8	13.5		81.4		2.4	2	8	3	
35-4	31.4		27.4			2.5		36.8			4	8	1	57 41
8-1	15.7		19.5					62.5		2.3	3	8	1	55
18-4	2.7				4.6	32.6		58.0		2.3	3	4	2	16

APPENDIX III--(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[e]
Bloomfield														
24-2	14.4							75.5	0.7	9.4	2	8	1	56 27
21-2	19.7		6.6					72.0		1.7	3	5	1	197 53
5-4	12.8					8.2		77.0		2.1	3	5	1	36
17-3	23.1		3.2	13.4				58.7		1.6	4	6	2	10 156
33-1	7.7			3.5			71.1	16.4		1.4	4	5	2	89
15-4			15.2					75.3		8.6	2	10	3	
8-4			7.4	5.1				53.7	31.1	2.7	3	6	3	
30-2	6.8		7.6					85.6			3	3	2	17
32-4			27.7	4.3				63.1		5.0	3	5	3	
31-1	4.0		5.2	19.7				71.1			4	4	2	10
Southfield														
26-3			7.0					90.0		3.0	2	2	3	
35-4	4.1							93.2		2.7	2	4	2	12
33-4			25.4		3.4	8.0		62.1		1.1	3	7	3	
21-3								100.1			1	1	3	
23-2	39.5							60.5			2	2	1	143
20-2	10.6		15.8					73.6			3	4	1	161
3-1	16.1		4.3	6.3				72.6		0.8	4	4	1	41
11-4			8.5			1.4		90.1			3	3	3	
13-2			5.4		1.8	17.6		71.2		4.0	3	8	3	
2-3	10.8					2.5		83.4		3.3	3	4	1	30

APPENDIX III--(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[a]
Addison														
23-4	4.7		22.1					73.2			3	4	2	40
33-3	25.4							74.6			2	2	1	86
36-4				3.1				96.9			2	2	3	
12-1	41.6		10.9					47.5			3	3	1	296
13-1	26.0							74.0			2	3	1	533
32-2	23.6		14.4					57.9	4.1		3	7	1	69
31-1	5.5							93.0		1.5	2	3	2	35
11-2	4.6		14.9		6.4			74.1			4	6	2	32
8-1	17.7							80.6		1.7	2	3	1	216
2-2	16.5		15.3					68.2			3	6	1	82 30
Oakland														
21-1	12.5							84.6		2.9	2	5	1	34 9
12-3	5.6		4.9					89.5			3	3	1	17
31-4	28.2							71.9			2	3	1	109
7-2	28.4		18.2					49.2	4.2		3	3	1	348
30-3								100.0			1	1	3	
10-2	15.4		37.2					47.4			3	6	1	23 14 21
28-1	8.2				3.1	4.1		80.3		4.4	3	8	1	13 38
3-2	37.7		21.5					40.8			3	6	1	10 26 137
36-4	12.6							85.7		1.7	2	5	1	15 34 37
27-4	7.2							90.5	2.3		2	3	2	9 13

APPENDIX III--(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[a]
Avon														
12-3	15.4							81.7		2.9	2	5	2	22 233
29-3	21.7		6.3					72.0			3	5	1	69 69
8-3	23.7		2.8	3.2				70.4			4	4	1	75
3-1	15.9			2.4				79.4		2.1	3	5	1	37 20
17-4	6.4							93.6			2	2	1	22
1-3	9.8		19.7		5.7			62.9		1.9	4	8	1	56
25-1	30.5							69.5			2	2	1	88
33-1	12.2							84.7		3.1	2	2	1	28
32-4	5.9		28.5			9.2		56.4			4	4	1	26
9-1	7.1		5.3					87.6			3	3	2	19
Troy														
16-1	8.6							91.4			2	2	1	63
3-3	4.8		9.5		2.9	1.3		81.7			4	5	2	15
31-2			13.0	3.3	1.7	23.3		55.3		3.3	4	8	3	
23-1	16.1					1.1		82.9			3	3	1	45
5-4	10.7							89.3			2	2	1	76
1-2			9.5			18.3		64.0		8.3	3	6	3	
12-4			10.5					89.5			2	2	3	
9-1			8.5			4.3		87.2			3	3	3	
33-3						12.4		86.4		1.2	2	7	3	
36-1								97.5		2.5	1	2	3	

