IDENTIFYING AND MEASURING AMENITY-BASED PARCELIZATION PATTERNS IN THREE RURAL WISCONSIN TOWNSHIPS

By

Dan McFarlane

A thesis submitted in partial fulfillment of the requirements of the degree

MASTER OF SCIENCE IN NATURAL RESOURCES
Land Use Planning
UNIVERSITY OF WISCONSIN
Stevens Point, Wisconsin

December 2007

APPROVED BY THE GRADUATE COMMITTEE OF:

Dr. Anna Haines, Committee Chairman
Associate Professor and Land Use Specialist

Eric Olson
Instructor and Land Use Specialist

Dr. Keith W. Rice
Professor of Geography

ABSTRACT

The land division process, or parcelization, is considered a instrumental step in the change in rural landscapes from areas that rely on natural resource extraction to communities that package and sell the landscape itself for real estate development. The process of parcelization can have cumulative affects that ultimately alter landscape patterns. Despite a growing perception of an increased rate of parcelization in rural Wisconsin and elsewhere, the land division process has rarely been studied. Research that does look at parcelization trends only extends about twenty years back and is mainly tied to either the growing number of landowners or changes in average parcel size (Brown, 2003; Butler, 2004; LaPierre, 2005). Little attention has been given to any spatial dimension of parcel creation.

Historic parcel information is stored in paper format, making it difficult to employ sophisticated spatial analysis. To overcome this, we interpreted paper plat maps and archived tax assessment rolls to accurately reconstruct historic parcel layers at various time periods utilizing Geographic Information Systems (GIS) in three rural Wisconsin communities. In addition, historic land cover and land use was also generated by interpreting archived aerial photos. Using multiple landscape ecology metrics, we documented and analyzed changes in both the parcel and physical landscape. Attaching landscape features to parcels also help us understand the extent that natural amenities influence parcelization.

In this study, GIS provided the basis for the reconstruction and spatial analysis of parcelization of three townships in Columbia County, Wisconsin. By using landscape ecology principles, the spatial dynamics of parcel creation and resulting fragmentation provides a new direction in characterizing parcelization and potential land use change. While it is apparent that parcelization has occurred in each township, this research has allowed one to measure the spatial dynamics of parcel creation, something that has rarely been done before. Finally, examining the spatial pattern of parcel creation in each community and its relation to land use variables over time helps us assess the features that appear to drive parcelization. The results provide useful tools for communities looking to better understand factors that drive parcelization and to preserve large blocks of land for both habitat and farmland preservation.

ACKNOWLEDGEMENTS

Many people contributed their knowledge to this thesis, especially my graduate committee. The assistance I received from them was imperative for the successful completion of this research. Foremost among these is my advisor, Dr. Anna Haines. I thank her for the opportunity to work on this project and for providing valuable comments and guidance along the way. I also wish to thank Eric Olson for answering countless questions, providing direction, and for reviewing several versions of my thesis. His knowledge and innovative ideas will always amaze me. I would also like to thank Dr. Keith Rice for his interest and technical support through all stages of the research.

This project would not have been possible without the generous funding support from the USDA Cooperative State Research, Education, and Extension Service – Natural Resource Initiative.

I would like to acknowledge the citizens of Columbia County, Wisconsin for their support and interest in this project. Kristin Anderson, Randy Thompson, April Goeske, and Edie Eberle provided data and real-world context for many of the methods used in this study.

Several undergraduate students provided support during the early stages of the project. Mark Swenson, Jake Sedivy, Patricia Diederich, and Gina John all dedicated numerous hours on this project and I value their work and companionship.

Lastly, I would like to thank those dearest to me including my mom and dad, Deb and Pat, and my brothers, Scott, Dean, and Matt. They all provided me with the

tools and encouragement to accomplish my goals. To my wonderful girlfriend, Erin, who has made this experience sweet.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: THE PROBLEM AND ITS SETTING

Introduction and Importance of the Study

Rural communities in America provide the food, fiber, and mineral resources for a growing national population. These areas are characterized by low density human development outside of towns and cites that are usually agricultural or natural forest. Ongoing residential migration and second home development into rural areas are transforming the landscape from one of resource extraction and renewal to one that carves up the land for consumption and development. The conversion of rural lands into a residential and urban landscape typifies the pressures of our growing population.

The division of large tracts of land into smaller pieces, known as parcelization, is considered a critical step in the transformation of rural landscapes. A precursor to rural land use change and landscape fragmentation, rural land subdivision undermines the incentives for long-term resource-based land management that humans depend on (Brabec & Smith, 2002; P. H. Gobster & Rickenbach, 2003; Holdt, Civco, & Hurd, 2004a; LaPierre & Germain, 2005; Mehmood & Zhang, 2001).

Over the past two centuries demographic, socioeconomic, and environmental factors have played an important role in the parcelization process. While many rural communities continue to lose population, areas with abundant natural amenities, such as lakes, topography, and public lands have steadily experienced higher population and economic growth than areas lacking these same features (Deller, 2005; Marcouiller, 2002). While people's perceptions of an increased rate of parcelization are common, empirical evidence of such changes in Wisconsin or elsewhere are largely tied to the growing number of land owners or changes in mean parcel size. The process of parcelization has rarely been studied, and what research does exists is limited and the analysis seldom extends further than twenty years (Drzyzga & Brown, 1999). A key reason for this lack of study is the accessibility of the data.

Until recently, counties have kept their land ownership data in a paper format as legal descriptions and published plat books. Because much of the historic parcel data remains in paper format, analyzing archival cadastre information is very difficult and time consuming. While the parcelization process is hardly new, the long-term trends have rarely been measured. It is unknown whether rural communities in the U.S. are experiencing higher rates of parcelization today than in the past, and researchers are unsure as to what, if any, spatial relationships of parcels exist or how that pattern has changed over time (Drzyzga, 1999; Gobster, 2003; Gobster, 2000).

Changes in land ownership boundaries may not affect the physical landscape, but could have numerous consequences on land use, land cover, and the social well-being of the local community, including habitat impacts, water quality, and economics (Rickenbach & Gobster, 2003; Theobald, Miller, & Hobbs, 1997). Landscape parcelization therefore is a growing concern because it not only affects land use, but can have cumulative affects that impact local governments, alter landscape patterns and structure, forest and agricultural sustainability, plant and animal diversity, and recreational opportunities (Croissant, 2004; P. H. Gobster & Schmidt, 2000; Mehmood & Zhang, 2001).

This study explores the potential for planners and researchers to employ a new set of tools taken from the field of landscape ecology to measure and quantify the changing spatial dynamics of parcelization. It will investigate specific relationships between landscape amenities and parcels that split.

By determining the rate and pattern of parcelization in rural communities, rural planners can benefit from new tools and ideas, ultimately mitigating the negative consequences of how development impacts natural resources and rural communities. Ultimately, this research will aid in understanding the significance of how certain landscape features influence the land division process so that local officials can better target conservation efforts towards parcel management.

CHAPTER 2: REVIEW OF THE RELATED LITERATURE

I. Known Trends and Drivers

Many definitions of rural areas exist today, including both subjective and quantitative qualities. For the most part, rural means places that are sparsely settled and are some distance from an urbanized city. The federal government considers rural, or non-metropolitan areas, as places with less than 2,500 people (Lane, 2005). While the actual delineation of rural areas may be ill-defined, one thing is for certain, the rural landscape in America is continuing to experience change. Over the last one hundred years rural populations have fluctuated, but a consistent trend has emerged: more people are leaving than arriving. Modern economic forces and advances in technology have reduced the demand for workers in many rural-based manufacturing businesses (Daniels, 1999). The result is a decrease in population especially in rural farming, logging, and mining communities. However, historic land division systems and the desire for open space shows that not all rural areas are facing population and economic declines. In fact, some rural communities are outpacing other rural and urban areas in terms of population and economic growth (Johnson, 2006). The dynamics of land use thus can be fairly complex, yet there is a written record. Since the age of European settlement, land parcels have been taxed, bought, and sold. It therefore has been tracted and recorded. We thus can trace the evolution of land division that will help us understand the process of parcelization and patterns of land tenure.

History of Land Division in the United States

An important process in human settlement and land use change is the division of land, therefore, it's important to understand the history of parcelization and how land ownership and division has been legally described in the U.S. Legal descriptions provide spatial coordinates, distances, and directions which "accurately" describe an owner's property. The first step in land ownership is to show who has rights or title to certain parts of the land. The way in which land is legally divided has a strong influence on property, administrative, and ecological boundaries (Hart, 1975).

Metes and Bounds System

The metes and bounds system for describing real property originated in England and is still used there today. Not surprisingly, this method became custom in the thirteen original colonies of the United States (Thrower, 1966). The metes and bounds system refers to known landmarks, such as tress, buildings, or ridge tops, that surveyors used for delineating property corners. Since landmarks, roads, streams, and other natural features may disappear over time, reestablishing, selling, or subdividing original property lines can be almost impossible. The United States acquired vast amounts of new land after the Revolutionary War through the Louisiana Purchase and other treaties. Land claims and disputes became serious and common not only with U.S. citizens, but also with Native Americans and other countries over much of the new territory (H. Johnson, 1976). Consequently, the Federal Land Ordinance, proposed by Thomas Jefferson, required that all lands west of Ohio be surveyed in an efficient, timely, and accurate manner, thus abandoning the cumbersome and confusing metes and bounds system (Hart, 1975).

Public Land Survey System

The new system of land division and describing newly created land parcels was called the U.S. Public Land Survey System (USPLSS). Unlike the metes and bounds description in eastern parts of the country, the PLSS cadastral system was established to provide an orderly procedure for measuring and defining unambiguous land boundaries. Administered by the General Land Office within the Department of the Interior, professional surveyors were ordered by the government to survey parts of Ohio and all lands to the west. They divided the land into townships six miles square, then further subdivided townships into thirty-six, one mile sections, designating Section 16 for rural schools (Figure 2.1). Sections were commonly subdivided into sixteen, forty acres parcels, commonly known as the current tax parcel. Ohio and areas west were chosen because these areas held the largest block of unsettled and unclaimed lands by Americans (Hart, 1975).

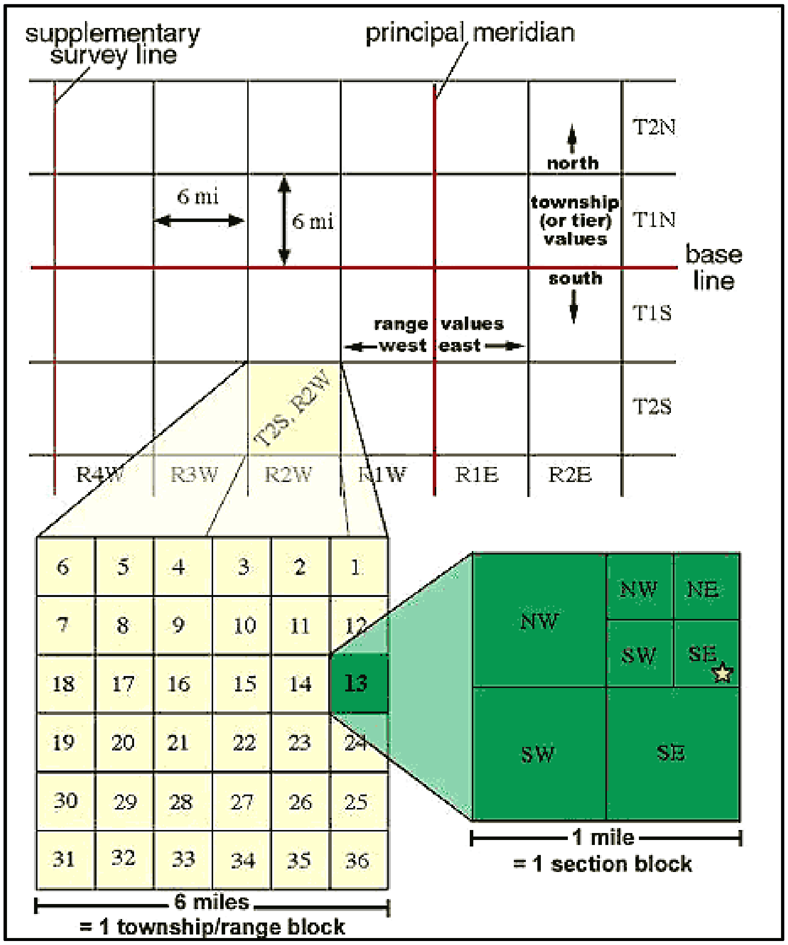


Figure 2.1. Diagram showing how the systematic division of land through the Public Land Survey System, source: Geospatial Training and Anaylsis Cooperative.http://geology.isu.edu/geostac/Field_Exercise/topomaps/plss.htm

The Land Ordinance of 1785 was successful in creating a rectangular land survey that was an easy way to subdivide large amounts of land and alleviating most property disputes. Over three-fourths of the continental U.S. came under this survey systems, which ultimately contributed to the orderly settlement pattern of the land. However, there has been some criticism of the rectangular survey system. Most notably, the system has required more money spent on rural services, such as transportation, electricity, and telephone lines. These features tend to follow section lines rather than a more fluid or spider web network found in the eastern parts of the country. In addition, the PLSS has encouraged the layout of farm fields to go against the grain of the local typography (Thrower, 1966). Lastly, sociologists have that the original "forty" ensured that homesteads would be isolated across the landscape, resulting in the "incomplete socialization" of rural communities (Bertrand, 1957).

Rural Population Trends

Rural Migration

In the first years of United States independence, large number of immigrants arrived from Europe. Some of these immigrants moved to cities where the jobs and money were. However, many wanted to preserve their agrarian pasts and saw inexpensive lands as an economic opportunity. Land was also a symbol of power, wealth, and social status, which made coming to the New World desirable because land was cheap and abundant (Shannon, 1936). In addition, during the mid 1800s, the federal government viewed the vast public domain as a source of revenue and development. The passage Homestead Act of 1862 was significant since it gave incentive for people to move into rural areas. The law allowed citizens over the age of 21 to acquire a quarter-section of unclaimed land if they were to develop and utilize the land for farming or forestry (Potter & Schamel, 1997). As a result of growing cities and a demand for food and fiber, the labor needed in agriculture and forestry was high and young workers migrated to rural areas (Shannon, 1936).

Rural Population Loss

During much of the 1900s, the most consistent trend was a rural to urban migration. Several factors are responsible for this pattern of migration. First, the demand for rural land decreased as mechanization and technology replaced the labor needed in agriculture and forestry. Employment opportunities diminished in many rural communities and younger people moved to cities (Johnson, 2006). Secondly, poor logging practices in forested regions resulted in the loss of productive timber and companies sold the cutover land to hopeful farmers. However, infertile soils in these areas proved too challenging and farms were abandoned. This along with the Great Depression further worsened the rural community scene and large amounts of land were reverted back to the public domain (WDNR, 2006).

Rural Rebound

The loss of rural population ended in the 1970s with the Rural Rebound (Johnson, 2006). Rural communities with abundant natural amenities, such as places with significant shorelands, public lands, and topography are outpacing other urban and rural areas in terms of population and economic activity (McGranahan, 1999). In the past, rural population balanced between natural increase and net migration, with rural communities usually losing people to urban areas. However, the gain in rural population since the 1970s, appears to be mostly from net migration.

Drivers of Rural Parcelization

Rural land parcelization and changes in subsequent land development revolves around several factors including demographics, preferences, and the land market (Daniels, 1999). Most of these forces are well known and documented, such as population growth and migration. As the population increases, the demand and need for more land grows, thus, some degree of parcelization and landscape fragmentation is inevitable. However, recent trends of distant exurban migration remains somewhat unclear. The literature suggests the causes of rural land consumption can be divided into two forces: supply and demand. The supply of rural land revolves around the land market, while the demand for rural land centers around demographics and lifestyle (Mehmood & Zhang, 2001). Traditionally, urban land use models were useful in describing land conversion at the metropolitan fringe, where development is driven by population changes, infrastructure, and in-migration (Capozza & Helsley, 1989). However, amenity-driven development and land use change in rural areas remains poorly understood.

Demand for Rural Land

Urban Push Factors

An important factor in the demand for rural land over the last several decades has been due to negative urban characteristics. Growing urban populations centered on metropolitan areas has caused a declining quality of life in many larger cities. Cities became notorious for their high crime rates, decreased quality of schools, limited green space, high land prices, and traffic congestion (Daniels, 1999). The decline in the urban quality of life was brought on by the Industrial Revolution, which caused a steady flow of rural residents to move to cities (USDA, 2006).

Rural Pull Factors

In addition to urban push forces, rural characteristics became appealing to city residents. Since the 1970s, more and more people began leaving cities and suburbs for more distant rural communities (Fuguitt, 1989; Johnson, 2006). They were attracted to rural areas for a variety of reasons including scenic beauty and a higher quality of life. Employment opportunities that were not available in the early part of the century were now abundant. Not only could people find work, but their children could attend quality schools. Rural areas also offered cleaner air and water, recreational opportunities, less traffic congestion, and cheaper, abundant land. Lower residential densities with lot sizes as large as ten to eighty acres offer many people with ample open space and scenic views not found in cities (Schultink, 2007). Transportation and infrastructure advances cut commuting time, allowing for people to live farther from the workplace.

Automobile and Accessibility

Prior to the automobile, rural residents were primarily farmers. After WWI, the automobile emerged and provided greater mobility for both the farmer and the city resident. Highway improvements and the construction of the interstate highway system in the 1950s allowed city dwellers easy access to the countryside where they first visited and then eventually purchased land for homes. After WWII, rapid growth in cities resulted in the outward expansion of development in the outskirts. This was so prevalent that the Census Bureau introduced the term "urban fringe" to describe dense non-farm development patterns (Hart, 1975).

Natural Amenities and Open Space

The demand for natural amenities and open space also plays an important part in people's decision to locate in rural communities. Social scientists have found that the demand for open space and solitude has been a significant driver for many migrants to rural areas. The desire for open space, especially since the 1950s, has resulted in a fourteen percent increase in rural population change (K. Johnson, 2006). In fact, amenity-rich communities today still outpace metropolitan areas in terms of population growth.

In a recent survey, Diamond and Noonan (1996) found that nearly 77% of surveyed respondents said that open space was their highest priority for residential living. The selling of large lots, where ninety percent of rural homes are on parcels greater than one acre, supports the demand for owning rural lands. Rural residential parcel sizes have increased over time (ERS & USDA, 2002). The increasing residential lot size in rural areas may not be entirely a matter of choice. State and local regulations, such as minimum lot sizes defined in local zoning ordinances, may promote this trend. Nonetheless, low density development brings new patterns of land ownership, including smaller average parcel sizes and new landowners to rural communities (Dwyer & Stewart, 1999).

Seasonal Home Ownership

Building or purchasing a seasonal home is a dream for many Americans, though it can be an expensive proposition. Personal incomes have been increasing over the years, giving many Americans the ability to afford such property near their favorite recreational area. Leading the way in second home ownership are retirees. With nearly seventy-million "baby boomers" in the U.S. today, a large portion of those seasonal homes are expected to become permanent residents (Stynes, Zheng, & Stewart, 1997). Seasonal homes in some Upper Midwestern counties make up nearly eighty percent of all houses. When surveyed, nearly half of the seasonal homeowners were retirement age (Stynes, Zheng, & Stewart, 1997).

The Price of Rural Land

In comparison to urban land, rural land is relatively cheap. As a result, housing affordability becomes a strong driver of rural parcelization. As more jobs move to the suburbs, distant rural communities become commutable (USDA, 2006). Even though the cost of living and property taxes are lower, rural residents usually are still provided with adequate services, such as garbage pickup, road maintenance, and quality schools (Nelson, Duncan, Mullen, & Bishop, 1995). Furthermore, when faced with choosing a higher salary in the city or a lower salary near popular recreational areas, residents frequently choose the later (USDA, 2006).

Supply of Rural Land

The ultimate driver of parcelization is population growth and urbanization (Heimlich & Anderson, 2001). As population and urbanization increase, the demand for land will increase and parcelization of these lands will take place. However, there are other factors that can contribute to the parcelization process. These forces are associated with the availability of rural land on the market and include death, taxes, land speculation, and regulations.

Death

The average landowner age in the United States is increasing (Butler, 2004). Yet, it is not the age of the landowner that is the concern, but rather what is done with the land after the owner's death. Several authors have noted that a landowner's demise can play a significant role in land parcelization. The heirs of the property divide the land amongst themselves. Other times the land is parceled off and sold to help pay for estate and property taxes (DeCoster, 1998; Mehmood & Zhang, 2001; Stroud, 1995). With the average landowner age increasing in both agricultural and forestry regions, there is a growing concern over the transfer of land to heirs and potential parcelization. The majority of landowner's offspring have moved from rural areas to the cities and have no interest in agriculture or forest management. Taxes and the lack of interest in resource management on the land deters the offspring from retaining the land (Butler & Leatherberry, 2004; USDA, 2006).

Taxes

Property taxes play an important role in the rural land market in some states. Preferential property tax assessments on forestland and farmland in Wisconsin is based on use-value rather than the highest and best use for development. Rural parcelization and subsequent development can still bring new demands for public services. In turn, property taxes are increased, which makes farming and forestry less profitable (Daniels, 1999). As a result, many private landowners look to maximize their financial returns from their land. Doing so, usually results in land subdivision, where the price of a lot far exceeds the financial return of keeping the land in a productive use (ERS & USDA, 2002).

Land Speculation

Land speculators and developers play a large role in the supply of rural lands. During much of the twentieth century, land speculators imagined rural open space as prime real estate for stressed urbanites. Buying cheap land, developers would quickly subdivide and advertise new lots to potential urban markets (Heasley, 2003). They've also been criticized for oversupplying markets with vacant lots known as premature subdivisions (Shultz & Groy, 1988). Sometimes the rush to sell as many lots as possible has resulted in poorly planned subdivisions. Since officials approved the layout of these subdivisions before any substantive land use regulations were in place many lacked adequate infrastructure services. Many developers platted subdivisions at parcel densities which no longer are consistent with current development standards. As a result, numerous nonconforming lots remain undeveloped and pose significant economic and environmental problems for communities, as well as, potential home builders (Stroud, 1995). Though many lots still remain vacant today, local officials fear that the pressure to eventually build on them will increase as the population grows and more people migrate to attractive rural areas.

Regulations

Lastly, because local governments depend on property taxes for various services, they often compete with other nearby local communities for development. In doing so, they sometimes zone land to encourage development that will increase the property tax base. Large areas of rural land become zoned for dense development, essentially encouraging parcelization even though the demand is not there. Since land is usually cheaper and regulations tend be more lax than in urban areas, commercial and residential developers have an incentive to locate in rural communities (Daniels, 1999).

II. The Consequences of Parcelization

The parcelization of rural lands is not without its impacts. The division of large contiguous parcels into smaller tracts among many owners has raised concern that parcelization will ultimately lead to residential or commercial development (P. H. Gobster & Rickenbach, 2003). Over sixty percent of the land in the United States is privately owned and these owners play a significant role in the socioeconomic and ecological well-being of rural America (NRCS, 2001).

Administrative workload

While most of the parcelization literature has discussed socioeconomic or ecological implications of smaller parcel sizes, none have actually addressed the basic issue of how communities must deal with more parcels. The most obvious consequence of parcelization occurs at the local level. Answering the question "whose land is it?" is not too complicated in areas with only a few large landowners. However, the rapid growth in landowners in amenity-rich areas can make this question very difficult. As parcel and ownership patterns go from simple (few landowners, large parcels, and few types of land uses) to complex (many landowners, a range of parcel sizes from large to small, and many land use types), so to do the jobs for personnel, such as registrar of deeds, tax assessors and agencies, current and long range planners, and elected officials.

Consequently, the workload demand for recording land transactions can become overwhelming. Historically, the registrar of deeds kept land title and land transaction information in paper format. Recent technological advances has allowed many counties to pursue more efficient methods of recording property ownership. The use of automated land information systems (LIS) to manage land records has made storing this information easier, but in rapidly developing rural communities trying to build a digital cadastre database and keep up with newly created parcels, can be very challenging (Kuhlman, 1994). According to the Wisconsin Land Information Program's 2003 Assessment Survey, three-quarters of the state has been converted from paper to a digital format (Wisconsin Land Information Program, 2003).

Socioeconomic Impacts

One of the challenges modern planners face is integrating new economies with the old. Protecting rural ways of life, such as farming, forestry, and mining becomes difficult when these lands become subdivided, paved, and converted to other uses. The perception that parcelization will ultimately lead to development raises concern about the social well-being and sense of community in rural areas (Gobster & Haight, 2004). Land division can limit recreational opportunities, putting more pressure on remaining public lands. Furthermore, residents paying more for land bordering protected areas, such as parks, limit accessibility for others while creating their own access points (USDA, 2006).

The financial benefits of rural open space are often unnoticed. While many feel that development brings tax relief to rural communities, many community service studies show otherwise. In fact, keeping lands in farmland or forest uses costs considerably less per acre than does residential use costs per acre (Farmland Information Center., 2002). This cost differential makes intuitive sense, because residential landowners, particularly households with children, demand more services than farmland where little service provision is necessary.

The potential for human-caused fires increases when more homes are constructed in the wildland interface (USDA, 2006). In Colorado and other western states, new homes are constantly be built in fire prone areas. These states have long suppressed forest fires, which has eventually led to built up fuels. When a fire does occur, it they are often devastating. With many homes situated in forests, prescribed burning also becomes difficult, if not impossible.

Since many of the rural migrants have urban roots, the views of long-time residents often clash (Marcouiller, Clendenning, & Kedzior, 2002). Urban migrants are more apt to support environmental protection policies as opposed to long-time rural residents (Creighton, Blatner, & Baumgartner, 2004). Rural residents, on the other hand, often welcome growth, and disdain government regulation. These differing viewpoints can lead to conflict between new migrants and the long-time residents, creating major separation on public policy issues (Creighton, Blatner, & Baumgartner, 2004).

In addition, new residents often criticize the current land management practices, such as agriculture or forestry (Rickenbach & Gobster, 2003). Because dust, noise, and odor can drift across property boundaries, non-farm residents may often complain about farming practices. From a landscape ecologist prospective, as smaller parcels perforate the rural landscape, the boundary or edge between different neighbors increases (Clark, Park, & Howell, 2006). For example, in an agricultural area when two acre parcels are created, the new landowners have more new neighbors than prior to the parcel's creation. Therefore the potential for conflict increases, especially when the smaller parcels result in a change in land use. Such social fragmentation may lead to the eventual loss of the local farming and forestry base (Creighton, Blatner, & Baumgartner, 2004).

Lately, there has been a substantial decrease in the amount of non-industrial private lands open for public recreation. As large tracts of continuous ownership land become parcelized, public access to open space and water bodies for hunting, fishing, and recreation becomes much more limited. With more land owners and less private land access, there is increased recreational pressure on public lands (Rickenbach & Gobster, 2003). This trend is troublesome because current demands in some places are exceeding the capacity of some public lands and causing “recreational conflicts” (Dennis, 1992).

Ecological Implications

Rural open space, including forests, grasslands, and fields provide many essential and natural processes, such as regulating water cycles, filtering of clean water, moderating climate, and wildlife habitats (USDA, 2006). The migration of people to previously undeveloped rural areas results in land division and low-density residential development (Odell, Theobald, & Knight, 2003). As this occurs, roads, homes, and utility lines divide the natural landscape into smaller fragments. Fragmentation reduces the natural habitat, decreases the diversity of wildlife, and contributes to water degradation (Turner, 2005) Because property boundaries often do not follow ecological arrangements and processes, it too can lead to landscape fragmentation. Today, nearly one-third of all housing units in the Midwest are located in the wildland-urban interface (Radeloff, Hammer, & Stewart, 2005). Keeping undeveloped areas whole and conserving farmlands and forests is an important step in protecting functioning ecosystems. Public health and the economy are linked to the environment, therefore environmental implications from unplanned rural growth can have negative impacts on local communities (Heimlich & Anderson, 2001).

The field of landscape ecology has become an important part of natural resource management. Recent advances in technology has allowed researchers to study the spatial patterns of landscapes at various scales (Turner, Gardner, & O'Neill, 2001). Landscape ecologists have developed numerous metrics that measure these patterns for an entire landscape. The results of such analysis have provided resource managers and planners with a better understanding of the functional, structural, and change processes in the landscape (Leitão & Ahern, 2002).

Biologists have learned that it is not necessarily the amount of core habitat as much as it is the pattern and configuration of the landscape that is essential for species survival (Arnold, 1999). While some species may actually thrive in human dominated environments, others need a certain amount of habitat with connecting corridors to function (Turner, Gardner, & O'Neill, 2001). Still, the total amount of disturbance and the spatial patterning of human development ultimately effects the movement of plants and animals (Bissonette & Storch, 2003). In a fragmented landscape, habitat corridors become more critical to providing avenues for animals, helping species maintain biodiversity and preventing population declines (Meffe, Nielsen, Knight, & Schenborn, 2002).

Changes in land ownership, often the result of land subdivision, reshapes land management practices which can gradually alter the landscape. The desire of people to live in areas with open space increases human densities in rural areas, and, in turn, increases road and building densities. With people come pets, traffic, and invasive species (Odell, Theobald, & Knight, 2003). The cumulative effect of these is landscape fragmentation and each has the potential to drastically alter local biodiversity (Theobald, Miller, & Hobbs, 1997). Researchers have shown that parcelization alters the spatial pattern of land cover and can ultimately lead to landscape fragmentation (Croissant, 2004; Drzyzga & Brown, 1999; Holdt, Civco, & Hurd, 2004b).

Whether agricultural or forestry-based, rural parcelization signifies potential changes in the ecological sustainability of remote areas (Daniels, 1999). Although the effects of parcelization may not be apparent at first, smaller parcel sizes may lead to scattered homes near ecologically sensitive areas, fragmenting large forests and wetlands, and degrading water quality (Hersperger, 1994).

III. Measuring Parcelization

Land ownership is a primary link between humans and the land. Owning land establishes the right to decide how to use that piece of property (Butler & Stanfield, 2002). Hence, understanding the relationship between people and landscapes requires an understanding of historical ownership changes. This is especially important in rural and exurban areas where development patterns do not follow standard urban models and tend to be more irregular (Elena G. Irwin & Bockstael, 2002). A few articles and books remark on the rapid increases in the number of landowners and parcelization, yet a few researchers have attempted to measure it. Within this small group of articles, the majority of them measure parcelization in non-spatial ways, primarily using basic summary statistics to report their findings.

One of the easiest ways to measure parcelization is to simply count the number of parcels. Several studies use this approach and report the total number of parcels for a given year, often displayed in size classes. Forest inventory surveys are typically used by researchers to document the number and size of new forest landowners every five years (Butler & Leatherberry, 2004). Though this method is effective in calculating trends, it shows nothing about the spatial distribution of new parcels on the landscape.

Recent advances in computing power and spatial technology, as well as improved aerial photography and data availability, make sophisticated examination of historical land tenure possible (Heasley, 2003). Several studies have used Geographic Information Systems (GIS) to map parcel boundaries to help visualize land ownership trends. Their findings have shown that even with population declines, parcelization, in terms of number of new parcels, can still occur (LaPierre & Germain, 2005).

In her study to document that social factors can have a strong influence on landscape composition and structure, Heasley used GIS to reconstruct land cover and land ownership patterns in three rural townships over a sixty-five year period. She found that digitizing georeferenced plat books provided the best way to reconstruct the property mosaic. Though her research did not measure parcelization, it traced land ownership patterns over time, providing insight into the complex forces that shape the landscape.

While most parcelization research has focused on ownership data, few studies have tracked landscape change at the tax parcel level. Because tax parcel data provides a finer resolution for analysis than does ownership parcels, Clark *et al.* used available tax parcel information and a landscape metric to calculate the fragmentation of farmland in a Tennessee county. They estimated changes in edge density between agriculturally assess tax parcels between 1986 and 2004 and found that farmlands have become more fragmented over time (Clark, Park, & Howell, 2006). The methods employed in their research provided a unique approach to characterizing farmland conversion. However, to adequately expand this research to other areas, especially in Wisconsin, counties ultimately need to archive land tenure data with associated tax assessment information.

Despite anecdotal evidence that parcelization is occurring, it is unknown to what extent it is occurring at the county or even larger scale. To address this issue, the degree of parcelization on private lands in four rural counties was analyzed between 1984 and 2000 in a New York watershed. Due to the extensive number of parcels in the study region, the LaPierre and Germain used a stratified sampling method to select tax map sheets. The historic parcel layer was created using GIS and interpreting the selected tax map sheet along with the current digital parcel layer. Where they found discrepancies in tax maps and the current digital parcel layer, the newer parcels were merged into the parcel they originated from. They expected to find greater parcelization with closer proximity to New York City. However, analysis of variance showed that the average parcel sizes among each county was no longer significantly different between 1984 and 2000. This suggests that enough parcelization had occurred in the county farther away from New York City to make the difference in parcel size no longer significant. LaPierre and Germain propose that once an area becomes heavily parcelized, longer commutes are worth trading for increased parcel size (LaPierre & Germain, 2005).

In Michigan, researchers also measured land ownership and parcelization. They generated land tenure using archived paper plat books. Land ownership patterns were manually digitized in GIS in a vector format from the spatially referenced plat maps. Because privately-owned small tracts do not show individual lot boundaries on plat maps, the authors did not map each lot. Instead, they assigned the small tract polygons an average size of 0.20 acres, the average size of a subdivision lot. They measured parcelization in two ways. First, they calculated and compared the parcel size frequency distributions for various dates. This method allowed them to understand temporal changes in the parcel landscape. Next, they compared the average parcel size for various dates. Due to skewed data, the researchers calculated the geometric average rather than the arithmetic average size as a method of showing changes in parcelization over time (Drzyzga & Brown, 1999).

In another study, Medley *et al*. also utilized historic plat books to reconstruct property boundaries back to 1912 in southwestern Ohio. Parcel boundaries were digitized to georeferenced plat maps, assigning a unique number for each owner. After rasterizing the parcel layers, the researchers then overlayed and subtracted consecutive land ownership grids. The result of this analysis showed the number and location of new landowners at various times (Medley, Pobocik, & Okey, 2003).

Researchers in Connecticut also used plat maps and assigned a specific year of parcel subdivision to the current digital parcel database of six towns over a forty year time span. They could then illustrate where parcelization had occurred. Areas of parcel subdivision were finally used as a mask to study the effect parcelization had on forest fragmentation over time (Holdt, Civco, & Hurd, 2004a).

Recently, more complex modeling techniques have been developed to regarding land use conversion. Because the decision to develop a parcel is made by the landowner, Irwin et al. (2002) utilized a spatially disaggregated model to analyze the conversion of undeveloped parcels. They used parcel characteristics and government regulations aimed at controlling residential development to model land use change. The authors determined that many of the government control variables were significant in influencing the extent of residential development (Irwin, Bell, & Geoghegan, 2003).

While many of the studies provide methods for measuring parcelization, there remains no detailed record of historic parcelization, both ownership or tax parcel, dating back longer than thirty to forty years. Also lacking are comprehensive investigations regarding the landscape drivers of such parcelization in a rural context.

IV. Addressing Parcelization

The process of parcelization is not new. However, within the last one hundred years or so, there has been a realization of the negative impacts of unplanned rural development. To address the negative consequences of parcelization, policies at the federal, state, and local levels have been created. State and local governments have been given the authority to control land use and growth. In the past, planners reacted to growth by imposing various land use controls. Recently, comprehensive planning laws allows for more active roles in directing future growth (Hoch, Dalton, & So, 1988).

Federal

The roots of land division regulation lie within the national government's Federal Land Ordinance of 1785 and the USPLSS. Broad policies, such as the Clean Water Act and the National Environmental Policy Act, are managed at the federal level and were established in the 1960s and 1970s because of the growing awareness of toxic pollution, habitat loss, and species extinctions (Meffe, Nielsen, Knight, & Schenborn, 2002).

Although purchasing land may seem like a safe investment, it can be risky. Land scams and speculation go way back in the U.S. For example, developers in the early 1900s promised ideal retirement sites in faraway places such as Florida and Arizona and were marketed to New York City residents (Stroud, 1995). Eager residents purchased lots without ever visiting the land only to find out years later that their property was under water and no longer conforming to current regulations (Shultz, 1988). This triggered Congress in 1968 to pass the Interstate Land Sales Act to protect consumers from scams in land sales. Now, developers are required to register subdivisions of one hundred or more lots with the Department of Housing and Urban Development. The purchaser of a lot is also provided a property report by the developer with subdivision information (U.S. Department of Housing and Urban Development).

State

At the state level, agencies set further land use controls. Subdivision control in Wisconsin can be traced back to 1849, in which a survey and plat was required to subdivide land (Ohm, 1999). Due to rampant land sales following World War II, the state's subdivision ordinance was amended by the legislature to include extraterritorial control for cites and allowed for broader local regulation of land plattage (Melli, 1953). The updated law set minimum lot sizes for new residential parcels as well as special requirements for platted subdivisions. The current statewide subdivision ordinance is defined as: “The division creates five or more parcels or building sites of 1½ acres each or less in an area; or five or more parcels or building sites of 1½ acres each or less in an area are created by successive divisions within a period of 5 years” Wis. Stat. § 236.02(12)).

In the early twentieth century, Wisconsin authorized counties and local towns to regulate the type and use of land through zoning. Due to poor land management decisions, Wisconsin encouraged rural zoning in the 1920s to restrict widespread farmland development on unproductive soils in the northern regions of the state (Rowlands, 1963). The Department of Resource Development (now the Department of Natural Resources [DNR]) recognized that uncontrolled development along shorelines could degrade water quality. In 1966 the DNR was granted general supervision and control of Wisconsin’s waters and as a result, in 1968, a statewide shoreland zoning program was established to protect lakes and rivers from adverse impacts caused by land uses (WDNR, 2005).

When subdivision and zoning regulation were introduced in Wisconsin, land owners and speculators often carved out many new subdivisions in fear of restrictive controls once regulations were in place. In addition, the standards set in the state’s subdivision ordinance contain loopholes that landowners and developers often take advantage of. Setting minimum acreages and number of land divisions unintentionally leads developers and landowners to create parcels just above the state requirements, avoiding more rigorous controls (Melli, 1953). For example, a landowner can create four parcels at two acres each and not have to abide by platting laws. Little is known about the process of the platting law in this respect.

Local

Though Federal and State regulations are set, most of the land use controls are administered at the local level, such as counties and townships. This is important because in Wisconsin, unincorporated areas cover over ninety percent of the states land and is home to nearly one-third of the total population (U.S. Census Bureau, 2002). The administrative responsibilities to carry out these regulations are significant and not all local communities have the wherewithal to carry out such obligations (Olson, 2005). As a result, an inconsistent spatial pattern of local zoning control in Wisconsin exists today (WDA, 2006).

Even though zoning is a widely used land use control today, it is not a simple tool for local governments to employ. For example, local towns may find state or county land use standards too general to protect certain natural resources. Towns can then adopt their own zoning ordinances, but the ordinances are subject to veto by the county board (Ohm, 1999). A county may not approve a township's zoning ordinance because of regional non-uniformity thus making administration more complicated (Olson, 2006).

Since 1951, the state has given local governments the statutory right to enact land division laws governing subdivision regulations in order to address specific issues such as septics, roads, and open space (Melli, 1953). Local governments can define a subdivision in any manner, as long as it is more restrictive than the state statute (Ohm, 1999). For example, a town or county could define a subdivision as any newly created lot, no matter the size. Land division ordinances are becoming more appealing to local towns facing development pressure because adopting and enforcing such regulations are somewhat easier than zoning. Local land division ordinances do not involve the review and approval process of the county, unlike local zoning regulations (Olson, 2005). Many towns have also used moratoriums to briefly stop development and parcel creation during a planning process. This allows communities to make sure that current developments are consistent with the objectives of the planning process (Adams, 2007).

In addition to regulatory approaches to control parcelization, several non regulatory methods exist. Easements provide a method for local communities to protect certain parcels from future activities. Easements are voluntary legal agreements between landowners and some other party. Typically, easements prohibit certain uses and activities of a parcel of land. In turn, the owner keeps the land and usually is compensated through tax benefits (Schultink, 2007).

Other non-regulatory methods for controlling land use include Transfer of Development Rights (TDR) and Purchase of Development Rights (PDR). The primary difference between the PDR and TDR is what’s done with the development rights after they are removed from the parcel. In the case of a PDR program, the development rights are maintained by the purchaser and then retired. Usually the purchaser is a government entity or some non-profit organization. In a TDR program, the development rights are transferred from one parcel to another, targeting growth to more appropriate areas (Schultink, 2007).

V. Summary and Research Gaps

Change in rural communities is underway in the United States. Despite longtime population decline in most of rural America, some distant rural communities with abundant natural amenities and recreational opportunities are experiencing rapid growth. Over the last several decades, amenity-rich areas have been outpacing metropolitan communities in terms of both population and economic growth (Beale & Johnson, 1998).

This trend in population growth from urban to rural areas has its consequences. More landowners increases the potential for property disputes. The views of amenity migrants often differ from the long-time residents. The new landowners may disagree with existing land practices. The subdivision and subsequent development of rural homes fragments the landscape, making resource industries difficult to operate. Low density development in agricultural districts increase the potential for conflict among farmers and non farmers. This type of development also raises property taxes in order to pay for public services. The subsequent tax increases make farming less profitable and the owner sometimes has no option but to subdivide.

As more people seek a rural lifestyle, scattered rural homes located in forested regions are at risk for fire. Furthermore, with homes comes people's pets. The disturbance from development in ecologically sensitive areas creates more forest edge, displaces wildlife, and degrades water quality.

