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Evaluating the Impacts of Residential Use on the Lapeer State Game Area

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# EVALUATING THE IMPACTS OF RESIDENTIAL USE ON THE LAPEER STATE GAME AREA

By

Eric M. Clark

A THESIS

Submitted to
Michigan State University
In partial fulfillment of the requirements
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ABSTRACT

EVALUATING THE IMPACTS OF RESIDENTIAL USE ON THE LAPEER STATE GAME AREA

By

Eric M. Clark

The state-owned portion of the Lapeer State Game Area (LSGA) is 8,246 acres. It is located in Lapeer County in Southeastern Michigan. This thesis evaluated the impacts current and future residential use inside the LSGA's Dedicated Management Boundary surrounding the LSGA that consists mostly of private lands. This was accomplished by utilizing landscape ecological metrics to quantify changes in the patch structure of non-built landcover types over the last 28 years (1978-2006) and for two alternative future development scenarios; The first scenario was a build out based on the full capacity allow by current zoning regulations in the townships surround the LSGA and the second was a build out that implements strategic conservation measures to protect ecologically significant non-built landcover patches.

This study showed that increased residential use from 1978 to 2006 has altered the patch structure of non-built landcover types. Projected increases in residential use under the capacity scenario showed further impacts to non-built landcover. Projected residential use under the conservation scenario showed that the preservation of ecologically significant patches could reduce the impact of residential use on non-built landcover patch structure. This research was intended to demonstrate methods incorporated biological information into both the planning efforts of the local municipalities and those for the LSGA.

## ACKNOWLEDGEMENTS

First I would like thank my graduate committee, Dr. Charles Nelson, Dr. Gary Roloff, and Dr. Christine Vogt for all their guidance through the course of this process. Second and by no means least; I thank my wife Robin for all her hours of effort.

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## INTRODUCTION

The Lapeer State Game Area (LSGA) has 8,246 acres of state owned as part of a 400,000 acre network of State game areas maintained by Michigan's Department of Natural Resources (MDNR) Wildlife Division. The LSGA is located in Lapeer County in the southeastern portion of Michigan. The LSGA maintains an important role as a social and ecological resource to the surrounding region. It forms the backbone of the surrounding municipalities' green infrastructure network. The LSGA performs valuable ecological services, such as water quality protection, nonstructural flood protection, and provision of wildlife habitat. Social services include recreational access, increased property values, decreased cost of service provision, and the attraction of tourists. The LSGA's significance in the region gives land planners and managers of the surrounding municipalities incentive to ensure the integrity of the LSGA by maintaining the grasslands, forest, and wetlands of the surrounding landscape.

The MDNR Wildlife Division is charged with managing the LSGA and all other State game areas "to provide benefits to hunters and trappers and to conserve wildlife resources for the benefit of all citizens and visitors to the State" (MDNR, 2003). The MDNR Wildlife Division is staffed primarily with biologists, whose work is focused on managing the natural resources of the State. It differs from the MDNR Parks and Recreation Management Division, which is primarily staffed with employees specializing in recreation, whose work emphasizes the role of people in recreation and management of the State Parks and Recreation Areas. The Wildlife Division is mandated to "develop annual operational work plans and budgets, develop long-range management plans for game areas and State forests, and participate in other landscape level or basin planning efforts" (MDNR, 2003). The LSGA 10-year Management Plan on-file is twenty years outdated (Douville, 1977). In 2001, the MDNR began a two year strategic planning process to create the Statewide Wildlife Action Plan, as part of their broader planning and management efforts (Michigan Department of Natural Resources, 2008). This planning process was "aimed at identifying and prioritizing the conservation needs of wildlife and their habitats, especially those species with low or declining populations" (Michigan Department of Natural Resources, 2008). During this process, the MDNR identified priority threats to wildlife in southern Michigan. Three of these threats were considered most significant: expansion of industrial, residential, and recreational development; invasive species; and fragmentation. The MDNR included recommendations for dealing with fragmentation and other issues associated with development, including working with local and regional land managers.

The LSGA is located in close proximity to two major metropolitan areas: Detroit and Flint (Figure 1). Due to its position at the urban fringe, the landscape surrounding the LSGA has been and continues to be impacted by residential development. The most visible impacts of residential development is the alteration of the landscape structure, including change in the pattern of grassland, forest, and wetland patches; yet social impacts are also apparent, including a reduction in the area of the LSGA open to hunting due to safety zones eliminating hunting opportunities within 450 feet of a residential structure.

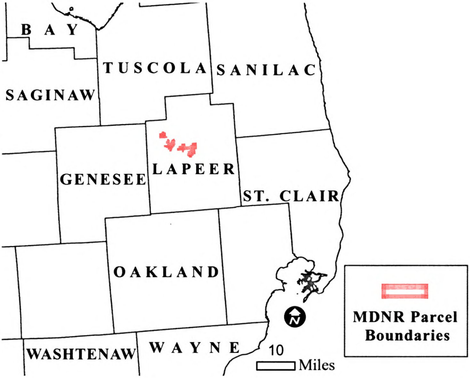



**Figure 1. Regional location of the Lapeer State Game Area in Southeast Michigan.**

The maintenance of the LSGA as a social and ecologic resource for the region requires active participation by the surrounding municipalities and the MDNR. Each entity has tools for guiding residential development in the surrounding landscape. Municipalities have the ability to guide the overall pattern of development with land use planning and zoning and Park, Recreation, and Greenspace Planning processes. The MDNR has fee simple ownership of 8,246 acres. One available tool is the fee simple acquisition of land through available funding sources such as the Michigan Natural Resource Trust Fund. The MDNR can also work through the Landowner Incentive Program to conserve and provide public access to land. Collaborative efforts between the MDNR and the surrounding municipalities could produce innovative strategies to control growth with the possibility of greater success. These strategies include incorporating ecological criteria into zoning ordinances and developing tax incentives for the conservation of ecologically important lands, among other possible strategies. In order for surrounding municipalities and the MDNR to employ their tools effectively, it is important that they understand the impacts of residential development on the LSGA and potential conservation lands.