APPENDIX III—(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[d]
Royal Oak														
3-3	18.0				10.1	49.1		20.6		1.5	3	7	1	24 24
25-4	15.8		21.2		3.6	29.5		25.9		4.0	4	11	2	8 9 9 9 9
18-2			11.4			69.7	4.6	11.4		3.0	4	8	3	
6-3					1.1	1.5		94.8		2.6	2	5	3	
10-2					14.0	34.0		49.5		2.7	2	9	3	
4-1					13.0	66.5		20.5			2	2	3	
24-3					9.9	38.7		47.9		3.5	2	12	3	
9-1	22.6		19.4		9.7			42.7		5.7	4	14	2	66 8 9
LAPEER COUNTY														
Elba														
16-3	19.1		3.8					77.1			3	4	1	64 10
30-1			6.1					93.9			2	2	3	
14-4			13.2		2.8			21.8	61.6	0.7	3	4	3	
36-3	33.7							66.3			2	3	1	143 22
13-4	22.2		10.8					65.7		1.3	3	5	1	148
28-1	22.5							77.6			2	2	1	66
7-3	14.2							85.5		0.4	2	2	1	43
33-4	4.2		5.6					90.2			3	3	2	12
11-1	6.3		8.7					82.3		2.7	3	5	2	106
34-2	49.0		9.4					36.6	5.0		3	3	1	228

APPENDIX III—(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[e]
Hadley														
6-3	24.4							75.6			2	3	1	66
16-1	5.3							90.7	0.7	3.3	2	4	2	16
33-3	17.9							82.1			2	2	1	96
2-1	7.1							89.8	1.5	1.5	2	3	2	167
35-4	23.0		14.3					62.7			3	5	1	109
20-3	41.4		15.4					43.3			3	5	1	1056
28-3	20.5							78.3		1.2	2	4	1	7 47 12
14-4	5.7		12.3					81.4		0.7	3	4	2	79
15-3	12.8		18.6					68.6			3	6	1	15 52
10-3	46.0							51.9	2.1		2	3	1	240
Lapeer														
18-2	11.4							87.5		1.1	2	3	1	30
32-1	6.1							93.9			2	2	1	17
17-3	26.8		11.4					54.6	7.1		3	5	1	13 76 145
36-1			3.5					96.5			2	2	3	
28-3	14.5		7.4		2.1			76.0			4	5	1	324
Metamora														
33-1				7.3				91.3		1.5	2	3	3	
2-1	37.3		8.5					54.2			3	4	1	1170
35-1	18.0			4.9				77.1			3	4	1	25 312
20-4	16.4							83.6			2	2	1	52
28-1	2.5							95.0		2.5	2	2	2	34
14-3	3.8		5.9					90.3			3	3	2	74
15-2	5.5							94.5			2	2	2	16

APPENDIX III--(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[e]
10-3	23.4		3.6					72.9			3	4	1	73
3-2								100.0			1	1	3	12
18-2	13.2		7.5					79.3			3	3	1	28
Attica														
18-3	6.4							93.6			2	2	1	79
32-3	11.9							86.9		1.3	2	3	1	571
36-1	11.2							84.7	4.1		2	3	1	33
28-2	4.4		20.1					74.7	0.7		3	4	2	13
Dryden														
33-3	10.8		8.7					80.5			3	4	1	31
22-1	6.8		4.8	4.1				84.3			4	4	2	20
8-1	13.5							86.5			2	2	1	137
7-4								100.0			1	1	3	
21-3	20.4		7.3					72.3			3	5	1	31
29-3			5.4					94.6			2	2	3	28
32-2	5.4		4.4					90.2			3	3	2	126
9-3	23.2							76.8			2	3	n.d.	107
16-1	5.4							94.6			2	2	1	15 16
3-1	22.6		3.5					73.9			3	3	1	177
GENESEE COUNTY														
Davison														
34-3	8.6							91.4			2	2	1	183
14-1								97.3		2.7	1	2	3	
10-3						10.4		89.6			2	2	3	
26-2	22.4		10.8					66.8			3	4	1	46
24-3	5.8		16.0					77.3		1.0	3	5	1	71 33
35-1	11.2							88.8			2	2	1	32
21-2	3.4							96.6			2	2	n.d.	21