There have been numerous regulations directed at land division. The Federal Land Ordinance of 1785 opened up millions of acres of rural land in the United States for private ownership. The PLSS set the framework for land subdivision west of Ohio and is still used today. Due to poor land management, states were allowed to further regulate land division in the early 1900s. Still, land speculators carved out thousands of residential parcels in ecologically sensitive areas, especially along lakes and rivers. Due to increased development pressure and degrading water quality, some states, including Wisconsin, developed state-wide shoreland zoning regulations, which communities were required to adopt. Currently, most of the land use regulations in Wisconsin are controlled at the local level.

Research Gaps

The process of parcelization has been going on in the U.S. for over two hundred years. Even though there is a theoretical link between parcelization and fragmentation, few researchers have developed empirical evidence of the relationship between them or to understand the process from one to another. Furthermore, there is no widely accepted measurement of parcelization and those that do exist neglect spatial dimensions. With the nation's population at an all time high and with more people seeking rural open space, one would expect today's rate of rural parcelization to far exceed any previous time period. However, historic parcel data remains largely in paper format; therefore, few researchers have actually measured long-term trends in land division. The spatial reconstruction of legal parcels over time can suggest geographic patterns that a simple parcel count could not convey.

Tax parcels represent an essential aspect for understanding changes in both land ownership and land use. Digital tax parcel information is becoming more available at the county level, but historic parcel maps are mainly in paper format, making spatial and temporal analysis challenging and difficult. The literature suggests several causes or drivers of parcelization, mostly related to socioeconomic variables. The physical landscape itself appears to influence the spatial pattern of parcel creation in rural communities. By actively tracking the parcelization process and related parcel characteristics over time, specific landscape features that are associated with land division can be examined.

CHAPTER 3: METHODOLOGY

Overview and the Statement of the Problem

Researchers in the planning field are continually measuring and predicting land use change. However, very few have examined changes in land tenure, where land use decisions are ultimately made. A growing concern among these professionals is that parcelization has and will continue to threaten working landscapes and sensitive natural ecosystems. To date, there has been little research carried out to document the long term trends or to understand the environmental influences caused by parcelization. While the parcelization process in nothing new, there is no accepted or standard way to measure it. Historic parcel and land use data is largely non existent or in paper format, making it difficult to analyze.

Study Area Description

This research focuses on rural townships experiencing growth in rural residential development. Columbia County, Wisconsin (Figure 3.1) was selected for this research based on several criteria: availability of a complete spatial parcel database of the county, adjacency to a metropolitan county, a community actively engaged in planning, and local officials showing favorable relationships with research personnel. Columbia County, located in south central Wisconsin, represents an area experiencing significant growth from both urban fringe development from nearby Madison (state capitol) and rural recreational development due to the scenic nature of the area. Ideally, all of Columbia County would have been included in the study, but construction of the database is a time consuming process. Consequently, data reconstruction efforts focused on three rural townships in Columbia County at nearly ten year increments based on data accessibility. The townships of Lodi, Springvale, and West Point were selected based on degree of parcel density: low, medium, and high. Figure 3.2 presents the long term population trends in each township.

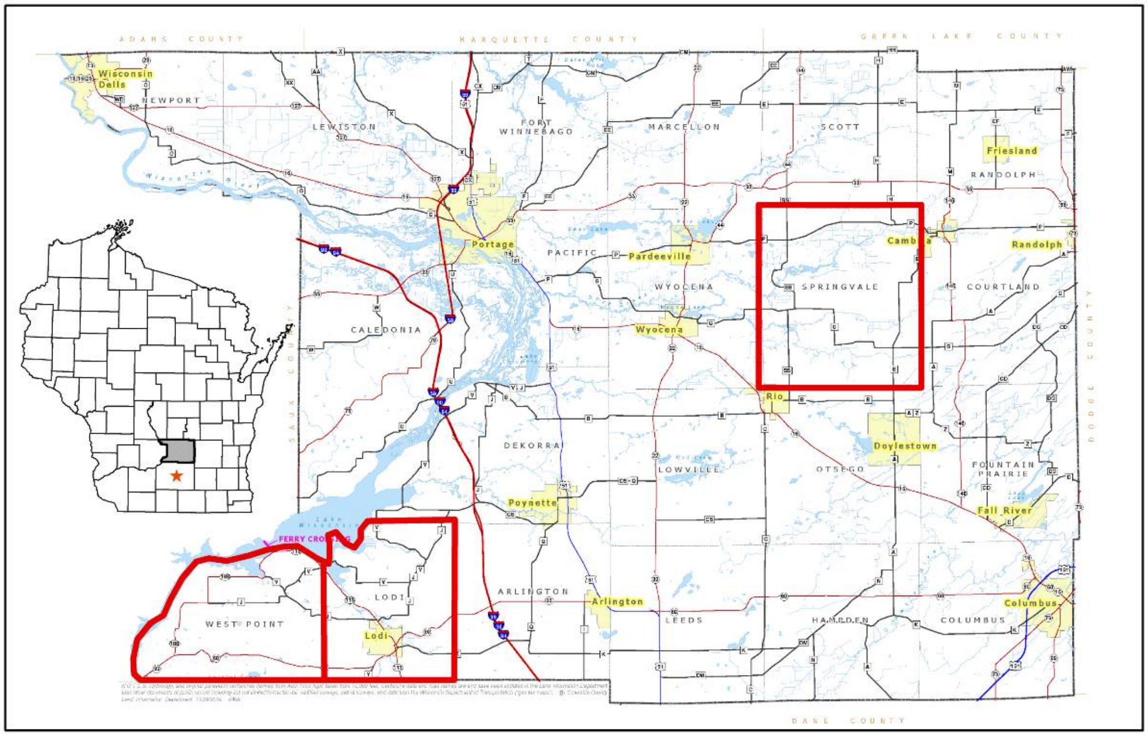


Figure 3.1. Columbia County, WI and local municipalities, outlined in red (Lodi, Springvale, and West Point) used in this research, source: Columbia County Land Information Office.

Although Columbia County remains mostly rural in nature with nearly 350,000 acres of active farmland and an overall population density of 70 persons per square mile, its convenient geographic location has resulted in a significant increase in rural residential development (Wisconsin Department of Tourism, 2007). With over 11,000 acres of lakes, 16,000 acres of public hunting and wildlife land, and numerous campgrounds, Columbia County has an abundance of recreational opportunities that attract both seasonal and new full time residents. Interstates 39 and

90/94 make this area also a short drive from Madison (30-40 minutes), Milwaukee (90-100 minutes), and Chicago (180 minutes or 5 hours).

The overall goal of this project was to document the parcelization process in an amenity-rich rural area in Wisconsin and explore the relationship of land use change by spatially reconstructing historic property boundaries and land cover at various years. The parcelization process was examined over time to detect patterns and trends in rural land division. From an analytical prospective, the effects and relative importance of many drivers of parcelization in an amenity-rich rural area were investigated.

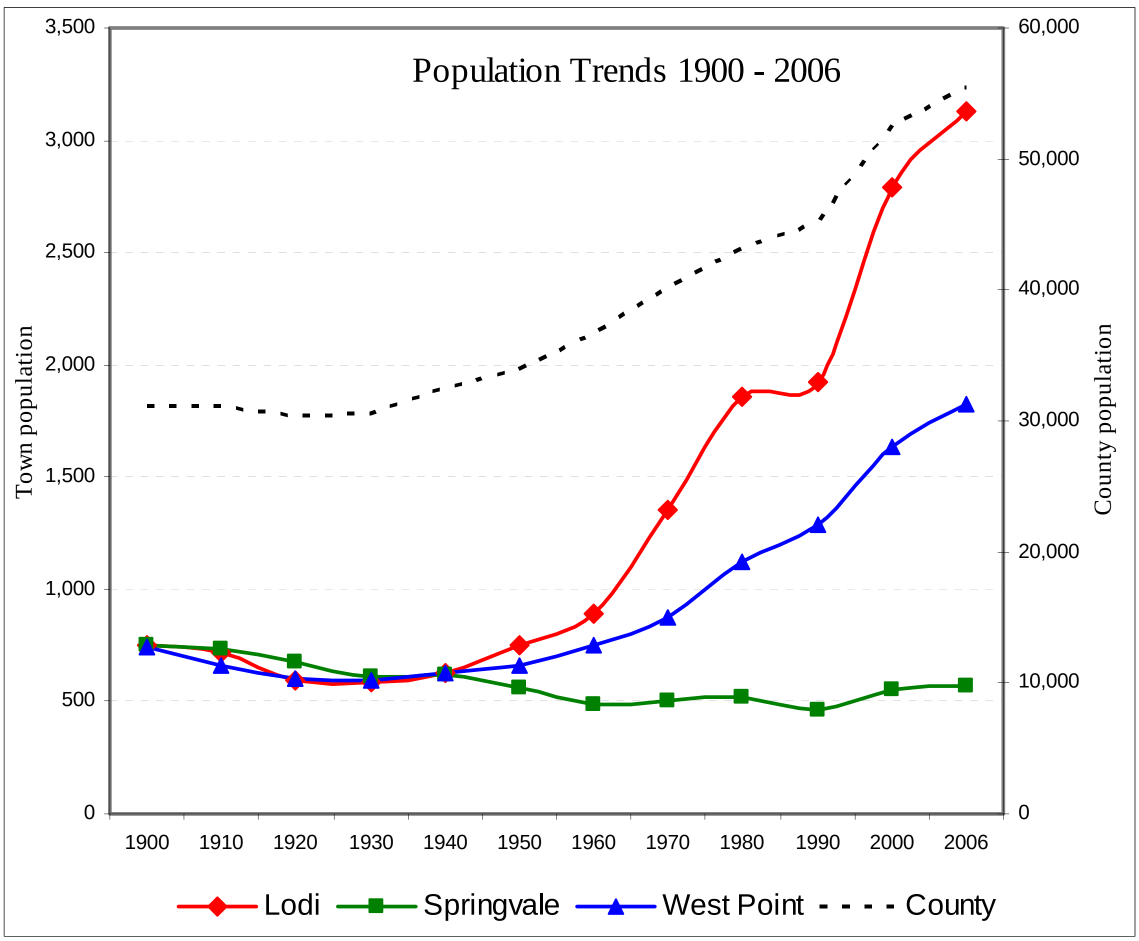


Figure 3.2. Population growth in each township and for the entire county from 1990 to 2006, source: U.S Census Bureau.

Subproblem 1

While parcelization in rural areas is becoming an important issue in rural communities, researchers and planners have largely used simple descriptive, such as change in land ownership or average parcel size. To characterize parcelization, multiple metrics are needed to analyze both the spatial and temporal trends, since no one measure can capture its complexity.

Problem Statement 1

This study will measure the spatial and temporal trends in parcelization by spatially reconstructing historic parcel patterns for three rural townships in Columbia County, Wisconsin. I hypothesize that parcelization has increased over the time period studied since population, income, and accessibility are at an all-time high.

Objective 1A.

Spatially reconstruct historic ownership boundaries at multiple years for three rural townships in Columbia County, Wisconsin.

Objective 1B.

Spatially reconstruct historic tax parcel boundaries at multiple years for three rural townships in Columbia County, Wisconsin.

Objective 1C.

Employ landscape ecology metrics to analyze the spatial and temporal distribution of new CSM and subdivision parcels over time for three townships in Columbia County, WI.

Subproblem 1 Methods

Objective 1A. Spatially reconstruct historic ownership boundaries at multiple years for three rural townships in Columbia County, Wisconsin.

Ideally, all of Columbia County would have been included in the study, but the construction of the database is time consuming. Consequently, parcel reconstruction efforts focused on three rural townships in the county. Studies of land tenure often focus on ownership boundaries, which defines property connected by a single person or entity. One reason for this is that data is more easily acquired in published plat books, which are often printed on a yearly basis and archived at numerous locations including county offices, town halls, libraries, and historical societies. To attain a representative sample of the area, we concentrated on townships representing different degrees of current parcelization (low, medium, high). The current 2005 digital tax parcel data was used as the base or foundation layer. It was obtained from the county, who had used coordinate geometry (COGO) digitizing to create a highly accurate landownership database. This layer was then employed to create older parcels through the process of "reverse parcelization" that involved selecting and merging present day parcels into historic parcels. Historic tax records were visually inspected and plat maps examinded to identify dates of parcel subdivision. Working backwards, I was able to spatially reconstruct ownership boundaries for the years 1927, 1936, 1947, 1953, 1961, 1967, 1972, 1983, 1991, 2000, and 2005. These years represented dates that tax rolls corresponded with published plat books, which were available from the county courthouse and the local public library.

The technique for reconstructing ownership parcels involved the following steps: (1) Hard copy plat maps were scanned to make a digital copy of the page (2) images were then rectified by assigning geographic coordinates to specific points on the image using PLSS section corners as control points (3) merge contiguous tax parcels owned by the same person or entity by using the Dissolve tool in ArcGIS. A detailed explanation of ownership reconstruction can be found in Appendix A.

Specifically, the process of recreating historic ownership parcels began by making a copy of the current 2005 GIS ownership layer and working “backwards”. It was then overlayed with the rectified image. Parcel lines that were not in conformity with the scanned image were identified, and the copied layer was edited so that it matched the corresponding plat year. Parcel lines that appeared in the GIS layer but not in the plat map, the smaller parcels were merged together to represent the previous un-subdivided parcel. This process was repeated for each historical plat book year.

Hard copy plat books did not distinguish subdivision lots or “Small Tracts” property boundaries. In this methodology all subdivision and “Small Tracts” parcels were maintained (from the current digital tax parcel) in the ownership parcel layer until a plat book no longer delineated the subdivision or “Small Tracts” area. To remove subdivision parcels, all small parcels in the GIS layer within the subdivision were merged together to represent the parcel before the subdivision occurred.

Subdivision approval dates were collected from the register of deeds office and were helpful in determining dates of lot creation.

This procedure of “reverse parcelization” was used to generate all ownership parcel years. The method of working backwards from the current data proved effective because only altered parcels were edited, saving time and ensuring geometric accuracy.

Objective 1B. Spatially reconstruct historic tax parcel boundaries at multiple years for three rural townships in Columbia County, Wisconsin.

Previous research focused on ownership parcels, where an individual or entity may own several contiguous legal tax parcels. To address the issue of legal parcel creation, parcels needed to be mapped at the tax parcel level. The methods for researching and reconstructing GIS tax layers are as follows.

Initially, I investigated property deeds for parcels that were no longer PLSS forties in the current tax parcel layer. It was thought that any parcel that deviated from an original forty acre parcel was a split. However, there were some significant challenges with this method. Since no parcel tracking system exits for Columbia County, the original property description had to be located in each owner’s deed. This process was very burdensome in situations where a parcel had changed owners several times. Therefore, the process of researching property deeds for acquiring parcel division dates was decided to be too time consuming and was eventually abandoned.

Instead of searching through property deeds, parcel data was gathered in tax assessment rolls that are stored at county courthouses. Assessment rolls are yearly documents that include property tax information and legal descriptions of real property, including land and improvements. In Wisconsin, tax records exist for most municipalities and date back to nearly the time of settlement. Rolls are organized by PLSS section, so one can identify new parcels by physically counting the number of parcels per section in consecutive years. From there, the legal descriptions can be used to identify the spatial location of any new parcel. However, like researching deeds, this method was not time efficient.

The most efficient method that I found for reconstructing historic tax parcels was to use the tax parcel number. In Columbia County, parcel numbers were developed in 1950 and are stored in both the tax assessment rolls and the current digital tax parcel layer. Parcel splits were recorded by keeping the parent parcel number and assigning a decimal suffix that included either a number or letter. However, after 1998, the original parcel number was abandoned for a new numbering system.

We identified new parcels by visually inspecting consecutive years of tax assessment rolls (e.g., 2000 & 2005) and marking any new parcel number in the 2005 tax roll. Pages with marked parcels were photographed to create a digital copy of the roll page for viewing in the lab. I then employed a process of “reverse parcelization” to select and merge parcels into the original large parcel of origin. A copy of the current digital tax parcel layer was made and the duplicate file was edited. New parcels created between 2000 and 2005 were merged into their “parent” parcels, the parcels from which the new parcels were originated, based on the legal description and parcel identification number in the 2000 tax roll. Unlike other parcels, platted subdivision lot numbers did not contain the parent parcel number. Instead, a block and lot numbering scheme was given to lots in the subdivision. Here, all lots were merged, including any road right-of-ways, to create the tax parcel of origin (see Appendix A for detailed steps of historic tax parcel reconstruction). Original survey maps were also obtained by the county to help with the reconstruction of Government Lots.

Parcels that split (parent parcels) were identified by generating a parcel identification tracking number. Columbia County started this process in 1950 with each municipality. However, the numbering protocol varied over the years, preventing us from using their parcel identification number for locating new splits. Instead, for each parcel layer, we developed a tracking index which indicated the parcel of origin and a unique parcel identification number for that particular parcel (Figure 3.3). The unique PARCEL_ID attribute was carried over to the next time period as the parcel of origin PARENT_ID for each parcel. Parcels that split were again given a unique PARCEL_ID, keeping the original prefix sequence.

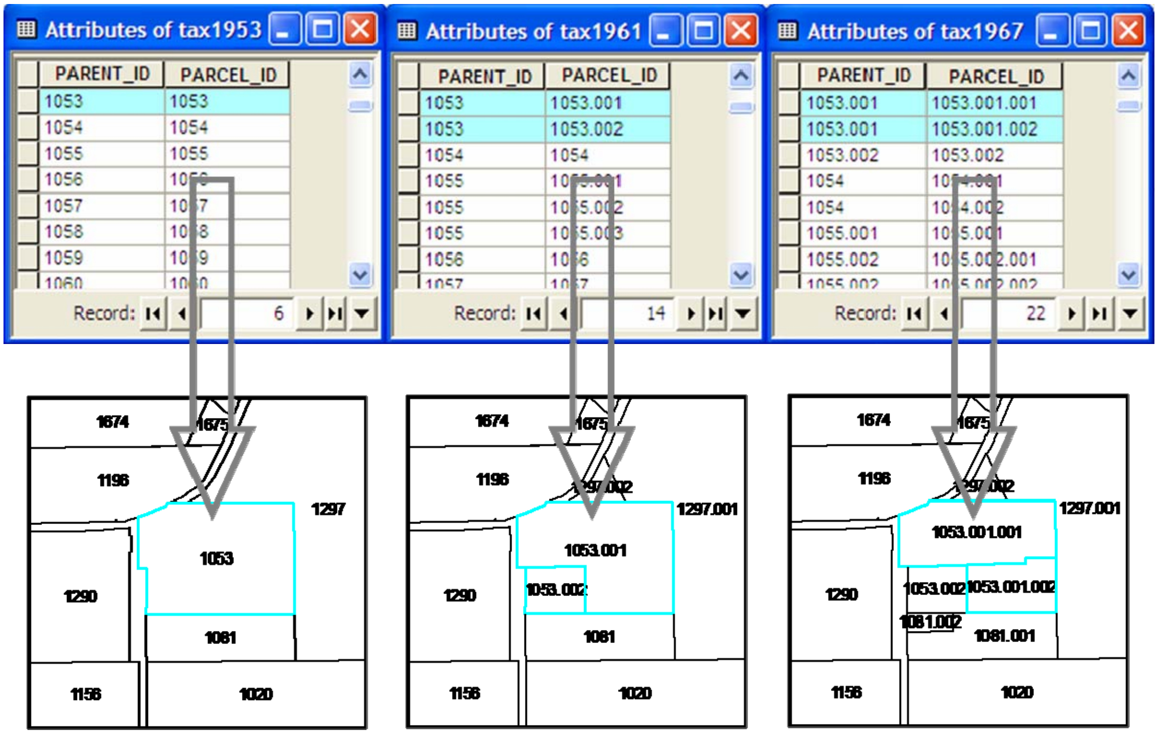


Figure 3.3. Example of parcel tracking index used to identify parent and offspring parcels.

Objective 1C. Employ landscape ecology metrics to analyze the spatial and temporal distribution of new CSM and subdivision parcels over time for three townships in Columbia County, WI.

To begin exploring the possible measures of parcelization, I used landscape ecology metrics to measure potential fragmentation. Landscape ecology is an emerging science which involves the study of landscape patterns and the interactions among patches within a landscape. Landscape ecologists employ metrics to make sense of the complex spatial patterns that exist on a landscape (Turner, 2000). Applying these principles to rural parcelization is appropriate to capture the spatial pattern of parcel creation and how that pattern changed over time. Though literally hundreds of landscape metrics exist, many of these are redundant and measure literally the same thing. However, a core set of landscape metrics, that are independent of each other, have been proposed to describe specific landscape structure and spatial processes (McGarigal & McComb, 1995; Hargis, Bissonette, & David, 1998). I focused on this proposed set of metrics because they measure fragmentation in multiple ways, they were easy to interpret, simple to calculate, and are understandable to professional planners.

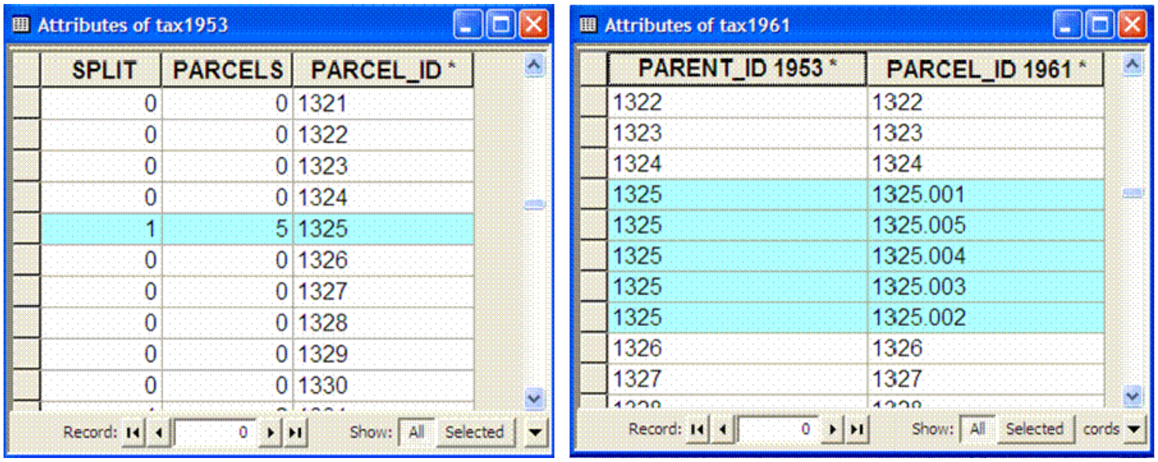
I used five metrics to quantify changes in parcelization at multiple time periods. These metrics are based on previous research that attempt to quantify landscape fragmentation and sprawl (Hasse, 2003; Irwin, 2002) and include: (1) number of new parcels (NP), (2) average new parcel size (AC), (3) average distance from new parcels to high density development (HD), (4) average nearest neighbor

(NN), and (5) average perimeter-area-ratio (PAR). Landscape ecologists have used these metrics to describe the patterns of patches, distribution, and dynamic component of landscape features and they provide a unique opportunity to quantify the parcelization process over time.

These metrics were computed separately for new CSM parcels and new platted subdivision lots so that the results would not be skewed. For example, it is obvious that platted subdivision lots will be relatively small and clustered, affecting the average parcel size and nearest neighbor metrics. In addition, local officials have expressed concern about landowners trying to slide past the subdivision review process by creating CSM parcels just below the regulatory minimum number of parcels or just above the regulatory lot size. Therefore, the above metrics were measured separately for CSM parcels and platted subdivisions lots.

Number of New Parcels

The number of new parcels provides a measure of the amount of parcels created in each municipality. In order to scale to the township level, all parcels were assigned a numeric code. I identified new parcels by joining the previous year's parcel attribute table to the subsequent parcel year's attribute table on the unique PARCEL_ID field. I then selected new parcels by querying features that had differing PARCEL_ID values in the later parcel year. After summarizing the PARENT_ID field in the joined table, I was able to then link the summary table back to the previous year attribute table and calculate parcels that split and the number of offspring parcels created by each parent (Figure 3.4). Parcel fragmentation is considered to increase with an increase in new parcels.



Attributes of tax1953

SPLIT	PARCELS	PARCEL_ID *
0	0	1321
0	0	1322
0	0	1323
0	0	1324
1	5	1325
0	0	1326
0	0	1327
0	0	1328
0	0	1329
0	0	1330

Attributes of tax1961

PARENT_ID 1953 *	PARCEL_ID 1961 *
1322	1322
1323	1323
1324	1324
1325	1325.001
1325	1325.005
1325	1325.004
1325	1325.003
1325	1325.002
1326	1326
1327	1327

Figure 3.4. 1953 and 1961 parcel attribute tables showing the process of identifying parent parcels and number of offspring parcels.

Average Parcel Size of New Parcels

The average parcel size component of parcelization measures how much land the average new parcel is consuming. This component provides information on the impact or effectiveness of minimum lot size policies. The average parcel size was calculated by selecting new parcels and summarizing the Acres field. Finding larger average sizes would indicate that new parcels are consuming more land.

Distance to Existing High Density Development

New parcels that are created at a large distance from previous urban areas are indicators of future land use change and potential development. Dispersed development like this can be considered rural sprawl and have many negative implications include higher service costs, low density residential development, and perforated working lands (Hasse, 2003). Urban areas were defined as previously existing platted subdivisions or city/village boundaries. Subdivision parcels were extracted from the previous time period shapefile and converted to a point file. City/village boundaries were converted to vertices so that points would represent the urban area's outer boundary. The subdivision and city/village point files were merged using the Append Tool and the point-to-point distance from new parcels to previous urban areas was measured using the Near Tool in ArcGIS 9.2. As the urban distance value increases, new parcels are being created farther from previously settled areas. This can be considered more fragmenting than if the new parcels were located in close proximity to developed areas.

Average Nearest Neighbor Distance for New Parcels

The fourth metric used to characterize parcelization is nearest neighbor. The average nearest neighbor metric gives an indication of the dispersion of new parcels over the landscape. It was measured similar to the urban distance measure, except straight-line distances were measured between new CSM parcels of the same layer. I did not measure the nearest neighbor between new subdivision parcels because parcels here are obviously clustered. Larger average nearest neighbor values indicate increased dispersion and potentially more fragmentation.

Perimeter Area Ratio

Finally, the average perimeter area ratio is the ratio of the mean parcel perimeter length to the mean area of all new parcels in a given time period. It is a measure of compactness. Low perimeter area ratio values indicate that parcels are less compact and the shape is more complex. This metric was measured separately for CSM parcels and subdivision parcels. New CSM parcels were selected and dissolved so that adjacent contiguous parcels were merged together. The same process was completed for subdivision parcels. Perimeter and area fields were added to the attribute table and calculated using the Calculate Geometry function. Finally, I added a 'Ratio' field and calculated it as the ratio of a feature's perimeter to area.

Automating the Process

Because my analysis extends over multiple time periods, the parcelization metrics needed to be repeated for each parcel layer. To automate the procedures for each parcel year, I created cartographic model consisting of the necessary GIS operations in ArcGIS 9.2 Model Builder. A graphic representation of the model flowchart is illustrated in Appendix B.

Comparing Metrics

Each measure provides useful analytical information, but cannot be compared against each other because they are measured using different units. For example, the average size is measured in acres and urban distance is measured in feet. To overcome this, I standardized each metric by calculating a Z-score, in which each average metric values for each township are compared to the three townships or "County" average. Larger Z-scores represent communities that exhibit more parcelization than the "County" average. Since the metrics chosen were independent of each other, the individual Z-scores can be summed to produce a single measure that generalizes the overall parcelization compared to other municipalities (Hasse, 2003).

Subproblem 2

Despite a growing concern about parcelization and fragmentation, little is known about the impacts of parcelization and whether it leads to land use fragmentation in rural areas.

Problem Statement 2

This research will evaluate the relationship between parcelization and land use fragmentation in rural areas by comparing land use trends in towns where land division has occurred to a town in which there has been limited parcelization. I hypothesize that landscape fragmentation will be greater in towns experiencing higher parcelization trends.

Objective 2A. Geo-rectify and mosaic historic aerial photographs from 1953 and 1968 for each township.

Objective 2B. Generate land use patterns using heads up digitizing, aerial photo interpretation, Wisconsin Land Economic Inventory maps, and public consultation for the years aerial photographs are available.

Objective 2C. Compute landscape metrics for categorical land use data to measure the amount of landscape fragmentation in towns with varying degrees of parcelization.

Subproblem 2 Methods

Objective 2A. Georeference and mosaic historic aerial photographs from various dates for each township.

I gathered information on aerial photography availability through visits to the Columbia County courthouse, e-mails, and discussions with department staff. The Soils and Water Conservation Department was the only source of historic aerial photographs for this project. Historical imagery of the study area was acquired for the years 1940, 1955, and 1968, each having a scale of 1:20,000. The photos covering our pilot study towns were previously scanned by Columbia County staff at an unknown resolution. Digital photos were copied to a DVD and stored on a portable 100GB hard drive. Due to time constraints, only the 1940 and 1968 photos were georeferenced in this study.

The geo-rectification process involved assigning map coordinates to the image data. The key element in the georeferencing procedure is having accurate ground control points (GCP). A minimum of four GCPs are needed in order to perform a photo rectification process. I used Erdas Imagine ™ 8.7 to perform the image rectification. Columbia County’s 2002 ortho photo was used as the source for identifying GCPs. Individual photos were assigned six to ten GCPs using landmark features, such as road intersections, building corners, and bridges, that existed on both source and historic photos. The root mean square (RMS) error was calculated for all GCPs and points with the highest RMS error were investigated or deleted from the set. Once each GCPs RMS error was at an acceptable level, each photo was rectified using a 1st order polynomial geometric correction algorithm. Since each photograph depicts only part of the study area, the research team generated a mosaic made up of all images using Imagine. The final mosaic was converted to a MrSid format with the LizardTech geospatial image compression program.

Objective 2B. Generate land use patterns using heads up digitizing, aerial photo interpretation, land use surveys, and public consultation for the years aerial photographs are available.

The georeferenced imagery was used as a backdrop for mapping and classifying areas into land use categories. In 2003, county planners developed a digital land use dataset as part of their comprehensive planning process. We used this data as a starting point for generating present and historic land use layers for 1940, 1968, and 2005. Two undergraduate intern trained in photo interpretation and GIS conducted land use mapping within the three township boundaries. Source layers for land use reconstruction included aerial photos, Wisconsin Land Economic Inventory (for the 1940 land use layer), and the 2003 digital land use data. Land use categories were taken from the American Planning Association's Land Based Classification System (LBCS), which classifies land uses based on their characteristics. We identified features to the 3^{rd} level of LBCS's Function dimension if possible, zooming in to a scale of 1:3,000. Our minimum mapping units varied depending on the land use category. For example, in this research we felt that all developed structures warranted delineation, so if we could identify a building or residence on the photo, we mapped it. However, a two-acre minimum mapping unit was encouraged for land uses with less distinctive boundaries such as agricultural lands and woodlots.

A personal geodatabase was created in ArcGIS to store the land use data in an effort to make the mapping consistent, simple, and efficient. I created domain tables in the geodatabase with the LBCS categories assigned to various fields within each land use layer's attribute table. This ensured accurate and consistent attributing of features.

Using ArcGIS 9.2, the 2005 land use categories were mapped by interpreting the 2005 NAIP orthophoto and incorporating line work from the counties 2003 land use data where land uses appeared coincidental or unchanged. For example, many residential, farmsteads, and commercial areas had not changed over the two year time span. By using the same line work, we limited our mapping variability of unchanged land uses. Where tree canopy was dense, we used the 2002 county photo to identify structures within forests. Interns initially mapped features using lines (arcs), snapping to vertices, end points, and edges. Eventually, we converted the line feature class to a polygon layer and the features were attributed using the geodatabase domains. To ensure coincident geometry, standard topology rules, such as no polygon overlap and no gaps were created in the geodatabase and errors were validated, and corrected.

The historic land use data was generated by copying and renaming the 2005 land use layer. Boundaries were edited in the duplicate file to reflect land use patterns at that time by overlaying it with the historic aerial photo. The Wisconsin Land Economic Inventory provided an additional data source for the spatial reconstruction of historic land use data (Bordner et al., 1929 - 1947). The Land Economic Inventory Survey was a Depression-era project to inventory land resources of Wisconsin by trained foresters. The purpose of the inventory was to survey and map all of Wisconsin's land resources so that local and state governments could manage them more productively. Columbia County Bordner Surveys took place in 1938, reasonably close to our 1940 photoset. We downloaded each township's Bordner Survey from the University of Wisconsin's Digital Collection website. Because of georeferenced survey maps did not match well with our digital data, we used them for comparison and reference purposes only.

Mapping historic land use was difficult, especially because we lacked detailed knowledge of the area and because numerous changes have occurred over the years. In the end, I turned to local citizens for help. I displayed the land use maps at each township hall for one month during the November 2006 election period in order to collect public input of our interpreted land use. Local citizens wrote comments, such as misinterpreted land uses and years of establishment for certain features, in a notebook that referenced a particular feature on the map. After one month, the maps were collected, and I made the necessary corrections to the data.

Objective 2C. Compute landscape ecology metrics for categorical land use data across townships experiencing different degrees of parcelization to determine the effects of landscape fragmentation.

In order to quantify the size, shape, and distribution of land use in the study site, landscape pattern metrics were computed for the historical and current landscape layers. I simplified the land use data into the following three classes: agriculture/open, developed, and woodlots. Before computing landscape metrics in the standalone software program FRAGSTATS 3.3, which require raster-based data projected in meters, the polygon land use layers were converted to a ten foot resolution grid and reprojected to the UTM NAD 1983 spatial reference system (McGarigal & Marks, 1995). Table 3.1 notes the metrics I utilized in FRAGSTATS to quantify changes in landscape fragmentation.

The townships of Lodi and West Point were analyzed as a single municipality because they are adjacent municipalities and both have experienced similar parcelization trends. Physical changes in the landscape were measured by computing area, edge, and shape metrics for each land use class. A batch file was created and loaded into FRAGSTATS, and metrics were computed for all raster images during one simulation. The results were tabulated in Microsoft Excel.

Landscape Ecology Metric	Description
Number of Patches	Measures the total number of patches in a specified land use of land cover class
Core Area	Measures the sum of core areas of each patch in a corresponding class
Largest Patch Index	The percentage of the landscape comprised by the largest patch
Fractal Dimension	Measures the shape complexity for each patch

Table 3.1. Landscape ecology metrics employed to quantify changes in land use fragmentation.

Subproblem 3

The literature only suggests socioeconomic factors that drive rural parcelization. Researchers have given very little attention to the actual landscape features and how they may influence the parcelization process. The relative extent to which certain landscape variables influence rural parcelization is unknown.

Problem Statement 3

This study will examine the spatial pattern of parcel creation and its relation to landscape variables over time to assess the landscape features that appear to influence land subdivision in rural areas.

Objective 3A. Assign landscape characteristic variables to each tax parcel in all layers.

Objective 3B. Compare parcel splits and landscape variables to determine which features are correlated with parcelization.

Objective 3C. Develop a parcelization model using a multiple logistic regression.

Subprolem 3 Methods

Objective 3A Assign landscape characteristic variables to each tax parcel in all layers.

The spatial reconstruction of both historical parcels and landscape allowed me to use GIS overlay and zonal statistic functions to assign landscape attributes to each parcel. I assigned landscape variables that appeared to influence parcel subdivision for each parcel layer that was closest to the same year of reconstructed land use. For example, 1953 parcels were assigned the 1940 land use variables and the 1961, 1967, and 1972 parcels were assigned the 1968 land use variables. Table 3.2 presents the landscape attributes for each parcel.

Adjacency-based variables were calculated by using the Select Features by Location function in ArcGIS that touched the boundary of a selected land use class. A small buffer distance was set in the selection process because of gaps in the road and water data obtained from the county. Adjacent parcels were given a value of 1.

I utilized the Nearest Features v3.8 tool (extension) in ArcView 3.3 to measure proximity and distance variables. This tool measures the distance from a features edge to the nearest edge of interest. Similar tools in ArcGIS only measure from a features centroid, therefore it was abandoned. I located public lands by identifying them on published plat books. The following city and subdivision boundaries were used to measure distance to public services, Harmony Grove, Lodi, Rio, Pardeeville, Cambria, and Prairie du Sac. All parcel years were measured to the current boundaries. Due to time constraints, past service boundaries were not mapped.

Abundance measures, such as percent forest, were calculated using the spatial analysis functions Hawth's Tools. The free tool was downloaded from http://www.spatialecology.com/htools/tooldesc.php. I specifically used the Polygon in Polygon Analysis tool which produces summary statistics for the area of overlap between two input polygon layers. Hydric soils as noted by the county were used as a proxy for wetlands throughout the entire time period.

I used ArGIS Network Analyst to develop travel time layers from downtown Madison and to schools because these locations are hypothesized to influence residential development (Daniels, 1999; Feitelson, 1993). The road layer developed by the Wisconsin Department of Transportation (wislr_road.shp) in 2003 was used to calculate travel times at 5 minute intervals from downtown Madison and 2 minute interval from schools within a short distance from each study township. Speed limits were calculated for roads based on category description field (ctgy_desc). For example, municipal streets were given a speed limit of 15 mph and county highways were assigned a speed limit of 45 mph. Because turns and stops were not taken into account, each road class was calculated with a speed limit that is below the state's legal limit. Major highway development was taken into account for travel times, such as prior to Interstate 39. Here, the current road layer was edited based on year of highway development. Dates were obtained from online sources or published plat books.

A 30-meter digital elevation model and zonal statistic functions within the Spatial Analyst toolbar were employed to calculate average parcel elevation and slope. To identify areas with favorable views, several processing steps were involved. I generated a polygon layer from the DEM that included the upper the upper 75% of all the county elevation values, or 330 meters. I also created a slope layer and selected slopes greater than 10%. The high elevation and steep slope layers were intersected to produce a favorable view layer (areas with high elevation and steep slopes). The Polygon in Polygon Analysis tool was finally utilized to produce the percentage of a parcel with a favorable view.

Variable	*Description*	*Expected Sign*
Acres	GIS calculated size of parcel	+
Size_Class	Parcel size class	+
Water_Adj	Parcel adjacent to water (0 - no, 1 - yes)	+
Dist_Wat	Distance from parcel edge to water (if not adjacent)	-
Road_Adj	Parcel adjacent to road (0 - no, 1 - yes)	+
Road_Dist	Distance from parcel edge to road (if not adjacent)	-
Dev	Whether the parcel is developed (0 - no, 1 - non-farm)	-
Per_Ag_Op	Percentage of parcel in agriculture or open	+
Per_Forest	Percentage of parcel in forest	+
Per_water	Percentage of parcel in water	+
Per_Hydric	Percentage of parcel with hydric soils	-
Services	Parcel within public service district (0 - no, 1 - yes)	+
Serv_dist	Distance from parcel edge to service district boundary	-
Avg_Elev	Average parcel elevation	+
Max_Elev	Maximum parcel elevation	+
Slope	Average parcel slope	+
Madison	Travel time to downtown Madison (based on road network)	-
Schools	Travel time to nearest school	-
Public_adj	Whether parcel is adjacent to public land (0 - no, 1 - yes)	+
Public_dist	Distance from parcel edge to public land	-
pseudo_adj	Whether parcel is adjacent to previously platted subdivision	+
road_1	Adjacent to state/federal highway (0 - no, 1 - yes)	-
road_2	Adjacent county highway (0 - no, 1 - yes)	+
road_3	Adjacent to local road (0 - no, 1 - yes)	+
Frontage	Length of water frontage measured in feet	+
Per_view	Percent of parcel with a favorable view	+

Table 3.2. Select variables generated and assigned to each parcel layer.

Objective 3B. Compare parcel splits and landscape variables to determine which features are correlated with parcelization.

All parcel tables were appended into one spreadsheet in Microsoft Excel and imported into SPSS. I removed parcels that never split for older time periods in order to limit redundancy. For analysis purposes, I only kept the most recent non split parcel record by removing records that never split and had a parcel year value of less than 2000. Pearson's correlation coefficient was used to test the relationship between landscape variables and parcels that split in SPSS. The value of the correlation coefficient ranges from 1 (perfect relationship) to -1 (perfect inverse relationship). A value near 0 indicates that the relationship between the two variables is negligible. Because I was interested in parcels that split, I analyzed the coefficients of the 'split' variable against all other variables. Parcel acres had a relationship with splits with a value of 0.374. Parcel sizes were also categorized into classes and their relationship to parcel splits was strong at 0.754. Other significant variables found were proximity to water, percent of parcel in agriculture and open space, average parcel elevation, average parcel slope, whether the parcel was adjacent to a waterfront parcel, county highway adjacency, local road adjacency, and parcel frontage.

Objective 3C. Develop a parcelization model using a multiple logistic regression.

Using the variables of some significance, I set up a multivariate model to explore rural parcel division using only landscape characteristics. Since the dependent variable is binary (split, no split), a multiple logistic regression (MLR) was employed to estimate the probability (with maximum-likelihood) that a parcel will subdivide. The MLR technique is designed to estimate the parameters in explanatory variables where the dependent variable is dichotomous. Variables in Table 3.2 were used to construct the MLR model to test the hypothesis that landscape features can be used to predict which parcels will subdivide. In this analysis, I considered parcel subdivision to include only those parcels that have split into three or more parcels, essentially eliminating forty acre parcels that divided into two twenty acre parcels. Forward selection procedures of independent variables were used to consider which variables would be included in the model. The model was run on the two most parcelized towns Lodi and West Point. Springvale has experienced little parcelization since 1950, so it was excluded in this first and exploratory model.

CHAPTER 4: RESULTS OF THE STUDY

Subproblem 1 Results

Objective 1A. Spatially reconstruct historic ownership boundaries at multiple years for three rural townships in Columbia County, Wisconsin.

and

Objective 1B. Spatially reconstruct historic tax parcel boundaries at multiple years for three rural townships in Columbia County, Wisconsin.