The over arching goal of this thesis is to demonstrate one possible method of linking the Michigan Department of Natural Resources' planning process for the Lapeer State Game Area to local-level land use planning processes for the five townships that intersect the Dedicated Management Boundary: Arcadia, Deerfield, Marathon, Mayfield, and Oregon Townships. The author will draw on the planning phases of Ecosystem Management, the paradigm on which the MDNR Wildlife Action Plan is based, as presented by Botequilha Leitao and Ahern (2002) citing McGarigal (1998). The focus lies on identifying areas where landscape ecology can be used to facilitate the inclusion of biological and/or ecological information in the MDNR and local municipal planning processes. This research is mainly concerned with two of McGarigal's planning phases: performing a needs assessment and evaluating alternative development plans by utilizing landscape ecology. This paper assumes a common goal of the MDNR and local municipalities of protecting the ecological function of the landscape in the face of expanding residential development.

This research furthers understanding of the impacts of past and future residential development on the Lapeer State Game Area. The author developed strategies for prioritizing important and at-risk areas for future conservation efforts. Michigan Department of Natural Resources and local municipality tools were identified for use in future conservation of prioritized areas. This work can serve as a model for utilizing landscape ecology in future MDNR and local municipality Master Plans.

## OBJECTIVES

1. Evaluate past and future residential development trends inside the Lapeer State Game Area Dedicated Management Boundary using landscape metrics to:

    a. Quantify the change in the patterns of residential use from 1978 to 2006.

    b. Quantify potential change in residential land use patterns from 2006 land use data for two alternative development scenarios:

        i. Build out to full capacity allowed by local zoning ordinances.

        ii. Build out guided by strategic conservation measures.

2. Evaluate the impact of past and future residential development patterns inside the Lapeer State Game Area Dedicated Management Boundary on the landscape structure of non-built landcover patches (grassland, forest, and wetland) using landscape metrics.

    a. Quantify the change in non-built landcover patches from 1978 to 2006 to evaluate the following hypotheses:

        i. *increases in residential landcover patches from 1978 to 2006 altered non-built landcover patch structure by:*

            1. *loss of grassland and wetland landcover patches.*

            2. *gain of forest landcover patches.*

    b. Quantify the change in non-built landcover patches for two alternative development scenarios to evaluate the following hypotheses:

        i. *projected increases in residential land use alter non-built landcover patch structure by decreasing grassland, forest,* *and wetland landcover patches.*

ii. *the implementation of strategic land conservation measures results in reduced impacts of future residential development by protecting landcover patches of ecological significance.*

## STUDY SITE AND SITUATION

### *Study Site*

The Lapeer State Game Area (LSGA) is located in Lapeer County, Southeast Michigan. It is composed of 8,246 acres owned by the State of Michigan. The LSGA Dedicated Management Boundary encompasses 12,956 acres and includes property owned by the State of Michigan (SOM) and property under private ownership. The SOM property is surrounded by private property in most areas of the Dedicated Management Boundary; yet in some areas the Dedicated Management Boundary ends at the SOM property line. In such areas, the SOM property is directly exposed to current and future development and consequent safety zones. A 450 foot safety zone exists around all residential structures, inside of which it is unlawful to discharge a firearm. The author buffered the LGSA Dedicated Management Boundary by 450 feet to account for these areas directly exposed to adjacent private property development. The site for this study is the area that lies inside of this 450 foot buffer of the Dedicated Management Boundary, which totals 14,907 acres.

The state-owned portion of the LSGA is owned by the SOM and managed by the MDNR Wildlife Division to "provide benefits to hunters and trappers and to conserve wildlife resources for the benefit of all citizens and visitors to the State" (MDNR, 2003). The majority of this area is open to public hunting with the exception of the field dog trial area, the waterfowl refuge, and the areas that fall inside the safety zones for adjacent residential structures. The field dog trial area is 474 acres of land set aside for the training of field dogs and competitive field dog trials. It is unlawful to possess a firearm loaded with ammunition other than blanks for the purpose of training dogs. The waterfowl refuge is 727 acres of land closed to hunting year-round and closed to entry during posted periods. Many other forms of recreation take place in the

LSGA, such as fishing, bird watching, and hiking (Nelson et.al., 2007).

The LSGA lies in the Flint River Watershed. The North and South Branches of the Flint River converge to form the Main Branch of the Flint River inside of the LSGA. The study site is located in a physiographic region composed of thick glacial deposits of the Wisconsinan glacial epoch which reached its maximum extent 18,000 years before present. These deposits are associated with ice proximal positions: end moraines of coarse textured till, outwash sands and gravels, and glacio-lacustrine clays and silts. Vegetation prior to European settlement consisted of open forests and savannas of black and white oak on moraines, beech-maple forests on loamy soils, and white pine and eastern hemlock scattered along the southern portions of the study site. Northern white cedar, tamarack, black ash, white pine, and eastern hemlock were common species found along kettle lakes and swampy depressions associated with outwash (Leonardi, 2001).

***Study Situation***

Lapeer County is a rapidly changing landscape. The once dominant agricultural and forest lands are being converted to residential, commercial, and industrial uses. Lapeer County is positioned in close proximity to both the City of Flint and the Detroit Metropolitan areas. In 2000, Lapeer County was designated part of the Detroit Metropolitan Statistical Area. Lapeer County's connection to these metropolitan areas is facilitated by a well developed transportation system. Interstate 69 provides easy access to the City of Flint and Michigan Highway 24 provides access to the Detroit Metropolitan Area. As built land uses sprawl across southeast Michigan's landscape, moving from urban centers to the exurban fringes, the population of Lapeer County has increased. According to the US Census Bureau, from 2000 to 2006 there has been over a six percent increase in population, from 87,904 to 93,761 people. This population increase is disproportionately small when compared to the expansion of built land. While explicit statistics describing this change in Lapeer County are not currently available, the Land Resource Project did this analysis in 2000 for the Detroit and Flint Metropolitan Statistical Areas.