APPENDIX III--(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[e]
Atlas														
3-3	16.0							79.8	4.2		2	2	1	195
26-1	17.1		4.0					77.2		1.7	3	6	1	116 29
30-2	3.9		13.1					83.0			3	3	2	218
11-2	11.1							88.9			2	3	1	45 26
24-3								100.0			1	1	3	
20-4								100.0			1	1	3	
33-2								100.0			1	1	3	
8-4	7.2		4.4		6.1			81.2		1.0	4	7	n.d.	88
9-4								95.5	4.5		1	1	3	
16-4	30.1							69.9			2	2	n.d.	381
Burton														
26-4						4.1		95.3		0.6	2	6	3	
32-3						41.0		53.6		5.1	2	5	3	
13-4			7.9			4.9		87.2			3	4	3	
Grand Blanc														
11-3	23.3		3.8					72.9			3	4	n.d.	224 88
28-1	5.5		5.1					87.5		1.9	3	5	1	52
18-4	8.3							91.7			2	2	1	107
25-4	7.1							92.9			2	2	1	22
6-3	9.3		24.1		1.2			63.5		1.9	4	7	n.d.	30
19-3	13.5		3.2					83.3			3	4	1	128 11
3-2	16.5							82.9		0.6	2	3	1	28 26
20-2	15.4		3.0					81.6			3	4	1	12 42
34-3	21.8							78.2			2	4	1	49 25
14-1								99.4		0.6	1	2	3	

APPENDIX III--(continued)

Quarter-section	1937													
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b]	Number of vegetation types	Number of vegetation patches	Distribution of tree cover[c]	Size, forest patches[e]
Mundy														
23-2	17.3					1.0		80.8	1.0		3	3	n.d.	268
12-1	5.9							94.1			2	2	n.d.	19
14-3	21.7							78.3			2	3	n.d.	29 150
13-1	8.9							91.1			2	3	1	13 169
Fenton														
9-1	5.7							94.3			2	2	n.d.	17
36-4				3.9	1.4			73.9	17.7	3.1	3	4	3	
1-2			6.1					90.5	3.4		2	2	3	
21-1	9.3							39.8	50.9		2	2	n.d.	48

APPENDIX III--(continued)

Quarter-section	1964																
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density, forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
OAKLAND COUNTY																	
Holly																	
33-3			6.7					93.3			2	2	6.6	3			
34-4			5.4		20.1			73.2			3	9	10.1	3			
5-2	9.5							90.5			2	2	10.3	1	2.3	2.7	106
4-2	26.4		8.8					59.8	5.0		3	6	29.9	1	2.3	2.7	168
27-4	16.5		15.7		8.1			5.9	47.9		4	6	16.5	2	2	2	39
															2	3	62
1-3	30.3			14.1				44.4			3	9	37.5	1	1.7	2.7	57
															2.7	3	100
															n.d.	n.d.	31
36-1			25.0					65.5	5.6		2	5	2.2	3			
17-1	20.1		13.4					64.7			3	8	26.3	1	2	3	11
															2	3	6
															2	2.7	40
35-1	10.1		33.8					54.4	0.9		3	8	16.3	1	2	3	33
															1	3	6
31-3	13.8		38.2					45.3	1.3		3	8	28.2	2	1	3	45
															1	3	41
															1	2.7	5
Rose																	
11-3	4.0		19.0					77.4			3	4	12.5	2	2	2	11
22-2		9.9	28.8					57.9			3	9	11.1	2	3	2	n.d.
7-3			10.5					89.5			2	3	7.2	3			
10-3	11.1			13.1				71.3	1.2		3	5	16.2	2	2	3	73
															2	3	25
12-1	14.3		16.0					66.4			3	7	24.5	2	n.d.	n.d.	87
															2	2.7	8
5-4	15.5		5.7					78.8			3	5	22.6	1	n.d.	n.d.	31
															3	3	7
															1	3	7
3-2	8.9		15.0	5.0	8.5			58.1	7.7		5	10	12.3	2	2	3	85
1-1	14.0							86.0			2	2	21.8	1	1.7	2.7	345

APPENDIX III--(continued)