Overall, the historic parcel reconstruction efforts in the three townships' study areas, both ownership and tax parcel layers, took approximately ten months to complete. Reconstructed ownership maps are illustrated in Appendix C. The towns of Lodi and West Point had the largest increase in parcels over the entire time period, whereas Springvale experienced only little parcelization in terms of number of new parcels. The number and distribution of parcel sizes and acres per size class are presented in Appendix D. While the number of smaller parcels (0-5 acres) increase dramatically, they only make up a small portion of the entire landscape.

Figures 4.1 (a) – (d) illustrates the years of tax parcel creation for the townships of Lodi, Springvale, and West Point. One can see that both Lodi and West Point experienced much more parcelization, in terms of number of parcels, than did Springvale over the entire study period. In addition, shoreline lot development dominated the trends in earlier time periods in both Lodi and West Point (Figure 4.1a, b, and c).

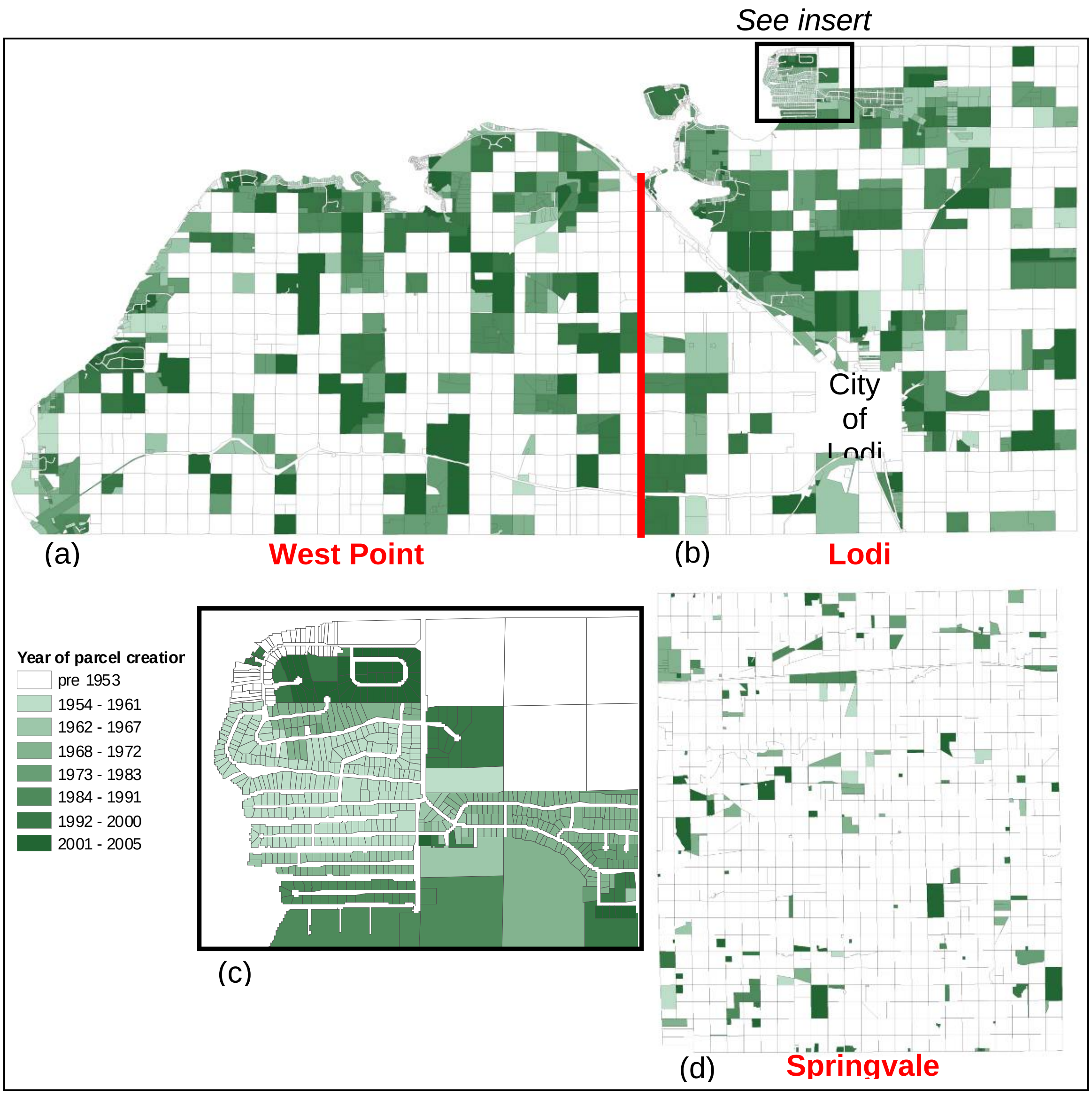


Figure 4.1. 2005 tax parcels color-coded by the most recent parcel splitting event (a) Town of West Point, (b) Town of Lodi, (c) Close up of Harmony Grove subdivision in Lodi, (d) Town of Springvale.

Objective 1C. Employ landscape ecology metrics to analyze the spatial and temporal distribution of new CSM and subdivision parcels over time for three townships in Columbia County, WI.

Countywide Parcelization

I utilized several landscape ecology metrics and principles to analyze the longitudinal and spatial data of parcel creation. The combined three township summary statistics provided in Table 4.1 present a measure of the average characteristics of parcelization for all new parcels within Columbia County during each period of analysis. Since each town represents varying degrees of parcel density, their combined average is considered the "county" average in which township level results are compared. The measures employ landscape ecology principles to quantify changes in the parcel landscape over space and time. The county average metrics were calculated for each time period for both new CSM and platted subdivision lots.

The number of new parcels, both CSM and subdivision, represent new patches on the landscape and an indicator of fragmentation. Overall, the number of new CSM parcels varied, with the largest number created between 1973 and 1983. The average number of subdivision lots was highest during the first time period at 108. After that, the numbers vary between time periods.

The average size metric reflects the amount of land area being consumed by new parcels. As expected, average new CSM parcels are much larger than new subdivision parcels. CSM parcels have increased over the last two time periods. The average new subdivision lot size increased from 0.44 acres to 0.88 over the period of analysis. The trend towards larger lots sizes appears to occur around the statewide adoption of shoreland zoning (Figure 4.2).

The urban distance metric is an indicator of leapfrog development. Larger values indicate that new parcels are being created at greater distances from previous urbanized areas, such as city or village boundaries or existing platted subdivisions. The urban distance values have consistently decreased over time. This may be a result of outward expansion of subdivisions from Lake Wisconsin.

The nearest neighbor metric is a measure of dispersion, or how close new patches are to each other. I only measured the nearest neighbor between new CSM parcels because it is evident that subdivision parcels are clustered. The results show that the average nearest neighbor distance at the “county” level has increased over the time period, suggesting that new parcels are being created farther away from each other.

Lastly, the perimeter area ratio metric measures shape complexity. Landscapes that exhibit higher perimeter area ratio metrics are considered fragmented. The average perimeter area ratio values decreased over the entire time period for both CSM and platted subdivision parcels.

1953-1961 (n=571)									
	NPcsm	ACcsm	UDcsm	NNcsm	PARcsm	NPplat	ACplat	UDplat	PARplat
Mean	80	11.6	6137	596	0.037	107.7	0.44	2535	0.065
Stdev	62.7	17.3	5097	1051	0.041	122.5	0.33	1778	0.035
Min	14	0.07	59	50	0.004	0	0.12	14	0.026
Max	136	80.1	20384	9282	0.225	241	4.26	7553	0.191

1962-1967 (n=232)									
	NPcsm	ACcsm	UDcsm	NNcsm	PARcsm	NPplat	ACplat	UDplat	PARplat
Mean	57.3	11.7	5627	772	0.011	20	0.39	121.3	0.007
Stdev	34.7	16.1	4605	1542	0.013	34.6	0.15	210.2	0.012
Min	9	0.03	51	40	0.002	0	0.25	0	0
Max	89	78.4	20884	16203	0.073	60	1.14	364	0.021

1968-1972 (n=469)									
	NPcsm	ACcsm	UDcsm	NNcsm	PARcsm	NPplat	ACplat	UDplat	PARplat
Mean	67.3	12.3	5933	758	0.011	89	0.38	1347	0.015
Stdev	11.9	16.9	6178	1200	0.017	120.4	0.24	1050	0.005
Min	51	0.09	102	33	0.002	0	0.03	70	0.007
Max	79	79.1	21005	10831	0.123	226	3.44	3427	0.026

1973-1983 (n=519)									
	NPcsm	ACcsm	UDcsm	NNcsm	PARcsm	NPplat	ACplat	UDplat	PARplat
Mean	110	9.8	4315	546	0.009	56	0.86	813	0.019
Stdev	81.7	14.5	4715	1307	0.01	71.8	1.36	1001	0.013
Min	5	0.04	67	67	0.002	0	0.03	11	0.005
Max	180	80	20735	22847	0.076	137	8.43	3526	0.058

1984-1991 (n=296)									
	NPcsm	ACcsm	UDcsm	NNcsm	PARcsm	NPplat	ACplat	UDplat	PARplat
Mean	69	13.9	4994	964	0.01	29.7	0.61	569	0.035
Stdev	28.4	16.5	5264	1379	0.014	27.8	0.8	471	0.044
Min	29	0.01	70	64	0.002	0	0.02	42	0.007
Max	92	78.4	21248	8697	0.097	55	6.97	1751	0.193

1992-2000 (n=472)									
	NPcsm	ACcsm	UDcsm	NNcsm	PARcsm	NPplat	ACplat	UDplat	PARplat
Mean	81.3	12.9	4693	929	0.011	76	1.39	769	0.027
Stdev	38.6	15.1	4825	1305	0.015	66.2	1.72	703	0.032
Min	27	0.05	67	80	0.002	0	0.04	16	0.005
Max	113	80	20088	9913	0.101	121	15.6	3490	0.141

2001-2005 (n=390)									
	NPcsm	ACcsm	UDcsm	NNcsm	PARcsm	NPplat	ACplat	UDplat	PARplat
Mean	74	16.3	6662	928	0.01	56	0.88	768	0.014
Stdev	21.3	19	5773	971	0.019	50	1.02	1164	0.01
Min	49	0.05	92	60	0.002	0	0.02	16	0.005
Max	101	79.7	20751	7115	0.156	96	7.97	6120	0.049

NP = Number of new parcels
AC = Size of new parcels measured in acres
UD = Distance to nearest urban boundary measured in feet (leapfrog)
NN = Nearest distance between new parcel measured in feet (dispersion)
PAR = Perimeter area ratio for new parcels (highway strip parcelization)

Table 4.1. Combined township level average statistics for all new CSM and platted subdivision parcels between 1953 and 2005.

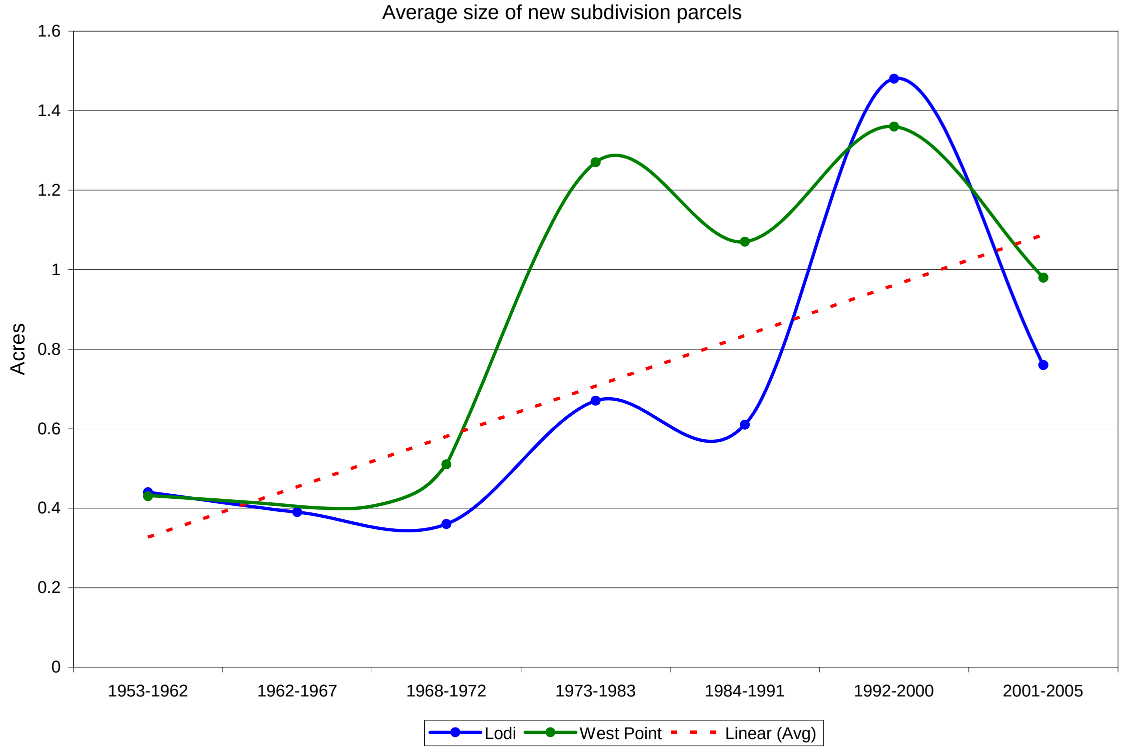


Figure 4.2. Average new subdivision lot size between 1953 and 2005 in the towns of Lodi and West Point with linear trendline.

Township Level Parcelization

Township level results expressed as their average metric value, as well as in standard deviations from the "county" average, are presented in Table 4.2 for all time periods. Townships that show signs of parcelization more fragmented than the "county" average have positive standard deviation values, while negative standard deviation values signify characteristics of less parcel fragmentation than the "county" average.

The time series analysis shows that spatial dimensions of parcelization varied for each township. Though Lodi and West Point experienced the largest increase in number of parcels, some measures find them less fragmenting than the county average. Not surprisingly, Springvale's parcelization metrics are less than the county average, except

1953 - 1961

Town	Total	NP_{csm}	AC_{csm}	UD_{csm}	NN_{csm}	PAR_{csm}	NP_{plat}	AC_{plat}	UD_{plat}	PAR_{plat}	Parcelization Score
Lodi	339	100	16.6	4356	537	0.04	239	0.44	1701	0.07	
		0.266	*-0.289*	*-0.349*	*-0.056*	*0.073*	*1.072*	*0*	*-0.469*	*0.151*	0.399
Springvale	14	14	18.4	14236	3545	0.02	0	0	0	0	
		-1.105	*-0.393*	*1.589*	*2.806*	*-0.415*	*-0.879*	*-1.332*	*-1.426*	*-1.857*	-3.012
West Point	218	136	7.2	6614	337	0.04	82	0.43	4967	0.049	
		0.841	*0.254*	*0.094*	*-0.246*	*0.073*	*-0.21*	*-0.030*	*2.065*	*-0.457*	2.384

1962 - 1967

Town	Total	NP_{csm}	AC_{csm}	UD_{csm}	NN_{csm}	PAR_{csm}	NP_{plat}	AC_{plat}	UD_{plat}	PAR_{plat}	Parcelization Score
Lodi		89	11.8	3704	466	0.011	60	0.39	364	0.021	
	149	*0.914*	*-0.006*	*-0.418*	*-0.198*	*0.000*	*1.156*	*0*	*1.155*	*1.167*	*3.770*
Springvale		9	5.6	14289	5408	0.014	0	0	0	0	
	9	*-1.392*	*0.379*	*1.881*	*3.006*	*0.231*	*-0.578*	*-2.6*	*-0.577*	*-0.583*	*-0.233*
West Point		74	12.4	6886	575	0.01	0	0	0	0	
	74	*0.481*	*-0.043*	*0.273*	*-0.136*	*-0.071*	*-0.578*	*-2.6*	*-0.577*	*-0.583*	*-3.834*

1968 - 1972

Town	Total	NP_{csm}	AC_{csm}	UD_{csm}	NN_{csm}	PAR_{csm}	NP_{plat}	AC_{plat}	UD_{plat}	PAR_{plat}	Parcelization Score
Lodi		79	12.8	2918	572	0.015	226	0.36	1399	0.016	
	305	*0.983*	*-0.03*	*-0.488*	*-0.155*	*0.235*	*1.138*	*-0.083*	*0.05*	*0.2*	*1.850*
Springvale		51	10.7	13931	1349	0.009	0	0	0	0	
	51	*-1.37*	*0.095*	*1.292*	*0.493*	*-0.118*	*-0.739*	*-1.52*	*-1.283*	*-3*	*-6.150*
West Point		72	13	3575	544	0.009	41	0.51	1067	0.014	
	113	*0.395*	*-0.041*	*-0.381*	*-0.178*	*-0.118*	*-0.399*	*0.542*	*-0.267*	*-0.2*	*-0.647*

Table 4.2. Township-level parcelization metrics for each time period. Standard deviations from the 'county' average are italicized (Z score) in the gray box. The parcelization score represents the summed Z scores across all metrics.

1973 - 1983

Town	Total	NP_{csm}	AC_{csm}	UD_{csm}	NN_{csm}	PAR_{csm}	NP_{plat}	AC_{plat}	UD_{plat}	PAR_{plat}	Parcelization Score
Lodi		148	7.7	2614	401	0.012	127	0.81	894	0.022	
	275	*0.731*	*0.115*	*-0.361*	*-0.111*	*0.300*	*0.989*	*-0.037*	*0.081*	*0.231*	1.938
Springvale		5	21.4	7180	7697	0.006	0	0	0	0	
	5	*-1.41*	*-0.8*	*0.608*	*5.47*	*-0.3*	*-0.78*	*-0.633*	*-0.812*	*-1.462*	-0.119
West Point		176	11.6	5975	491	0.005	31	1.27	483	0.011	
	207	*0.682*	*-0.124*	*0.352*	*-0.042*	*-0.4*	*-0.348*	*0.301*	*-0.33*	*-0.615*	-0.524

1984 - 1991

Town	Total	NP_{csm}	AC_{csm}	UD_{csm}	NN_{csm}	PAR_{csm}	NP_{plat}	AC_{plat}	UD_{plat}	PAR_{plat}	Parcelization Score
Lodi		92	16.1	2551	604	0.012	55	0.61	352	0.04	
	147	*0.801*	*-0.133*	*-0.464*	*-0.261*	*0.143*	*0.91*	*0*	*-0.461*	*0.114*	0.649
Springvale		29	13.1	12262	3332	0.01	0	0	0	0	
	29	*-0.141*	*0.048*	*1.381*	*1.717*	*0*	*-1.068*	*-0.763*	*-1.208*	*-0.795*	-0.829
West Point		86	11.8	5157	550	0.007	34	1.07	919	0.021	
	120	*0.599*	*0.127*	*0.031*	*-0.3*	*-0.214*	*0.155*	*-0.763*	*0.743*	*-0.318*	0.060

1992 - 2000

Town	Total	NP_{csm}	AC_{csm}	UD_{csm}	NN_{csm}	PAR_{csm}	NP_{plat}	AC_{plat}	UD_{plat}	PAR_{plat}	Parcelization Score
Lodi		113	13.9	3132	609	0.014	107	1.48	443	0.035	
	220	*0.821*	*-0.066*	*-0.324*	*-0.245*	*0.200*	*0.468*	*0.052*	*-0.464*	*0.25*	0.692
Springvale		27	7.5	10781	3822	0.012	0	0	0	0	
	27	*-1.407*	*0.358*	*1.262*	*2.237*	*0.067*	*-1.148*	*-0.808*	*-1.094*	*-0.844*	-1.377
West Point		104	13.2	4808	526	0.006	121	1.36	1057	0.017	
	225	*0.588*	*-0.02*	*0.024*	*-0.309*	*-0.333*	*0.68*	*-0.017*	*0.41*	*-0.313*	0.710

Table 4.2. Township-level parcelization metrics for each time period. Standard deviations from the 'county' average (Z scores) are italicized in the gray box. The parcelization score represents the summed Z scores across all metrics.

		2000 - 2005									
Town	**Total**	**NPcsm**	**ACcsm**	**UDcsm**	**NNcsm**	**PARcsm**	**NPplat**	**ACplat**	**UDplat**	**PARplat**	**Parcelization Score**
Lodi	144	72	17.1	3047	673	0.01	72	0.76	650	0.018	
		-0.094	*-0.042*	*-0.626*	*-0.263*	*0.000*	*0.32*	*-0.118*	*-0.101*	*0.4*	-0.524
Springvale	49	49	12.3	12526	1936	0.001	0	0	0	0	
		-1.174	*0.211*	*1.016*	*1.038*	*-0.474*	*-1.12*	*-0.863*	*-0.66*	*-1.4*	-3.426
West Point	197	101	17.7	6395	621	0.009	96	0.98	858	0.009	
		1.268	*-0.074*	*-0.046*	*-0.317*	*-0.053*	*0.8*	*0.098*	*0.077*	*-0.5*	1.253

Table 4.2. Township-level parcelization metrics for each time period. Standard deviations from the 'county' average (Z score) are italicized in the gray box. The parcelization score represents the summed Z scores across all metrics.

for the urban distance and nearest neighbor measures. Springvale is a large township with no urbanized area, so any new parcel will have large urban distance value, especially compared to Lodi and West Point. However, new parcels in Springvale reflect a more dispersed pattern, indicated by a positive Z-score for the nearest neighbor index.

Individual metrics provide useful information that reflect some characteristic of fragmentation. Because individual values were measured with differing units, they cannot be compared. Standardizing the metrics through Z-score calculations allows for the values to be cross-compared. Once standardized, the individual Z-scores can be summed, creating a single number that reflects the different dimensions of parcelization. The Parcelization Score (Figures 4.2 and 4.3) represents the cumulative Z-scores for each township. For each time period, the Parcelization Score indicates if each township is parcel fragmenting or sprawling more than the "County" average. The range of parcelization values for each municipality demonstrate the different dimensions of parcelization and fragmentation.

Not surprisingly, Lodi had the highest parcelization scores throughout most of the period of analysis because more parcels were created in this township at each time period. The highest degree of parcelization occurred between 1962 and 1967, with declining scores post 1967. West Point's parcelization score reflects an opposite trend than what is seen in Lodi. Over time, the parcelization scores in West Point have increased, while parcelization scores in Springvale fluctuate dramatically. This is expected because a small amount of new parcels was created during each time period compared to Lodi and West Point (Figure 4.3).

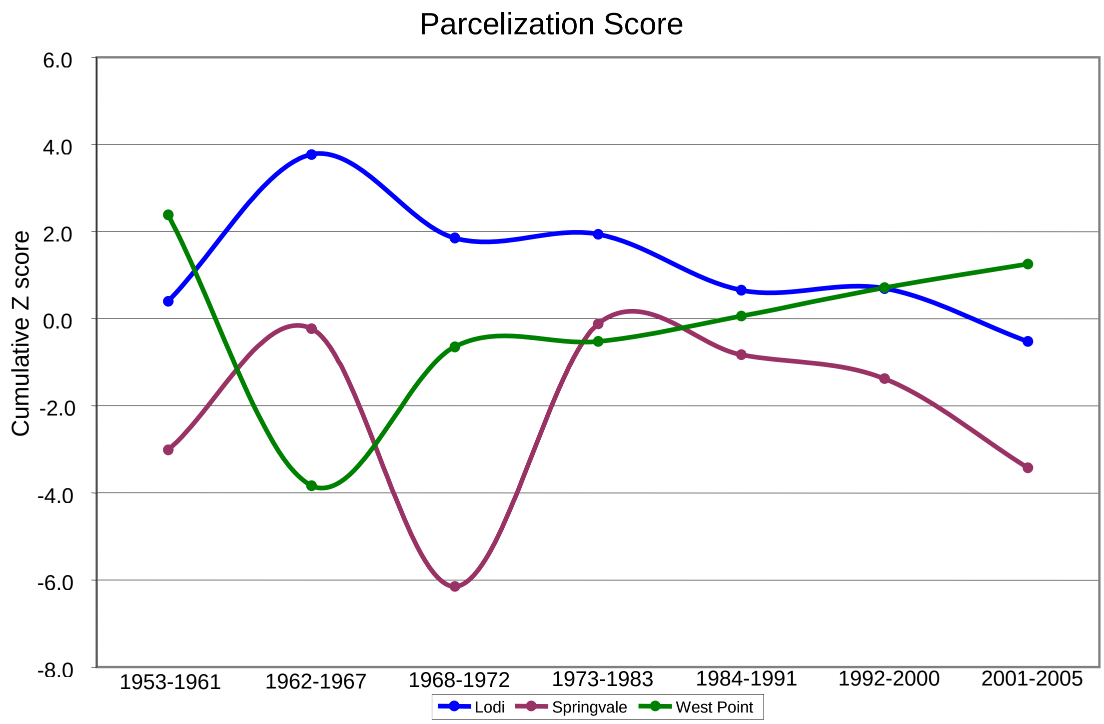


Figure 4.3. Parcelization scores for each township from 1953 to 2005.

Subproblem 2 Results

Objective 2A. Georeference and mosaic historic aerial photographs from various dates for each township.

and

Objective 2B. Generate land use patterns using heads up digitizing, aerial photo interpretation, land use surveys, and public consultation for the years aerial photographs are available.

Historical aerial photos were available for the years of 1940 and 1968 for the area of study. RMS errors were not recorded during the georeferencing process of individual photos, but visual inspection between the manual georeferenced photos and the county's orthorectified images showed that accuracy was acceptable.

Photo interpreted land use and land cover results for each town are displayed in

Table 4.3. In each township, the amount of agriculture land has decreased throughout the entire time period, except in Springvale between 1940 and 1968. The acres of forest land has increased throughout the period of study and for all three towns.

		1940	1968		2005	
Municipality	Class	acres	acres	Change	acres	change
Lodi	Agriculture/Open	13,550	12,477	(-8%)	10,012	(-20%)
	Non Farm Development	315	686	(115%)	1,744	(154%)
	Forest	3,399	4,054	(19%)	5,465	(35%)
Springvale	Agriculture/Open	22,370	22,620	(1%)	20,950	(-7%)
	Non Farm Development	329	334	(2%)	535	(60%)
	Forest	3,611	3,355	(-7%)	4,819	(44%)
West Point	Agriculture/Open	15,124	13,410	(-11%)	11,607	(-13%)
	Non Farm Development	348	661	(90%)	1,369	(107%)
	Forest	3,123	4,449	(42%)	5,564	(25%)

Table 4.3. Total acres of land use and percent change for each class in Lodi, Springvale, and West Point between 1940, 1968, and 2005.

Objective 2C. Compute landscape ecology metrics for categorical land use data across townships experiencing different degrees of parcelization to determine the effects of landscape fragmentation.

I used landscape metrics to analyze the pattern of land use change in Columbia County from 1940 – 2005 (Table 4.4). Fragmentation of the land use pattern was measured by calculating the number of patches, core area, largest patch index, and fractal dimension for each class. A more fragmented pattern is associated with larger number of patches and fractal dimension values, and smaller core area and largest patch index values. The number of ag/open and developed patches increased through the period of study in Lodi and West Point, while the amount of ag/open core area decreased in the same area. The same is true for Springvale, except that the ag/open core area increased by 1.1% between 1940 and 1968. The amount of core area increased in Lodi and West Point during the entire study, while decreasing only in Springvale between 1940 and 1968. The largest patch index decreased for the ag/open class during each period and in each township, while it increased for both developed and woodlot classes. The fractal dimension metric increased for the ag/open class in Lodi and West Point during each time period. The fractal dimension metric first increased by 10.4% between 1940 and 1968, then decreased by 1.5% from 1968 to 2005. In Springvale, the fractal dimension increased slightly between 1940 and 1968, while increasing drastically between 1968 and 2005.

1940 - 1968

Municipality	Parcels	Patch Class	Number of patches	Core Area (acres)	Largest patch index	Fractal Dimension
Lodi - West Point	*n=656 40%*	Ag/Open	80.7% (67)	-9.7%	-15.5%	3.0%
		Developed	47.4% (9)	104.0%	113.7%	10.4%
		Woodlot	10.6% (15)	30.4%	20.0%	-2.9%
Springvale	*n=23 2.8%*	Ag/Open	9.4% (5)	1.1%	-11.8%	-2.0%
		Developed	0.0% (0)	1.7%	2.4%	1.7%
		Woodlot	-15.1% (-21)	-7.1%	34.5%	-2.5%

1968 - 2005

Municipality	Parcels	Patch Class	Number of patches	Core Area (acres)	Largest patch index	Fractal Dimension
Lodi - West Point	*n=1281 56%*	Ag/Open	19.3% (29)	-16.5%	-27.4%	3.0%
		Developed	110.7% (31)	130.8%	139.7%	-1.5%
		Woodlot	-9.6% (-21)	29.7%	43.2%	3.8%
Springvale	*n=115 14%*	Ag/Open	81.0% (47)	-7.4%	-44.0%	-3.5%
		Developed	192.9% (27)	59.8%	48.0%	34.0%
		Woodlot	-15.3% (-18)	43.6%	56.4%	15.0%

Table 4.4. Percent change in fragmentation metrics for Lodi/West Point (combined) and Springvale from 1940-2005. The actual number of new patches for each land use class are displayed in parentheses.

Subproblem 3 Results

Objective 3A. Assign landscape characteristic variables to each tax parcel in all layers.

and

Objective 3B. Compare parcel splits and landscape variables to determine which features are correlated with parcelization.

A correlation analysis (Table 4.5) demonstrates the degree to which each landscape variable is correlated to each other variable and the dependent variable, titled ‘split’. The results show that acres, size class, and frontage are most highly correlated with parcel splits. This is not unexpected because of the amount of parcelization near Lake Wisconsin. The distance to water variables and pseudo-adjacent variables had weak correlations with Split, which is somewhat surprising, because it appears from the parcel maps that much of the parcelization has occurred near the shoreline.

Correlations

	ACRES	SIZE CLASS	DIST H2O	% AG-OP	AVG ELEVATION	PSUEDO ADJ	COUNTY HWY	FRONTAGE	SPLIT
ACRES	1								
SIZE CLASS	.754 (**)	1							
DIST H2O	.081(**)	.216(**)	1						
% AG - OP	.243(**)	.526(**)	.270(**)	1					
AVG ELEVATION	.148(**)	.376(**)	.552(**)	.237(**)	1				
PSUEDO ADJ	-.247(**)	-.290(**)	-.289(**)	-.267(**)	-.149(**)	1			
COUNTY HWY	.312(**)	.227(**)	.086(**)	.180(**)	-.045(**)	-0.013	1		
FRONTAGE	.612(**)	.234(**)	-.201(**)	-.046(**)	-.231(**)	-.211(**)	.121(**)	1	
SPLIT	.374(**)	.431(**)	-.192(**)	.206(**)	-.123(**)	-0.014	.211(**)	.354(**)	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.5. Covariance matrix of parcel characteristics included in the model using Pearson's Correlation Coefficient.

Objective 3C. Develop a parcelization model using a multiple logistic regression.

The preliminary logistic regression model results are presented in Table 4.6. All variables included in the model are statistically significant, probably due to our large sample size, and each of them has the expected sign. The parcel subdivision model had an adjusted r^2 of .551. Most variables in Table 3.2 had a weak relation with the dependent variable, but, collectively, they did an adequate job of predicting potential splits. Positive parameters of the coefficient estimates indicate that larger values of the independent variable will increase the likelihood of a parcel split. Likewise, negative values indicate that larger values of the independent variable will decrease the likelihood of parcel division. That said, as expected, parcel size, frontage, and distance to water had a positive impact on parcel subdivision. As a parcel's elevation and acres decreases, the likelihood of subdivision decreases. The categorical variables, county highway adjacency and zonal distance to water (pseudo adjacent) were all good predictors of parcel splits. The Wald test tests the statistical significance of each coefficient in the model. However, authors have identified problems with the use of the Wald Statistic, especially when large coefficients present because the standard error tends to be inflated (Pawitan, 2000).

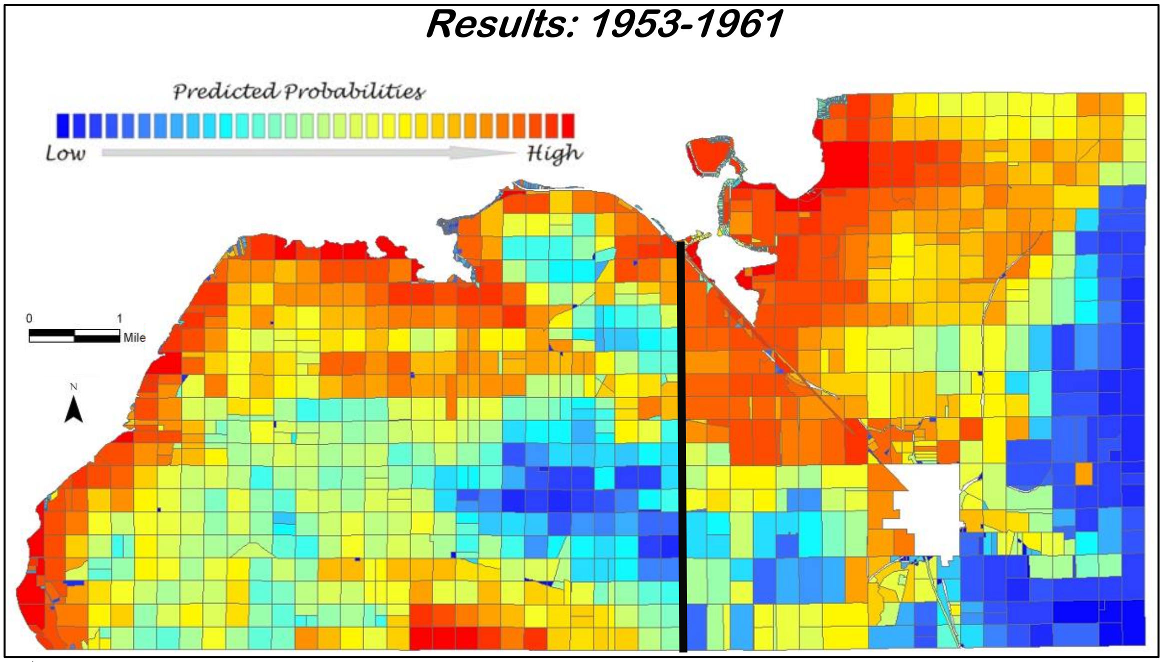
Dependent variable = Split (1 if parcel split)

	Coefficient	Standard Error	Wald	Exp(B)
Acres	0.044	0.002***	457.682	1.045
Size Class			1,052.289	
0-2 Acres	-3.420	0.155***	489.739	0.033
10-20 Acres	0.257	0.152*	2.846	1.293
2-5 Acres	-0.681	0.159***	18.394	0.506
20-30 Acres	0.802	0.153***	27.654	2.231
30-40 Acres	0.628	0.136***	21.200	1.874
40+ Acres	0.419	0.139**	9.096	1.520
Water	0.000	0.000***	102.446	1.000
Frontage	0.001	0.001***	113.692	1.001
County Hwy	-0.721	0.084***	73.113	0.486
Ag/Open	0.009	0.001***	87.183	1.009
Elevation	-0.020	0.002***	77.456	0.980
Pseudo_adj	-0.694	0.092***	57.429	0.499
Constant	6.218	0.581	114.456	501.460
r^2	0.396			
Adjusted r^2	0.551			
N	6372			

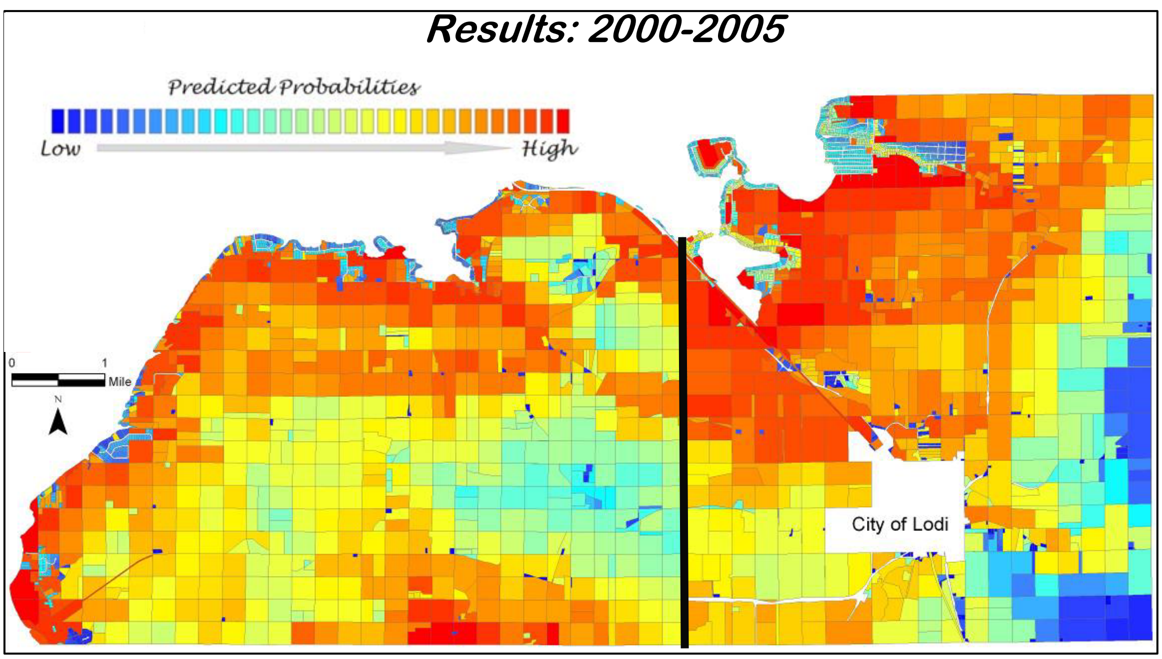
*p<0.10 **p<0.05 ***p<0.01

Table 4.6. Best predictors of the likelihood for a parcel to split. Logistic regression with forward stepwise results.

Joining the calculated probabilities from SPSS to our parcels layers, we were able to visualize our model results (Figure 4.4 a, b). As expected, large parcels near the water with abundant frontage had high probabilities of splitting. In contrast, parcels away from the water and not adjacent to a road had low probabilities of splitting.



a) West Point Lodi



b) West Point Lodi

Figure 4.4. Probability map for parcel subdivision based on the MLR model between (a) 1953-1961 and (b) 2000-2005.

When joined with the spatial data, one can visually compare observed and predicted parcel splits. Though the model did not predict parent parcels very well, the parcels it did accurately predict were "productive" (Table 4.7). For example, between 1953 and 1961, the model correctly identified 34.4% of the parcels that split. Of those parcels, they produced 64% of the new lots created during that time period, except that in later years the model's accuracy decreased.

Year	Observed	Predicted	% Correct	Total parcel offspring	Total predicted offspring	% offspring correctly predicted
1953-1961	32	11	34.4%	445	285	64.0%
1962-1967	26	6	23.1%	201	119	59.2%
1968-1972	26	4	15.4%	349	67	19.2%
1973-1983	56	9	16.1%	404	120	29.7%
1984-1991	28	4	14.3%	139	43	30.9%
1992-2000	48	4	8.3%	337	70	20.8%
2001-2005	38	3	7.9%	266	62	23.3%

Note: Parcel division consisted of 3 or more new lots

Table 4.7. Model predictions compared to observed parcel splits and total number of new parcels

CHAPTER 5: CONCLUSIONS AND DISCUSSION

Subproblem 1 Discussion

Objective 1A. Spatially reconstruct historic ownership boundaries at multiple years for three rural townships in Columbia County, Wisconsin.

and

Objective 1B. Spatially reconstruct historic tax parcel boundaries at multiple years for three rural townships in Columbia County, Wisconsin.

In this project, I set out to explore the process of parcelization in rural communities using GIS to construct the history and spatial dynamics of three townships in Columbia County, Wisconsin. Data was acquired and generated from a wide variety of sources and provides a useful database for observing both parcelization and landscape change. However, the construction of the spatial data required considerable time and inordinate human resources to complete. It is little wonder that other researchers have not actively tracked and analyzed changes in parcelization over time. The lack of a consistent parcel number in the tax assessment rolls made the process of tax parcel reconstruction difficult. Identifying parcel splits was also tedious, and, without careful investigation, one could easily misinterpret tax assessment rolls. Nevertheless, the process of "reverse parcelization" by merging parcels into their parcel of origin, starting with the current digital tax parcel layer and working backwards through time, allowed for accurate parcels to be reconstructed.

Resulting parcel maps show the spatial trend in parcel development over time in each community (Appendix C). Classifying parcels by size helped to show the trend in new parcel sizes and the amount of land area each category encompasses.

Overlaying ownership maps with legal tax parcel maps of the same year shows where owners have divided their property while still maintaining ownership of new legal parcels. This is especially helpful in identifying owners who try to evade the subdivision review process by creating parcels larger than the regulation minimum or by creating parcels in successive years just under the regulatory minimum number.

As stated earlier, there is a difference between tax and ownership parcelization. In most cases, tax parcels are created before an ownership change occurs. Due to the length of time between reconstructed parcel layers in this study, it was difficult to examine the time lag between tax parcel creation and ownership change. Having annual parcel data or dates of parcel creation and transaction as attributes in the county's current parcel layer would help planners to understand the relationship between parcel creation and resulting ownership change.

Objective 1C. Employ landscape ecology metrics to analyze the spatial and temporal distribution of new CSM and subdivision parcels over time for three townships in Columbia County, WI.