The Land Resource Project, conducted by Public Sector Consultants and a collection of academic institutions in Michigan, worked to understand how future land use change will impact the States land based economy. The project calculated the land to population growth rates for the period from 1960 to 1990 for the Flint and Detroit MSAs as 7:1 and 13:1, respectively. This expansion of built land comes at the cost of agricultural, forest, grassland, and wetland areas. The Land Resource Project used the Land Transformation Model, developed at Michigan State University. This model simulated land use change from 1980 to 2040 based on detailed information characterizing land use change in 16 counties in Michigan. The Land Transformation Model projected a drastic increase of built lands throughout the State. The Land Resource Project showed that past and future changes to Michigan's landscape could have serious impacts on the land-based economy that is already struggling.

Two land based industries are especially important in Lapeer County: agriculture and natural resource-based recreation and tourism. The Land Resource Project suggests that the number of working farms in Michigan is likely to decrease from about 42,000 in 2000 to 24,000 in 2040. The total area of farm land in Michigan's metropolitan areas is projected to decrease by 25 percent in that same time period. The medium size farms (50-500 acres) are projected to experience the largest decrease. Of the land adjacent to the LSGA, 12% is in agricultural use. Over 10% of adjacent landowners are likely to split and over 23% are likely to sell their land (Nelson et. al., 2007). This suggests that the findings of the Land Resource Project have merit with regard to the area surrounding the LSGA.

While the economic impacts of recreation and tourism are difficult to directly measure, these two industries make a significant contribution to Lapeer County's economy and to the quality of life of area residents. The LSGA is the single largest piece of public land to facilitate natural resource-based recreation in Lapeer County. It receives heavy use by those who live inside and outside of the County. According to Nelson et. al. (2007), in the year 2006 over 67,659 user hours were spent by those who travel from surrounding areas and over 21,653 user hours were spent by adjacent land owners recreating in the LSGA.

The LSGA is also an important entity that defines a sense of place for local residents. The Lapeer State Game Area was one of the top green and open spaces of importance according the Genesee, Lapeer, and Shiawassee Counties (GLS) Greenlinks Conservation Needs Assessment conducted in 2006 (Vogt et. al., 2006). It also forms the backbone of the most ecologically significant potential conservation area in the GLS region (Hyde, Paskus, & Enander, 2006).

# LITERATURE REVIEW

This literature review will focus first on the need to control residential development taking place on the urban fringe in order to maintain ecosystem services and natural resources provided ecological processes. Second, it will focus on the importance of including biological and ecological information in the planning process in order to direct development patterns away from ecologically significant areas. Finally, it will conclude with a discussion on the use of landscape ecology to evaluate changes in landscape structure for both past and future residential development.

What is urbanization? Where does the urban area become the suburban, the suburban become the exurban, and the exurban become rural? These questions have been answered differently by nearly all disciplines. Pickett et. al. (2001) suggests that, from an ecological perspective, there is little use in distinguishing urban areas from abutting "wild" lands. They write that a systemic approach, as in urban ecology, is most valuable to science and resource management. Urban ecology defines an urban system as one that accounts for the interactions and exchanges between cities and their surrounding landscapes (Pickett, et. al., 2001). Pickett et. al. (2001) cites the United Nations (1993) as estimating that in the next 30 years, over 60% of the world's population will live in urban areas. In developed countries around the globe, 75% of the population lives in urban areas and these areas are physically expanding (Bierwagen, 2007).

Urbanization is generally defined as "the process by which cities grow or by which societies become more urban" (The American Heritage, 2005). Suburbanization is the process by which cities and their surrounding footprints expand to form multinucleated edge cities (Stern & Marsh, 1997). Edge cities are characterized by isolated areas of residential, commercial centers, and corporate or industrial campuses (Kaufman & Marsh, 1997). Forman (1995) identifies what he calls 'a few common mosaic sequences' associated with suburbanization: concentric rings spreading outward from an urban center; growth along an exurban transportation corridor; and spread from satellite towns, plus infilling. Exurbanization, is defined as low density residential development outside the urban service boundary (Theobald, 2007a). Distinguishing these types of landscape change elucidates the complexity of patterns created by urban expansion. For the purposes of this paper, urbanization refers to all of these processes of urban expansion, including urbanization, suburbanization, and exurbanization. In southern Michigan, urbanization is typically the transformation of forested and agricultural lands to uses associated with urban areas (i.e. residential, commercial, or industrial). Urban sprawl can be thought of as consumptive urbanization or the migration of the urban complex beyond what is needed for current use.

Theobald (2007a) cites Benedict and McMahon (2001), who suggest that land resources in the United States have been use inefficiently. From 1982 to 1997, Benedict and McMahon estimate that the rate of land conversions due to urbanization has outpaced population growth by 47.1% to 17%, respectively. Exurbanization is occurring at an even higher rate than urbanization and the overall footprint of this is 10 times larger than the high density development: 77.6 vs. 6.7 million acres (Theobald, 2007a).

Human social systems depend on goods and services provided by ecosystems. Without natural resources such as oil, trees, and water, current social and economic systems would collapse. Ecosystem alterations and stresses caused by human and natural actions decrease the ecosystem's ability to provide natural resources and services. Land use change is the major driving force behind habitat loss and ecosystem degradation (Merenlender, 2007). Land use changes often result in non-built habitat fragmentation, isolation, and degradation, simplification and homogenization of species composition, disruption of hydrological systems, and modification of energy flow and nutrient cycling (Alberti & Marzluff, 2004). The extent to which non-built areas are impacted by land use change depends on the spatial configuration of land uses that results from the physical planning process employed by the agencies responsible for land management.