Quarter-section	1964															
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density, forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
Groveland																	
6-2	8.5		3.8					87.7			3	4	15.2	2	n.d. 3	n.d. 2	19 25
8-2	52.7		27.2					14.3	4.5		3	6	57.1	1	2.3	2.3	501
4-2	44.4		22.2					33.9			3	7	50.0	1	2.7	2.3	231
28-4	31.3		26.6					11.6	28.3		3	8	38.3	1	2.3 2 2 2	3 3 3 3	178 46 51 48
1-1	34.8		36.9					26.2			3	11	46.3	2	2.3 2	2.7 2	144 7
24-1	11.8		39.2		18.6			29.5			4	10	34.0	2	2 2 2	2 2.7 3	53 17 6
29-4	4.4		47.1					44.9	0.9		3	9	15.4	3	2	2.3	36
27-3	6.9		23.3					68.5			3	5	19.2	2	3	3	85
33-4	27.4		32.2					35.7			3	5	34.7	1	2.7	3	340
16-2	58.9		28.6					13.8			3	8	65.6	1	2.7 2 2	2.3 2.7 3	90 117 65
Springfield																	
3-1	37.3		3.2					59.5			3	3	29.8	1	1.3	2.3	194
22-1	10.0		51.0					22.8	13.7		3	8	21.9	2	1.3	3	47
26-2	3.0							68.8		27.4	2	3	6.2	2	3	2	51
31-1	20.4		31.9					42.7	1.9		3	8	24.2	1	2 1.7	3 3	128 114
19-4	9.1		5.8					84.8			3	4	12.9	1	2	3	27
20-3	18.0				1.6			80.4			3	4	28.2	1	2 2	3 3	29 116
27-2			27.2					71.0			2	4	15.4	3			
16-1	18.9		36.1					42.5			3	5	35.0	2	2.3	2.3	157
25-1	31.0		36.8		1.3			31.0			4	6	42.5	1	2 n.d.	3 n.d.	191 28
15-3	32.4		32.4					32.0			3	7	36.5	1	2.3 2 1 2 1	2.3 3 3 3 3	33 38 2 47 169

APPENDIX III—(continued)

Quarter-section	1964															
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density, forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
White Lake																	
16-1	35.2		6.5					58.3			3	4	34.4	1	2	3	129
26-3					47.6				52.4		1	2	13.7	3			
15-1	12.0		18.0		3.0			63.7			4	12	19.8	2	1	2	33
															n.d.	n.d.	8
															n.d.	n.d.	7
14-1			3.0		43.6			2.5	48.3		3	9	22.9	3			
22-1	34.4		11.9		22.5			11.0	15.9		4	5	36.3	1	2.3	2.7	119
11-3	29.5		34.4					18.3	15.8		3	7	32.8	1	3	3	392
															1	3	16
															2	2	8
9-4	28.1				1.3			67.4			3	6	41.2	1	2.7	2.7	905
															3	3	30
															3	2	19
28-1	13.6				28.9			9.4	43.8		3	6	21.2	2	2.7	2.3	157
															2	2	10
															2	2	17
Brandon																	
21-1	19.2		5.1					64.3	10.2		3	6	35.6	1	2	2	18
															2	3	23
															2	3	16
15-3	8.7		40.7	3.9				46.8			4	5	14.4	2	2	3	24
12-3	40.2							59.8			2	2	48.5	1	3	2.7	123
36-1	18.3		15.7					66.0			3	4	20.6	1	2	3	27
															2	2	54
26-1			16.1					83.9			2	2	5.6	3			
11-2	28.5							70.6			2	2	36.1	1	2.3	2.7	184
5-2	25.9		29.7					44.1			3	7	33.8	1	2.3	2.7	57
															2.3	3	275
8-1	39.2		10.2					49.8			3	3	45.5	1	2.7	2.7	111
35-1	4.3		14.1					81.6			3	5	7.5	2	n.d.	n.d.	12
4-4								100.0			1	1	9.0				

APPENDIX III--(continued)

Quarter-section	1964															
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density, forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
Independence																	
21-4	14.8				3.0			82.3			3	5	26.2	1	1 2	3 2	25 17
13-3	6.0				25.3			66.5			3	6	31.5	2	n.d	n.d	17
12-1			1.7					97.0	1.3		2	2	9.8	3			
1-1	58.7				2.1			39.3			3	5	87.0	1	2	3	421
20-3	9.1		18.6		49.4			14.3	6.9		4	7	32.3	3	n.d. n.d.	n.d. n.d.	13 12
7-4	14.4							85.6			2	2	19.4	1	3	3	44
3-4	13.5		9.7		49.6				31.1		3	6	25.9	2	2.7 n.d.	2 n.d.	318 21
4-4	15.3		33.1					36.8	13.6		3	7	33.0	2	2	3	99
17-3	5.6	2.2	2.2		11.6			59.9	1.3	15.1	5	9	13.0	3	n.d.	n.d.	16
Waterford																	
28-1	18.7				48.9				32.3		2	5	33.4	2	2 2.3	2 2.7	160 11
17-4								100.00			1	1	0.0	3			
9-4	11.0		14.0		38.6			25.0		11.4	4	6	14.4	1	2	3	120
30-4	12.9		37.3		49.8						3	3	38.7	2	3	2.7	189
32-4			27.8		27.8			43.5			3	7	10.4	3			
5-4					11.1			80.1	1.3		2	9	9.7	3			
11-3			5.5		10.9			22.7	52.1		3	4	4.5	3			
24-3	9.8		31.1		36.9			22.7			4	8	25.1	2	2 1	3 3	13 23
23-4	2.6				39.7			57.6			3	5	17.3	2	n.d.	n.d.	7
33-1	26.0		6.8		31.1			18.3	20.0		4	8	36.9	1	2 1 3	2 3 2	42 12 28