This research demonstrates how landscape ecology metrics provide a new direction in measuring and characterizing the spatial dynamics of parcelization in rural communities. Evident in the results are the trends in parcelization scores between the three municipalities. Most interesting are the trends for both Lodi and West Point, especially between 1953 and 1961, in which the parcelization scores move in opposite directions. Because both townships are adjacent to one another, it seems surprising that they would have such differing parcelization trends. However, upon further examination, the steep rise in the parcelization score in Lodi seems to be caused by the encouragement of parcel development in that town. Much of the early parcel subdivision occurred on the land owned by the Wisconsin Power and Light Company. After the completion of the Lake Wisconsin dam near Sauk Prairie in 1924, the power company took advantage of its assets by subdividing and selling much of the shoreland property and creating what is now Harmony Grove, a city-style subdivision. In the Harmony Grove subdivision, for example, the developer created long channels inland from Lake Wisconsin, essentially generating more waterfront property. The dip in West Point's parcelization score during the same time period may not reflect the absence of demand. It likely means that Lodi satisfied the demand for new parcels with the Harmony Grove development, in effect pulling the demand away from West Point.

However, over time, the parcelization score in West Point eventually surpasses that of Lodi, even though during most time periods there are more new parcels in Lodi. When observing the parcel maps for each township, it becomes evident why this trend is occurring. The pattern of parcel creation in Lodi appears to be more compact and clustered in subdivisions, resulting in a less fragmenting pattern and a lower parcelization score. Many of the new parcels in Lodi are in situated in subdivisions that are additions to the initial Harmony Grove development. A Harmony Grove Sanitary District, built in 2003 and provides sewer and water utilities, has also allowed landowners and developers to create numerous small lots that would otherwise not meet size requirements for onsite private septic systems.

In West Point, the pattern of parcelization seems to be more dispersed on larger parcels throughout the entire township. This may be due to more restrictive land division regulations in Lodi, which were adopted in 1989. The new parcels in West Point are less clustered than in Lodi and are perforating the landscape, which can be considered more fragmenting, thus the higher parcelization score. However, a recent subdivision in West Point includes a municipal-type septic system that serves nearly one hundred lots. In 2005, the capacity of the treatment system was at 50%, so there maintains potential for additional homes to be serviced by this facility (Township of West Point, 2007).

The widening of US Highway 12 from Madison to Prairie du Sac may also contribute to increased parcelization in West Point. Completed in 2005, Highway 12 is now a four-lane highway which extends from Prairie du Sac to Madison. This easier access to Madison may result in a greater demand for residential development in West Point, which was not part of the Highway 12 easement program. This program is purchasing development rights along Highway 12 in both Dane and Sauk counties, but not neighboring Columbia County (Wisniewski & Anderson, 2003). And because the Town of West Point is adjacent to both Dane and Sauk counties, it may experience spillover development due to the protected land within the corridor project area.

The fluctuation of the parcelization score in Springvale can probably be attributed to the small amount of new parcels in each time period. Springvale lacks significant water features and, therefore, does not have any shoreland development. No platted subdivision exists in Springvale because land values are not high enough.

Developers have not and probably will not invest in city-style developments with sewer and water services in Springvale because there is no financial incentive. The size of Springvale also plays a considerable role in the difference between parcelization scores. Springvale is a much larger township and has more space for new parcels to be created. Therefore, due to the size and location of the town, any new parcel that is created will be a significant distance from an urban or subdivision boundary significantly increasing the Z-score for that particular metric.

Even though the parcelization score provides an appropriate single number for characterizing parcel development in municipalities, it should be interpreted carefully. Parcelization is multi-dimensional in both time and space and may be more complex than what a single number can convey (Hasse, 2003). However, the parcelization score encompasses several landscape ecology metrics that are characteristic of fragmentation and provides a new approach to summarizing new parcel creation. Calculating standard deviations from the county average allows one to cross compare townships to the county average. Because this study is limited to three diverse townships, the results are somewhat expected. Ultimately, this research should be expanded to the county or regional scale.

A disadvantage of the parcelization score approach is that it is data intensive and requires at least two years of digital parcels. In Wisconsin, the digital tax parcel layer has traditionally not been archived by county Land Information offices. Instead, Land Information Officers have commonly overwritten previous parcel layers with a new parcel dataset that reflects annual changes. The UWSP Center for Land Use Education staff, however recommend counties actively archive tax parcel layers with associated assessment values. This would ultimately save time and effort in identifying new parcels in the future, as well as, contain property values which researchers use for hedonic modeling purposes.

The metrics employed in this study requires several processing steps. The spatial model I developed for calculating individual spatial metrics (Appendix B) helped me to measure parcelization consistently between townships and over time. The model can ultimately be used, shared, and modified by researchers, planners, and others interested in measuring parcelization in their own communities.

Continued research should focus on using landscape ecology metrics to quantify the characteristics of parcelization. Simple parcel counts or changes in average parcel size do not capture the multiple dimensions of parcelization. Future studies should incorporate larger scales with both tax and ownership parcels, with tax assessment data, as well as, alternative landscape metrics.

Subproblem 2 Discussion

Objective 2A. Georeference and mosaic historic aerial photographs from various dates for each township.

There was limited amount of time for image process and land use data reconstruction. Therefore, multiple short term staff from the UWSP College of Natural Resources assisted with certain tasks. Specifically, they were responsible for accurately setting control points and georeferencing historical aerial photos. The lack of georeferencing experience along with limited quality of some photos made the process of rectifying individual photos time consuming and challenging. Quality control and monitoring of completed photos helped to ensure that each feature was accurately georeferenced.

The task of reconstructing past land use patterns was even more challenging. Because each staff member was assigned an individual township, the reconstructed land use was interpreted inconsistently and the resulting line work was of varying quality. I found many inconsistencies between municipalities regarding line work and interpretation. A considerable amount of time was needed to clean and edit data. Perhaps assigning land use reconstruction efforts to a single staff member would benefit this process, depending on project timelines.

Objective 2B. Generate land use patterns using heads up digitizing, aerial photo interpretation, land use surveys, and public consultation for the years aerial photographs are available.

and

Objective 2C. Compute landscape ecology metrics for categorical land use data across townships experiencing different degrees of parcelization to determine the effects of landscape fragmentation.

The land use layers alone do not reveal change, however, by creating multiple temporal GIS layers, one can observe the alteration of the landscape. The land use pattern analysis shows that the amount of each class has changed over the years. Declines in agriculture/open lands in Lodi and West Point can be attributed to increases in non-farm development and farm abandonment. The amount of agriculture/open land actually increased in Springvale between 1940 and 1968. This was somewhat surprising, but after further investigation, I noticed that large wetland areas were drained and converted to farmland during this time. The recent loss of farmland in Springvale is not a consequence of residential development, but a result of the public land acquisition by the WI DNR. Understanding the dynamics of land use change can help planners and local officials contribute to better policies regarding land management (Brown, Johnson, Loveland, & Theobald, 2005).

It is apparent in this analysis that parcelization has led to land use fragmentation in my study area. The results of the fragmentation analysis using FRAGSTATS help to describe the spatial pattern of landscape classes over time.

Based on the findings of the landscape metrics, the pattern of the agriculture/open areas in each township has become more fragmented. I was not surprised to find that agricultural land in Lodi and West Point has become more fragmented over time because of the amount of parcelization and subsequent development. What is interesting is the amount of fragmentation, or lack thereof, that has occurred between 1968 and 2000. While the number of parcels increased dramatically, the fragmentation of the landscape did not keep pace. This finding is similar to that of Gonzalez-Abraham et al, where they found dense lakeshore development limited landscape fragmentation in Northern Wisconsin because of the clustering of buildings (Gonzalez-Abraham, 2007). People's desire for certain landscape amenities, such as water, has resulted in a more compact and clustered development pattern in Lodi and West Point as well. However, the number of agriculture/open patches still seems quite high and that may be due to our definition of agriculture/open patch. Setting a minimum patch size for this class may have more effectively identified viable agriculture operations from treeless non-farm patches and reduced the number of patches.

Despite a larger increase in the number of parcels in Lodi and West Point, new development appears to be taking place adjacent to existing developed patches, essentially creating a larger developed patch and less fragmenting productive farmlands. However, the core area and largest patch index metrics indicate that the amount of farmland is still decreasing in these towns. By clustering development, the rate of farmland fragmentation appears to be decreasing. One the other hand, forestlands appear to becoming less fragmented over time, suggesting abandonment of farmland and forest succession to occur. This may also be a result of non-farm residents' desire for forests and privacy.

As expected, the amount of landscape fragmentation in Springvale is less than the other two towns. However, landscape fragmentation is still happening despite limited parcelization, indicating that landscape fragmentation can still occur, even with little population growth. Because new development in Springvale is dispersed, the number of developed patches is increasing more so than in Lodi and West Point. Any new development essentially creates a new individual patch, which is slowly perforating the farmland. With accessibility, affluence, and the desire for open space at an all time high, this trend may continue and ultimately transform the landscape here.

Studying land use change in rural areas in a spatially explicit manner can improve the understanding of various factors, including parcelization. Comparing areas of differing parcelization trends helps to illustrate the extent of land fragmentation occurring in parcelized areas. Despite extensive parcelization in Lodi and West Point since 1950, the demand for certain natural amenities, such as water and favorable views, has clustered development. Even though landscape change is occurring in these townships, the amount of fragmentation has been offset by compact development. The dispersed pattern of development in Springvale is creating more developed patches, which perforate the landscape. This type of pattern is considered fragmented and can increase the cost of public services, particularly road maintenance and school busing. However, the growth in Springvale is small, therefore the amount of landscape fragmentation is limited.

The use of FRAGSTATS ™ to quantify landscape change proved effective. This version of the software program is free and contains detailed operating instructions. A drawback to this version of FRAGSTATS is that the data needs to be in a grid or raster format and the units must be meters. The conversion to a grid format reduces the accuracy of the data. The multiple data processing steps may deter others from utilizing this program. Another drawback to analyzing landscape change over time is that it is data intensive. The lack of detailed landscape data at multiple time frames may limit the applicability of this methodology in some communities.

<u>Subproblem 3 Discussion</u>

<u>Objective 3A.</u> Assign landscape characteristic variables to each tax parcel in all layers.

GIS technology was the foundation of this research for reconstructing historic land tenure and spatial dynamics of parcel and landscape change. It took considerable time, effort, and quality control steps to build a spatial-temporal database, but in the end, spatial analysis will result in better decisions. In some cases, one could analyze a map alone to draw conclusions. Yet, drawing inferences from just a map is not always easy and most geographic process are not controlled by a single attribute. With the use of GIS analysis, I was able to combine the characteristics of several spatial datasets into one layer.

Ideally, I would have used ArcGIS for all GIS operations because most county Land Records offices are equipped with such programs. However, due to the limited ability of some tools, specifically the proximity tool, I used ESRI's ArcView 3.3. The proximity tool in ArcGIS measures distance from a features centroid rather than the closest edge. The Nearest Features extension in ArcView allowed me to calculate accurate edge to edge distances.

Combining attributes from raster based data such as elevation and slope layers required additional work. Due to the small size of some parcels and the coarse resolution of the elevation and slope data, many smaller parcels lacked zonal values. Perhaps converting the raster data to a polygon layer and then employing the polygon-in-polygon analysis would correct this issue.

<u>Objective 3B.</u> Compare parcel splits and landscape variables to determine which features are correlated with parcelization.

and

<u>Objective 3C.</u> Develop a parcelization model using a multiple logistic regression.

The process of parcelization was analyzed by examining various parcel characteristics. By reconstructing historic parcel patterns I was able to identify key attributes that appeared to be influencing land division. A multiple logistic regression was developed to see how well landscape variables accurately predicted parcelization. Due to the exploratory nature of this work and the use of geographic data, one must examine the effects of spatial autocorrelation and multicollinearity. Future research should build off this and generate more sophisticated models that address these issues.

As expected, I was not surprised to find that parcel size strongly influenced parcel splits. Larger parcels are more likely candidates of splitting than are smaller parcels. However, length of water frontage and distance to water variables were also strong drivers of parcelization. It was evident that small parcels along or near the shore with considerable frontage still maintained high probabilities of splitting. This was also expected due to the attractiveness of near-shore development. It is not uncommon even for developed properties with adequate waterfront property to carve out lots with the minimum required frontage, especially given the value placed on that land, where in Wisconsin, the average value of waterfront property can exceed $1,000 per linear foot of shoreline, compared to off-shore land valued around $2,000 to $3,000 per acre.

One potential reason for the small percentage (20% - 30%) of correctly identified parcel splits are the two lakes located at the southern edge of the West Point. During the entire time period, very little parcel subdivision had taken place along those lake shores. Perhaps social reasons or certain land use regulations, such as easements are playing an important part here. Our results will be shared with local officials, who may be able to offer important suggestions.

The pseudo adjacency variable, which is a zonal distance measurement from the shoreline, helped to explain the pattern of land subdivision when waterfront areas have been completely subdivided. This can be thought of as the pattern of second and third tier development along water bodies, where the configuration of subsequent parcelization is a result of the original creation of shoreline lots.

An area where the model performed poorly was in locations where parcelization had occurred on ridges or rims with attractive views. The model predicted low probabilities for most of the parcels along a steep ridge within the town in 1953. However, later on, many smaller parcels were carved out along certain ridges, offering views to new landowners. A more robust viewshed analysis may perhaps capture this recent trend. Initial observations indicate that views to water appear to be more correlated with parcelization than views without a view of water. A zonal distance from water approach may capture this newer trend.

This analysis of parcelization included only parcels that had divided into three or more parcels. I attempted to model all parcel splits with the current set of variables, but the results were mixed. By focusing on subdivisions of three or more lots, I was able to more accurately model parcelization. I also assigned a weighting factor in the model, which essentially weighted the data by the number of “offspring” parcels created by a parent parcel. This helped to give more attention to parcels that created many lots rather than just a few, such as large subdivisions along Lake Wisconsin.

Over time, the model accuracy progressively decreased (Table 4.7). Though I cannot give a detailed explanation of this, it may be due to the complete parcelization of waterfront land. Because the number of parcel offspring weighted the model, more attention was given to parcels that created many lots (i.e., parent parcels of subdivisions). Most of these subdivisions were platted along the waterfront. When these areas became parcelized, future land division had to take place further away from the water, making water less influential and new parcels more difficult to predict due to the many different factors at work.

The issue of spatial autocorrelation and multicollinearity are present in the model. Others have used a spatial filtering or a sampling approach to correct for spatial autocorrelation (Brown, 2003; P. H. Gobster & Schmidt, 2000). However, due to the relatively small number of parent parcels in the data, I felt that the sample size would not be large enough for an adequate model. Alternative sampling techniques should be examined to deal with local trends.

This research presents an early step in a larger research project studying the consequences of planning and policy variables on land parcelization. Future research should build off this exploratory work by integrating spatial econometric modeling techniques (Elena G. Irwin & Bockstael, 2002) to address landscape variables and rural parcelization.

Summary & Recommendations

This study examined the long term parcelization process in three rural communities in Wisconsin. The spatial reconstruction efforts in this study were intense due to the amount of data, time, and resources needed to recreate historical layers. A detailed, process-based approach was developed to apply landscape ecology metrics to quantify and measure the spatial dimension of parcelization. The study shows that parcelization is a multi-dimensional process that includes both time and space. Individual metrics were summarized into a single numeric value which encompasses various fragmentation characteristics. The results of the township-scale parcelization metrics were compared to the three township average at each time period. The parcelization score revealed how each community was parcelizing compared to the three township average.

The use of landscape metrics to quantify landscape change in each community exposed the degree of landscape fragmentation caused by parcelization. Despite limited parcelization in Springvale, landscape fragmentation did occur, though much less than Lodi and West Point. Comparing areas with extensive parcelization to an area with little parcelization revealed the extent of natural landscape change and fragmentation.

Examining parcel splits over time and their relationship to landscape features demonstrated that a parcel's size, proximity to water, and amount of frontage were the most important variables in predicting parcel splits. The model was developed to inspect how a primitive, logistic regression performed, without addressing spatial autocorrelation. Had the model performed better, one could conclude that perhaps more sophisticated statistical procedures would not be necessary in predicting future parcelization. However, the model results were not extremely accurate, but it does provide a basis for future research in associating landscape variables with parcel splits.

Recommendations

The research in this thesis has been exploratory in nature and future studies will both improve and build off the results that are presented. The methods of reconstructing historic parcels proved effective, but difficult and time consuming. I realize that this research may be difficult to replicate, so it is recommended that communities digitally archive current digital tax parcel layers with associated assessment data at least once a year. With recent advances in technology, such as ArcSDE and data storage capabilities, archiving large dataset should no longer be an issue. If digitally archived, parcel layers will not have to be manually reconstructed and this analysis could be conducted at much larger scales. With the number of counties in the state and nation with digital parcel information increasing, it is anticipated that this research will be expanded elsewhere in Wisconsin and the country.

In Wisconsin, the Parcel Identification Number (PIN) is inconsistent over time and between counties. The lack of a consistent PIN makes it difficult for one to identify parcel splits and the parcel of origin. It is recommended that a uniform protocol for storing parcel information includes a PIN that incorporates a parcel tracking index. In addition, an attribute that stores a parcel's birth year would be beneficial. Having a consistent PIN and birth year will allow one to quickly identify new parcels and the year of origin. With an increasing number of counties throughout the state having a complete digital parcel data in a GIS format, I believe that this research approach could be used to illustrate parcelization patterns at multiple spatial scales.

Numerous landscape metrics exist, therefore, the research community should decide on a core set of landscape metrics for rural land use planning. These metrics should be useful, understandable, and the necessary data should be available. The benefits of incorporating landscape ecology principles in rural planning also needs to be addressed. Because parcelization in rural communities is a precursor to residential development and potential land use and landscape change, landscape ecology concepts should be included in land use regulations such as zoning and land division ordinances. These policies ought to protect continuous blocks of large parcels while clustering smaller parcels to less productive areas.

Modeling parcelization needs to address spatial dependency and spatial autocorrelation. These were both neglected in the logistic regression model. Future research should test and measure the degree of spatial autocorrelation at various scales and determine whether to use it as variable or to remove it entirely from the study.

REFERENCES

Adams, B. (2007, November 28, 2007). Town to face Realtors, builders in high court. *Wisconsin State Journal*.

Armstrong, T. D., & Jacobs, H. M. (1996). Centralized growth management policy and local land-use decision making: Learning from Oregon's experience. *Journal of Soil and Water Conservation*(July-August), 295-287.

Arnold, C. (1999). *Carving Up the Landscape: Habitat Fragmentation and What to Do About It*.

Beale, C. L., & Johnson, K. M. (1998). The identification of recreational counties in nonmetropolitan *Population Research and Policy Review, 17,* 37-53.

Bertrand, A. (1957). An Analysis of Contemporary Rural Life. *Rural Sociology, 37*(4), 377.

Bissonette, J. A., & Storch, I. (2003). *Landscape ecology and resource management : linking theory with practice*. Washington: Island Press.

Bordner et al. (Cartographer). (1929 - 1947). *The Wisconsin Land Economic Inventory (1929-1947)*

Brabec, E., & Smith, C. (2002). Agricultural land fragmentation; the special effects of three land protection strategies in eatern United States. *Landscape and Urban Planning, 58*, 255-268.

Brown, D. G. (2003). Land use and forest cover on private parcels in the Upper Midwest USA, 1970 to 1990. *Landscape Ecology, 18*, 770-790.

Brown, D. G., Johnson, K. M., Loveland, T. R., & Theobald, D. M. (2005). Rural Land Use Trends in the Conterminous United States, 1950-2000. *Ecological Applications, 15*(6), 1851-1863.

Butler, B. J., & Leatherberry, E. C. (2004). America's Family Forest Owners. *Journal of Forestry, 102*(7), 4-9.

Butler, B. J., & Stanfield, B. J. (2002). *Land Ownership Dynamics in the Big Elk Valley in Oregon During the 20th Century*: United States Department of Agriculture Forest Service.

Capozza, D. R., & Helsley, R. W. (1989). The fundamentals of land prices and urban growth. *Journal of Urban Economics, 26*, 295-306.

Clark, C. D., Park, W., & Howell, J. (2006). Tracking farmland conversion and fragmentation using tax parcel data. *Journal of Soil and Water Conservation, 61*(5), 243-249.

Creighton, J. H., Blatner, K. A., & Baumgartner, D. M. (2004). *The Future of Washington State Family-Owned Forests in an Increasingly Fragmented Landscape.* Paper presented at the Human Dimensions of Family, Farm, and Community Forestry, Pullman, WA.

Croissant, C. (2004). Landscape patterns and parcel boundaries: an analysis of composition and configuration of land use and land cover in south-central Indiana *Agriculture, Ecosystems and Environment, 101*, 219-232.

Daniels, T. (1999). *When city and country collide: Managing growth on the metropolitan fringe*. Washington, D.C.: Island Press.

Daniels, T., & Bowers, D. (1997). *Holding our ground : protecting America's farms and farmland*. Washington, D.C.: Island Press.

DeCoster, L. A. (1998). The Boom in Forest Owners--A Bust for Forestry. *Journal of Forestry, 96*(5), 25-28.

Dennis, D. F. (1992). Parcelization and Affluence: Implications for Nonindustrial Private Forests. *Northern Journal of Applied Forestry, 9*, 1992.

Diamond, H., & Noonan, P. (1996). *Land use in America*. Washington DC: Island Press.

Drzyzga, S. A., & Brown, D. G. (1999). *Proceedings of the Society of American Foresters*. Paper presented at the Conference Name|. Retrieved Access Date|. from URL|.

Dwyer, J. F., & Stewart, S. I. (1999, September 19-23, 1998). *Changing Demographics Affecting Sprawl.* Paper presented at the Proceedings of the Society of American Foresters 1998 National Convention, Traverse City, MI.

ERS, & USDA. (2002). Major Uses of Land in the United States. from http://www.ers.usda.gov/publications/EIB14/eib14j.pdf

Farmland Information Center. (2002). Farmland Information Center. from http://www.farmlandinfo.org/

Feitelson, E. (1993). The spatial effects of land use regulations: A missing link. *Journal of the American Planning Association, 59*(4), 461.

Fish, A., & Henderson, T. R. (1978). *Historical Perspectives*. Paper presented at the Conference Name|. Retrieved Access Date|. from URL|.

Gobster, P., & Haight, R. (2004). *From Landscapes to Lots: Understanding and Managing Midwestern Landscape Change*. St Paul, MN.

Gobster, P. H., & Rickenbach, M. G. (2003). Private Forestland Parcelization and development in Wisconsin's Northwoods: perceptions of resource-oriented stakeholders. *Landscape and Urban Planning, 69*, 165-182.

Gobster, P. H., & Rickenback, M. G. (2004). Private forestland parcelization and development in Wisconsin's Northwoods: Perceptions of resource-oriented stakeholders. *Landscape and Urban Planning, 69*, 165-182.

Gobster, P. H., & Schmidt, T. L. (2000). *The Use of Amenity Indicator in Anticipating Private Forestland Parcelization: A Look at the Lake States' Northwoods*. Paper presented at the Conference Name|. Retrieved Access Date|. from URL|.

Gonzalez-Abraham, C. E., Radeloff, V. C., Hammer, R. B., Hawbaker, T. J., Stewart, S. I., & Clayton, M. K. (2007). Building patterns and landscape fragmentation in northern Wisconsin, USA. *Landscape Ecology, 22*(2), 217-230.

Hargis, C. D., Bissonette, J. A., & David, J. L. (1998). The behaviour of landscape metrics commonly used in the study of habitat fragmentation. *Landscape Ecology, 13*, 167-186.

Hart, J. F. (1975). *The Look of the Land*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Heasley, L. (2003). Shifting Boundaries on a Wisconsin Landscape: Can GIS Help Historians Tell a Complicated Story? *Human Ecology, 31*(2).

Heimlich, R. E., & Anderson, W. D. (2001). *Development at the Urban Fringe and Beyond: Impacts on Agriculture and Rural Land*. Washington, D.C.: U.S. Department of Agriculture.

Hersperger, A. M. (1994). Landscape Ecology and its Potential Application to Planning. *Journal of Planning Literature, 9*(1), 14-30.

Hoch, C., Dalton, L. C., & So, F. S. (1988). *The Practice of Local Government Planning* (Second ed.). Washington D.C.: Library of Congress.

Holdt, B. M., Civco, D. L., & Hurd, J. D. (2004a). Forest Fragmentation Due to Land Parcelization and Subdivision: A Remote Sensing and GIS Analysis [Electronic Version], 1-8.

Holdt, B. M., Civco, D. L., & Hurd, J. D. (2004b). *Forest Fragmentation Due to Land Parcelization and Subdivision: A Remote Sensing and GIS Analysis.* Paper presented at the ASPRS, Denver, Colorado.

Irwin, E. G., Bell, K. P., & Geoghegan, J. (2003). Modeling and Managing Urban Growth at the Rural-Urban Fringe: A Parcel-Level Model of Residential Land Use Change. *Agricultural and Resource Economics Review*.

Irwin, E. G., & Bockstael, N. E. (2002). Interacting agents, spatial externalities and the evolution of residential land use patterns. *Journal of Economic Geography, 2*(1), 31-54.

Johnson, H. (1976). *Order Upon the Land*. New York, NY: Oxford University Press.

Johnson, K. (2006). *Demographic Trends in Rural Small Town America*. Durham: Carsey Institute.

Kuhlman, K. M. (1994). *Measuring the influences on land records modernization in Wisconsin counties.* University of Wisconsin-Madison, Madison.

Lane, M. B., & McDonald, G. (2005). Community-based Environmental Planning: Operational Dilemmas, Planning Principles and Possible Remedies. *Journal of Environmental Planning and Management, 48*(5), 709-731.

LaPierre, S., & Germain, R. H. (2005). Forestland Parcelization in the New York City Watershed. *Journal Of Forestry*(April/ May), 139-145.

Leitão, A. B., & Ahern, J. (2002). Applying Landscape Ecological Concepts and Metrics in Sustainable Landscape Planning. *Landscape and Urban Planning, 59*, 65-93.

Marcouiller, D. W., Clendenning, J. G., & Kedzior, R. (2002). Natural Amenity-Led Development and Rural Planning. *Journal of Planning Literature, 16*(4).

McGarigal, K., & Marks, B. J. (1995). FRAGSTATS: spatial analysis program for quantifying landscape structure. *USDA Forest Service General Technical Report PNW-GTR-351*.

McGarigal, K., & McComb, W. C. (1995). Relationships between landscape structure and breeding birds in the Oregon coast range. *Ecol. Monogr., 65*(3), 235-260

McGranahan, D. A. (1999). *Natural Amenities Drive Rural Population Change* (No. 781). Washington DC: US Department of Agriculture.

Medley, K. E., Pobocik, C. M., & Okey, B. W. (2003). Historical Changes in Forest Cover and Land Ownership in a Midwestern U.S. Landscape. *Annals of the Association of American Geographers, 93*(1), 104-120.

Meffe, G. K., Nielsen, L. A., Knight, R. L., & Schenborn, D. A. (2002). *Ecosystem Managment: Adaptive, Community-Based Conservation*. Washington D.C.: Island Press.

Mehmood, S. R., & Zhang, D. (2001). Forest Parcelization in The United States. *Journal Of Forestry*(April 2001), 30-34.

Melli, M. S. (1953). Subdivision Control in Wisconsin. *Wisconsin Law Review*, 389-457.

Nelson, A. C., Duncan, J. B., Mullen, C. J., & Bishop, K. R. (1995). *Growth Management Principles Practices*: American Planning Association.

NRCS, N. R. C. S. (2001). *National Resources Inventory 2001 Annual NRI: Urbanization and Development of Rural Land*.

Odell, E. A., Theobald, D. M., & Knight, R. L. (2003). Incorporating ecology into land use planning - The songbirds' case for clustered development. *Journal of the American Planning Association, 69*(1), 72-82.

Ohm, B. W. J. D. (1996). Subdivision Regulation.

Olson, E. (2005). *Raising the Gangplank: A Defense of Localims Aimed at Resource Protection.* New York: Edward Elgar Publishing.

Pawitan, Y. (2000). A Reminder of the Fallibility of the Wald Statistic: Liklelihood Explanation. *The American Statistician, 54*(1), 54-56.

Potter, L. A., & Schamel, W. (1997). The Homestead Act of 1862. *Social Education, 61*(6), 359-364.

Radeloff, V., Hammer, R. B., & Stewart, S. I. (2005). Rural and Suburban Sprawl in the U.S. Midwest from 1940 to 2000 and Its Relation to Forest Fragmentation. *Conservation Biology 19*(3), 793-805.

Rapson, R., Sept. 29, 2002 (2002). Changes in Communities Don't Just 'Happen' plus linked article of "20 Things You Can Do" by Embrace Open Space. *Minneapolis-St. Paul Star Tribune*.

Rickenbach, M. G., & Gobster, P. H. (2003). Stakeholders' Perceptions of Parcelizations in Wisconsin's Northwoods. *Journal Of Forestry*(September 2003), 18-23.

Rowlands, W. A. (1963). The History of Rural Zoning In Wisconsin. *Wisconsin Academy Review, 10*(2).

Schultink, G. (2007). Sustainable Land Use and Urban Growth Management: Demand-Supply Factors and Strategic Planning Considerations. *Journal of Agricultural, Food, and Environmental Sciences, 1*(1).

Shannon, F. A. (1936). The Homestead Act and the Labor Surplus. *The American Historical Review, 41*(4), 637-651.

Shultz, M. M., & Groy, J. B. (1988). The Failure of Subdivision Control in the Western United States: A Blueprint for Local Government Action. *Utah Law Review*, 569-674.

Stroud, H. B. (1995). *The promise of paradise : recreational and retirement communities in the United States since 1950*. Baltimore: Johns Hopkins University Press.

Stynes, D. J., Zheng, J., & Stewart, S. I. (1997). *Seasonal homes and natural resources patterns of use and impact in Michigan*. St. Paul, Minn.: U.S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station.

Theobald, D. M., Miller, J. R., & Hobbs, N. T. (1997). Estimating the cummulative effects of developement on wildlife habitat. *Landscape and Urban Planning, 39*, 25-36.

Thrower, N. (1966). *Original Survey and Land Subdivision*. Chicago, IL: Rand McNally and Company.

Township of West Point. (2007). *Town of West Point Comprehensive Plan 2030*. West Point, WI: Township of West Point.

Turner, M. G. (2005). Landscape Ecology: What is the State of the Science. *Annual Review of Ecology and Systematics, 36*, 319-344.

Turner, M. G., Gardner, R. H., & O'Neill, R. V. (2001). *Landscape Ecology In Theory and Practice*. New York Springer-Verlag.

US Census Bureau (2002), *2000 Decennial Census,* retrieved on 11 January 2008, from http://www.census.gov.

USDA. (2006). *Cooperating Across Boundaries: Partnerships to Conserve Open Space in Rural America*. Washington D.C.

U.S. Department of Housing and Urban Development. Interstate Land Sales. from http://www.hud.gov/offices/hsg/sfh/ils/ilshome.cfm

WDA, W. D. o. A. (2006). *Zoning in unincorporated areas in Wisconsin*. Madison, WI.

WDNR, W.D.N.R. (2006, November 3, 2006). County Forests Program History. Retrieved March 2007, from http://dnr.wi.gov/org/land/forestry/history/history_county.htm

WDNR, W.D.N.R. (2005). *Floodplain and Shoreland Zoning: A Guidebook for Local Officials*. Retrieved. from.

Wisconsin Department of Tourism. (2007). *2006 Economic Impact Fact Sheets: Columbia County*. Madison, WI: Wisconsin Department of Tourism.

Wisconsin Economic Development Institute, I. a. C. f. T. T., Inc 2004. (2004). *Wisconsin's Forest Products Industry Business Climate Status Report*.

Wisconsin Land Information Program. (2003). 2003 Assessment Survey.

Wisniewski, S., & Anderson, R. (2003). *County Executive Falk Announces County Receives $340,000 Federal Grant to Preserve Farmland in the Highway 12 Corridor*. Madison Wisconsin: County Executive's Office, NRCS.

Appendix A

Data Collection and Spatial Reconstruction Methods

Historic Ownership and Tax Parcels

Reconstructing Land Tenure: Procedures and Implications for Ownership and Tax Parcels

Authors: Dan McFarlane and Doug Miskowiak
Date: February 13, 2007
This research is funded by The USDA's National Research Initiative for Rural Development

DATA COLLECTION AND CREATION

Data Collection Objectives

The principle objective of this project is to measure trends in parcelization over time and to identify significant landscape amenity features, both natural and manmade that influence parcelization. To achieve this objective, data will be collected and reconstructed from present (2005) to 1940 in approximate 10 year increments in the pilot project areas. The remainder of this report section documents the actual data, sources, and procedures used to achieve data collection objectives. The procedures used relate only to data within Columbia County, WI.

Data Sources

Table 1 identifies our data collection and creation assumptions at the time this grant was written. Actual data sources and collection/creation procedures sometimes varied from our original assumptions (see Table 2). Data at the present time (2005) were often in a digital format. Archival data were often derived from hardcopy sources, made digital, and examined in comparison to other sources before developing a digital archival record.

Data Category	Data	Sources*
Cadastral/Parcel	Digital tax parcels	LIO
	Archival cadastre	HC, LIO
	Archival Tax Assessments	DOR, LIO, HC
Aerial-photography	Orthophotography	LIO, RPC, USGS
	Aerial photography	LIO, RPC, USGS, HC
Land Use	Land use/ current, archival	LIO, RPC, USGS
	Digital Line Graphs	USGS
	USGS quad sheets	USGS
	Residential, commercial, industrial	LIO, RPC, USGS
	Agricultural lands	LIO, RPC, USGS
	Public land uses	LIO
Natural Resources	Lakes, rivers, streams	DNR
	Slopes	LIO, RPC, USGS
	Elevations	LIO, RPC, USGS

	Forest cover	LIO, RPC, USGS
	Soils	NRCS
Infrastructure	Roads/ current, archival	LIO, RPC, DOT,
	Electricity	LIO
	Sewer/water	LIO
Administrative	County boundaries	DNR
	Town boundaries	DNR
	Special districts	LIO

Table 1

Data Category	**Data**	**Sources***
Cadastral/Parcel	Digital tax parcels	LIO
	Archival cadastre	HC, LIO
	Archival Tax Assessments	LIO, HC
	Plat books	LIO, HC
Aerial-photography	Orthophotography	CCD
	Aerial photography	CD, LIO
Land Use	Land use/ current, archival	LIO, UW
	Residential, commercial, industrial	LIO
	Agricultural lands	LIO
	Public land uses	LIO
Natural Resources	Lakes, rivers, streams	DNR
	Slopes	LIO
	Elevations	LIO
	Forest cover	LIO
	Soils	LIO
Infrastructure	Roads/ current, archival	LIO
	Electricity	LIO
	Sewer/water	LIO
Administrative	County boundaries	LIO
	Town boundaries	LIO
	Special districts	LIO

Table 2

***Sources Key**	
LIO	County Land Information Office/Land Records Department
RPC	Regional Planning Commission
USGS	United States Geological Survey
NRCS	Natural Resource Conservation Service
DNR	WI Department of Natural Resources

DOT	WI Department of Transportation
DOR	WI Department of Revenue
HC	Hardcopy sources available at courthouse/library/historical society
CCD	County Conservation Department
UW	University of WI digital library

Hardware and Software Utilized
A Maxtor 100gb external hard drive was used to store original data. All reconstructed data layers were stored on a network server where it was backed up weekly. Leica's Erdas Imagine and ESRI's ArcGIS 9.1 software packages were utilized for data manipulation and creation.

Data Collection/Creation Procedures
The following section describes the collection and creation procedures for each data set collected for this project.

Ownership Parcels (present day 2005)
An ownership parcel defines land in contiguous and connected ownership by a single person or entity. Ownership parcels may consist of one or more tax parcels (see Figure 1). In the project, ownership parcels are constructed from two sources, the current digital tax parcels and published hardcopy plat books.

Ownership parcels helped us to measure land tenure patterns over time. Measuring the spatial distribution indicated if any patterns existed and what features were influencing it.

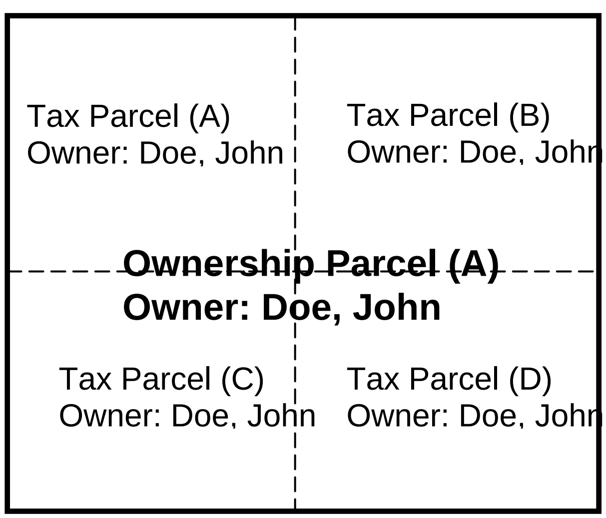


Figure 1. Tax parcel ownership parcel relationship. For this project, contiguous tax parcels owned by the same person created an ownership parcel.

Step 1. Scan Hard Copy Plat Books

Hard copy plat books, gathered from the county LIO and the public library, were collected and digitally scanned for the following dates: 1936, 1947, 1953, 1961, 1967, 1972, 1983, 1991, 2000, and 2005. These dates were chosen based on the availability of plat books and to get the best representation of data in 10-year increments. Initially, we thought that geo-referencing plat books would make it easier to identify changes in the parcel landscape by overlaying years. Geo-referencing the plat books, however, proved problematic. Plat books from various dates were of various qualities and did not match well with our digital tax parcel data. Instead, printed copies of each scanned plat were used for comparison and interpretation of data.

Step 2. Dissolve Ownership from Current Year Tax Parcel Database

The current tax parcel database was used to create the ownership parcel layer for the same year. The tax parcel layer was merged using the "Dissolve" tool. Parcels were dissolved by owner name using the "Owner_NM" field (Figure 2). The new ownership parcel data set was named "ownership_2005".

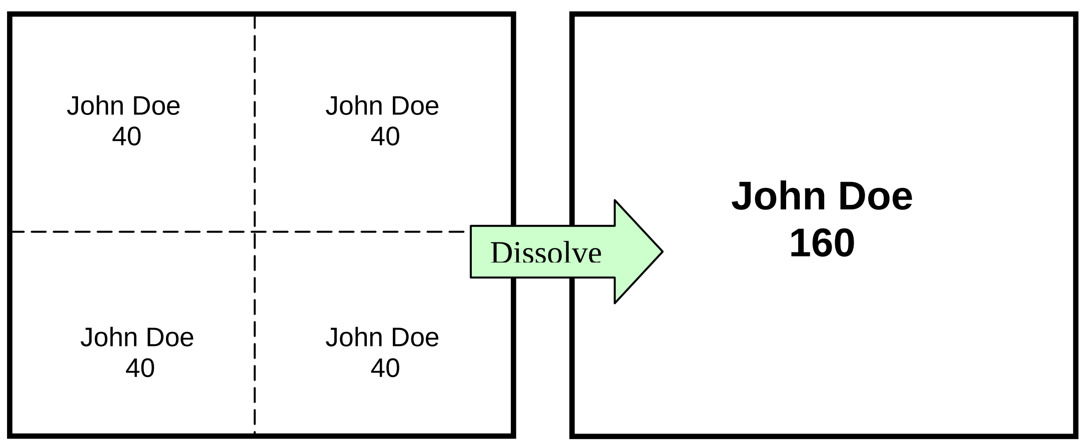


Figure 2. The example shows how the dissolve function works by merging all tax parcels with the same name to create a new ownership parcel layer.

Step 3. Separate Non-Adjacent Parcels Under Same Ownership

The dissolve function merges all parcels owned by the same person even if the parcels are not contiguous, an undesirable result. To remedy the situation, the "Explode" tool in the Advanced Editing toolbar was used to unmerge any non-contiguous ownership parcels.

Step 4. Update the "Area" and "Acres" Fields

Using Dissolve and Explode tools alters the accuracy of spatial data attributes, notably "Area." The areas of Ownership Parcels were updated using the following syntax in the "Field Calculator". It is important to note that since the data coordinate system is defined in feet, these calculations were made in square feet.

```
Dim dblArea as double
Dim pArea as IArea
Set pArea = [shape]
dblArea = pArea.area
```

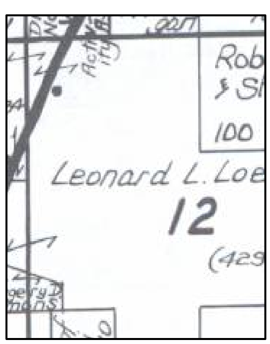
Acreages for each parcel were calculated by dividing parcel area by 43,560, the number
of square feet per acre.

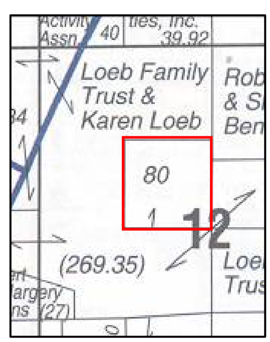
Challenge: Dissolving on Owner Name
The Dissolve tool combines data with the same attributes. This project dissolved parcels that had the same owner name. The tool, however, cannot distinguish and account for errors in the data. The tax parcel data had such errors. Owner's names were misspelled or included minor variations, such as including middle initials. Left unchanged, data in error would not merge and would be seen as a separate and unique ownership parcel.
To fix the problem, dissolved parcels were sorted by owner name. Owner names with slightly different attributes were further investigated using plat books. Those ownership parcels found to be in error were manually merged.

Archival Ownership Parcels (1927 – 2000)
Archival ownership parcels are reconstructed using a snapshot approach, working backwards from the current digital ownership data. Using this method, we only edited parcels that were created between each 10 year increment; therefore, we did not have to reconstruct every parcel for each 10 year increment. We construct historical ownership parcels by examining published hardcopy plat books.