As with many States, land management decisions are made at the local level in Michigan. Local municipalities have the authority to control land use patterns through the master planning and zoning processes. Typically, these processes tend to focus on the social impacts of land use patterns, giving less consideration to biology and ecology. Insufficient consideration of biology and ecology in land use planning is inappropriate because humans depend on the ecosystem services and natural resources provided by the landscape. Inherent social and ecological connections necessitate the consideration of biological and/or ecological information in the local-level land management process. The challenge, however, is deciding what biological and/or ecological information needs to be incorporated and how to incorporate it. There are two sides to this issue: 1) how can local land managers incorporate biological and/or ecological concepts in to the management process, and 2) how can biologists and ecologists help to facilitate the use of this information in the land management process.

There are several ways that local land managers can alter the local land management process so that ecological and biological information is incorporated in to decision-making land use. Many researchers agree that it is important that land use decisions are made using a landscape context (Theobald, 2007a; Merenlender, 2007; Perlman, 2007). There are spatial mismatches between the scale at which land is managed, the boundaries of local municipalities, and the scale of ecological processes. Landscapes that would be contiguous ecological units are divided amongst tens or even hundreds of local municipalities. The result is often disconnected land management with small un-contiguous blocks of protected lands. Opportunities to protect corridors that cross jurisdictional lines are seldom realized (Berke, 2007). Coordinating planning across multiple jurisdictions is essential to address the exurban development that occurs at scales larger than one jurisdiction (Merenlender, 2007). Perlman (2007) writes that it is important for local land managers to understand the spatial scale of ecological processes. Perlman asserts that, as regulations and ordinances are developed without an understanding of the scale of the ecological process they seek to protect, they can miss the mark. It is not only important to focus on the spatial scale of processes but also on the temporal scale. Theobald (2007b) writes that alternative development scenarios should be used to augment planning in order to understand the temporal effects of land management decisions.

Theobald (2007b) identifies two aspects of an information gap that exists between the implementation of sustainable goals for landscape planning and the possible pathways to achieve these goals through land use planning. One aspect is the need to explore alternative development scenarios. A scenario is defined as a "hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points" (Theobald, 2007b). Scenario planning is a systemic method of exploring the uncertainties of possible futures. The focus is not on accurate predictions, rather, the focus is on facilitating discussion about planning and management outcomes.

The other aspect of the information gap asserted by Theobald (2007b) is the need to develop useful and creditable forecasts of future development. One way of creating future development forecasts is through the use of spatially explicit land use change models. These models have been developed using several modeling approaches, including cellular automata (White, Engelen, & Uljee, 1997; Verburga, Koninga, Koka, Veldkampb, & Bouma, 1999; and Jenerette & Wu, 2001), spatial transition probablilities (Theobald, 2003), regression based relaionships (Landis, 1995; Bradshaw and Mueller, 1998), and "studio-based" planning scenarios (Stienz et. al., 1996). One type of simulation model has been increasingly employed in land use planning: build out analysis. This simulation projects end states of planning assumptions, such as zoning ordinances (Theobald, 2007b).

Ecologists and biologists have an important role in facilitating the use of biological and ecological information in the local land management process. Theobald (2000) asserts that two of the reasons that biological information is rarely included in the local land use planning process are: 1) biological information is difficult to access and, 2) it is unclear to planners how the information can be used. In tending to these two issues, it is first important for the research agenda of ecologists and biologists to focus on the development of more reliable indices, models, and tools regarding the impacts of land cover change on natural resources and ecosystem services. These indices, models, and tools must be developed in a manner that is usable by local level officials and planners. This would help overcome the problem of limited access or availability as well as the problem of uncertainty in use by local level planners.

Ecologists and biologists can help deal with these issues by being directly involved in the land management process. There are several vehicles for ecologists and biologists to enter and contribute to the land use planning process. They can sit as members of the planning board or work with advocacy groups, provide educational opportunities for local decision makers, testify in public hearings, confer with local municipality staff, and help revise ordinances as part of citizen review panels (Broberg, 2003).

While these measures will help local level planners incorporate biological and/or ecological information in to the land management process, they could also benefit the MDNR in carrying out State management objectives presented in their Wildlife Action Plan (WAP). This plan repeatedly identifies fragmentation as a threat of the highest priority to Michigan's wildlife. The identified conservation needs for land, water, and species management in the WAP includes the incorporation of "identified areas of high biological significance into local, regional, and statewide planning and management efforts" (Michigan Department of Natural Resources, 2008). Potential Natural Areas Assessments are one method of identifying these areas, which has been used increasingly in Michigan by the Michigan Natural Features Inventory. The Genesee, Lapeer, Shiawassee GreenLinks Project used this method to identify important biological resources at the regional scale (Hyde, Paskus, & Enander, 2006). It is the author's belief that this method is applicable at a finer-scale, given the use of corresponding finer-scale land use data.

The MDNR's WAP was developed based on the principals of Ecosystem Management presented by Christensen et. al. (1996). The planning stages in Ecosystem Management (McGarigal, 1998) share similarities with other ecological-based planning methodologies advanced as solutions for creating ecologically functional landscapes:

Landscape Planning (Fabos, 1985), Rural Planning (Golley and Bellot, 1999), and Sustainable Land Planning (Botequilha Leitao and Ahern, 2002). One method particularly relevant to this research is the evaluation of alternative development scenarios to understand the impact of proposed management actions on the structure of the landscape.