APPENDIX III--(continued)

Quarter-section	1964															
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density, forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
W. Bloomfield																	
24-4					32.3			3.0	64.7		2	3	15.8	3			
5-3	30.3	15.0	3.4		18.8			17.1	15.4		5	5	37.0	1	2 2	3 2	86 n.d.
4-2	8.5		9.2	2.5	12.0			63.4	0.7		5	11	17.0	2	1	3	83
17-1	18.5		19.3		23.6			38.2			4	7	24.8	2	2	3	86
10-2	8.9				52.8			6.0	31.5		3	3	33.2	2	n.d.	n.d.	25
14-2	6.0				18.4			41.9	25.4		3	8	14.2	2	n.d.	n.d.	46
7-1	2.6			11.8	14.9			68.1	2.6		4	5	16.4	3	n.d.	n.d.	7
1-4					74.8			3.2	18.9	3.2	2	2	7.9	3			
3-4									99.2		0	0	0.3	3			
Oxford																	
18-1	27.6				1.7			70.7			3	4	28.7	1	2.3	2.3	77
33-3	12.8		10.5					63.5	11.9		3	5	22.6	2	2.3	2.7	699
26-1			3.7					45.9	50.0		2	6	1.3	3			
8-2	25.9							74.2			2	3	30.7	1	2 1	3 3	30 44
2-4	3.4		3.4					93.1			3	3	15.9	2	1	2	10
3-1	15.1	10.2	15.1					60.2			4	7	31.4	1	1.3 1.7 3	3 2.7 2	411 108 117
32-4	77.3		16.0					4.1	0.5		3	3	76.1	1	2.3	2.7	644
19-4	4.0							92.9			2	2	16.0	2	2	3	91
35-2								89.4	0.9		1	7	5.4	3			
25-3	12.9		12.0					62.2	13.3		3	4	20.0	2	3 1	2 2	40 18
Orion																	
34-2	20.4		29.2					50.4			3	7	15.6	1	2	3	56
13-1	9.5		44.8					32.0		7.5	3	9	23.2	2	n.d. 2	n.d. 3	21 10
9-1					32.7			52.0	13.3		2	3	13.7	3			

APPENDIX III—(continued)

Quarter-section	1964																
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density, forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
24-1	52.0		28.4					17.3	2.2		3	4	48.3	1	2.3 1.7	2.7 3	540 39
19-4	22.3	18.0	18.0					41.8			4	4	33.8	1	2.3 3	2.7 2	1623 74
36-2	10.8							83.1			2	4	19.6	1	2 2 2	3 3 3	8 8 33
20-1	27.8							28.6	43.6		2	4	22.3	1	1.7	2.7	310
28-4	26.5		27.8					46.6			3	6	32.7	1	2 1	2 2	117 42
16-3	9.7		21.9					18.6	50.6		3	7	13.0	2	1.3 1.7	2 2.7	174 318
5-2	35.8		19.0		2.2			44.4			4	5	42.0	1	2.7	2	300
Pontiac																	
25-1	6.0		35.2					56.2			3	6	18.3	2	2.7	2.7	171
13-2	4.2				44.7			50.2			3	5	24.1	2	2	3	13
22-2					79.9			18.0		2.1	2	3	16.4	3			
16-1			9.9		36.8			37.7		15.7	3	5	8.5	3			
15-1	11.7		10.4					72.5			3	7	16.1	1	1	3	31
21-4					15.0			53.0		5.6	2	26	6.7	3			
9-1					68.1			31.9			2	3	13.5	3			
35-4	44.0				2.2			46.1			3	6	47.4	1	1 2	3 3	94 45
18-4			22.0		50.0			29.3			3	3	13.8	3			
8-1	33.5		19.1		4.7			38.6			4	10	40.9	1	3 3 1	2 2 3	80 267 12
Bloomfield																	
24-2	14.6				68.7			9.0			3	5	40.2	2	n.d.	n.d.	41
21-2	21.7		27.4		19.1			26.1	1.7		4	7	32.8	1	3 2	2 3	206 40
5-4					19.7			50.4		23.7	2	3	5.0	3			
17-3					100.0						1	1	24.5	3			
31-1					97.9				2.1		1	1	11.7	3			

APPENDIX III--(continued)