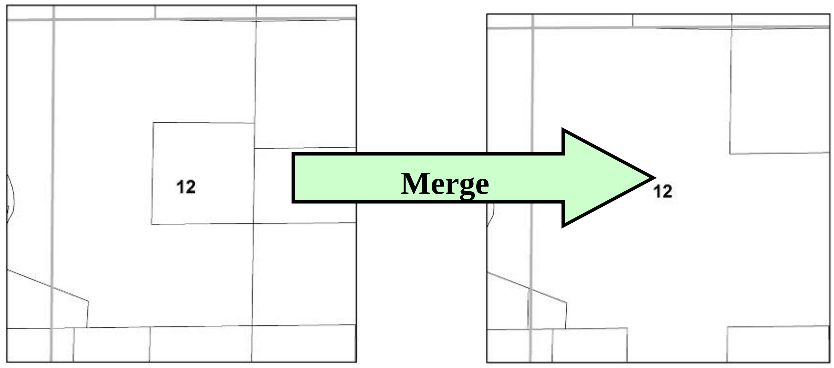
Step 1. Copy and Rename Ownership_2005
Using the Ownership_2005 layer, we created the 2000 ownership parcel boundaries. The Ownership_2005 was copied and renamed to Ownership_2000. All ownership boundary changes between 2000 and 2005 were edited in the Ownership_2000 parcel layer.

Step 2. Identify New Parcels
Examining the 2000 and 2005 plat books, new parcels that appeared on the 2005 plat book were merged into their parent parcel in the Ownership_2000 layer (Figure 3).





2000 Plat book 2005 Plat book

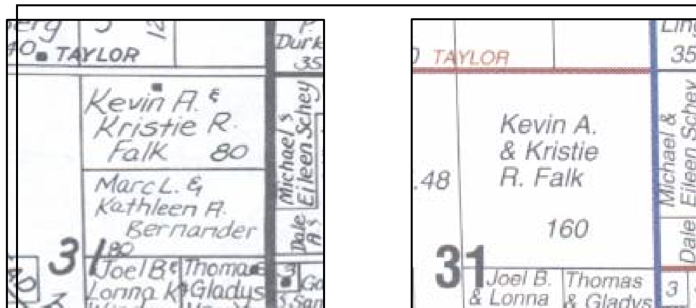


Ownership_2000 before merge Ownership_2000 after merge

Figure 3. The red ownership parcel above in the 2005 plat book does not show up in the 2000 plat book. Editing the ownership_2000 layer, the parcel was merged into its parent.

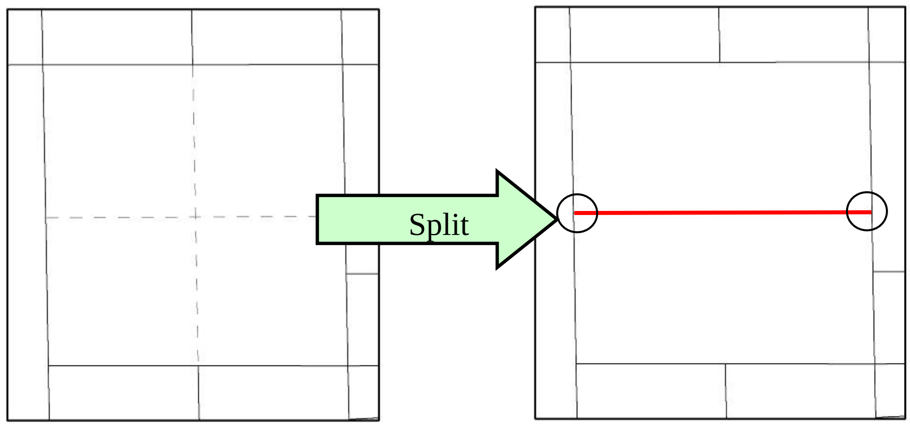
Step 3. Splitting Parcels That Grew

Our assumption that parcels only get smaller over time was not necessarily true. In some cases, parcels consolidated. These parcels were identified when they appeared on the 2000 plat book, but not on the 2005 plat book (Figure 4). The ownership parcel that grew was split using the current tax parcel layer as a guide. The "Cut Polygon" editing tool was used to split the selected parcel. Ownership parcels follow tax parcel boundaries; therefore, the tax parcel vertices were snapped to when cutting polygons (Figure 5).



2000 Plat book 2005 Plat book

Figure 4. Ownership consolidation over time. Kevin and Kristie Falk added to their property from 2000 to 2005.

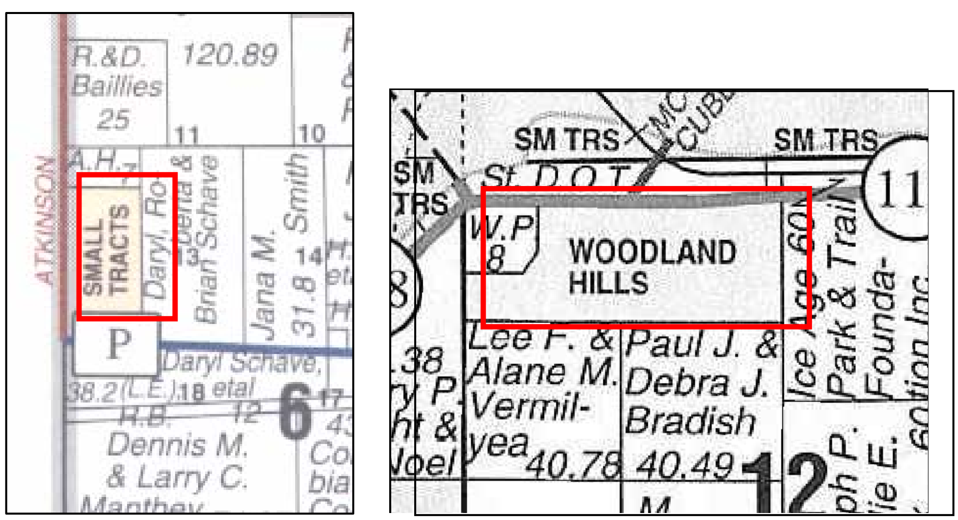


Ownership_2000 before split   Ownership_2000 after split

Figure 5. The figure on the left shows the 2000 ownership parcels and the hashed 2005 tax parcel lines. Snapping to the tax parcel lines, the ownership parcel was cut into two 80 acre parcels, reflecting what is shown on the 2000 plat book in Figure 4.

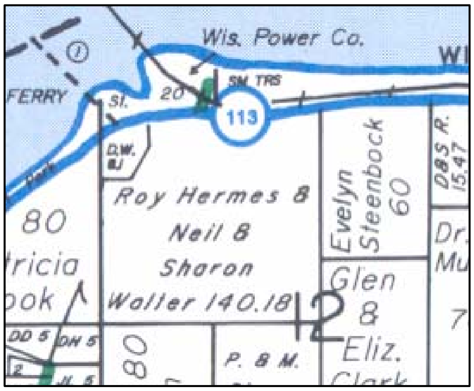
Step 4. Subdivisions and Small Tracts

Hard copy plat books did not distinguish subdivision lots or “Small Tracts” property boundaries (Figure 6). Here all subdivision and “Small Tracts” parcels were maintained in the ownership parcel layer until a plat book no longer showed either a subdivision or a “Small Tracts” area. Parcels were then merged, replicating what was shown on the plat books (Figure 7). Subdivision approval dates were collected from the Register of Deeds Office and helped to determine when lots needed to be merged.

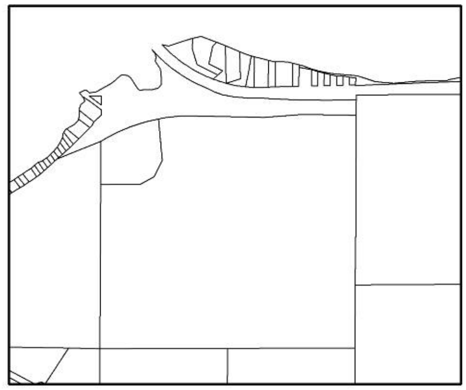


Small Tracts   Subdivisions

Figure 6. The red box in the plat books highlight small tracts and platted subdivisions. The parcel boundaries within these areas are not shown.



2000 Plat Book

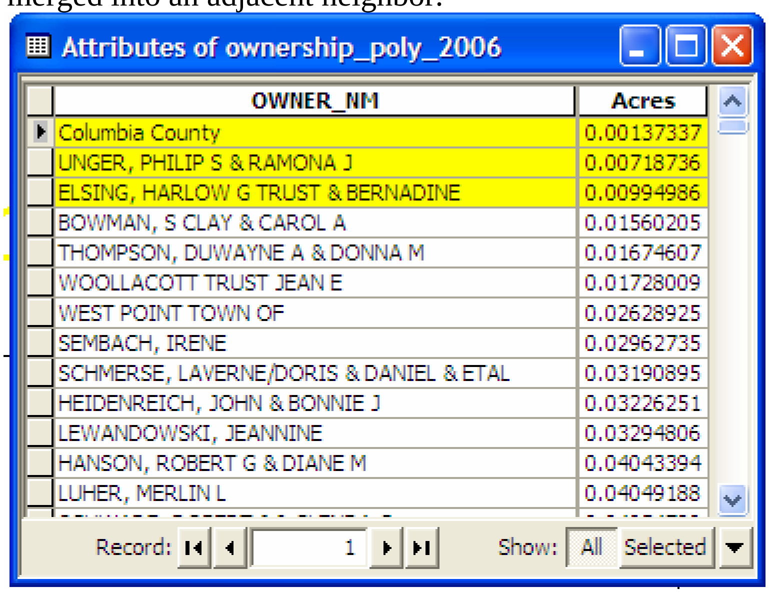


Ownership_2000

Figure 7. When working backwards through time, the 2000 plat book does not show the Woodland Hills subdivision. All the Woodland Hills lots were merged in the ownership_2000 parcel layer to produce an ownership boundary similar to the plat book boundary.

Step 5. Update "Area" and "Acres" Field
Once the entire year was complete the "Area" and "Acres" field were updated.

Step 6. Sliver Polygons
Sorting the data on the "Acres" field in ascending order helped to identify "sliver" polygons (Figure 8). Sliver polygons can be created when splitting parcels and often occur along the edge. Parcels with extremely small acreages were investigated. Sliver polygons were merged into an adjacent neighbor.



Attributes of ownership_poly_2006

OWNER_NM	Acres
Columbia County	0.00137337
UNGER, PHILIP S & RAMONA J	0.00718736
ELSING, HARLOW G TRUST & BERNADINE	0.00994986
BOWMAN, S CLAY & CAROL A	0.01560205
THOMPSON, DUWAYNE A & DONNA M	0.01674607
WOOLLACOTT TRUST JEAN E	0.01728009
WEST POINT TOWN OF	0.02628925
SEMBACH, IRENE	0.02962735
SCHMERSE, LAVERNE/DORIS & DANIEL & ETAL	0.03190895
HEIDENREICH, JOHN & BONNIE J	0.03226251
LEWANDOWSKI, JEANNINE	0.03294806
HANSON, ROBERT G & DIANE M	0.04043394
LUHER, MERLIN L	0.04049188

Record: 1 Show: All Selected

Figure 8. Sorting the data on the Acres field, three records show extremely small areas. Zooming to each parcel helped to determine if they were sliver polygons.

Step 7. Copy and Repeat
The Ownership_2000 parcel layer was copied and renamed to Ownership_1991. ***Archival Ownership Parcels*** Steps 1-7 were repeated for the remaining years.

Tax Parcels (present day)

Current tax parcel boundaries, except for two townships, were in a digital format for the entire county. Because ownership parcels did not distinguish tax parcels lines, we were unable to get the full picture of the parcel landscape. For example, some owners had subdivided their property, but still owned every parcel (Figure 9). Using the current digital tax parcel layer to work backwards through time, we researched tax assessment rolls to generate accurate historical tax parcels layers. Tax parcel boundaries were reconstructed for the same years as ownership parcels. With historical tax parcel maps, we then could more accurately map and analyze parcel patterns over time.

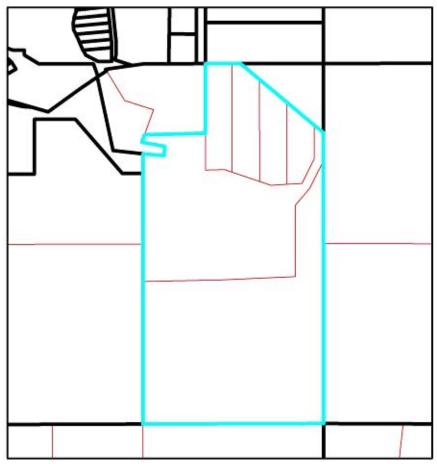


Figure 9. The blue parcel outlines an ownership parcel containing several small tax parcels.

Tax Assessment Rolls and the Parcel Number

Tax assessment rolls contained the necessary information for constructing historical tax parcels, including a legal description and a parcel number. The rolls were stored at the county building and were not allowed off the property. Tax rolls were available for every year back to 1940. However, in 1950, a unique parcel number was assigned to every parcel within a municipality. Parcels created after 1950 were assigned the parent parcel number with an attached decimal and number or letter (Table 3). The same parcel number is also stored in the current digital tax parcel layer and was used to identify parent parcels.

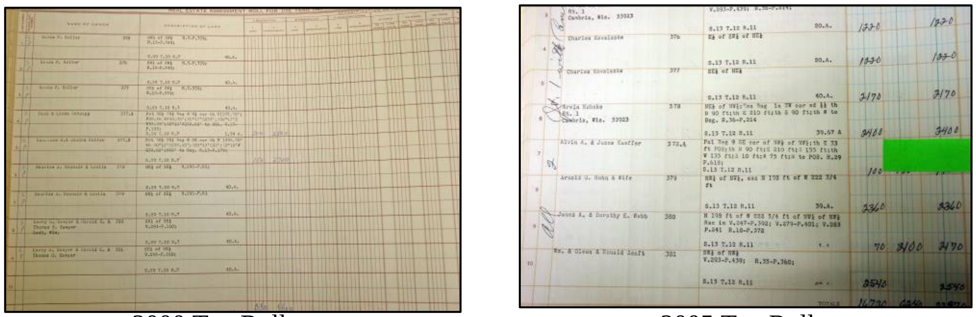
2005 Tax Parcel Attribute Table	
Parcel Number	**OWNER_NM**
137	SCHOEPP,DAN & CHRIS LIVING TRUST
138	ENGE, DELORMAN & LOUISE
138.A	CARNCROSS, GORDON & EMILY L
138.B	FOTH, MICHAEL G & SHARRON
139	ENGE, DELORMAN & LOUISE
139.1	HANKS, HARRY I & ELAINE D
139.2	WEST POINT TOWN OF

Table 3. The 2005 tax parcel attribute table. Parcels number with an attached decimal are splits (e.g. 138.A split from 138).

Archival Tax Parcels

Step 1. Identify New Tax Parcels

New tax parcels were identified using tax assessment rolls stored at the county building. Setting consecutive rolls side-by-side (e.g. 2000 & 2005), any new parcel number in the 2005 tax rolls was marked with a post-it (Figure 10).



2000 Tax Roll 2005 Tax Roll

Figure 10. Parcels with a post-it indicate that the tax parcel was added since the previous assessment.

Step 2. Photograph Tax Assessment Rolls

Pages with post-its were photographed so we would have a digital copy of the tax roll page for viewing in the lab. After photographing a particular year, the pictures were downloaded to a laptop and organized in a folder with that year's heading (Figure 11).

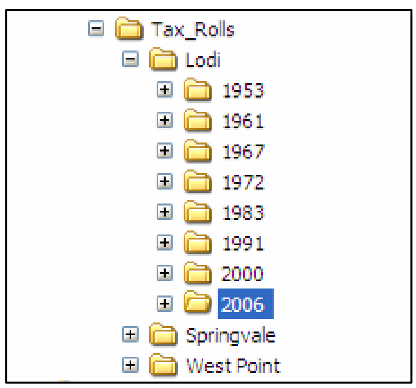


Figure 11. Folder structure for storing digital tax assessment photos.

Step 3. Copy and Rename Current Digital Tax Parcels

The current digital tax parcel was copied and renamed to tax_parcel_2000.

Step 4. Locate Tax Parcel

Examining the 2005 digital tax assessment photos, we identified post-its, representing new tax parcels created after the year 2000. In the tax_parcel_2000 attribute table, the new parcel number was selected from the "Par_Num" field. The "Zoom to Selection" tool zoomed to the tax parcel location. Labeling the tax parcels with the "Par_Num" field helped to target tax parcels and their parents.

Step 5. Merge New Tax Parcel Into Parent

Locating the new tax parcel, we merged it into its parent, based on the parcel number in the 2000 tax roll (Figure 12).

Figure 12. Merging parcel 232.A into its parent tax parcel.

Step 6. Dealing With Subdivisions

Dates of platted subdivisions were collected from the Register of Deeds Office. Unlike other parcels, subdivision lot parcel numbers did not contain the parent parcel number, making it difficult to locate the parent. Here, all lots were merged together, including any road right-of-ways (Figure 13). If the merged parcel spanned more than one forty line, it was split in Step 7.

Step 7. Reconstructing 40's

Working backwards through time, historic parcel lines no longer existed in the current digital tax parcel layer where large subdivisions were platted. Reconstructing tax parcels prior to a platted subdivision required splitting the merged lots from Step 6. Snapping to the current tax parcel layer and the county's quarter-quarter sections, tax parcels were constructed by using the "Cut Polygon" tool and interpreting the tax parcel's legal description in the tax roll (Figure 13).


Figure 13. Snapping to section lines (blue hashes), parcels were cut to create tax parcels that did not exist in the digital tax layer.

Step 8. Update "Area" and "Acres" Field
The areas of tax parcels were updated using the following syntax in the "Field Calculator". It is important to note that since the data coordinate system is defined in feet, these calculations were made in square feet.

```
Dim dblArea as double
Dim pArea as IArea
Set pArea = [shape]
dblArea = pArea.area
```

Acreages for tax parcels were calculated by dividing parcel area by 43,560, the number of square feet per acre.

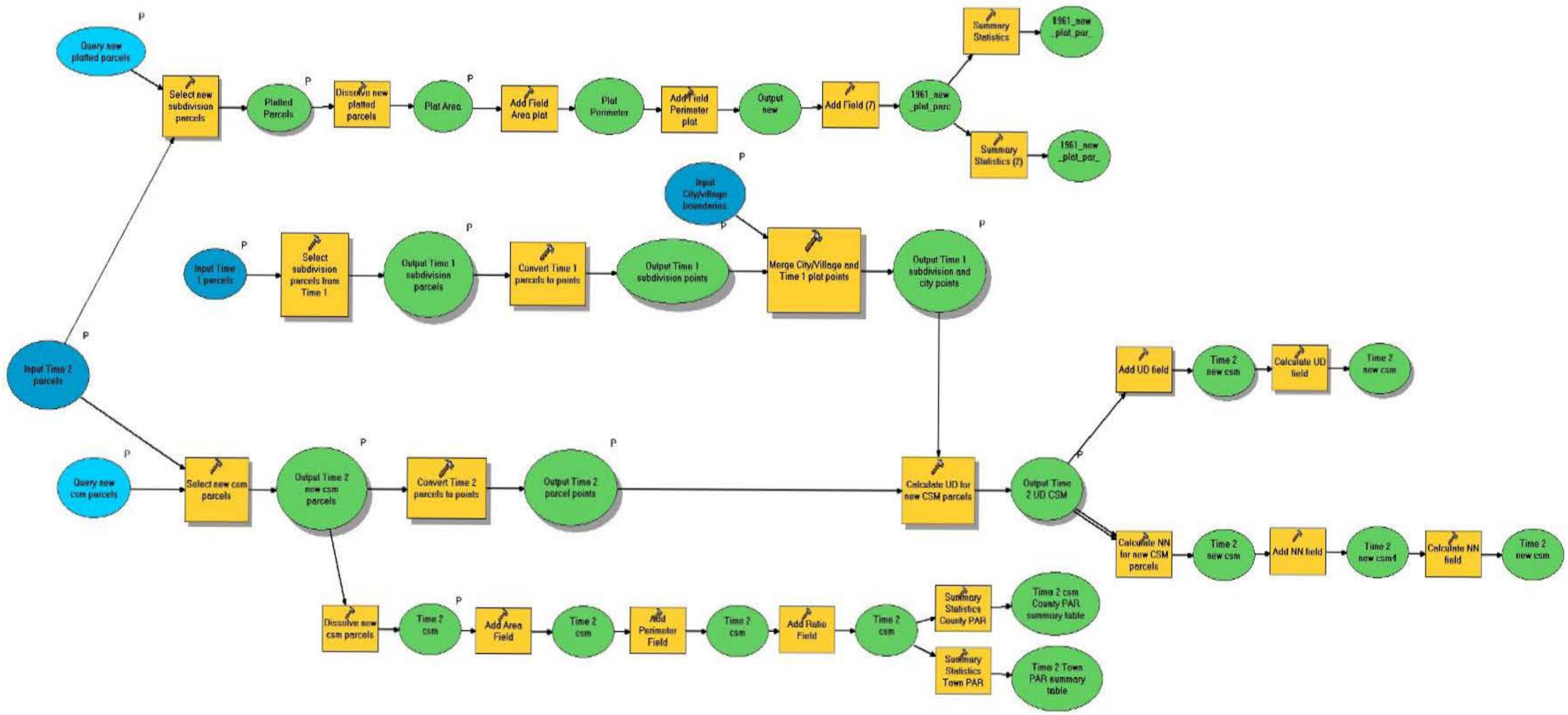
Step 9. Sliver Polygons
Sorting the data on the "Acres" field in ascending order helped to identify "sliver" polygons (Figure 8). Sliver polygons can be created when splitting parcels and often occur along the edge. Parcels with extremely small acreages were investigated. Sliver polygons were merged into an adjacent neighbor.

Step 10. Copy and Repeat
The Tax_parcel_2000 layer was copied and renamed to Tax_Parcel_1991. ***Archival Tax Parcels*** Steps 1-10 were repeated for the remaining years.

Challenges: Missing Tax Numbers
In some cases, tax parcel numbers were non-existent in the digital data. For example, a tax assessment roll might have indicated that parcel number 25.B was a new tax parcel. However, that parcel number no longer existed in the tax parcel attribute table. To correct this, we interpreted the tax assessment legal description of the parcel and reconstructed it with an accuracy of a quarter mile (quarter-quarter section).

Appendix B

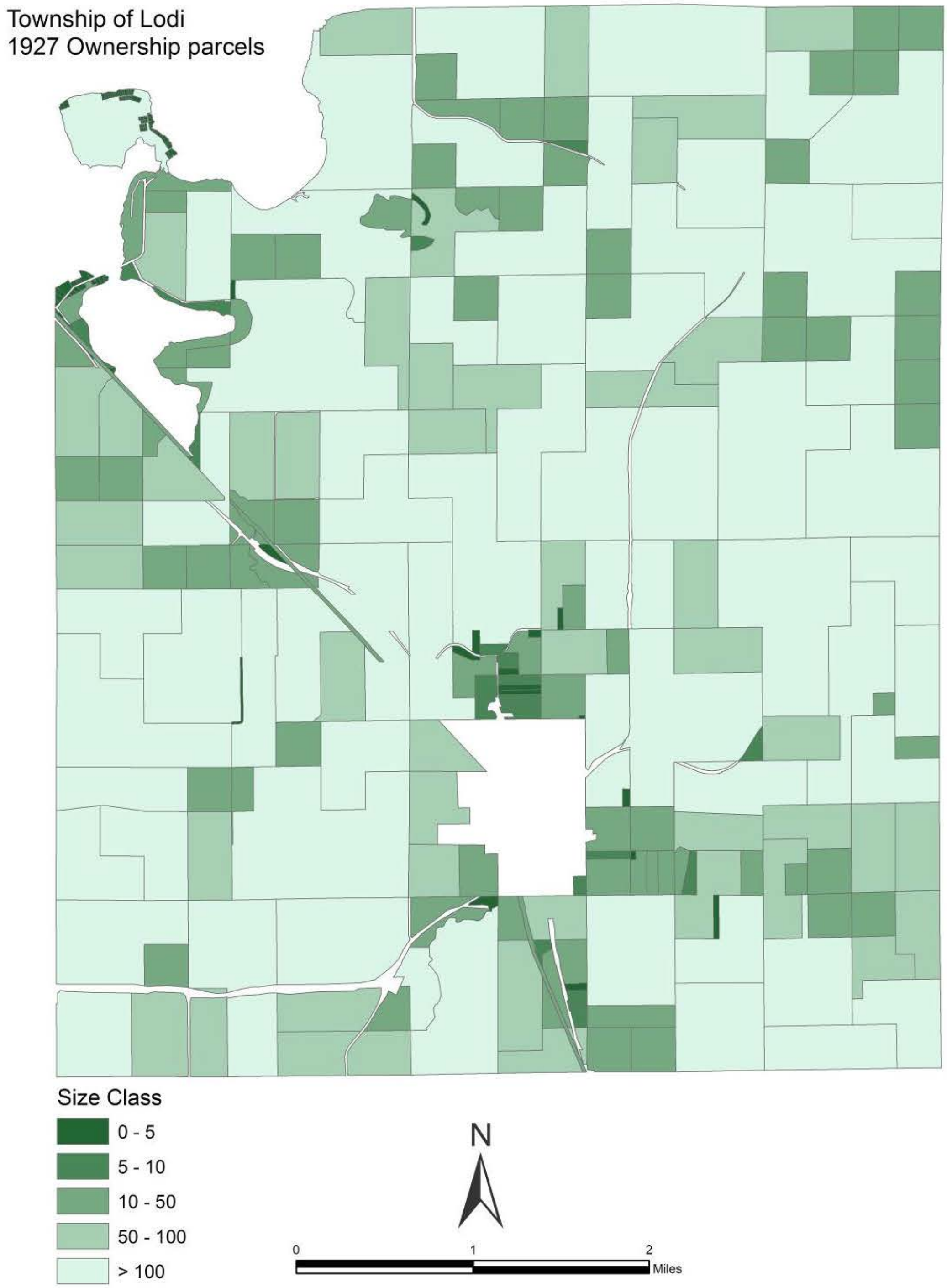
Spatial Model Flowchart

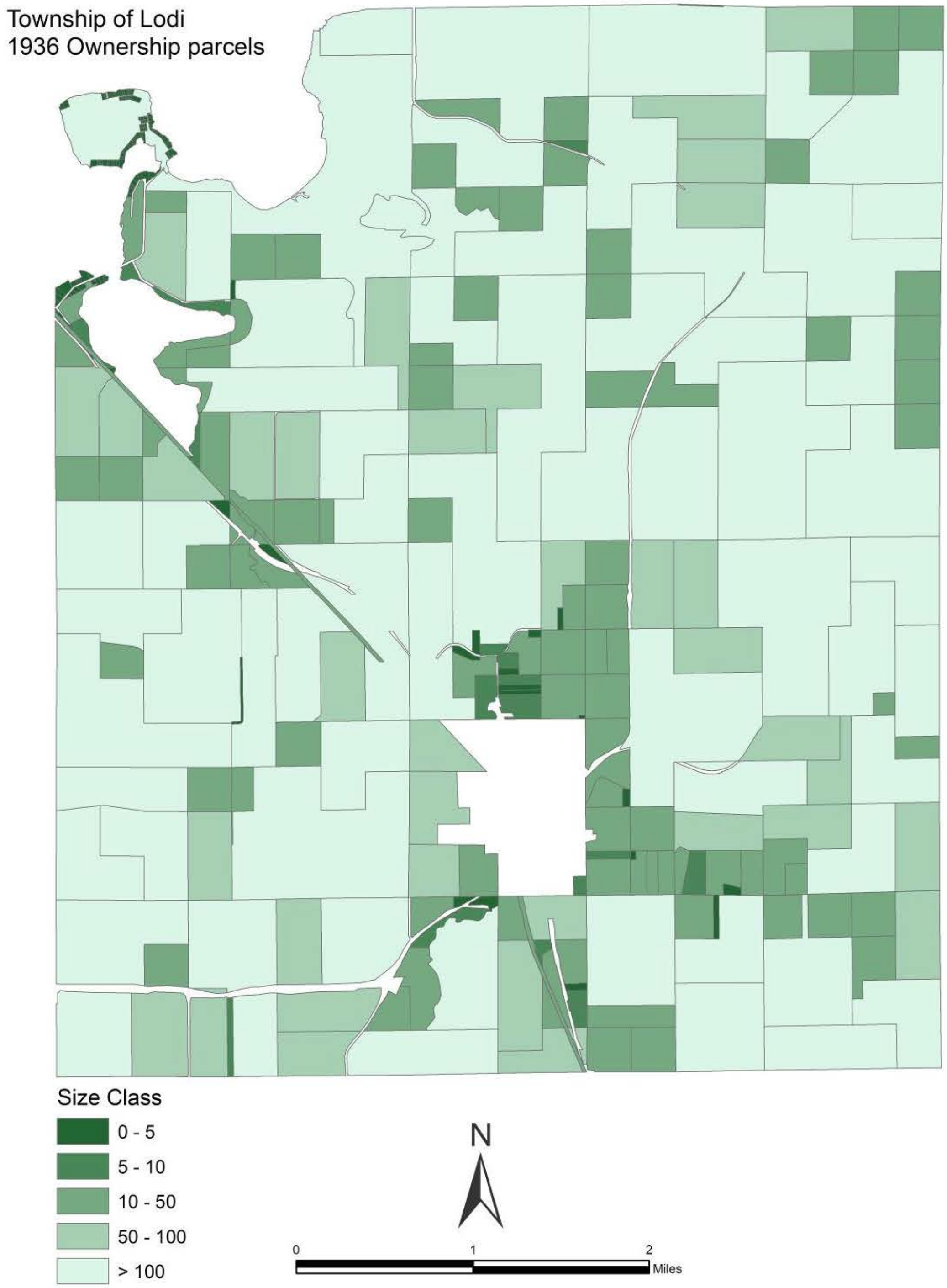


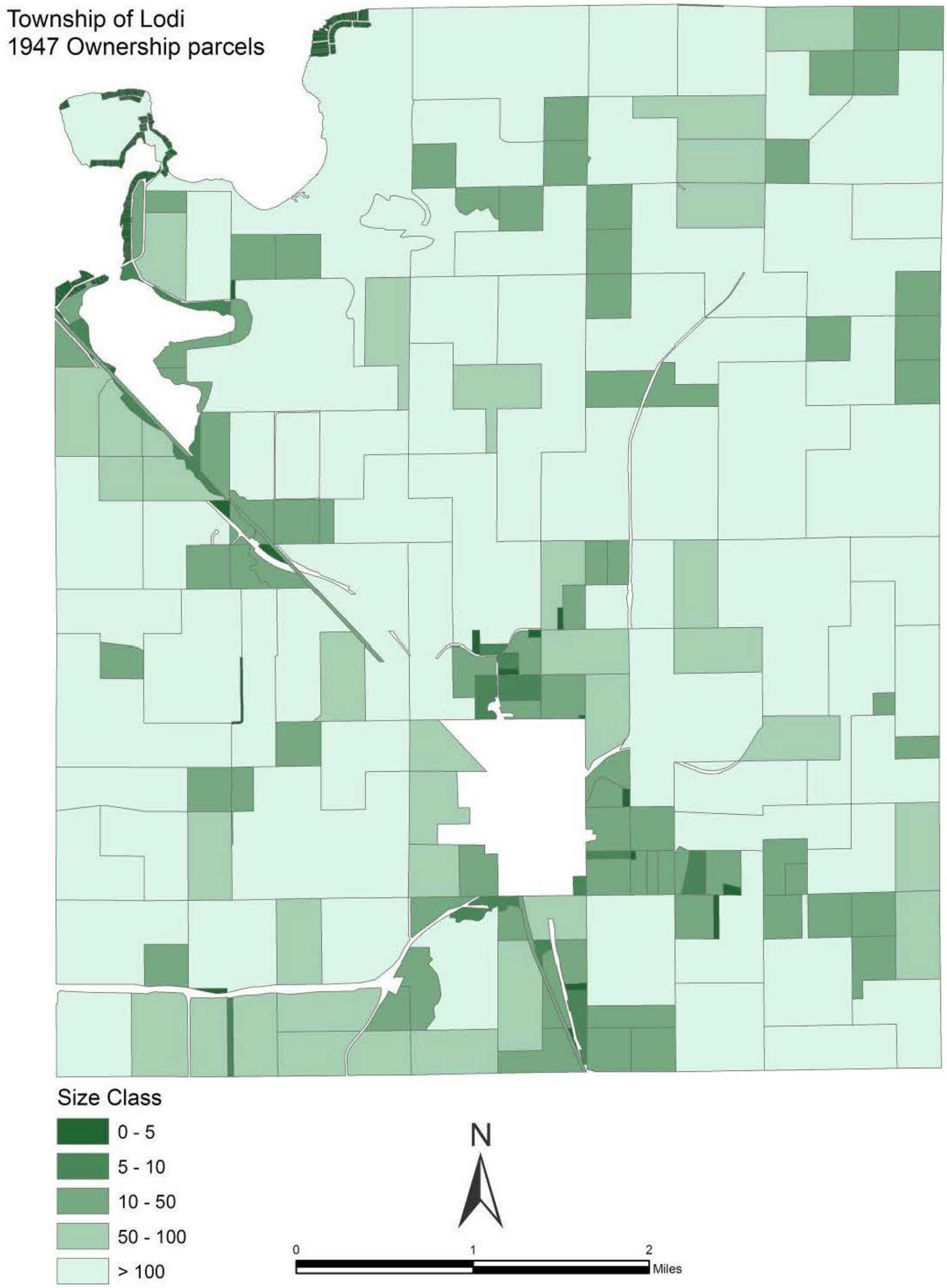
Query new platted parcels
Select new subdivision parcels
Platted Parcels
Dissolve new platted parcels
Plat Area
Add Field Area plat
Plat Perimeter
Add Field Perimeter plat
Output new
Add Field (7)
1961_new_plat_parc
Summary Statistics
1961_new_plat_par_
Summary Statistics (2)
1961_new_plat_par_
Input City/village boundaries
Input Time 1 parcels
Select subdivision parcels from Time 1
Output Time 1 subdivision parcels
Convert Time 1 parcels to points
Output Time 1 subdivision points
Merge City/Village and Time 1 plat points
Output Time 1 subdivision and city points
Input Time 2 parcels
Query new csm parcels
Select new csm parcels
Output Time 2 new csm parcels
Convert Time 2 parcels to points
Output Time 2 parcel points
Calculate UD for new CSM parcels
Output Time 2 UD CSM
Add UD field
Time 2 new csm
Calculate UD field
Time 2 new csm
Calculate NN for new CSM parcels
Time 2 new csm
Add NN field
Time 2 new csm4
Calculate NN field
Time 2 new csm
Dissolve new csm parcels
Time 2 csm
Add Area Field
Time 2 csm
Add Perimeter Field
Time 2 csm
Add Ratio Field
Time 2 csm
Summary Statistics County PAR
Time 2 csm County PAR summary table
Summary Statistics Town PAR
Time 2 Town PAR summary table

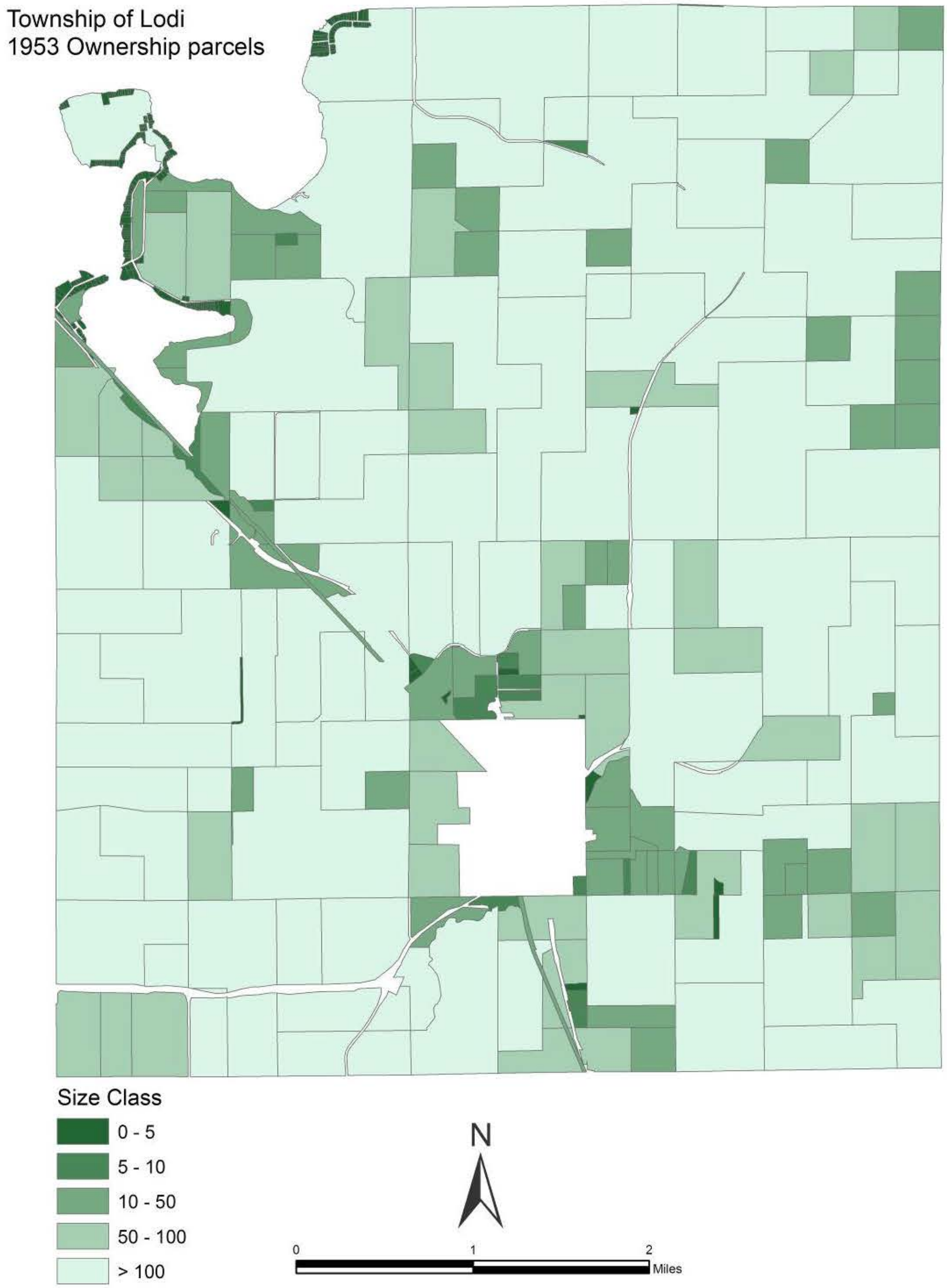
Appendix C

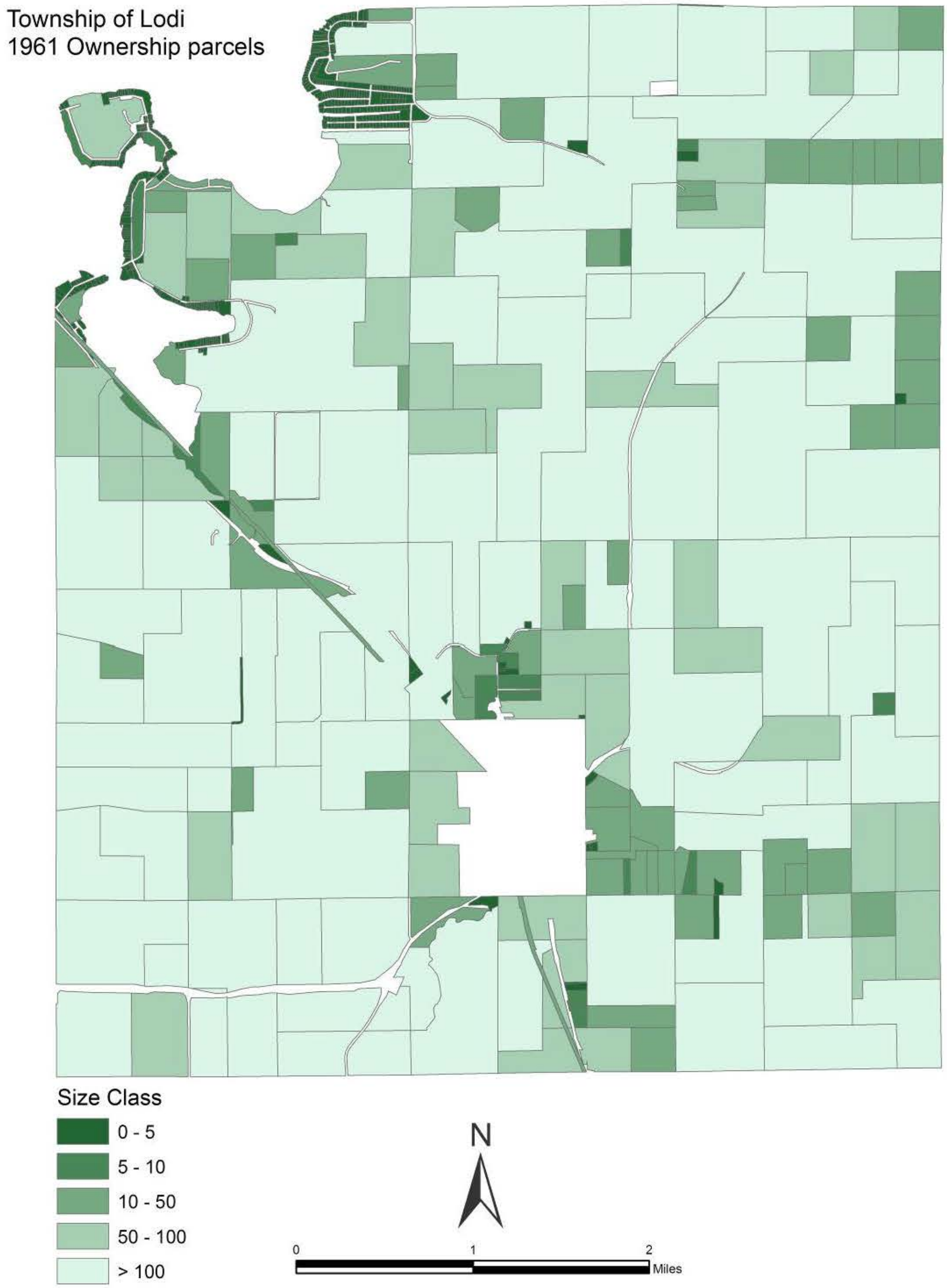
Historic Ownership Parcel Maps by Township from 1927 - 2005