As a discipline, landscape ecology is useful for evaluating proposed alternative development scenarios. It is concerned with the relationship between pattern and process or structure and function. Landscape ecology can provide the tools needed to understand the ecological implications of landscape structure. There are two components of landscape structure: composition and configuration. Composition is not spatially explicit and does not deal with patch geometry or geographic location. Composition deals with measures of richness, diversity, evenness, and dominance (Botequilha Leitao and Ahern, 2002). Configuration addresses patch geometry and the spatial distribution of landscape elements. Landscape ecologists have developed a series of pattern metrics to quantify landscape configuration and composition. This study will focus on five of these metrics: total class area, mean patch size, total core area, number of patches, and mean proximity index.

The following set of landscape metrics are designed to calculate the composition of the landscape. The total class area is the sum of all patches of a corresponding patch type in square meters divided by 4046.9 to convert to acres. The formula is as follows, where the $a_{ij}$ is the area in square meters of patch $ij$:

$$TCA = \sum_{j=1}^{n} a_{ij}\left(\frac{1}{4046.9}\right)$$

The mean patch size is the sum of the areas, in square meters, of all the patches of corresponding patch type, divided by the number of patches of the same type, divided by 4046.9 to convert to acres.

$$MPS\_c = \frac{\sum_{j=1}^{n} a_{ij}}{n_i}\left(\frac{1}{4046.9}\right)$$

The total core area is the sum of the core areas, in square meters, of all patches of the corresponding patch type, divided by 4046.9 to convert to acres.

$$TCA\_c = \sum_{j=1}^{n} a_{ij}{}^{c}\left(\frac{1}{4046.9}\right)$$

As previously mentioned, landscape configuration deals with the spatially explicit aspects of the landscape. The important measures of configuration are landcover patch location and shape. The landscape context in which a landcover patch resides may have a greater affect on its function and sustainability than does its own characteristics (Forman, 1995b). The distance between landcover patches and the nature of the landcover matrix between similar landcover patches will influence species survival (Ruggiero et. al., 1994; Ander, 1997 cited in Environmental Law Institute, 2003). In this study, the mean proximity index was used to quantify landscape configuration.

The mean proximity index measures the degree of isolation and fragmentation of corresponding patch types. The mean proximity index is the sum of patch area in square meters divided by the nearest edge-to-edge distance squared (square meters) between the patch and the focal patch of all patches of the corresponding patch type whose edges are within a specified distance in meters of the focal patch.

$$MPI = \sum_{s=1}^{n} \frac{a_{ijs}}{h_{ijs}^{2}}$$

The mean proximity index is represented in the calculation above. Here, $a_{ijs}$ is equal to the area of patch *ijs* within specified neighborhood of patch *ij* and $h_{ijs}$ is equal to the distance between patch *ijs* and patch *ijs*, based on patch edge-to-edge distance, computed from cell center to cell center. The mean proximity index is 0 when there are no patches of corresponding patch type within the defined search radius.

Using these metrics, it is possible to quantify changes in landcover that cause shifts from one mosaic pattern to another. Some landcover classes increase and some decrease through human and natural processes. In this study, the amount of landcover associated with residential uses increases and causes changes in the pattern of non-built landcover including forest, wetland, and grassland patches. In recent decades, fragmentation of these natural landcover patches has been widely examined as a source of habitat loss and degradation. In this case, fragmentation is defined as the division of large landcover patches in to smaller ones. Fragmentation is but one of many spatial processes that occur when mosaics shift from one pattern to another. Forman (1995) provides a useful framework for understanding the spatial processes that occur during the transformation of mosaic patterns due to decreases in undeveloped landcover. This framework places fragmentation in the broader context of landscape change. Forman suggests that there are five spatial processes in land transformation that are associated with loss of landcover patches: perforation, dissection, fragmentation, shrinkage, and attrition (Figure 2).

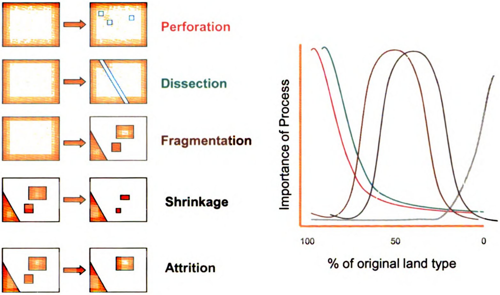



**Figure 2. Spatial Processes in Land Transformation. The above graph depicts the relative importance of each spatial process in relation to the amount of existing original land cover type (adapted from Forman 1995a).**

Perforation and dissection are important spatial processes when the amounts of original landcover are high, as is typically found in exurban environments (Figure 2). An example of perforation is low density residential development in a landscape dominated by forests. Dissection occurs as new roads are built in a forested landscape. Perforation and dissection decrease the average patch size and total core area of a landcover type. These two processes impact species with a high sensitivity to edge conditions or with large area requirements. Fragmentation is the division of landcover patches in to smaller pieces. Fragmentation is important when half or more of the original landcover still exists (Figure 2). It is a common spatial process associated with suburban landscapes. Fragmentation can result in an increased number of generalist and multi-habitat species (Forman, 1995). Attrition and shrinkage are important spatial processes when the amount original landcover type is low (Figure 2). An example of attrition is the loss of small patches of woodlots between agricultural fields. Attrition and shrinkage can cause the loss of the last few remaining species with large area requirements. However, the actual ecological impacts of the first three spatial processes are greater. Forman (1995) suggests that the most rapid ecological changes take place in the first 40% of land transformation. In this period, land planning and conservation are most important and effective. Landscape ecology can help in understanding the impacts of the spatial distribution of landscape elements on the function of the landscape; however, the responsibility of making decisions regarding spatial distributions falls on land use planners and local municipalities.