Quarter-section	1964																
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
15-4	7.9				92.1						2	3	39.9	3	2	3	83
8-4					62.2			13.4	24.4		2	2	17.8	3			
30-2					60.1			30.8	4.0		2	6	11.8	3			
32-4	8.3		33.3		8.8			40.7			4	15	19.8	2	2	2	22
33-1					30.8		69.2				2	3	26.9	3			
Southfield																	
26-3					90.8			6.3			2	2	8.5	3			
35-4					100.0						1	1	19.8	3			
23-2	32.5				32.7			27.8		7.0	3	3	38.0	1	1	3	98
11-4					21.6			66.7		4.7	2	11	5.8	3			
21-3					85.4			14.6			2	3	6.8	3			
2-3	11.3				18.9			67.0			3	12	17.6	1	n.d.	n.d.	33
33-4	11.7				37.8			40.7		4.0	3	7	20.5	1	n.d.	n.d.	31
20-2	27.0				22.2			50.2			3	5	31.2	1	2	2	82
3-1					100.0						1	1	18.5	3			
13-2					56.8			33.9		1.4	2	13	10.6	3			
Addison																	
23-4	25.2		24.0					52.4			3	7	30.7	1	2	2.7	137
33-3	41.5		8.1					50.4			3	4	42.8	1	2 n.d.	3 n.d.	100 36
36-4								100.0			1	1	5.6	3			
12-1	43.7		29.8		2.8			23.8			4	5	36.7	1	2	3	311
13-1	32.4							67.6			2	2	31.6	1	2.3	2.7	593
32-2	44.9		4.7				37.6	10.7	2.1		4	5	49.3	1	2	3	154
31-1	13.7		76.4					8.0			3	4	27.2	2	1.7	3	68
11-2	27.6				7.6			64.8			3	6	27.9	1	1 1	2 3	31 69
8-1	21.2		6.5					69.3			3	4	29.6	1	2.7 2	3 3	267 204
2-2	19.1		45.7					35.2			3	5	25.7	1	1.7	3	117

APPENDIX III--(continued)

Quarter-section	1964																
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
Oakland																	
21-1	18.5		3.4					78.5			3	6	17.8	1	2 1.7 n.d.	2.7 2.7 n.d.	35 8 248
12-3	5.9		3.8					90.3			3	3	9.6	1	3	3	17
31-4	27.3							72.7			2	3	32.8	1	2.7	2.3	103
7-2	41.8		38.8					15.5	3.9		3	5	45.7	1	2.3 2	2.7 2	398 18
30-3			11.4					88.6			2	2	2.3	3			
10-2	55.8		14.1		4.8			25.3			4	8	45.8	1	2.3	2.3	275
28-1	10.4		58.8		18.0			8.0			4	7	27.1	2	2	2	54
3-2	53.2		3.4					43.5			3	4	49.1	1	1.7 2.3	2.7 2	139 171
36-4	14.6		17.6					67.0			3	6	18.9	1	2.7 2 1	2.3 2 2	108 31 40
27-4	7.5							90.5			2	2	14.8	2	1	2	22
Avon																	
29-3	21.5		8.5					68.3	1.8		3	4	26.6	1	3 1.3	2 2.3	73 133
12-3	24.6		26.7					45.0			3	10	27.0	1	1 1 2	3 3 3	22 224 12
8-3	26.2							73.8			2	2	26.8	1	3	3	79
3-1	14.9		14.5		38.7			27.8			4	10	26.1	1	n.d. 3 n.d.	n.d. 2 n.d.	27 10 17
17-4	4.3		5.4		3.5			80.3			4	13	8.5	2	n.d.	n.d.	13
1-3	18.4	12.3	13.9		7.0			45.5			5	9	22.9	1	2 2	2 1	87 36
25-1	31.8		3.4		25.0			39.8			4	6	37.2	1	2	3	91
33-1	13.6				2.2			81.0		3.3	3	3	18.1	1	2	2	61
32-4	16.1		34.3		14.9			34.7			4	6	18.2	1	1 n.d.	3 n.d.	22 27
9-1	13.1				1.5			84.0			3	5	21.7	1	1.7	3	33

APPENDIX III--(continued)