Township of Lodi
1927 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

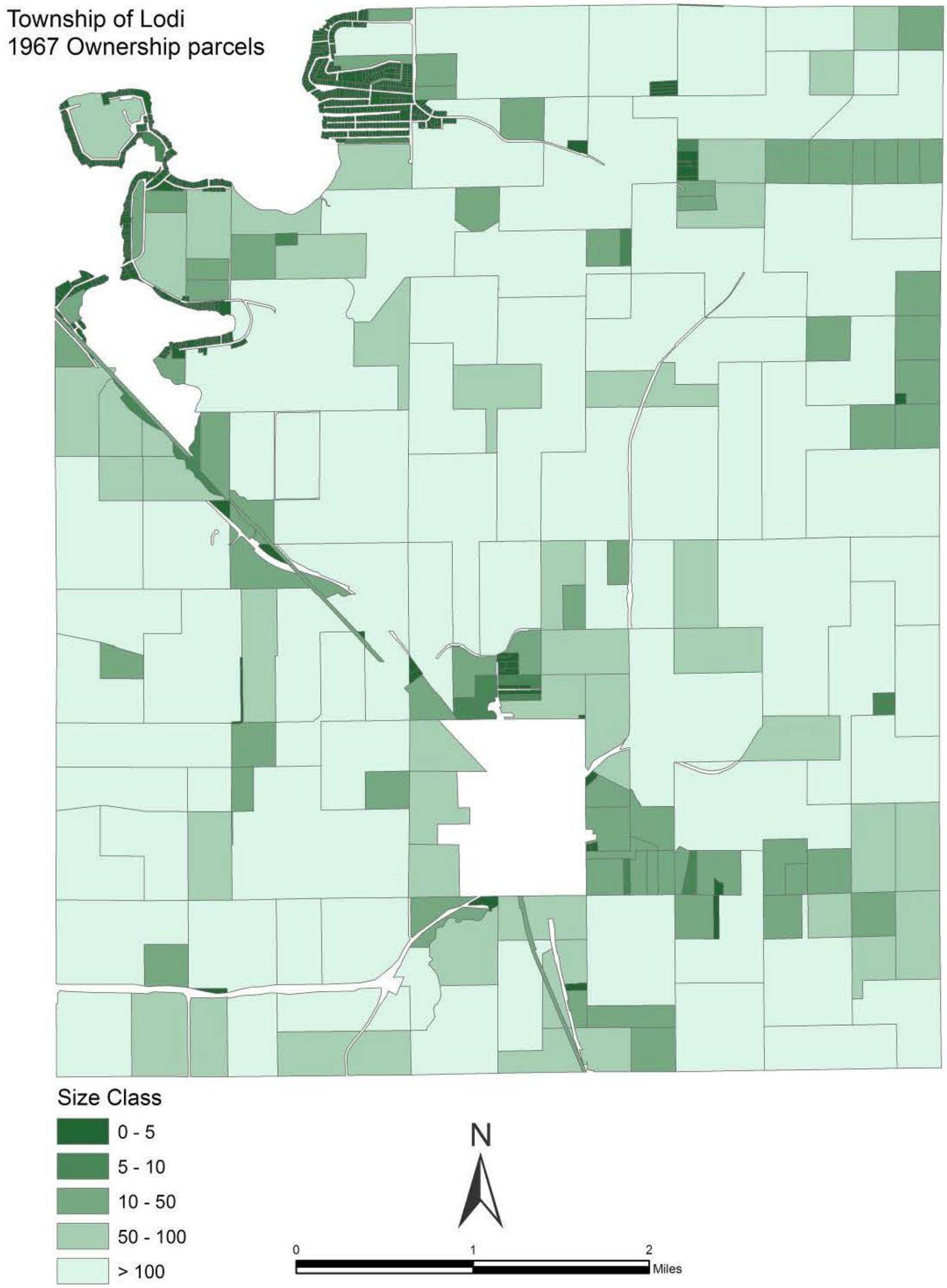

Township of Lodi
1936 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

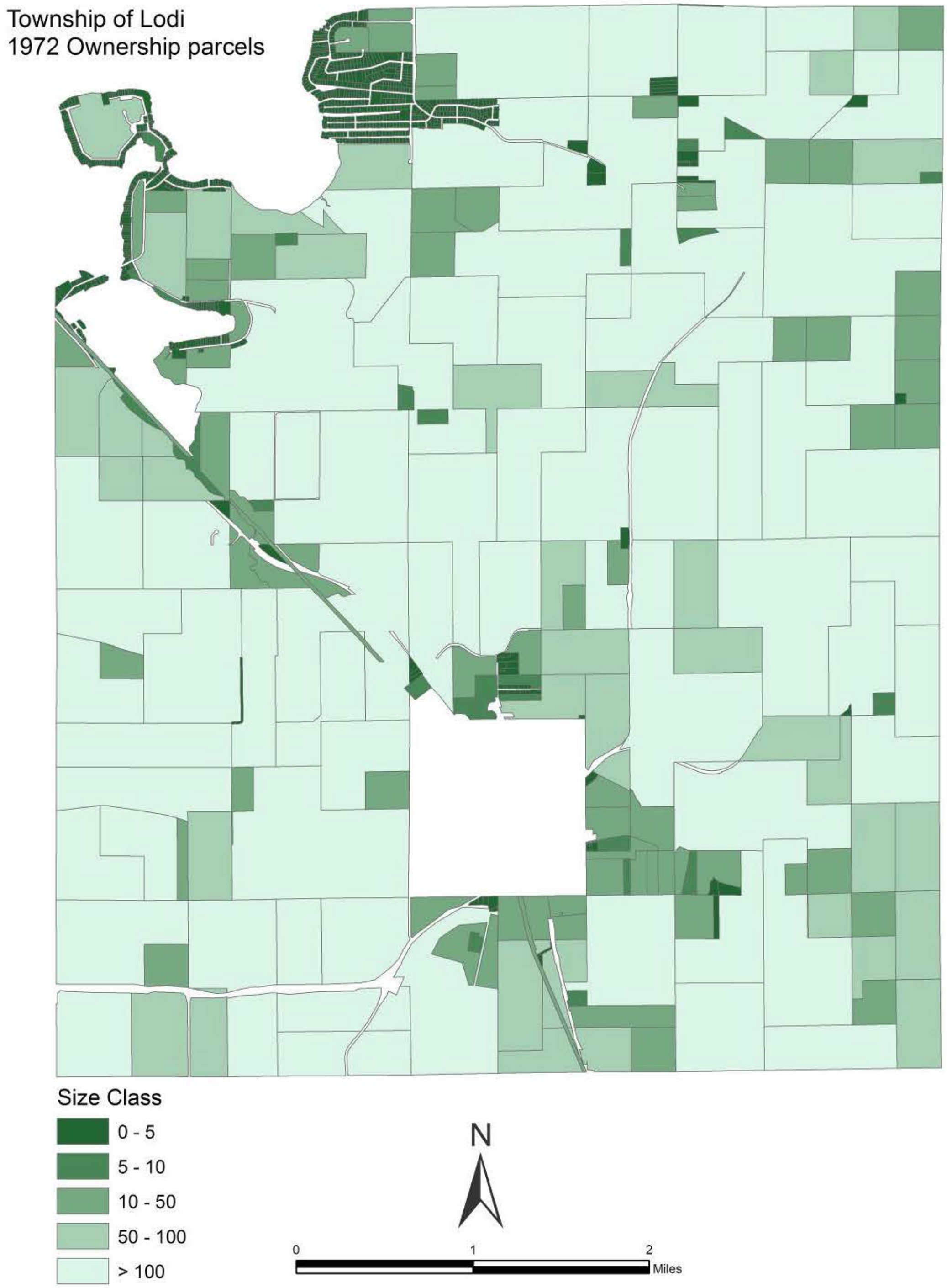

Township of Lodi
1947 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

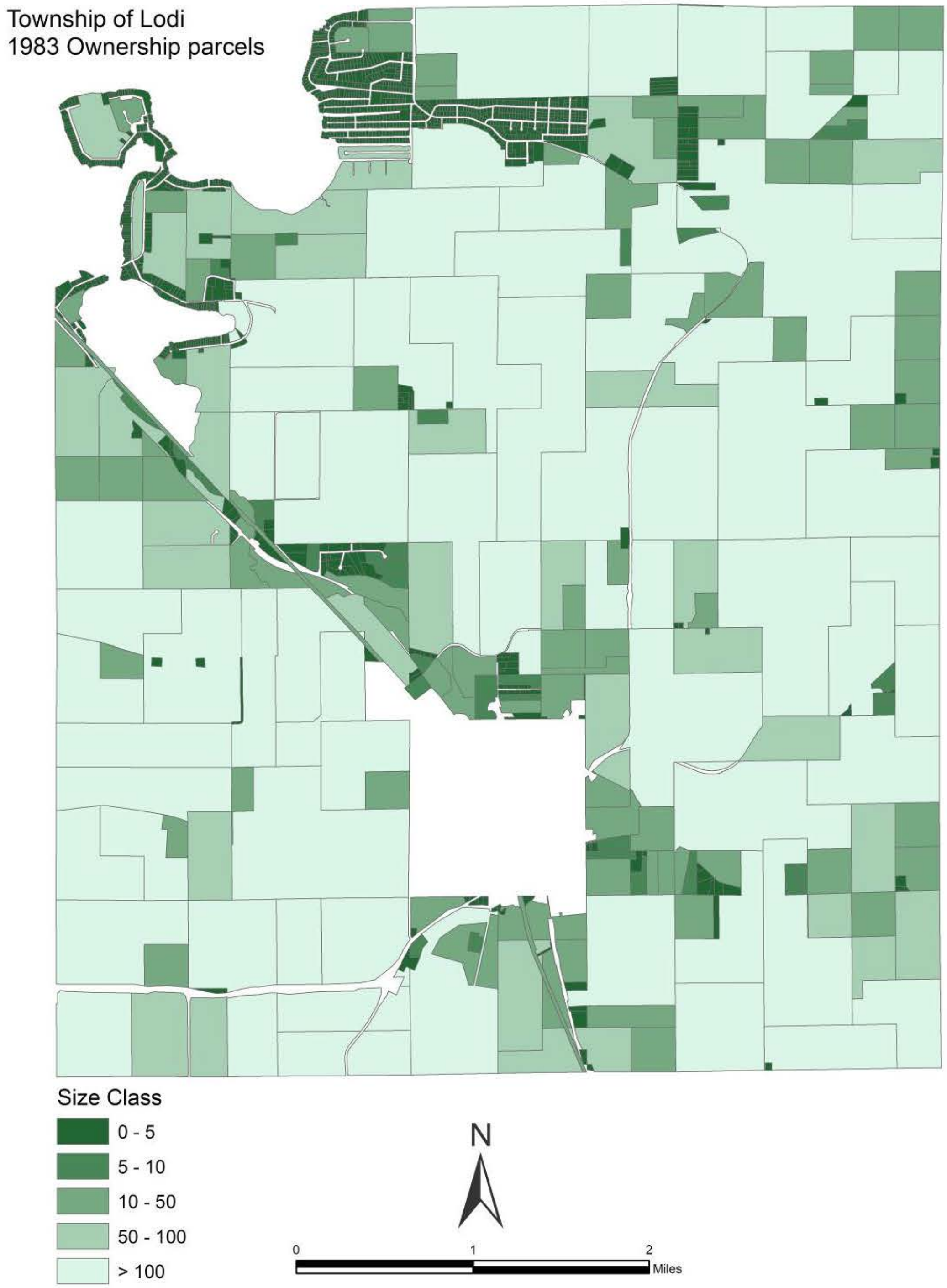

Township of Lodi
1953 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

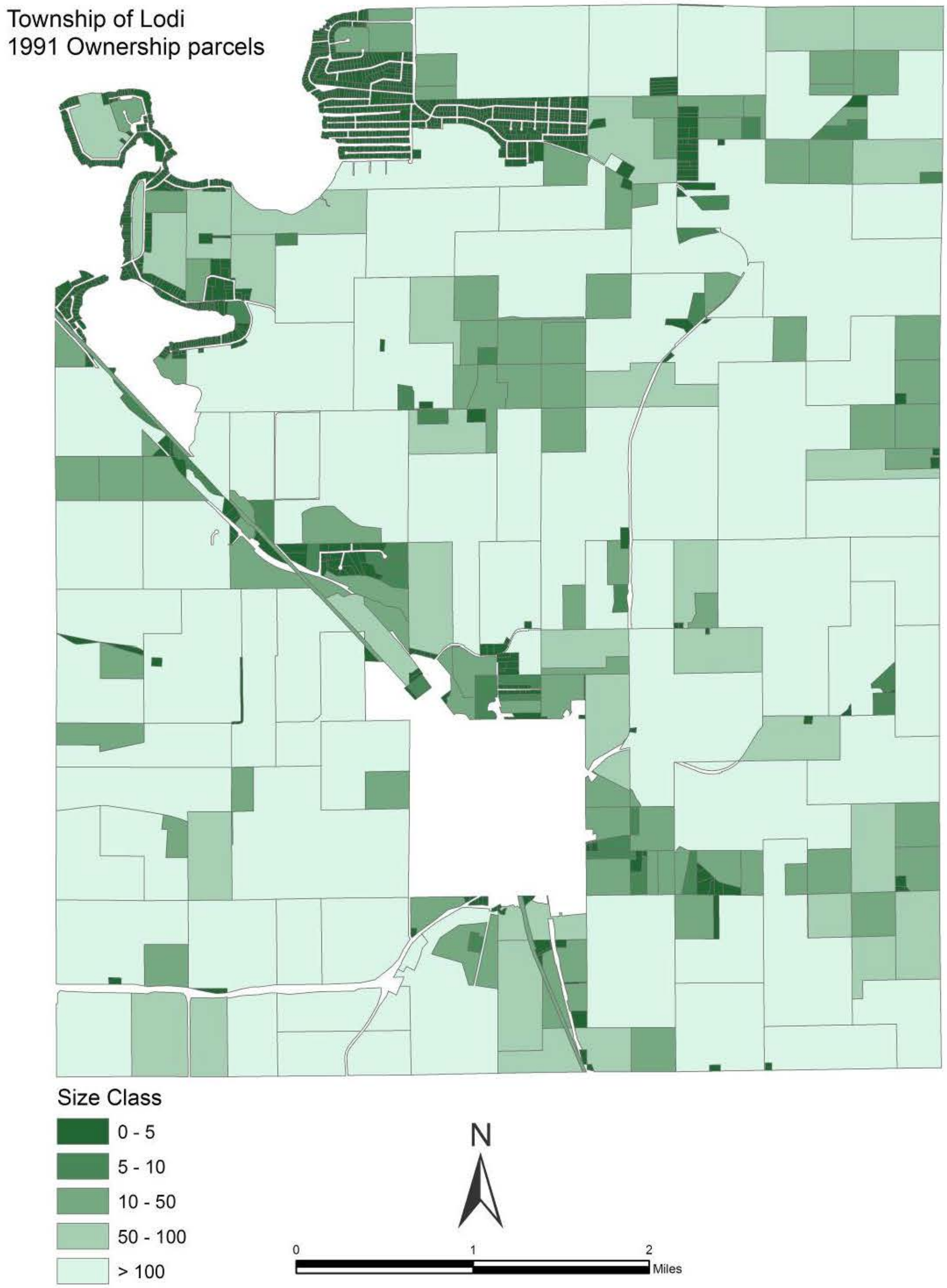


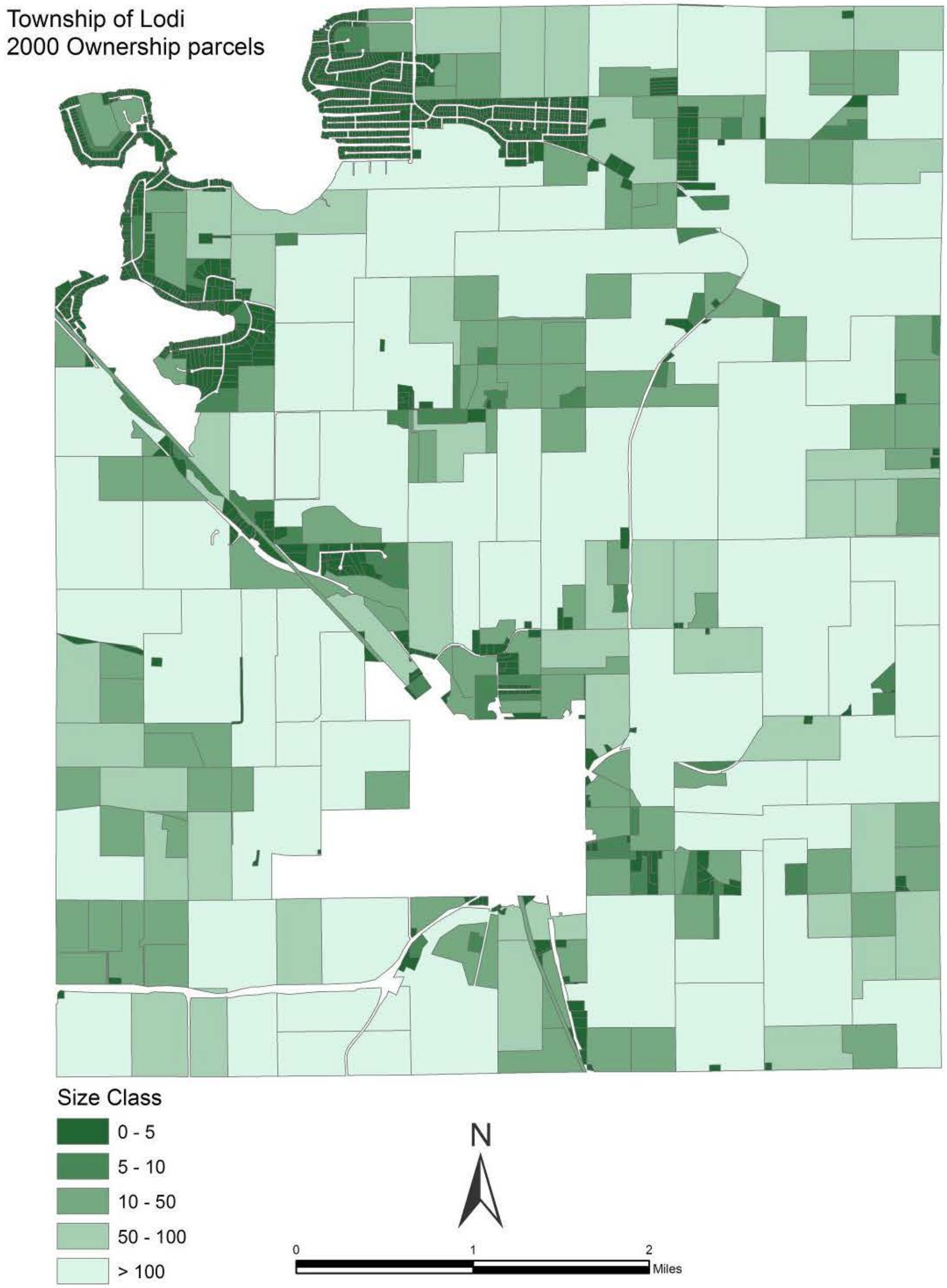
Township of Lodi
1961 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

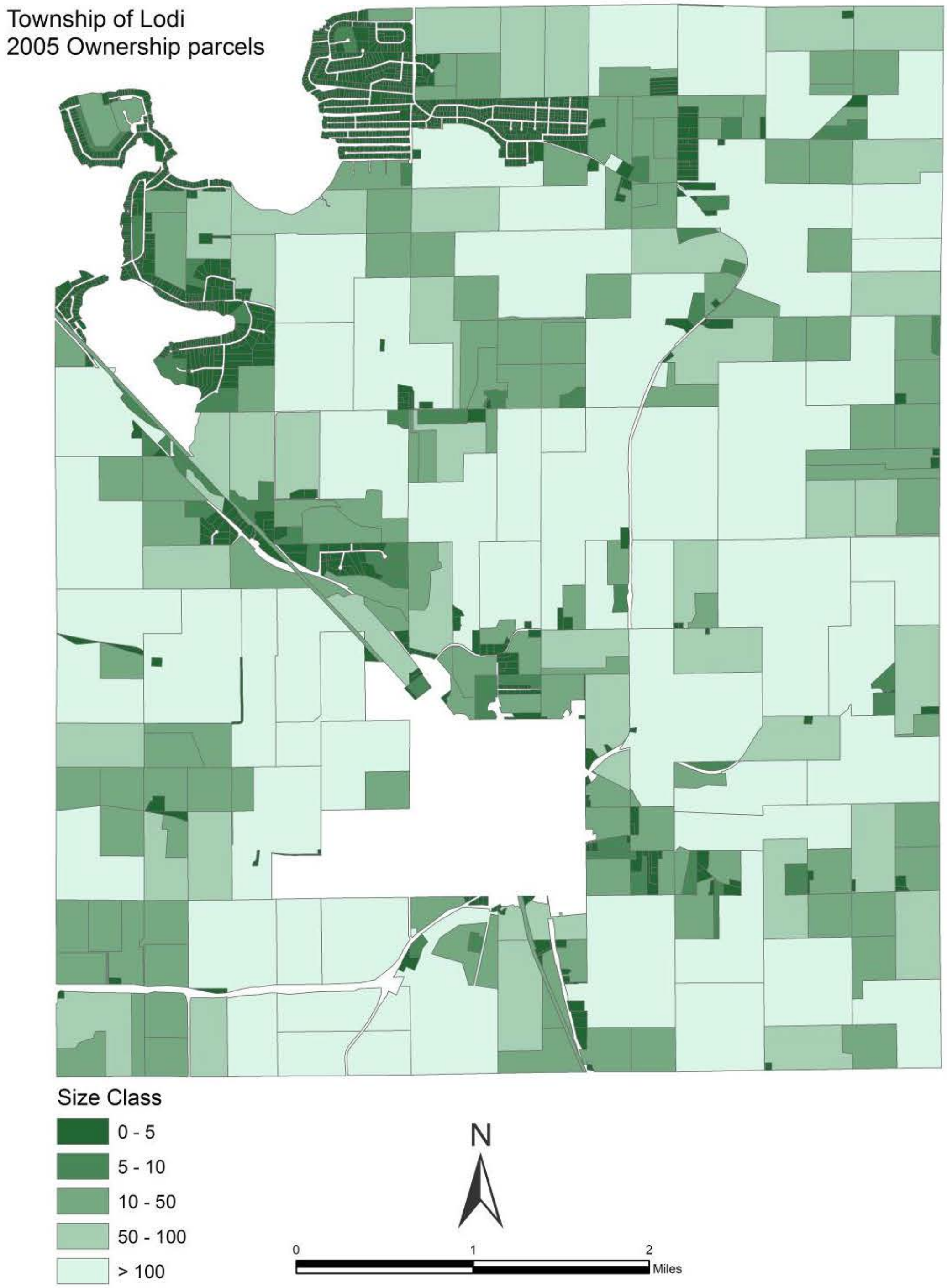

Township of Lodi
1967 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

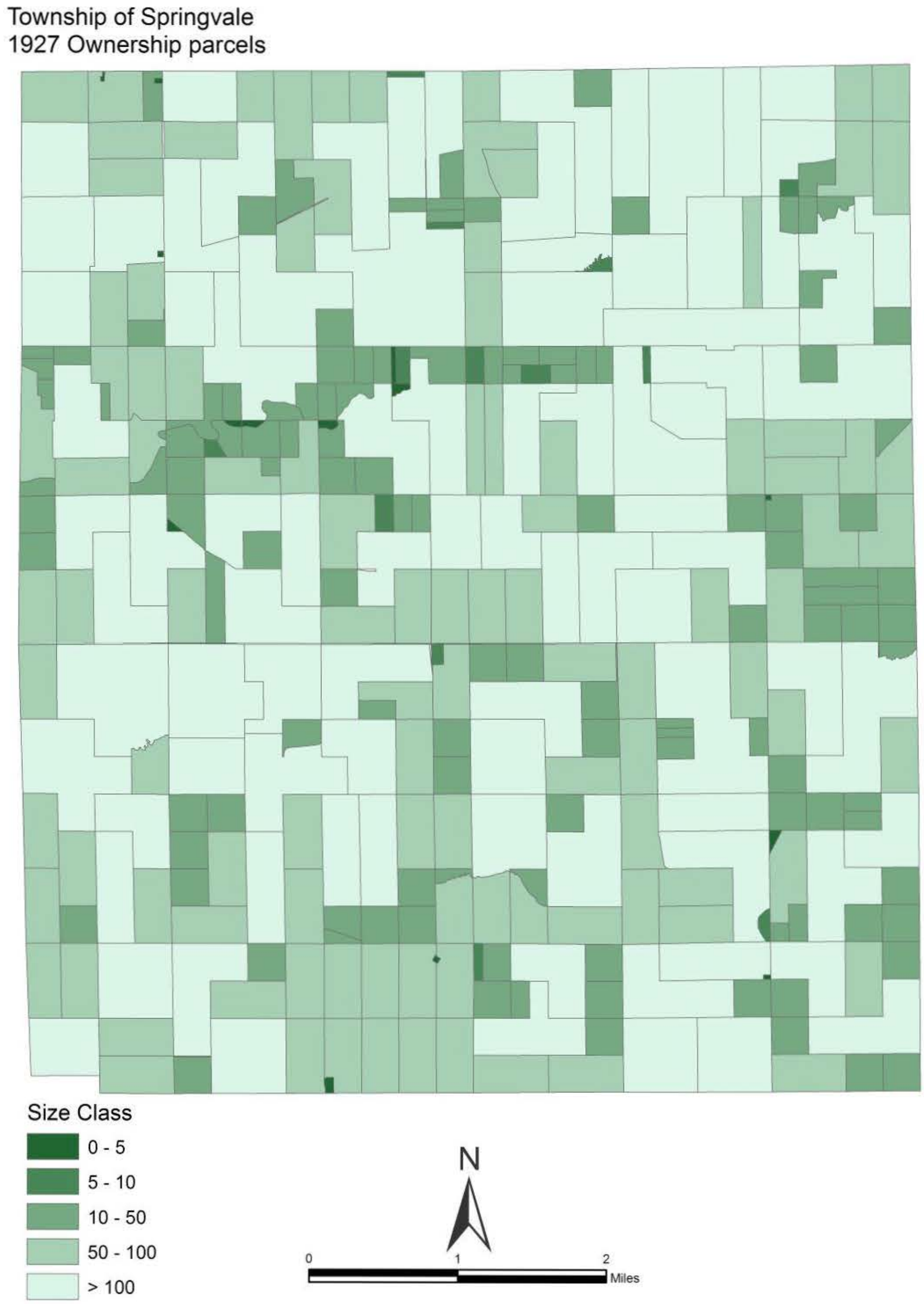

Township of Lodi
1972 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles


Township of Lodi
1983 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

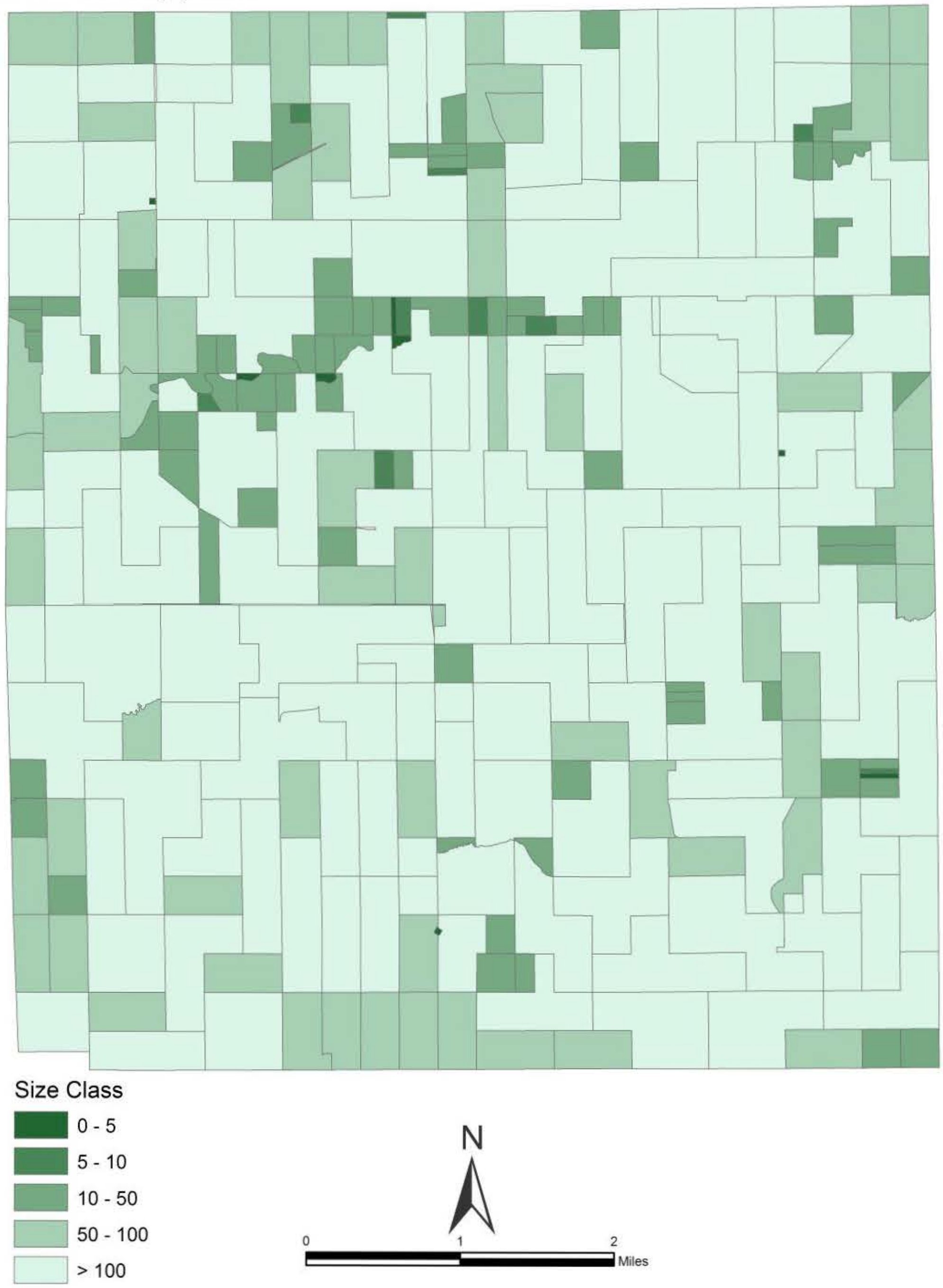

Township of Lodi
1991 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles


Township of Lodi
2000 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

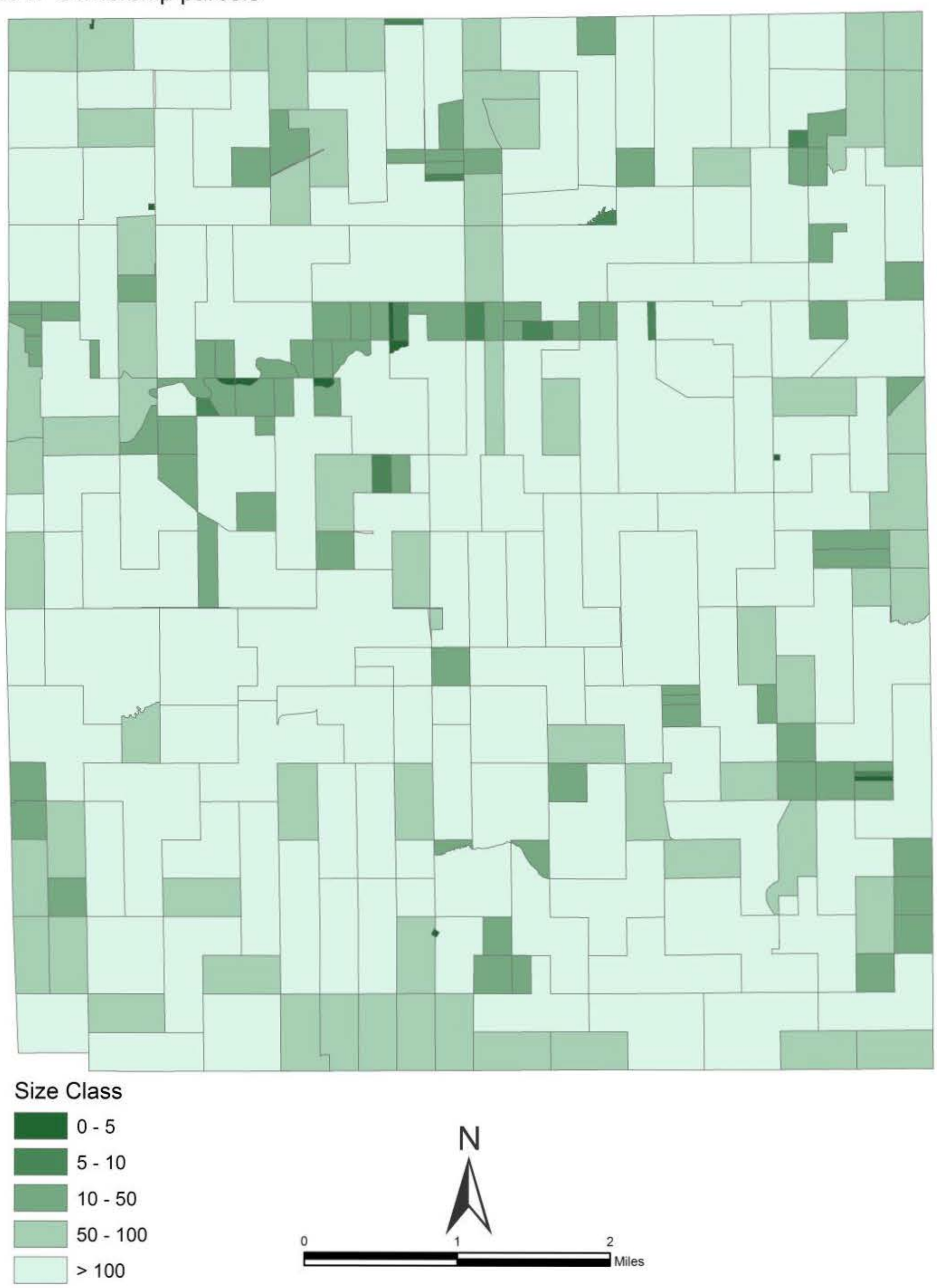

Township of Lodi
2005 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles


Township of Springvale
1927 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

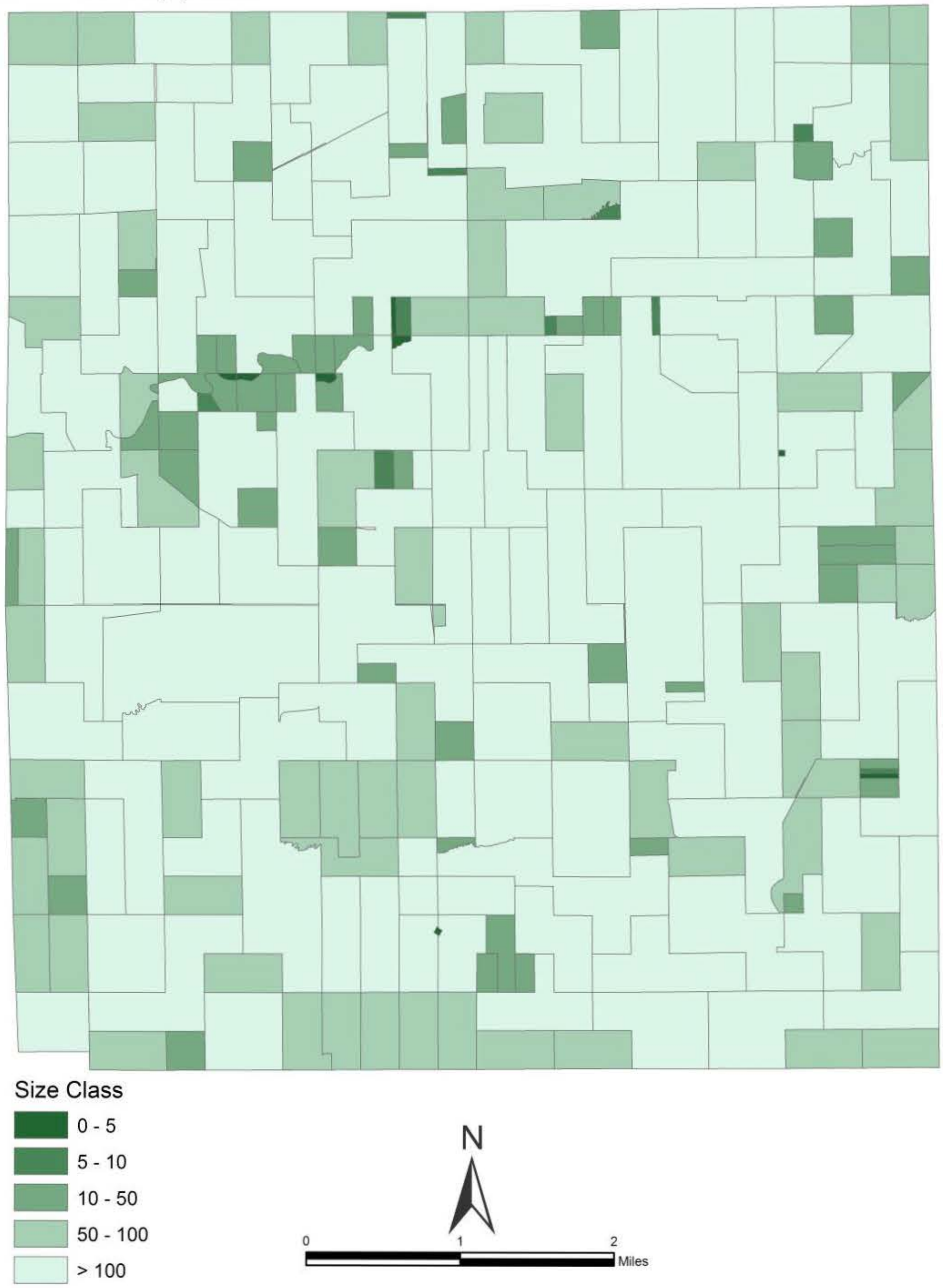
Township of Springvale
1936 Ownership parcels



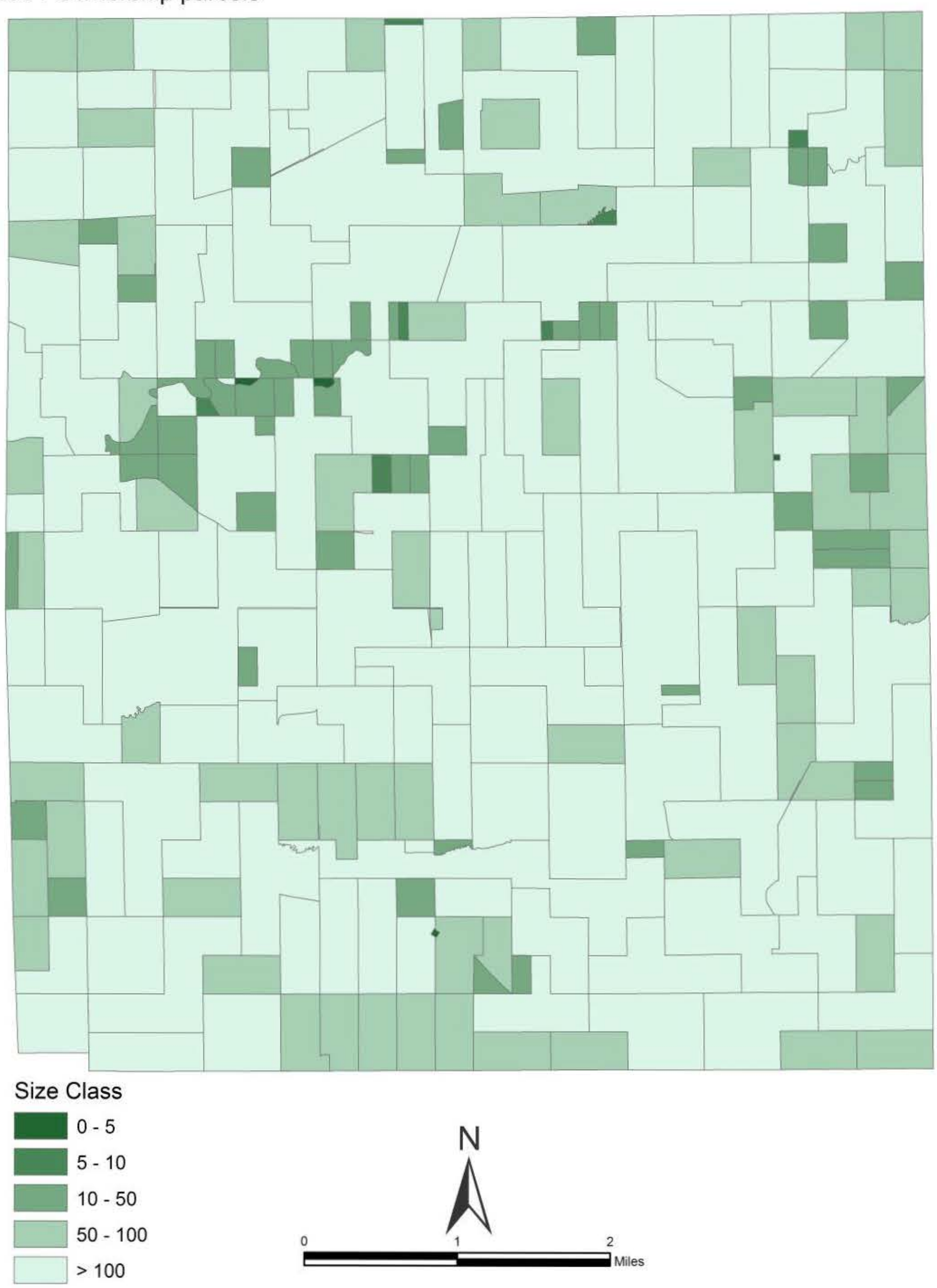
Township of Springvale
1947 Ownership parcels