# METHODS

This study documents landscape-level changes in the structure of grassland, forest, and wetland patches inside the LSGA Dedicated Management Boundary as a result of increased residential use. The analysis strategy consists of three sections. The first section is an analysis of the change in landscape-level patch structure from 1978 to 2006. The second section includes build out analysis and construction of two alternative development scenarios for the LSGA Dedicated Management Boundary: one based on development at the full capacity allowed by current township zoning ordinances and the second based on the targeted conservation of ecologically significant landcover patches in areas where the LSGA Dedicated Management Boundary and the GLS Greenlinks green infrastructure network intersect. The third section is an analysis of the potential impacts of the alternative development scenarios on the landscape structure of grassland, forest, and wetland patches.

***Land Use Mapping***

To analyze the change in landscape structure, a 2006 land use dataset was compared to the 1978 Michigan Resource Information System (MIRIS) land use dataset. The 2006 land use dataset was interpreted from digital orthophotos obtained from the United States Department of Agriculture (USDA). The digital orthophotos were 1-meter resolution leaf-on aerial photography taken during the growing season. Land use polygons were digitized on screen in a geodatabase using ArcGIS 9 at a scale of 1 to 5000 and were classified using the MIRIS 2000 scheme. A 2.5 acre minimum mapping unit was used (Figure 3). In order to delineate wetland polygons, the author used two datasets: the updated 1996 National Wetlands Inventory obtained from the Great Lakes Regional Office of Ducks Unlimited and the hydric soils information from the Soil Survey Geographic (SSURGO) Database obtained from the Michigan Center for Geographic Information (MCGI). The 1978 MIRIS dataset was interpreted from National Aerial Photography color-infrared photographs and obtained from MCGI.

The MIRIS classification scheme was developed in 1980 based on the Anderson Classification system. There were minor changes in the land use classification schemes between 1978 and 2000, "including the restructuring of the forest groups, new names for some group headings and categories, the addition of new descriptions of feature assignments" (MDNR, 1998). While landuse data for both the 1978 and 2006 data were mapped using more than 30 classes, the differences in classification schemes necessitated that they be aggregated into 11 common land use categories. The changes in wetland and forest groups proved to be particularly problematic in this case. Table 1 contains the land use classes that were used in mapping and comparison.

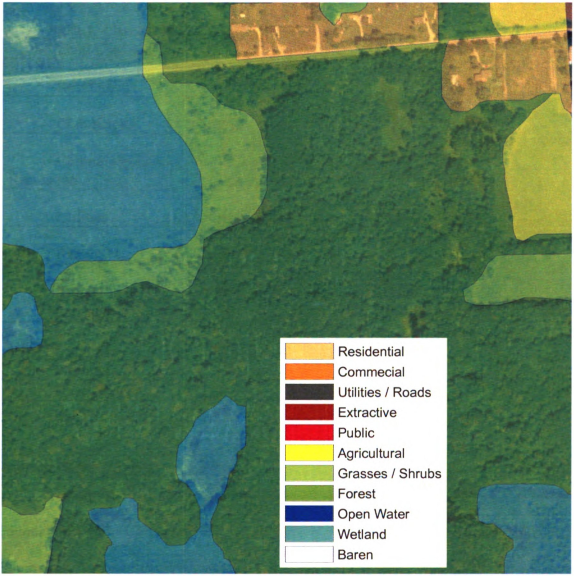



**Figure 3. 2006 land use dataset displayed with 40% transparency with the 2006 1-meter leaf on photography at a scale of 1:5000**

**Table 1. Classes used for land use mapping and comparison**

| Land Use Class | Class Description |
|---|---|
| Residential | Areas maintained as part of a residential parcel (lawns and garages) |
| Commercial | Areas maintained as part of a commercial parcel (gas stations and stores) |
| Community/Outdoor Recreation | Areas maintained for use as a outdoor recreation or public building (DNR offices and Outdoor Youth Camps) |
| Utilities | Areas maintained for utilities (roads and gas line corridors) |
| Extractive | Areas used for mineral Extraction (gravel pits and oil fields) |
| Agricultural | Areas used for agricultural production (corn fields, cow pastures, and orchards) |
| Forested | Areas with over 25% tree cover |
| Grassland | Areas with less than 25% tree cover, also includes shrub lands |
| Wetland | |
| Open Water | |
| Barren | |

### *Alternative Development Scenarios*

In creating the two alternative development scenarios, the author used the Orton Foundation's Community Viz 360 for ArcGIS 9. The "Build Out Wizard" module of Community Viz calculated the spatial arrangements of buildings based on user inputted zoning parameters, including minimum lot size and setbacks, and constraints based on spatial data. Three spatial datasets were produced prior to running the "Build Out Wizard:" zoning boundaries, minimum lot size, and constraint layers datasets. The zoning boundaries dataset represented the spatial extent of the zoning classes for each of the five townships intersecting the LSGA Dedicated Management Boundary: Arcadia, Deerfield, Marathon, Mayfield, and Oregon Townships (figure 7). This dataset was created by scanning township zoning maps into jpegs at 600 dots per inch. The jpegs were georeferenced to the Framework Version Six Transportation Dataset from the MCGI using the georeferencing toolbar in ArcGIS 9. The resulting zoning polygons were digitized in ArcGIS 9 on-screen in a geodatabase.

The second spatial dataset was developed to contain the minimum lot sizes. The third dataset needed for the alternative development scenarios was a constraint layer, or a spatial dataset containing all areas *not* open to development. In the full capacity development scenario, the build out was constrained by areas presently occupied by built uses identified in the 2006 land use dataset, i.e. residential, commercial, industrial, and road right-of-way polygons (Figure 9). The road right-of-way polygons were calculated by buffering the road centerlines in the Framework Version Six Transportation Dataset from MCGI by 66 feet.