Quarter-section	1964															
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
Troy																	
16-1	9.1		20.6		3.3			67.1			4	5	18.6	1	2	2	74
3-3			13.6		77.7			8.7			3	6	12.8	3			
31-2					94.9					5.1	1	1	26.1	3			
23-1	15.3		6.8		4.7			73.3			4	6	21.3	1	1	3	44
5-4	10.5							89.5			2	2	14.6	1	2	3	99
1-2	3.1		2.7		39.6			54.6			4	7	10.9	2	n.d.	n.d.	10
12-4	4.3		3.0		10.7			82.1			4	4	8.6	2	1	3	134
9-1					96.9		3.2				2	2	5.9	3			
33-3			5.3		46.0			41.6		6.6	3	8	7.8	3			
36-1					94.6			5.4			2	2	9.7	3			
Royal Oak																	
3-3	8.8				86.7					3.8	2	3	31.2	2	n.d. n.d.	n.d. n.d.	13 11
10-2					89.7			8.5		1.4	2	4	20.0	3			
25-4					72.0			11.3		15.9	2	4	19.1	3			
24-3					92.8					7.2	1	2	18.1	3			
18-2					96.0					4.0	1	1	23.2	3			
6-3					93.6					6.4	1	2	6.8	3			
4-1					90.4		3.0			6.6	2	3	14.5	3			
9-1	4.8				95.1						2	4	28.0	3	n.d.	n.d.	12
LAPEER COUNTY																	
Elba															n.d. hereafter		
16-3	12.0		18.1					67.2	2.7		3	4	28.2	1			22 9
30-1	5.7		9.8					84.5			3	3	11.8	2			37
14-4			11.3		3.1			21.1	64.5		3	4	6.8	3			
36-3	31.5		3.1					65.4			3	4	38.8	1			108 16
13-4	33.3							65.5			2	4	41.0	1			166

APPENDIX III—(continued)

Quarter-section	1964															
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
28-1	26.7							73.3			2	2	29.1	1			93
7-3	17.1		6.1					76.7			3	3	22.1	1			328
33-4	3.9		14.8					81.3			3	4	7.1	2			10
11-1	3.5		15.6		1.6	14.8		63.0			4	8	8.6	2			9
34-2	59.2							36.6	4.2		2	3	61.3	1			281
Hadley																	
6-3	23.8		5.3		0.9	3.1		67.0			4	6	22.4	1			54
16-1	4.7					1.2		90.7	0.8		3	5	9.5	2			12
33-3	12.9		5.7					81.4			3	3	17.3	1			60
2-1			20.8					76.4	1.4		2	4	10.4	3			
35-4	38.0		10.7					50.9			3	4	45.9	1			140
20-3	48.6		46.7					4.7			3	3	53.9	1			843
28-3	21.2		59.5					15.6	3.7		3	9	32.8	1			10 32 15
14-4	3.4		15.0					74.9	6.0		3	4	17.3	2			64
15-3	8.1		21.2					70.7			3	4	18.5	2			11 36
10-3	47.5		13.3					35.7	3.5		3	5	44.9	1			223
Lapeer																	
18-2	12.3					1.7		84.7			3	4	20.3	1			29
32-1			8.5					79.2		12.4	2	2	10.9	3			
17-3	34.2		7.8					52.1	5.8		3	4	36.1	1			120 187
36-1								100.0			1	1	11.1	3			
28-3	13.5		15.0		3.7			64.8		3.0	4	6	27.6	2			278
Metamora																	
33-1			40.9					56.6			2	6	24.2	3			
2-1	43.1		10.8					46.1			3	5	52.1	1			1398
35-1	25.3		26.4					48.4			3	5	47.7	1			31 365

APPENDIX III--(continued)

Quarter-section	1964																
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
20-4	15.0							85.0			2	2	21.9	1			43
28-1	7.9		29.2					60.6			3	3	27.1	2			57
14-3	15.6		79.2					3.9			3	4	30.5	2			99 59
15-2	16.7		20.2			2.3		60.7			4	6	22.5	1			65 13 14
10-3	27.5				0.8			71.7			3	3	34.4	1			87
3-2								97.6		2.4	1	1	5.3	3			
18-2	24.8		6.8					68.4			3	4	25.5	1			51
Attica																	
18-3	8.3							91.7			2	2	12.3	1			90
32-3	18.0		5.6	9.8				64.7			4	6	31.1	2			536 112
16-1	18.9							76.9	4.2		2	5	22.5	1			42 31
28-2	32.7							66.5	0.8		2	2	35.1	1			180
Dryden																	
33-3	20.1		44.4					35.1			3	4	34.3	2			52
22-1	4.2			3.4				92.3			3	3	16.9	3			11
8-1	16.2		9.6					74.2			3	3	19.9	1			154
7-4								100.0			1	1	7.5	3			
21-3	39.6		44.1					16.3			3	5	43.9	1			107
29-3			6.8					93.2			2	2	10.3	3			
32-2	14.3		5.7					80.0			3	3	17.8	1			322
9-3	22.7							77.3			2	3	27.1	1			132 15
16-1	6.7							93.3			2	2	9.9	1			18
3-1	33.4		5.9					60.7			3	3	38.7	1			220