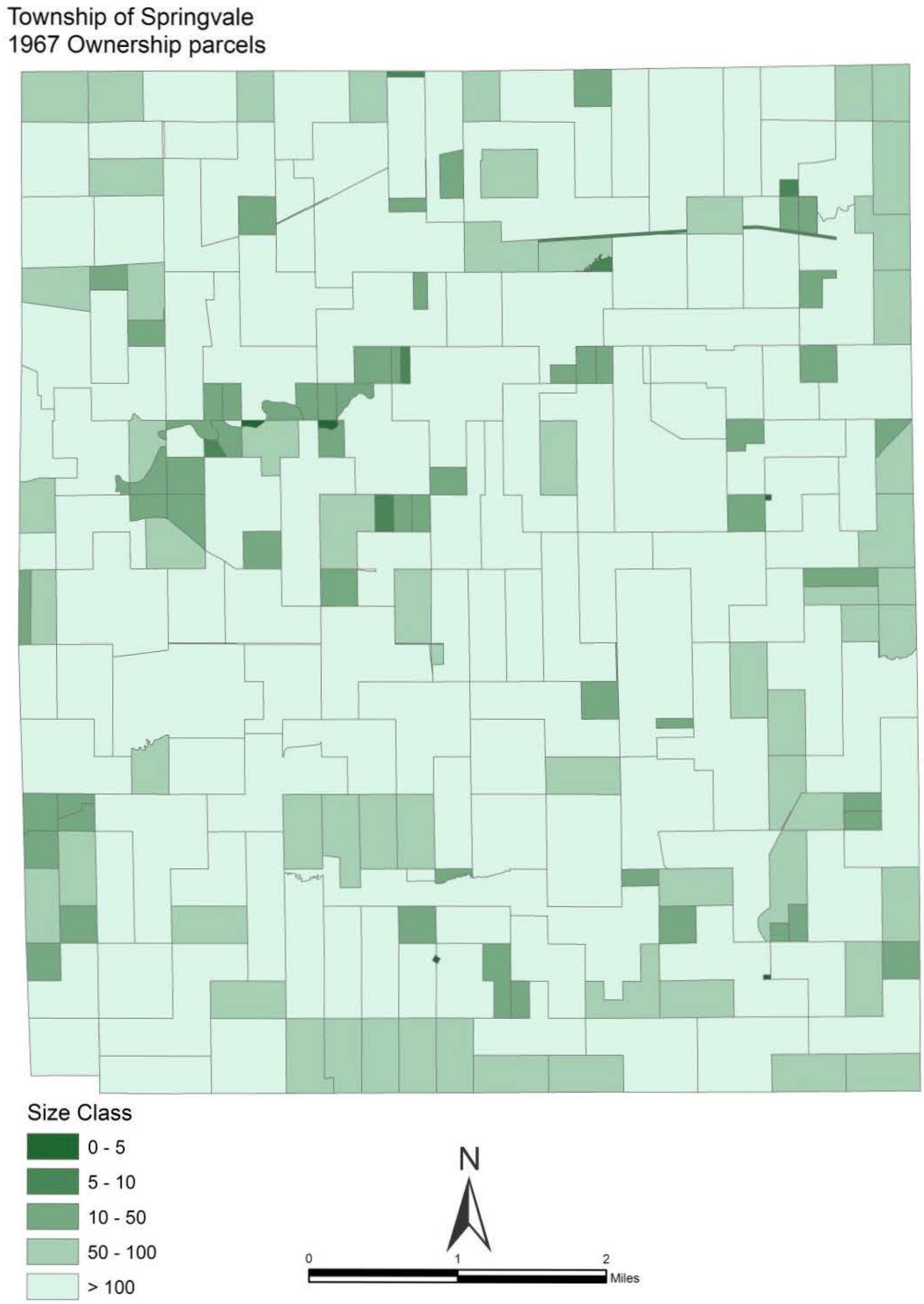


Township of Springvale
1953 Ownership parcels

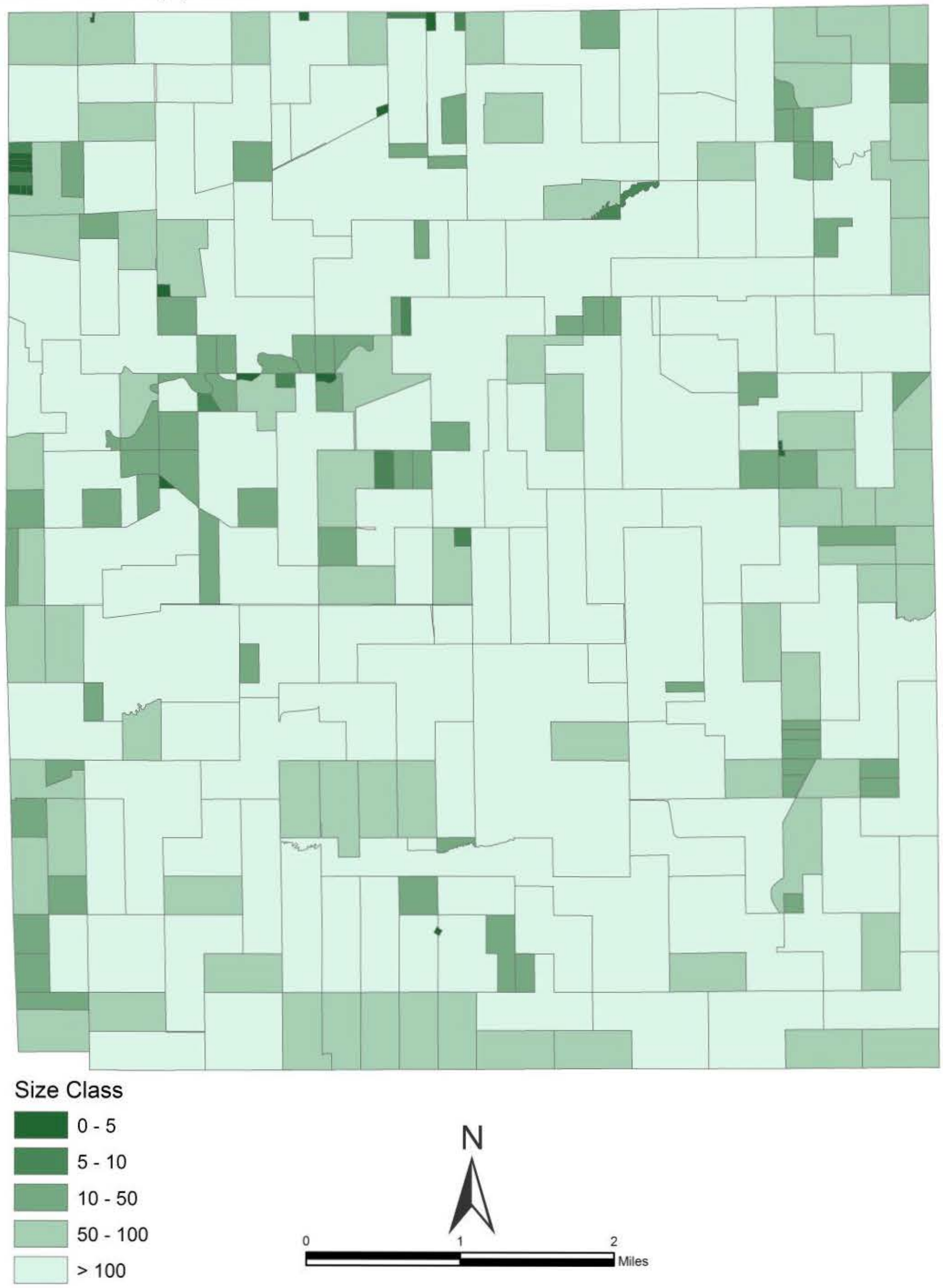


Township of Springvale
1961 Ownership parcels

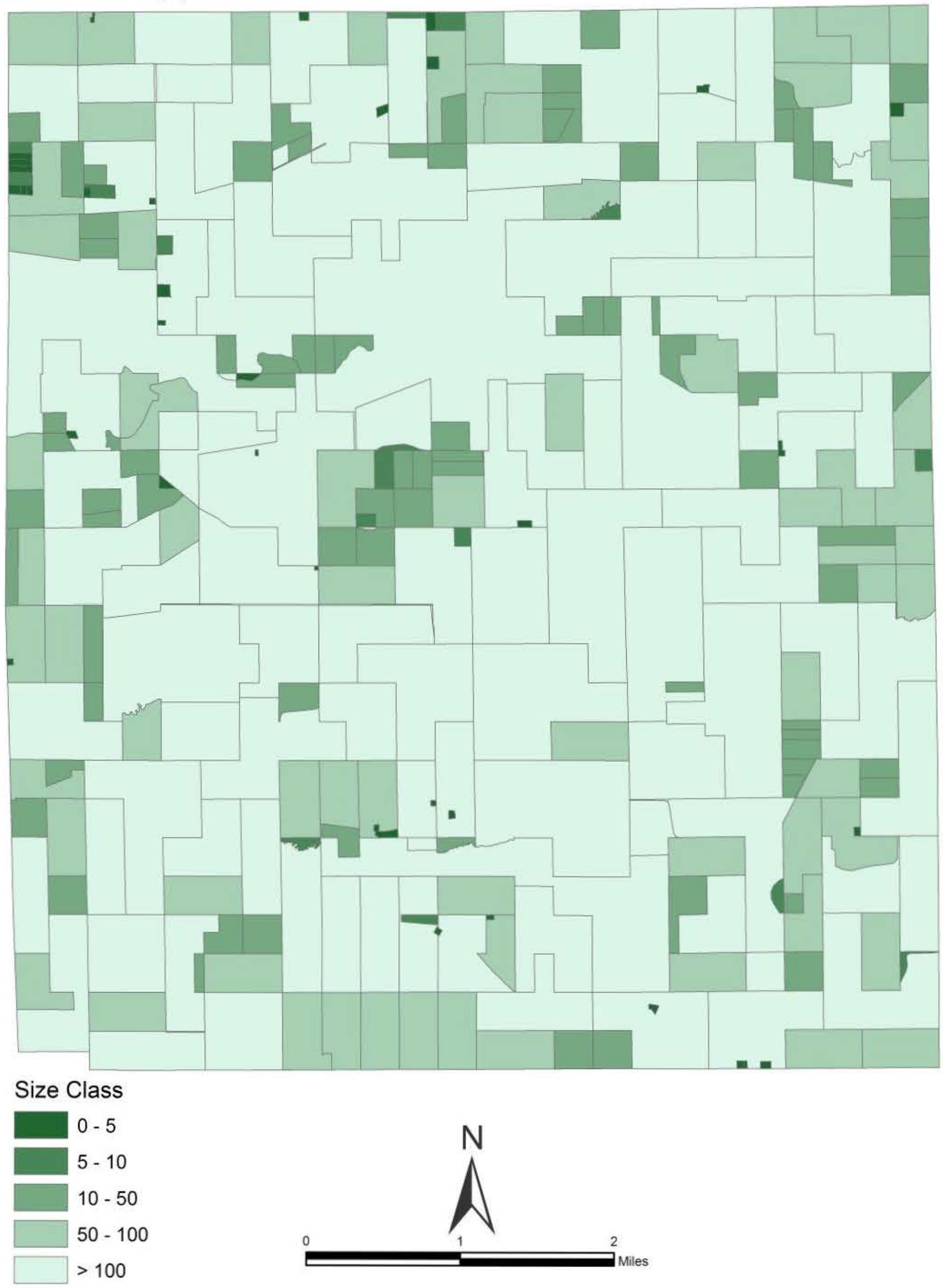



Township of Springvale
1967 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

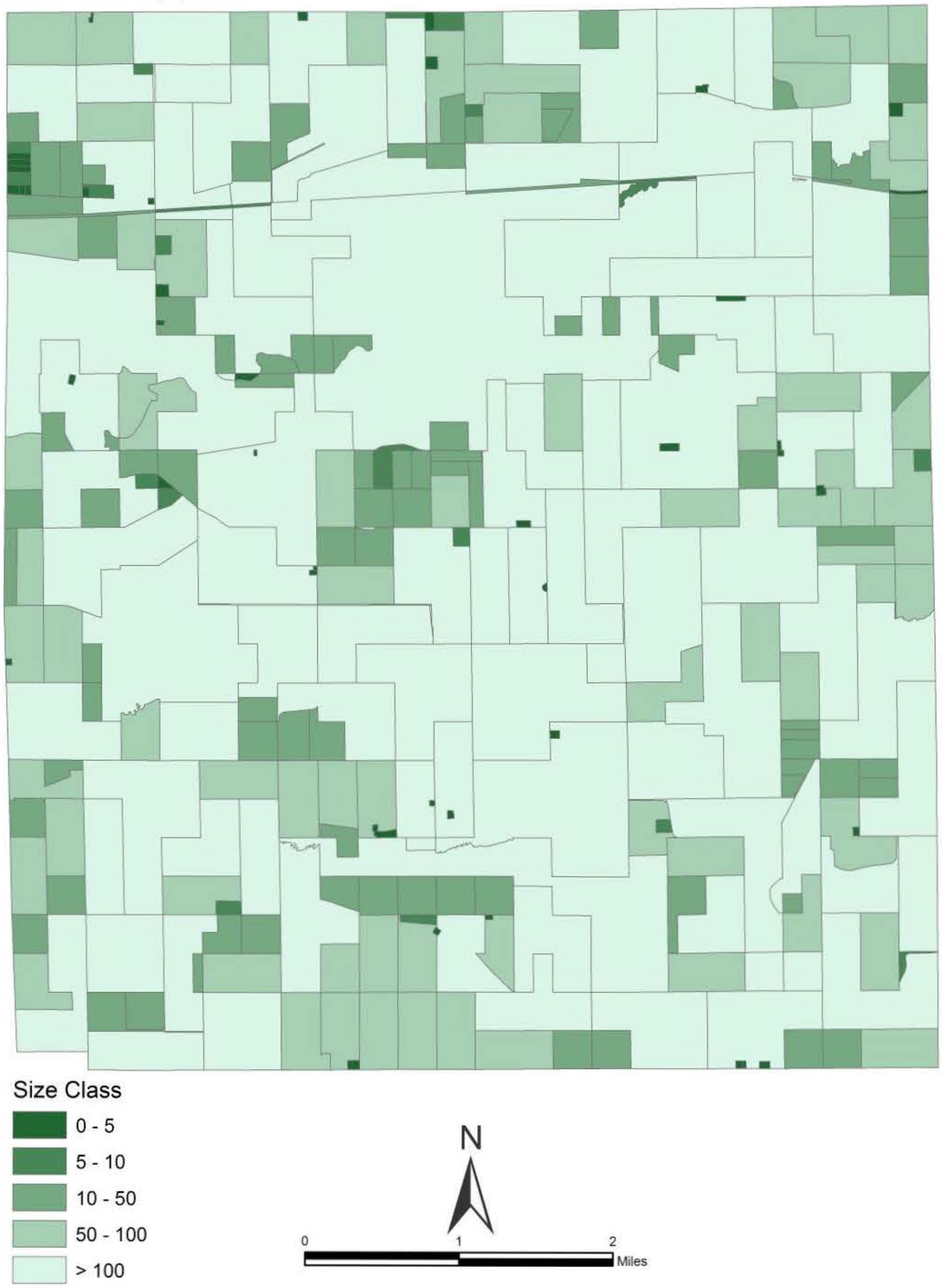
Township of Springvale
1972 Ownership parcels

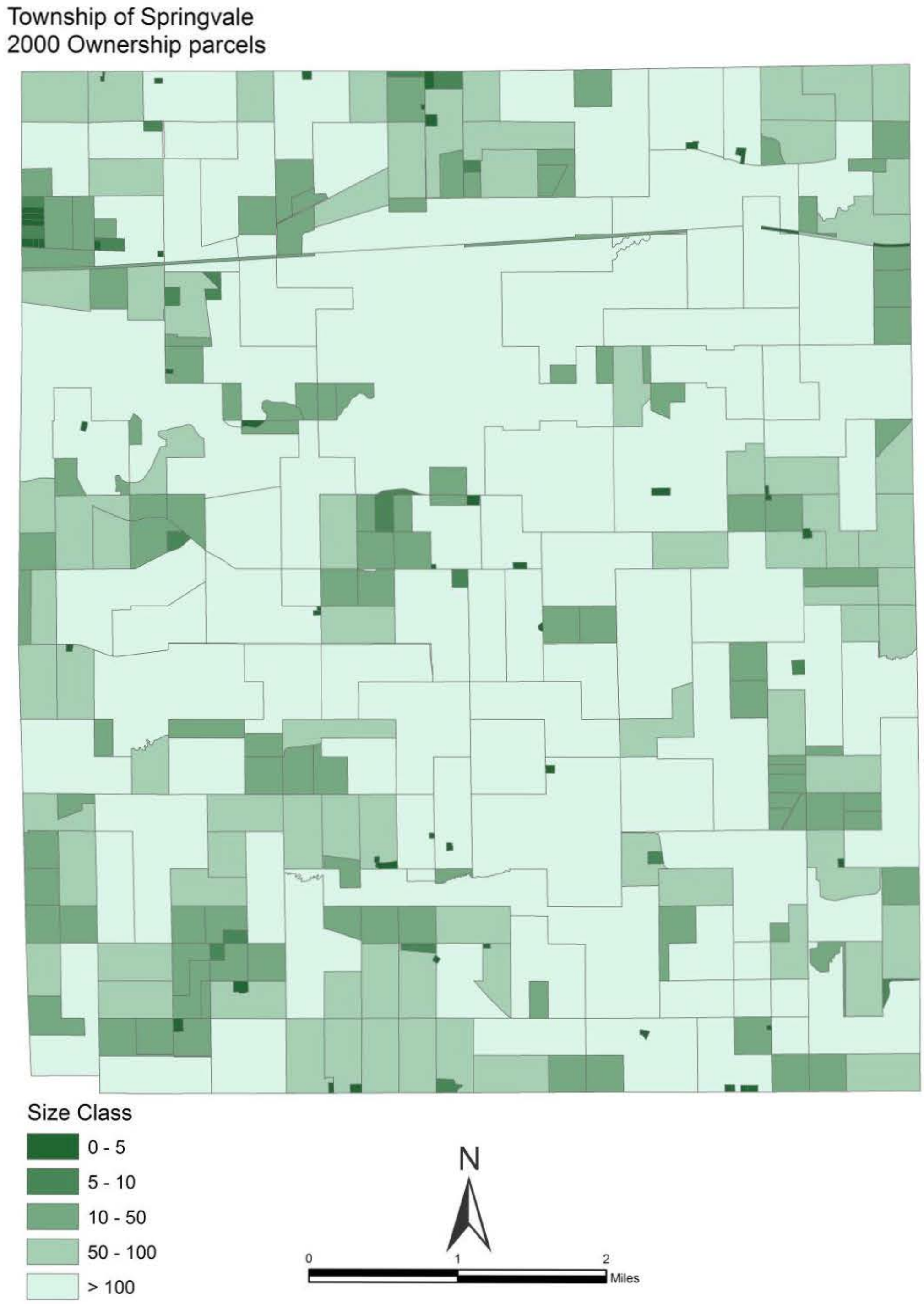


Township of Springvale
1983 Ownership parcels

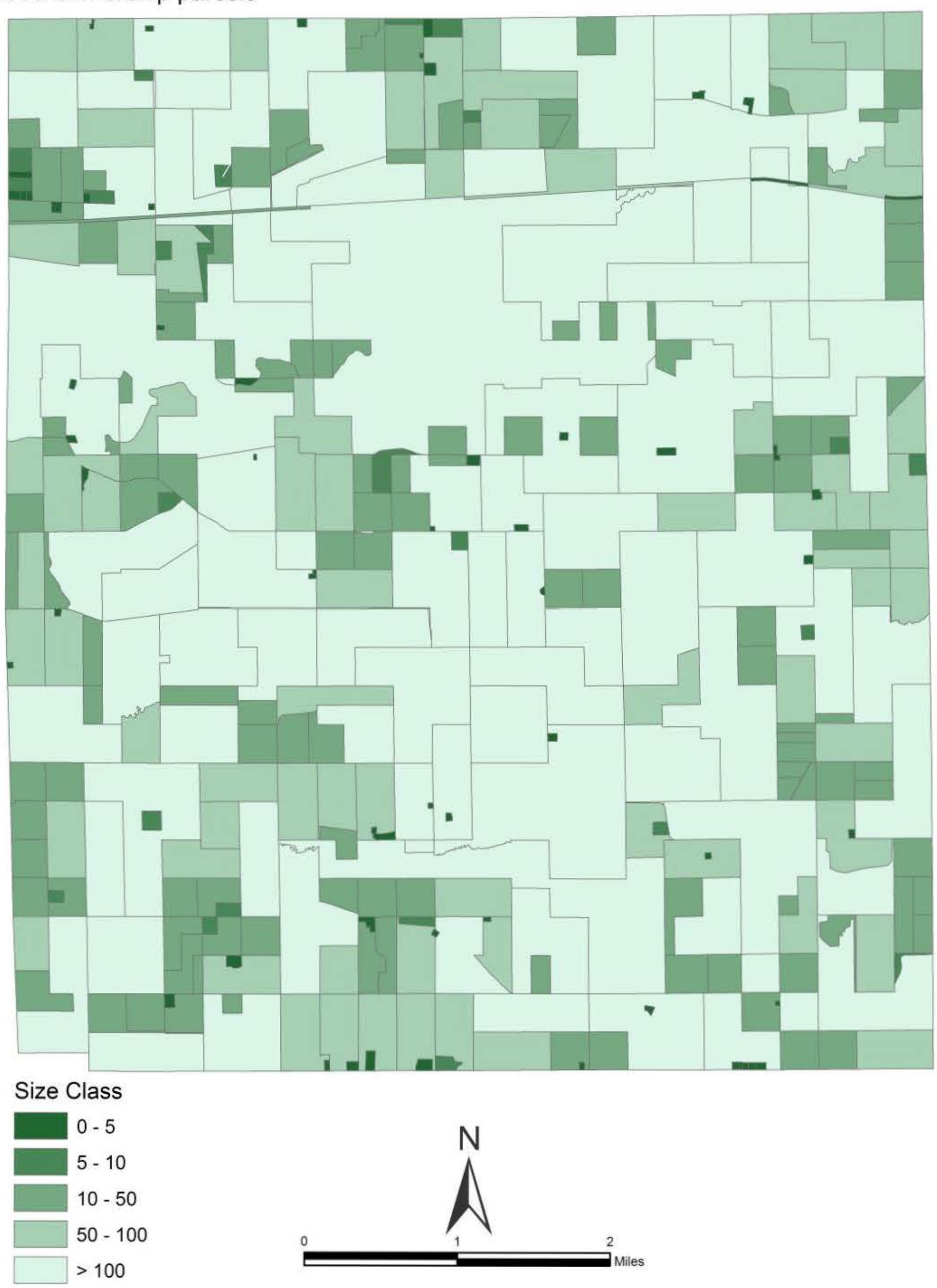


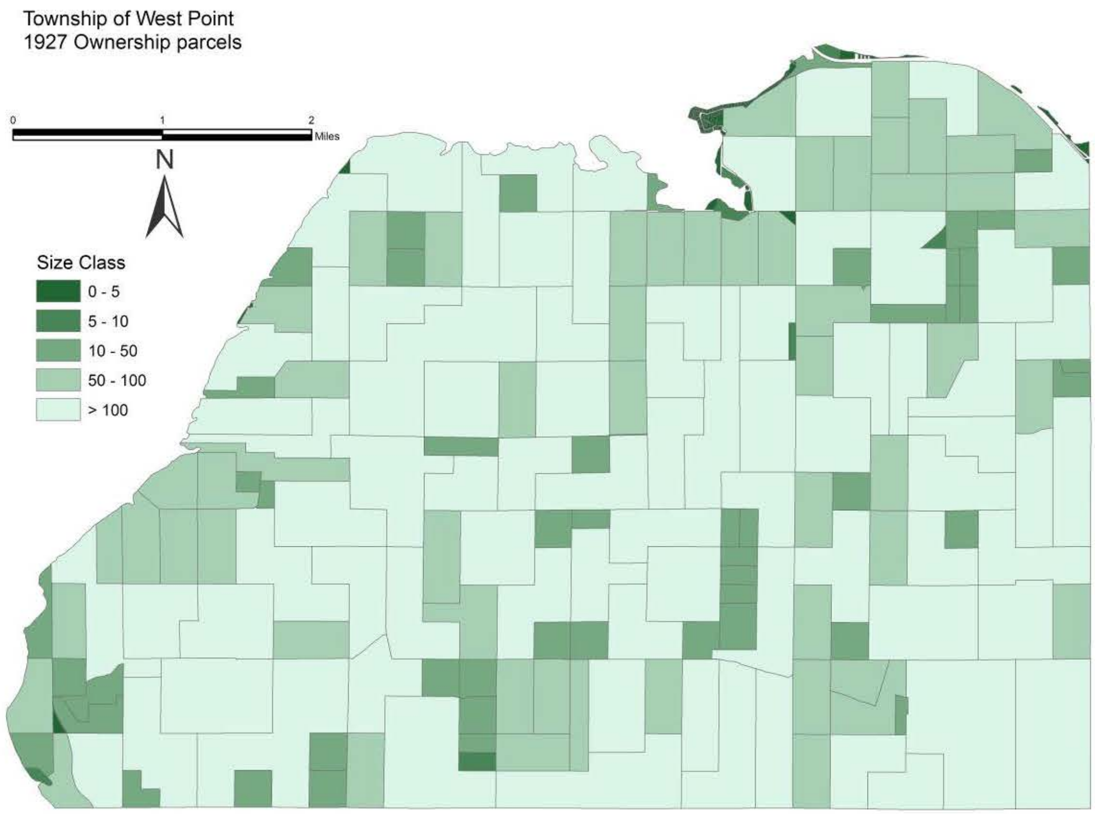
Township of Springvale
1991 Ownership parcels

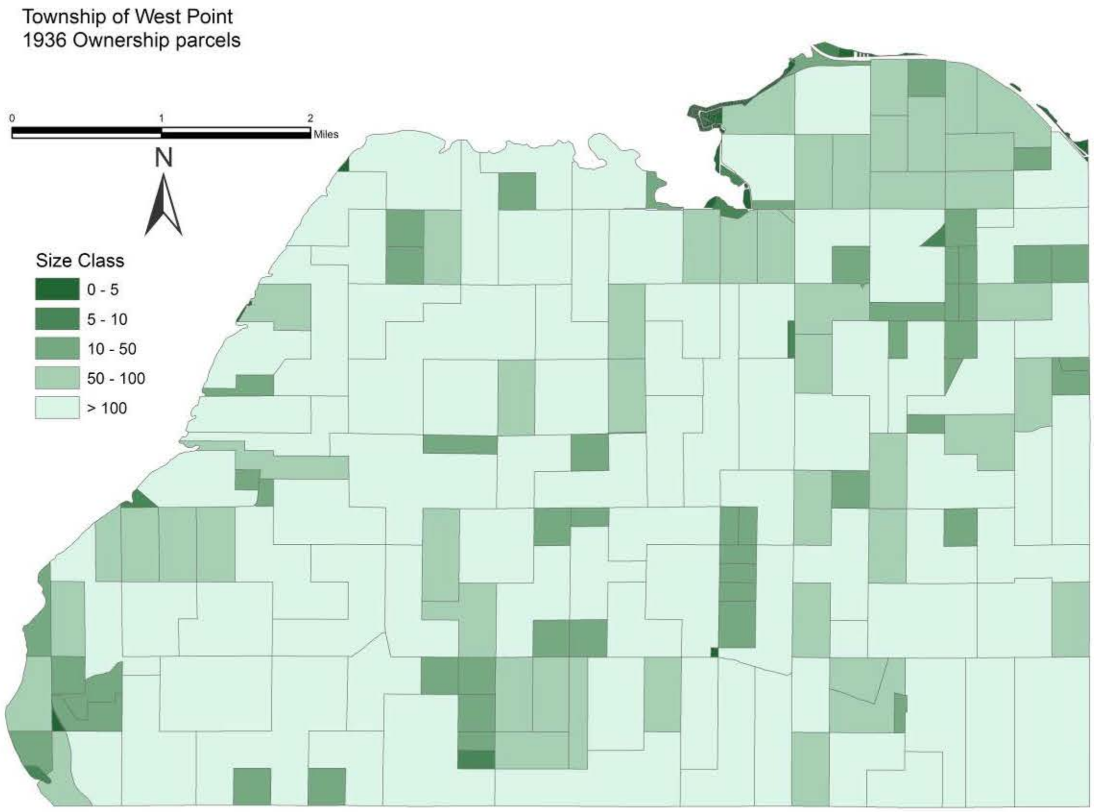


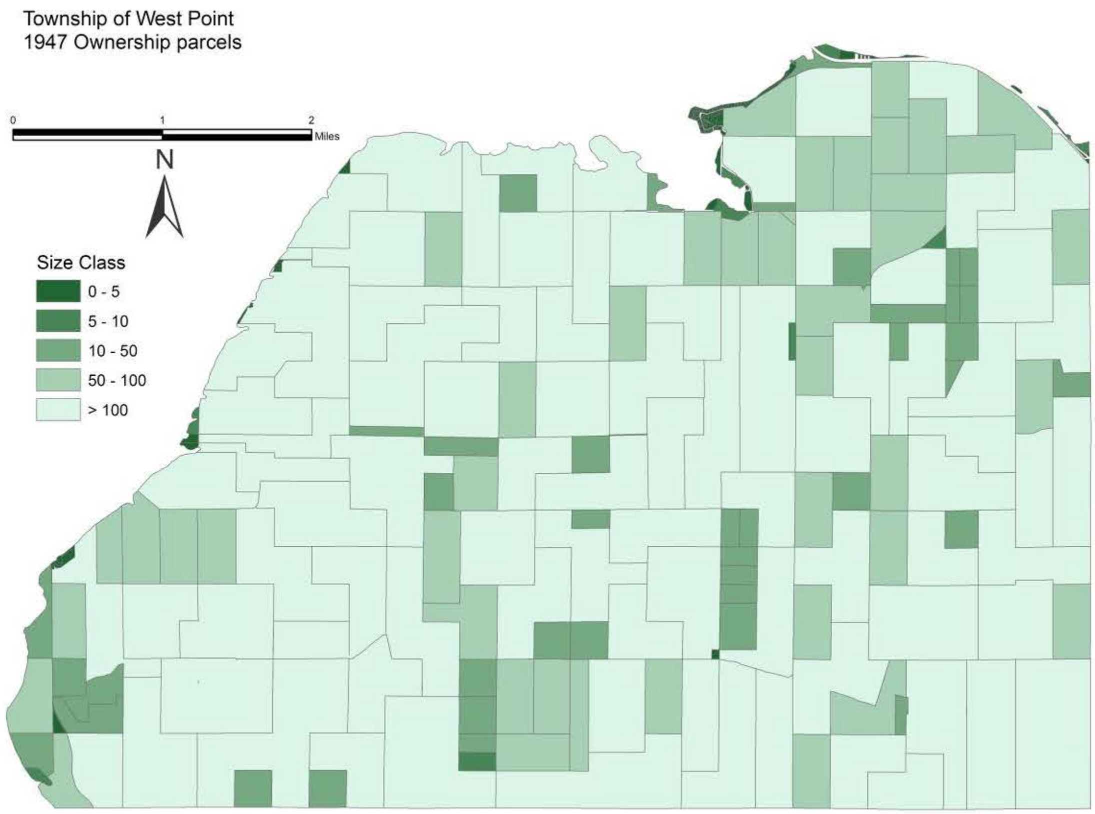

Township of Springvale
2000 Ownership parcels
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100
N
0
1
2
Miles

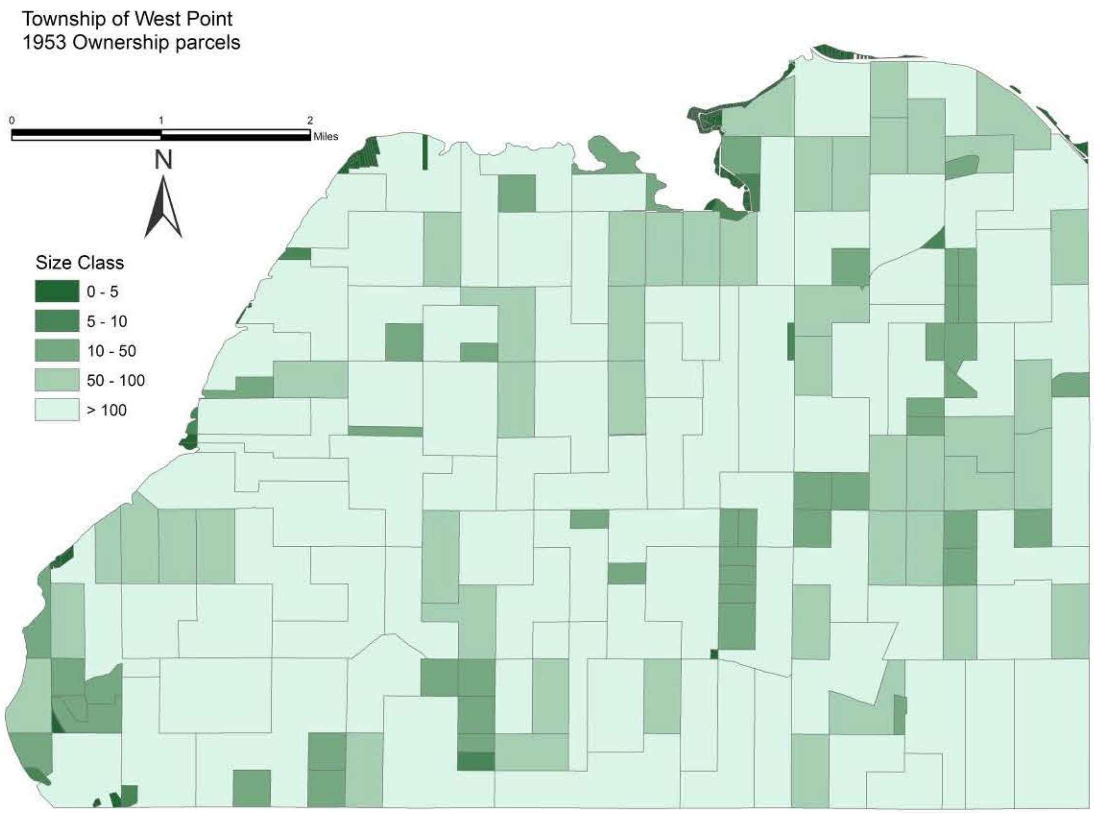
Township of Springvale
2005 Ownership parcels

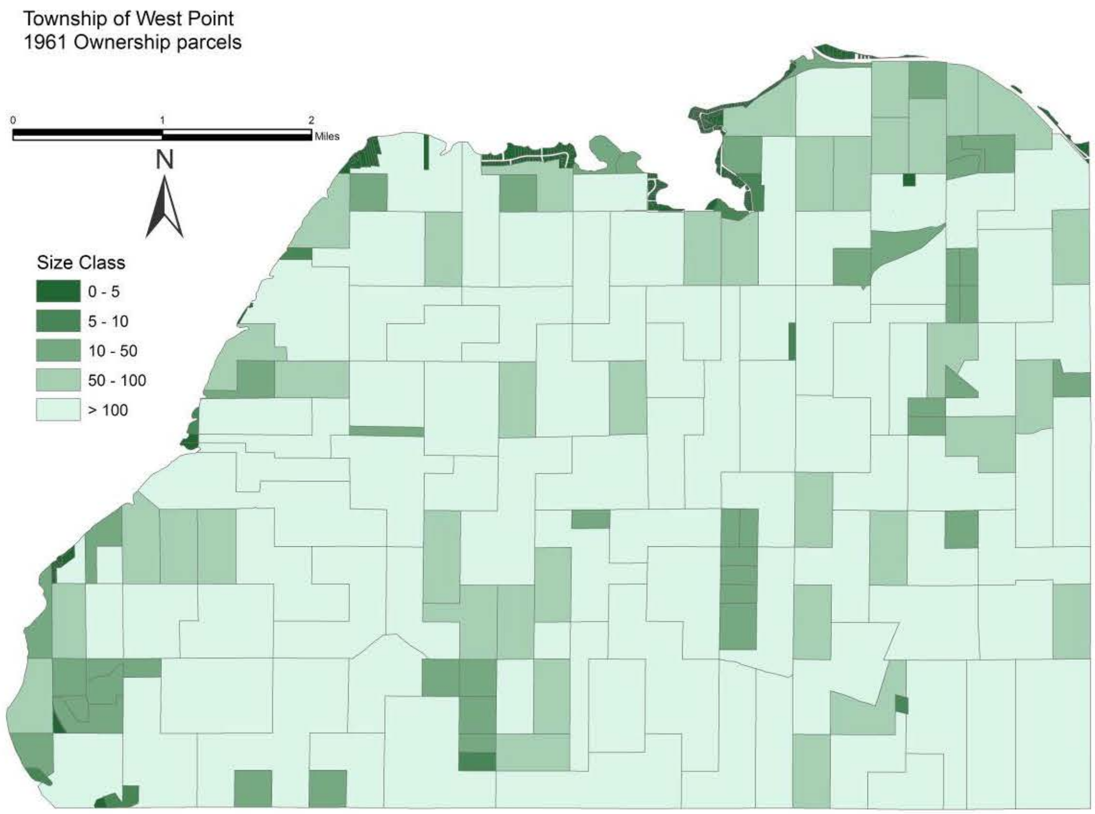



Township of West Point
1927 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100

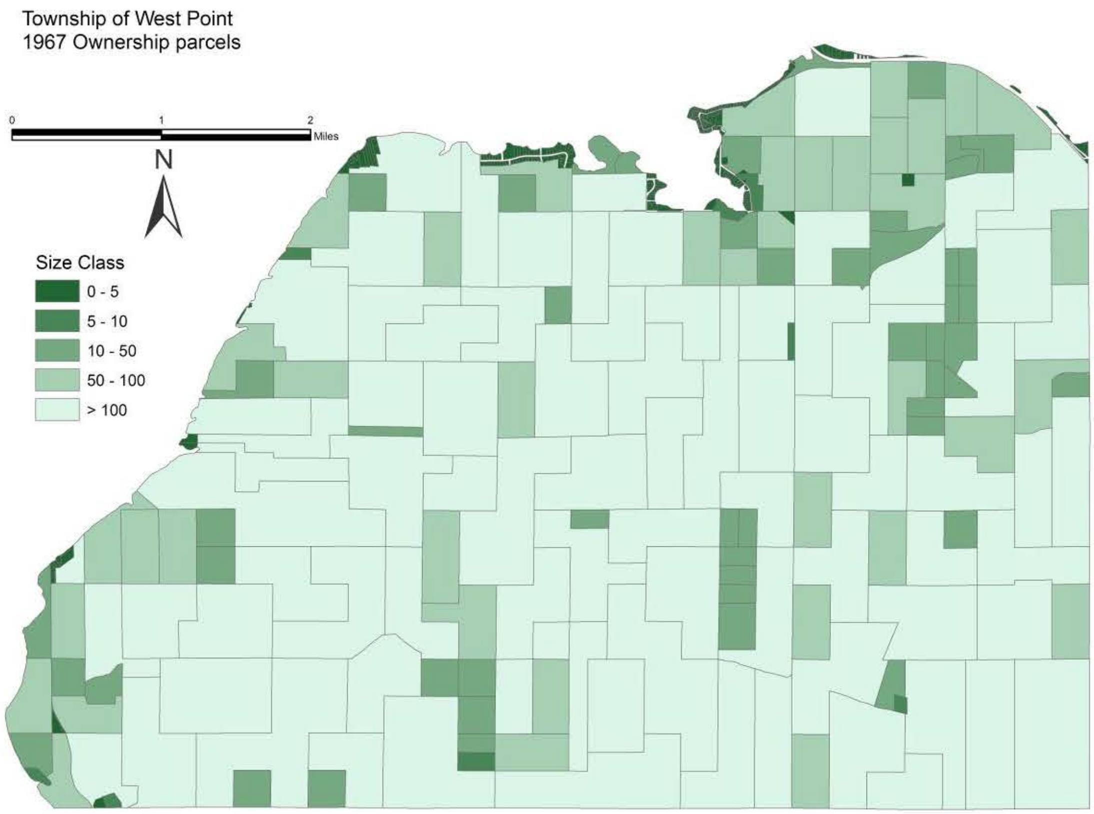

Township of West Point
1936 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100