The conservation alternative development scenario necessitated an extra set of constraints to the build out. This constraint layer addressed the non-built landcover patches within the LSGA Dedicated Management Boundary that lie outside of the MDNR owned parcels and inside the GLS Greenlinks green infrastructure network boundaries. These landcover patches were prioritized based on three criteria: total area, core area, and presence of water. To prioritize these landcover patches, grassland, forest, and wetland datasets were extracted from the 2006 land use data and clipped by the green infrastructure network boundaries in ArcGIS 9 (Figure 4). The grassland and forest datasets were filtered to include only patches larger than one acre. Because zero tolerance wetland loss ordinances are common to the townships, all wetland patches were included in the constraint layer. Grassland and forest patches were prioritized using an additive scale based on four natural breaks in the in the landscape metrics. This way, grassland patches were only compared with other grassland patches and forest patches with forest. Table 2 presents the scoring criteria for grassland and forest patches. A final score for each patch was calculated by adding the scores for each of the three criteria together. Based on four natural breaks in the scores, the highest ranking patches for each landscape element was selected and merged, along with all of the wetland polygons, into one final conservation constraint layer (Figure 4). This final conservation constraint layer covered 1,880 acres and included seven forest patches totaling 1,541 acres, six grassland patches totaling 56 acres, and 71 wetland patches totaling over 282 acres (Figure 5).

**Table 2. Scoring criteria for the conservation constraints data layer.**

| Class | Metric | Score |
|---|---|---|
| Grassland | Class Area | 4 (>8 acres) |
| | | 3 (3.6-7.9 acres) |
| | | 2 (1.8-3.5 acres) |
| | | 1 (< 1.8 acres) |
| | Core Area | 4 (>3 acres) |
| | | 3 (1.5-2.9 acres) |
| | | 2 (0.3 -1.4 acres) |
| | | 1 (< 0.3 acres) |
| | Presence of Water Feature | 4 (present) |
| | | 0 (not present) |
| Forest | Class Area | 4 (>208 acres) |
| | | 3 (98-207 acres) |
| | | 2 (30-97 acres) |
| | | 1 (<30) |
| | Core Area | 4 (> 147 acres) |
| | | 3 (67-146 acres) |
| | | 2 (20-66 acres) |
| | | 1 (< 20 acres) |
| | Presence of Water Feature | 4 (present) |
| | | 0 (not present) |

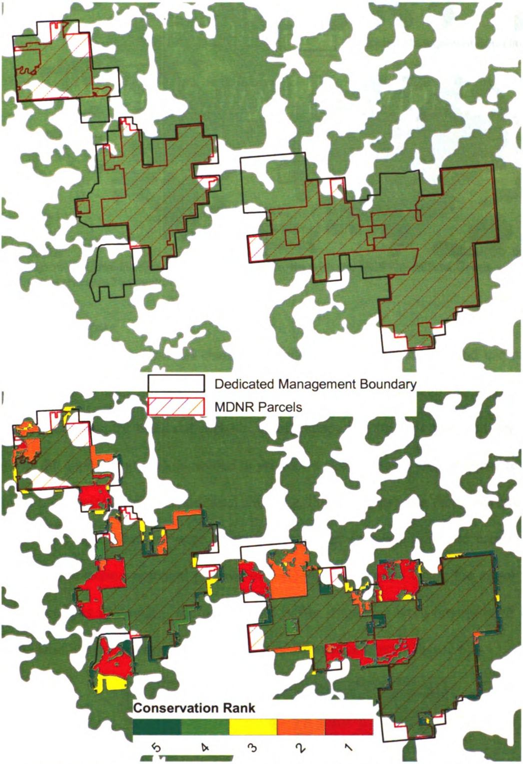



**Figure 4. Forest and grassland conservation rankings. Four is the highest conservation value based on total class area, core area, and presence of water bodies. The top image displays grassland features and the bottom image displays forest features; both are displayed with the GLS Greenlinks Green Infrastructure Network boundaries.**

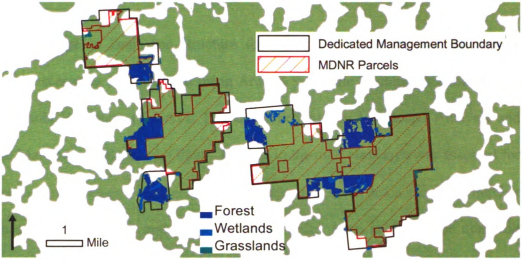


**Figure 5. Conservation constraint dataset shown with the GLS Greenlinks Green Infrastructure Network.**

### *Landscape Structure*

To calculate the potential change in landscape structure, future land use maps were produced for each alternative development scenario. Future land use maps were created by buffering the build out analysis, a point shape file, by 35.9 meters in ArcGIS. This was the approximate radius needed to produce a circle with an area of one acre, the assumed area maintained per residential dwelling, these buffers were then converted to squares. The square buffers were dissolved, based on common fields, to create two shapefiles representing potential patterns of residential land use. Using the editor and topology toolbars in ArcGIS, the new square buffer shapefiles were incorporated into the 2006 land use dataset as residential polygons for each scenario (Figure 6).

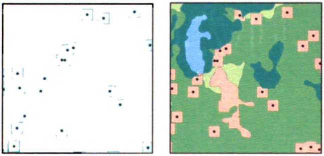


**Figure 6. One acre square buffers used to create the land use datasets for the alternative development scenarios.**

The change in landscape structure for 1978, 2006, and the two alternative development scenarios was analyzed using ArcGIS 9 and the Vector-Based Landscape Analysis Tools Extension (V-LATE 1.1) developed by the Landscape Analysis and Resource Management Research Group. Change in the total class area was assessed for all eleven land use classes. Change in the total class area, mean patch size, total number of patches, total core area, and mean proximity index were analyzed for non-built landcover: wetland, forest, and grassland classes. For residential and agricultural land classes, total class area, number of patches, the mean patch size and mean proximity index were calculated.