APPENDIX III—(continued)

Quarter-section	1964															
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetation types	Number of vegetation patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
GENESEE COUNTY																	
Davison																	
34-3	8.5		3.5		3.8	4.2		76.9	3.1		4	5	11.1	1			155
14-1								94.9			1	1	3.0	3			
10-3					28.0	36.2		35.8			3	4	6.4	3			
26-2	24.8		11.4					63.8			3	5	29.9	1			42 66 7
24-3	5.2							91.8			2	2	12.2	1			63
35-1	7.8							92.2			2	2	9.7	1			20
21-2	3.3		22.1		1.2			73.4			4	5	9.3	2			16
Atlas																	
3-3	16.5							80.5	2.9		2	2	19.8	1			231
26-1	17.8		9.4					71.2			3	6	23.9	1			143 30
30-2	10.4							89.6			2	3	15.9	2			167 14
11-2	11.3							88.7			2	3	17.2	1			41 25
24-3			11.7					87.9			2	3	6.9	3			
20-4								100.0			1	1	2.7	3			
33-2								100.0			1	1	3.3	3			
8-4	12.1		5.3		15.9			66.7			4	7	17.0	1			86 38
9-4			5.3					91.7	3.0		2	2	6.0	3			
16-4	49.6							50.4			2	2	39.8	1			277
Burton																	
26-4					13.2	0.7		85.7			2	6	3.1	3			
32-3			14.7		52.4	8.3		21.0			3	7	6.7	3			
13-4			14.5		9.4	14.5		61.7			3	4	7.1	3			

APPENDIX III--(continued)

Quarter-section	1964															
	Per cent deciduous forest[b]	Per cent coniferous forest[b]	Per cent brush[b]	Per cent orchard[b]	Per cent PR[b,f]	Per cent PR'[b]	Per cent PO[b]	Per cent herbaceous[b]	Per cent water[b]	Per cent non-vegetated[b,g]	Number of vegetated types	Number of vegetated patches	Per cent total tree cover[h]	Distribution of tree cover[c]	Density forest patches[i]	Diameter class, forest patches[i]	Size, forest patches[e]
Grand Blanc																	
11-3	26.3							73.7			2	3	27.3	1			167
28-1			15.2		4.8	2.2		58.9			3	7	6.8	3			87
18-4	6.7				1.9			82.2	1.5		3	5	9.0	1			65
25-4								100.0			1	1	1.1	3			
6-3	5.9				53.8	16.2		10.7			3	3	29.4	2			15
19-3	10.7		10.6		5.7	4.6		68.4			4	7	15.9	1			107
3-2	17.0				2.9			78.6			3	4	24.0	1			24
20-2	18.8		11.5		2.7			60.9			4	8	19.8	1			23 10
34-3	26.0				8.2			65.8			3	5	32.2	1			79 106
14-1					2.3			97.7			2	2	1.7	3			21
Mundy																	
23-2	8.1		22.8		7.4			53.3	0.7		4	8	8.7	2			54
12-1			8.3		35.6	25.0		29.6			3	5	11.2	3			
14-3	29.1							64.2			2	5	30.1	1			24
13-1	8.2				3.9	12.8		69.7			3	7	12.4	1			200 12
Fenton																	120
9-1	5.2					1.9		92.9			3	3	9.5	1			14
36-4			18.8	4.3	14.1	1.4		40.4	18.1		4	10	9.9	3			
1-2					4.6	1.2		86.1	8.1		2	5	7.9	3			
21-1	8.1				9.3	7.0		19.3	56.3		3	3	13.5	2			66

[a]Quarter-section code: 2 1 / 3 4

[b]See pp. 52-53 for definition. Percentages do not always equal 100, because of rounding or small measurement errors. "Percent non-vegetated" includes roads.

[c]See pp. 53-54 for explanation of code.

[d] No data.

[e] Expressed in number of dots at rate of 121 per square inch. Multiply by 0.53 to express in acres.

[f] For 1964, PR includes PR' for townships in Oakland County (Holly through Royal Oak).

[g] For 1964, "percent non-vegetated" does not include roads. To obtain an approximation of area in roads, sum percentages of vegetation types, water, and "non-vegetated" and subtract from 100.

[h] Recorded for 1964 only.

[i] Data available only for townships in Oakland County (Holly through Royal Oak), for 1964. See page 54 for explanation of code.

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