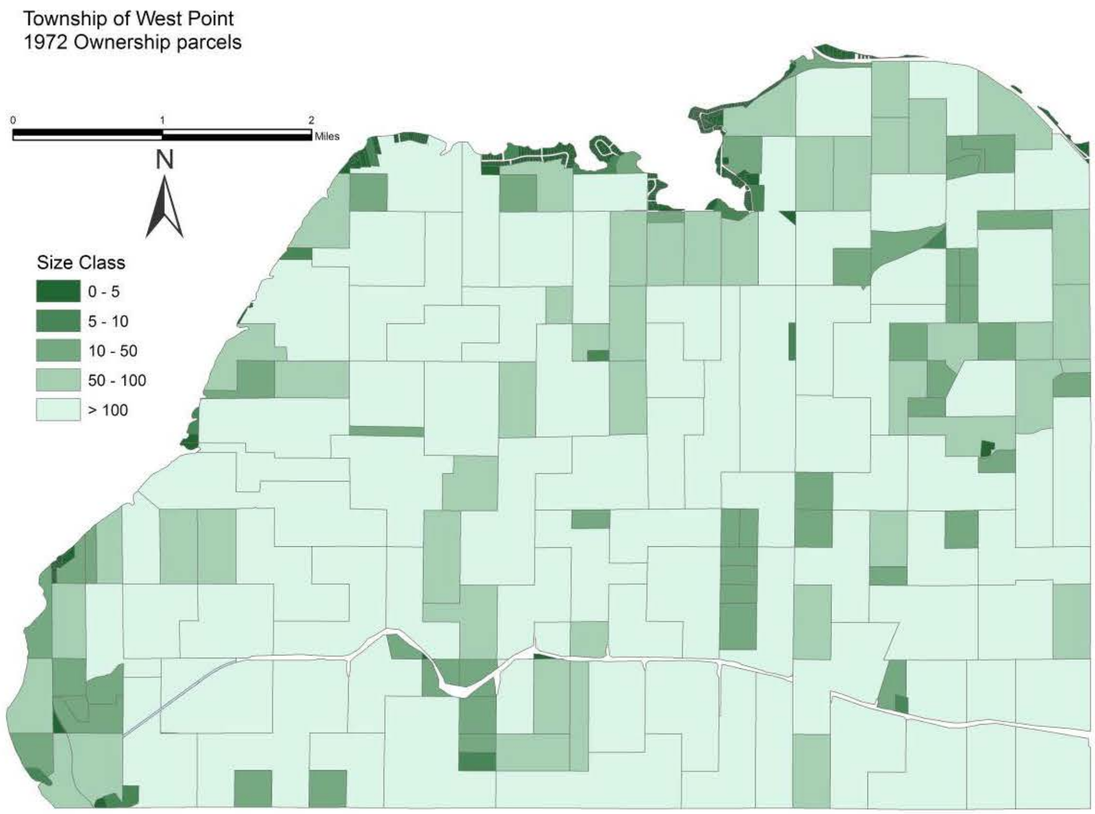

Township of West Point
1947 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100


Township of West Point
1953 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100

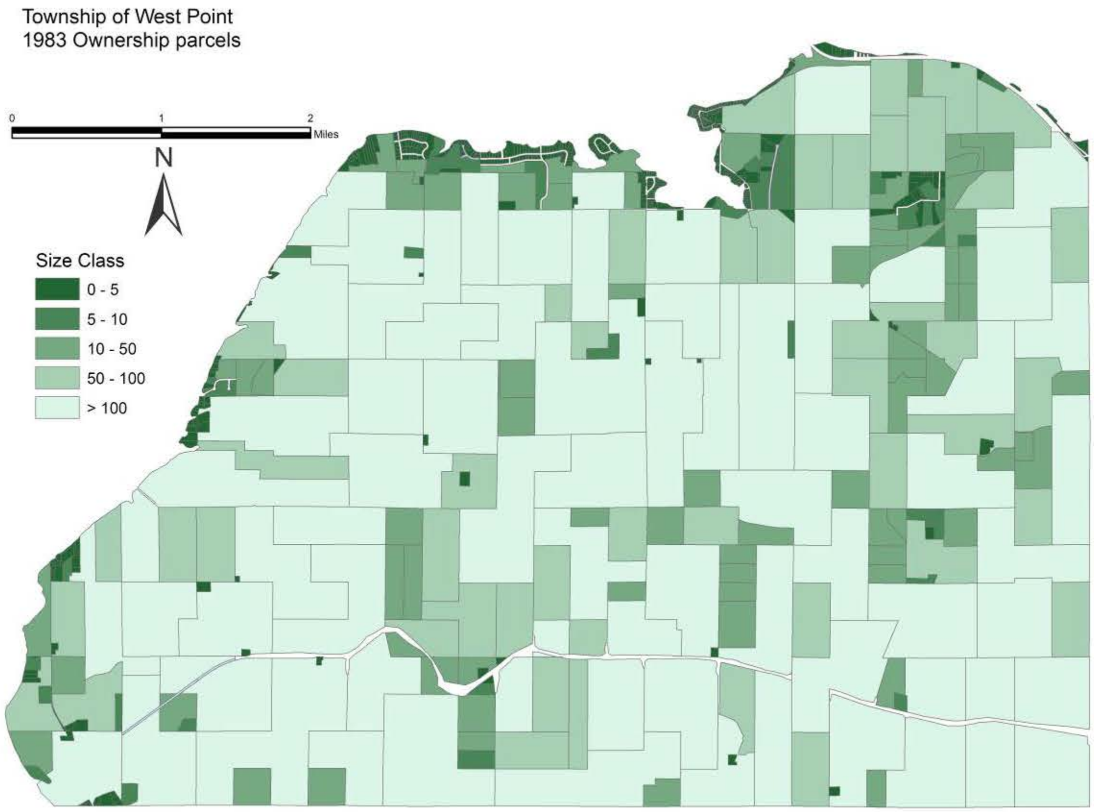


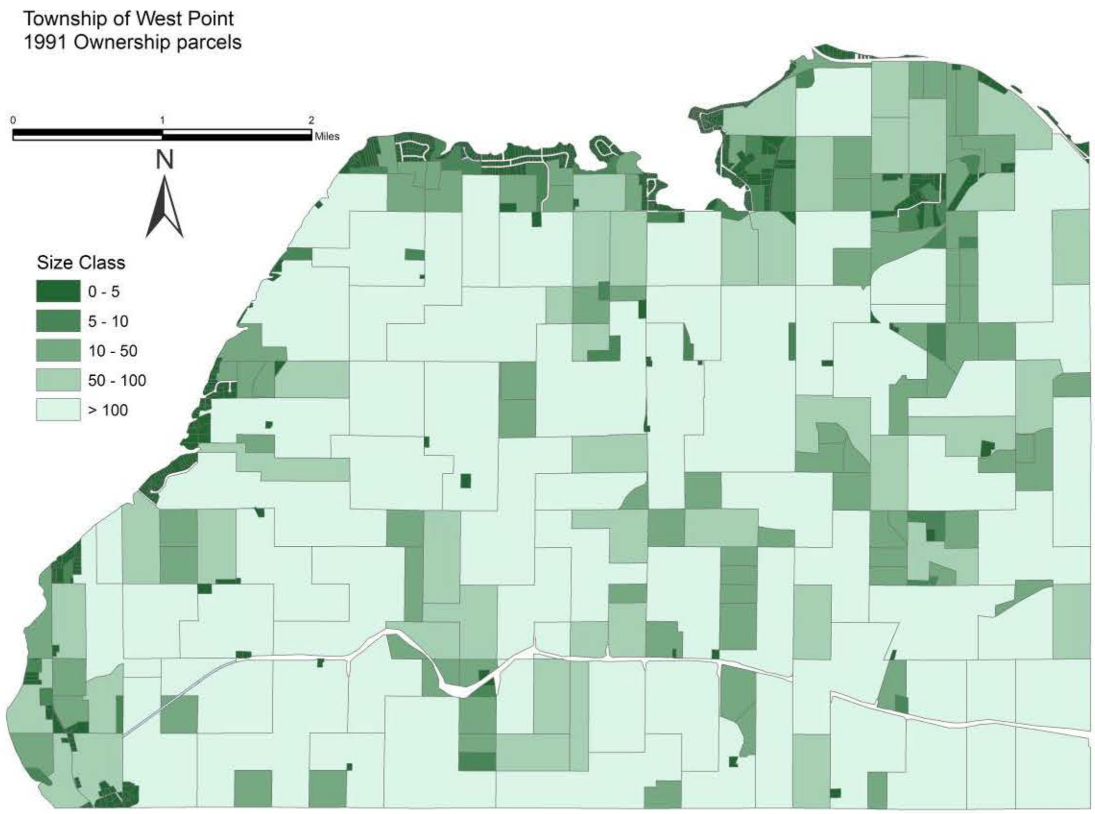
Township of West Point
1961 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100

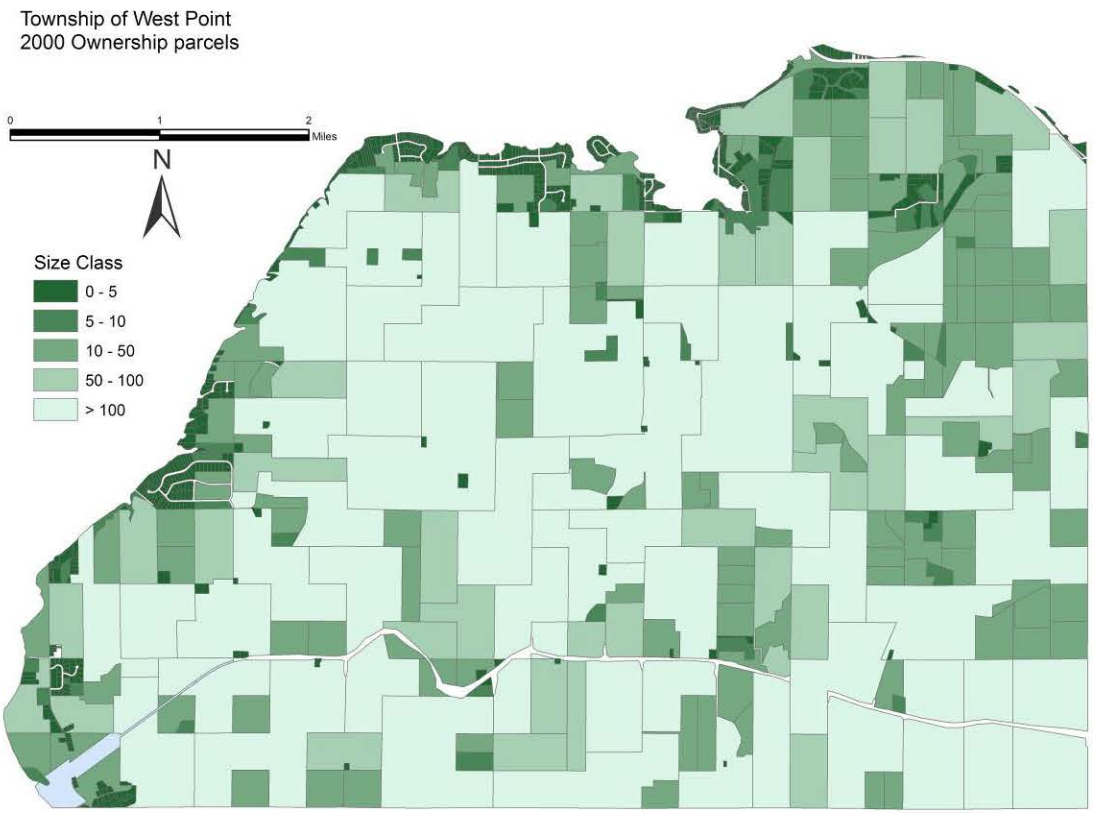

Township of West Point
1967 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100



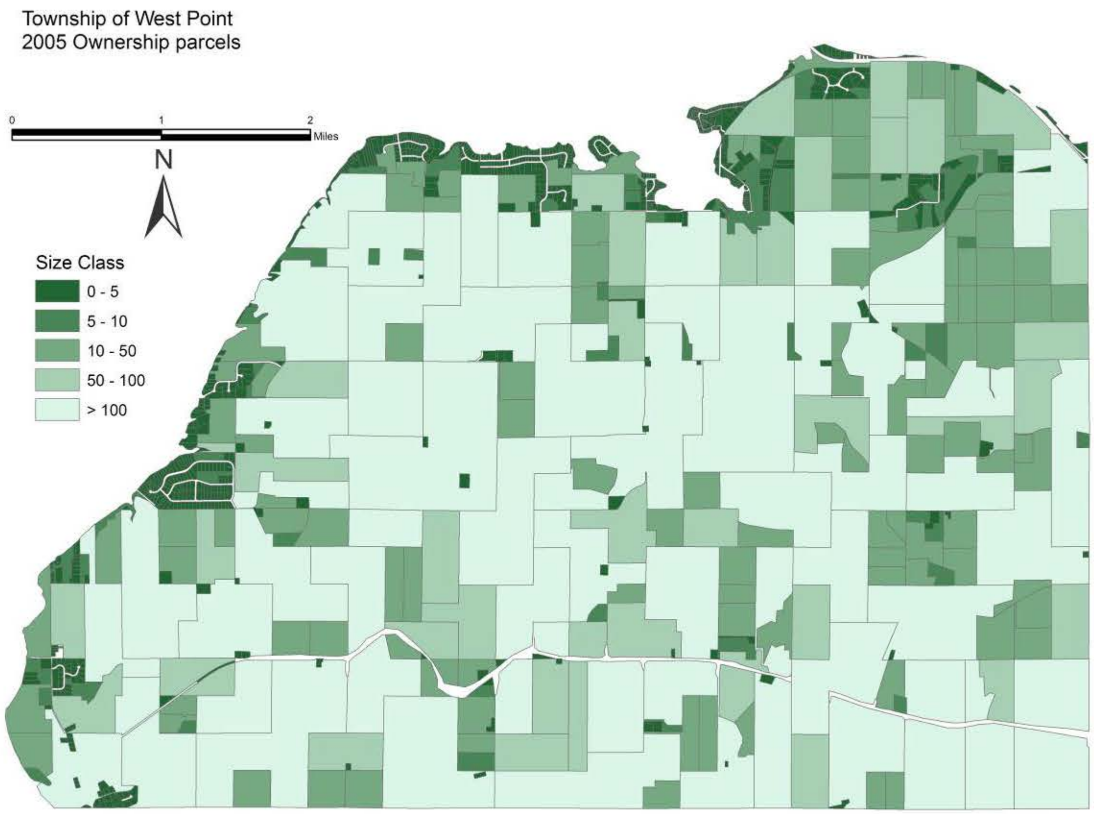
Township of West Point
1972 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100


Township of West Point
1983 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100


Township of West Point
1991 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100

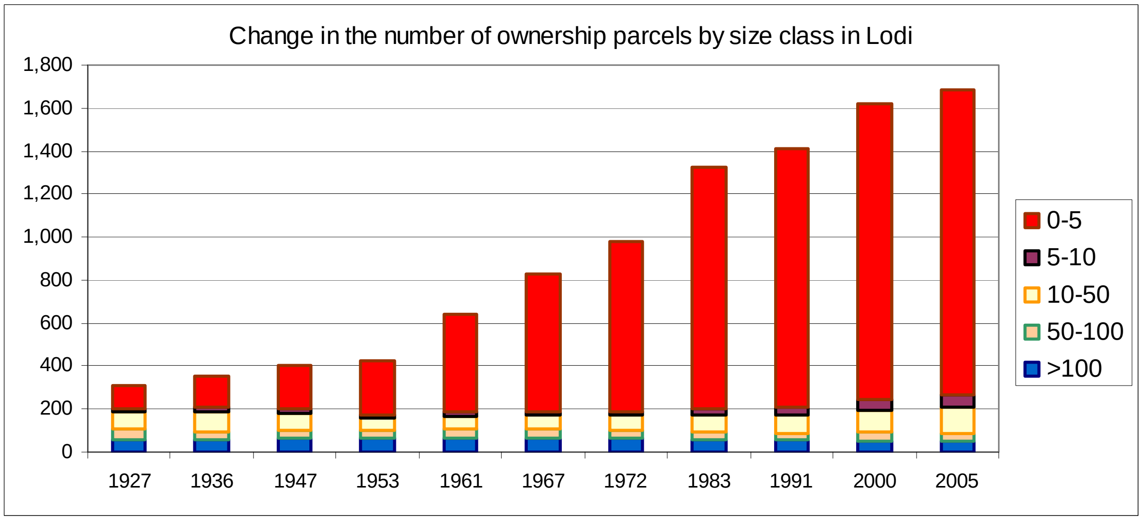


Township of West Point
2000 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100

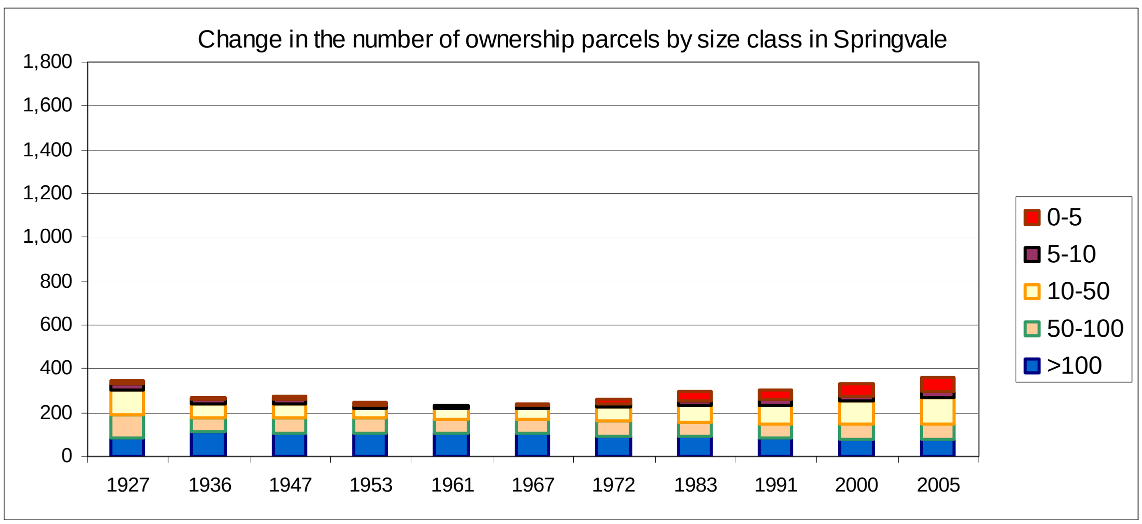

Township of West Point
2005 Ownership parcels
0
1
2
Miles
N
Size Class
0 - 5
5 - 10
10 - 50
50 - 100
> 100

Appendix D

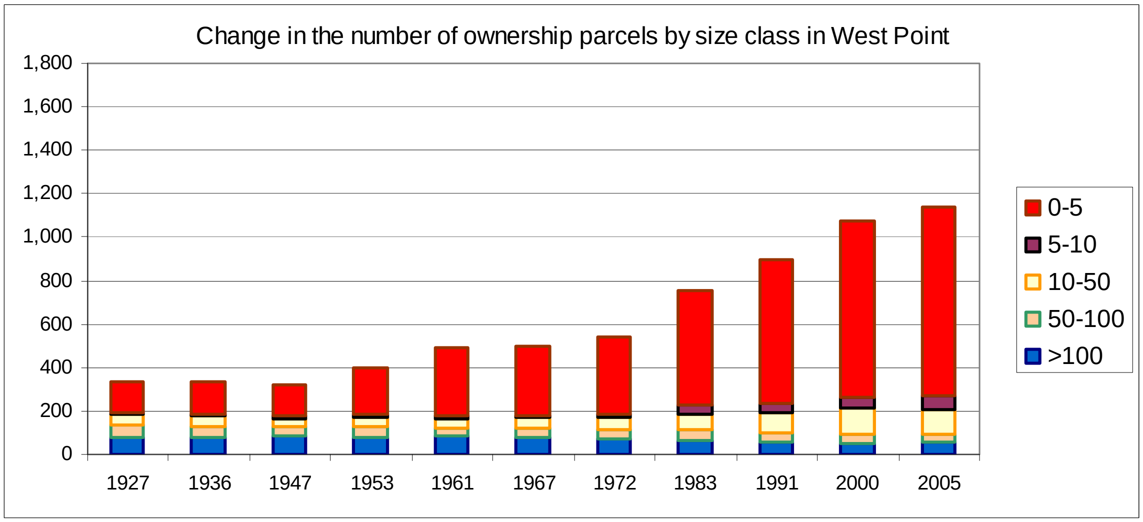
Number and Distribution of Ownership Parcels by Township From 1927 – 2005



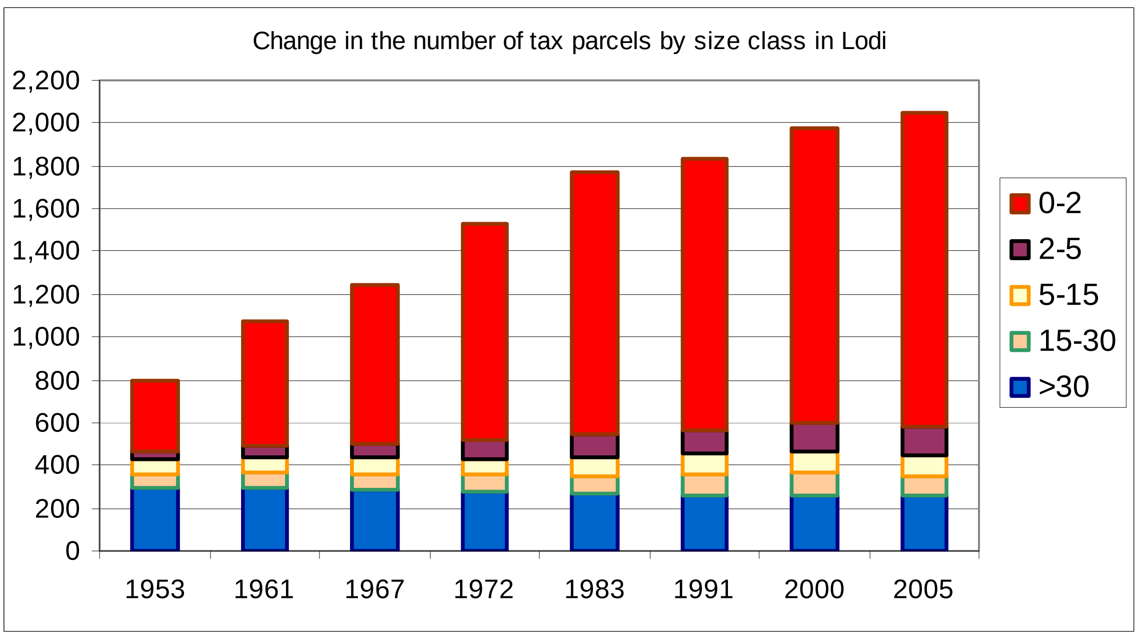
Change in the number and distribution of ownership parcels in Lodi.



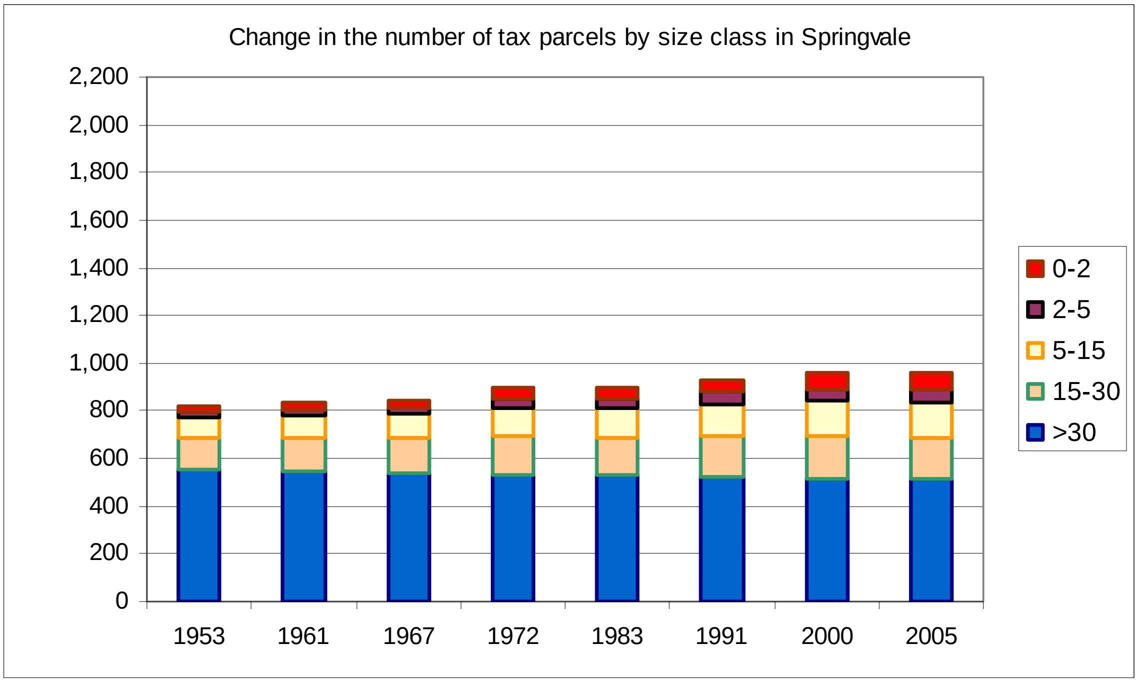
Change in the number and distribution of ownership parcels in Springvale.



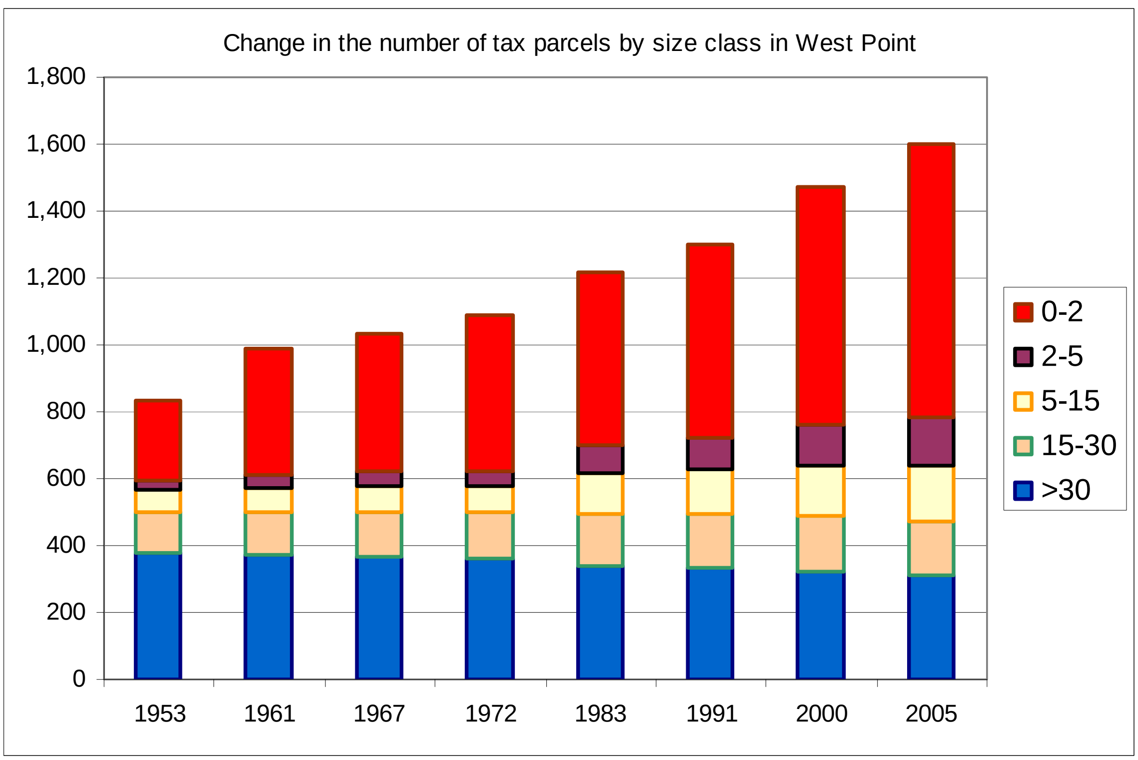
Change in the number and distribution of ownership parcels in West Point.



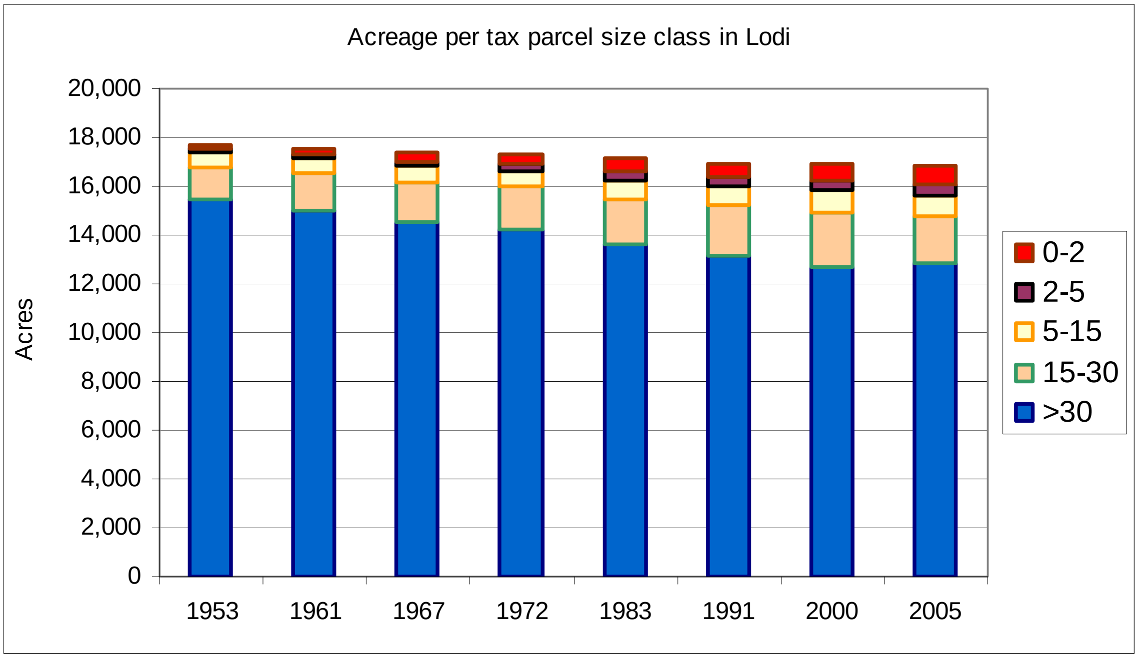
Change in the number and distribution of tax parcels in Lodi.



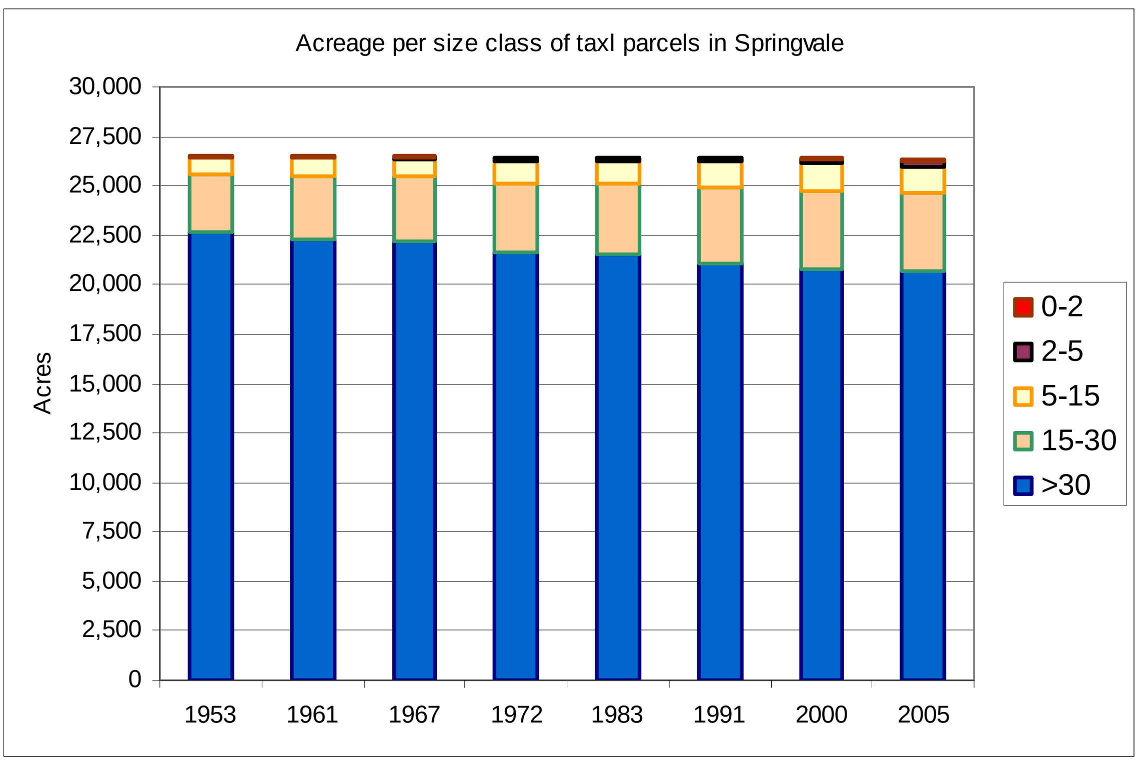
Change in the number and distribution of tax parcels in Springvale.



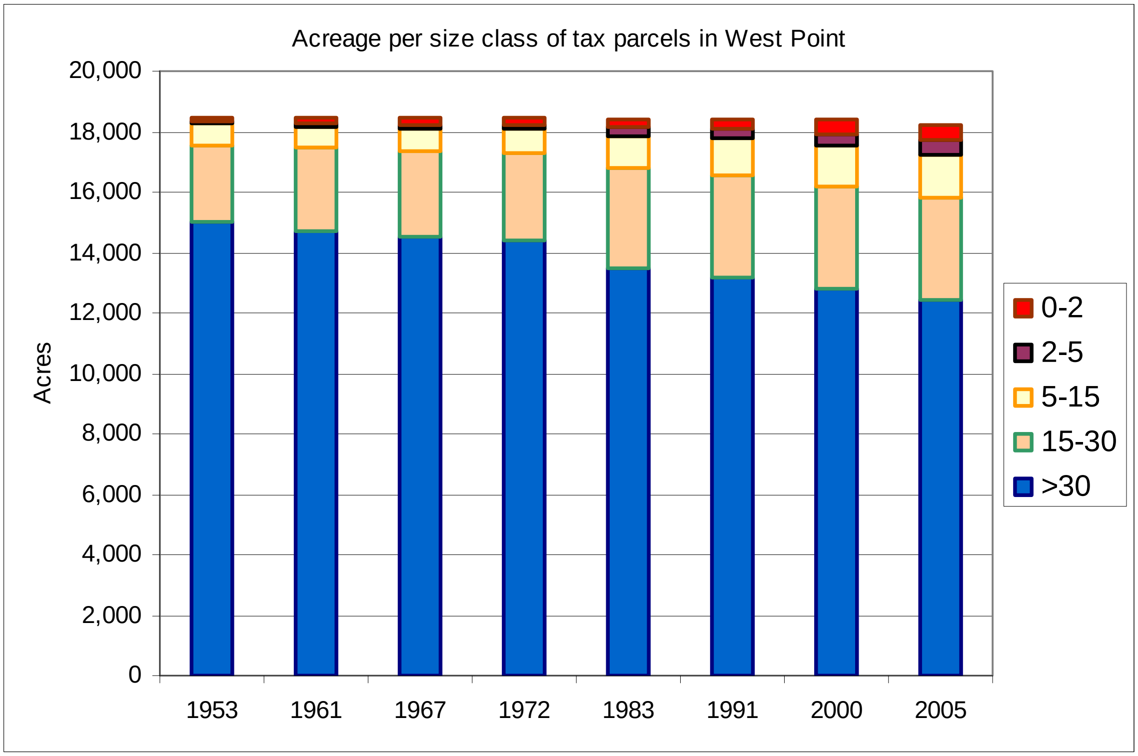
Change in the number and distribution of tax parcels in West Point.



Acreage per tax parcel size class in Lodi.



Acreage per tax parcel size class in Springvale.



Acreage per tax parcel size class in West Point.

Appendix E

Average Township Parcelization Metrics by Time Period

	Number of Parcels 1953-1961			Average new parcel size 1953-1961		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	100	14	136	16.6	18.4	7.2
	0.266	*-1.105*	*0.841*	*0.289*	*0.393*	*-0.254*
Plat	239	0	82	0.44	0	0.43
	1.072	*-0.879*	*-0.21*	*0*	*-1.332*	*-0.030*

	1962-1967			1962-1967		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	89	9	74	11.8	5.6	12.4
	0.914	*-1.392*	*0.481*	*0.006*	*-0.379*	*0.043*
Plat	60	0	0	0.39	0	0
	1.156	*-0.578*	*-0.578*	*0*	*-2.6*	*-2.6*

	1968-1972			1968-1972		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	79	51	72	12.8	10.7	13
	0.983	*-1.37*	*0.395*	*0.03*	*-0.095*	*0.041*
Plat	226	0	41	0.36	0	0.51
	1.138	*-0.739*	*-0.399*	*-0.083*	*-1.52*	*0.542*

	1973-1983			1973-1983		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	180	5	176	7.7	21.4	11.6
	0.731	*-1.41*	*0.682*	*-0.115*	*0.8*	*0.124*
Plat	127	0	31	0.81	0	1.27
	0.989	*-0.78*	*-0.348*	*-0.037*	*-0.633*	*0.301*

	1984-1991			1984-1991		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	92	29	86	16.1	13.1	11.8
	0.801	*-0.141*	*0.599*	*0.133*	*-0.048*	*-0.127*
Plat	55	0	34	0.61	0	1.07
	0.91	*-1.068*	*0.155*	*0*	*-0.763*	*-0.763*

	1992-2000			1992-2000		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	113	27	104	13.9	7.5	13.2
	0.821	*-1.407*	*0.588*	*0.066*	*-0.358*	*0.02*
Plat	107	0	121	1.48	0	1.36
	0.468	*-1.148*	*0.68*	*0.052*	*-0.808*	*-0.017*

	2001-2005			2001-2005		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	72	49	101	17.1	12.3	17.7
	-0.094	*-1.174*	*1.268*	*0.042*	*-0.211*	*0.074*
Plat	72	0	96	0.76	0	0.98
	0.32	*-1.12*	*0.8*	*-0.118*	*-0.863*	*0.098*

Average township metric values are in regular typeface and standard deviationsfrom the three town average are italicized in the gray box.

	Average urban distance 1953-1961			Average nearest neighbor 1953-1961		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	4356	14236	6614	537	3545	337
	-0.349	*1.589*	*0.094*	*-0.056*	*2.806*	*-0.246*
Plat	1701	0	4967			
	-0.469	*-1.426*	*2.065*			

	1962-1967			1962-1967		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	3704	14289	6886	466	5408	575
	-0.418	*1.881*	*0.273*	*-0.198*	*3.006*	*-0.136*
Plat	364	0	0			
	1.155	*-0.577*	*-0.577*			

	1968-1972			1968-1972		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	2918	13931	3575	572	1349	544
	-0.488	*1.292*	*-0.381*	*-0.155*	*0.493*	*-0.178*
Plat	1399	0	1067			
	0.05	*-1.283*	*-0.267*			

	1973-1983			1973-1983		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	2614	7180	5975	401	7697	491
	-0.361	*0.608*	*0.352*	*-0.111*	*5.47*	*-0.042*
Plat	894	0	483			
	0.081	*-0.812*	*-0.33*			

	1984-1991			1984-1991		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	2551	12262	5157	604	3332	550
	-0.464	*1.381*	*0.031*	*-0.261*	*1.717*	*-0.3*
Plat	352	0	919			
	-0.461	*-1.208*	*0.743*			

	1992-2000			1992-2000		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	3132	10781	4808	609	3822	526
	-0.324	*1.262*	*0.024*	*-0.245*	*2.237*	*-0.309*
Plat	443	0	1057			
	-0.464	*-1.094*	*0.41*			

	2001-2005			2001-2005		
	Lodi	Springvale	West Point	Lodi	Springvale	West Point
CSM	3047	12526	6395	673	1936	621
	-0.626	*1.016*	*-0.046*	*-0.263*	*1.038*	*-0.317*
Plat	650	0	858			
	-0.101	*-0.66*	*0.077*			

Average perimeter area ratio

1953-1961

	Lodi	Springvale	West Point
CSM	0.04	0.02	0.04
	0.073	*-0.415*	*0.073*
Plat	0.07	0	0.049
	0.151	*-1.857*	*-0.457*

1962-1967

	Lodi	Springvale	West Point
CSM	0.011	0.014	0.01
	0	*0.231*	*-0.071*
Plat	0.021	0	0
	1.167	*-0.583*	*-0.583*

1968-1972

	Lodi	Springvale	West Point
CSM	0.015	0.009	0.009
	0.235	*-0.118*	*-0.118*
Plat	0.016	0	0.014
	0.2	*-3*	*-0.2*

1973-1983

	Lodi	Springvale	West Point
CSM	0.012	0.006	0.005
	0.3	*-0.3*	*-0.4*
Plat	0.022	0	0.011
	0.231	*-1.462*	*-0.615*

1984-1991

	Lodi	Springvale	West Point
CSM	0.012	0.01	0.007
	0.143	*0*	*-0.214*
Plat	0.04	0	0.021
	0.114	*-0.795*	*-0.318*

1992-2000

	Lodi	Springvale	West Point
CSM	0.014	0.012	0.006
	0.2	*0.067*	*-0.333*
Plat	0.035	0	0.017
	0.25	*-0.844*	*-0.313*

2001-2005

	Lodi	Springvale	West Point
CSM	0.01	0.001	0.009
	0	*-0.474*	*-0.053*
Plat	0.018	0	0.009
	0.4	*-1.4*	*-0.5*