Core areas were calculated using an inside buffer of 100 meters. This parameter was used in effort to be consistent with the GLS Greenlinks Potential Conservation Areas Assessment (Hyde, Paskus, & Enander, 2006). For the mean proximity index, a radius of 15,960 meters was used to specify the neighborhood. This number was calculated based on the extent of the LSGA's Dedicated Management Boundary.

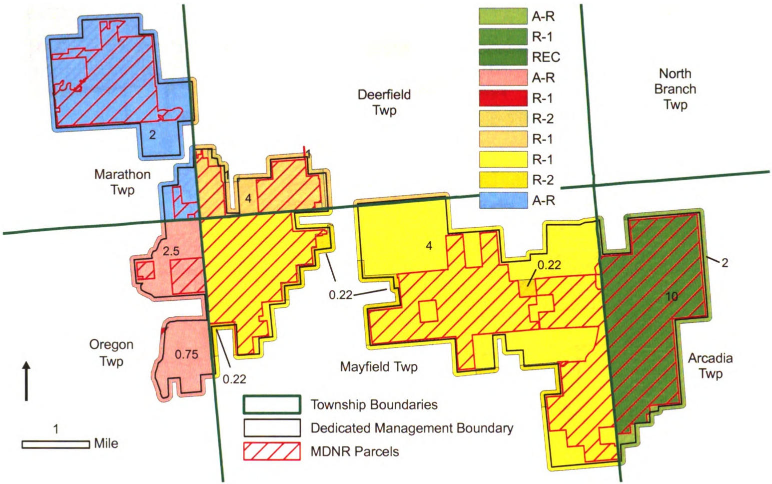



**Figure 7. Zoning classes for the five townships that fall within the Lapeer State Game Area Dedicated Management Boundary.**

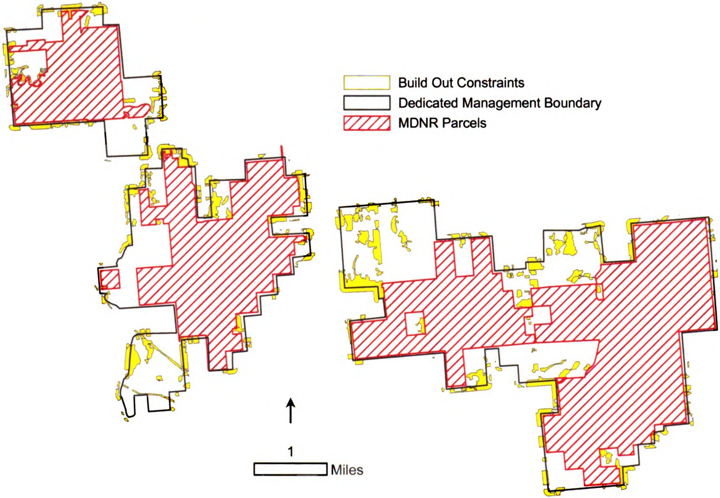



**Figure 8. Constraints to the build out analysis. The image displays roads, existing "built" land use polygons, and utility corridors.**

**Table 3. Zoning types with minimum lots sizes and total area of each zoning within the Lapeer State Game Area Dedicated Management Boundary**

| Township | Zoning Class | Minimum Lot Size (acres) | Total Area (acres) |
|---|---|---|---|
| Arcadia | Recreational (REC) | 10.00 | 2,148.53 |
| | Single Family Residential (R-1) | 0.69 | 4.86 |
| | Agriculture- Residential (AR) | 2.00 | 462.39 |
| Deerfield | Single Family Residential (R-2) | 1.00 | 102.03 |
| | Residential-Agriculture (R-1) | 4.00 | 995.20 |
| Marathon | Residential-Agriculture (R-1) | 2.00 | 2,382.66 |
| Mayfield | Residential-Agriculture (R-1) | 4.00 | 7,054.68 |
| | Single Family Residential (R-2) | 0.22 | 478.55 |
| Oregon | Agriculture- Residential (AR) | 2.50 | 1,274.78 |
| | Single Family Residential (R-1) | 0.75 | 4.22 |

### *Limitations of the Study*

Discrepancies between the 1978 and 2006 land use dataset serve to limit the accuracy of the land use change comparison. The 1978 land use dataset was interpreted from a different aerial photography base than was the 2006 dataset. The 2006 dataset was digitized using a higher resolution aerial photography at a finer scale. The differences in scale and resolution can impact some of the landscape metrics.

Limitations in the build out scenarios resulted in over-simplified development patterns. The full capacity development and conservation development scenarios assumed zero land transformation outside of the expansion of residential land. This assumption was necessary because it was not within the scope of this study to produce models of ecologic processes (i.e. forest succession, old field succession) or to model changes in the spatial configuration of land use types (i.e., rezoning residential areas as commercial or industrial). The conservation scenario also did not take in to account important social criteria necessary to conduct conservation on privately owned lands, such as property ownership patterns, property values, or risk of development. Finally, the land use patterns that resulted from the full capacity development scenario assumed standard one acre square footprints associated with each residential dwelling. This assumption may have over-simplified the configuration of residential lots on the landscape.

## RESULTS

### ***Increased Residential Land Use from 1978 to 2006 and Alternative Development Scenarios***

*1978 to 2006*

The Lapeer State Game Area (LSGA) is 8,246 acres of land under the ownership of the State of Michigan. The LGSA Dedicated Management Boundary encompasses a larger area of 14,907 acres. Inside the LSGA property boundaries owned by the State of Michigan, landcover is mostly grassland, upland and lowland forest, and wetlands. Fifty-five percent of the area inside the LSGA Dedicated Management Boundary was in private ownership in 2006. The majority of land use change occurred on these private lands during the 28 years from 1978 to 2006. The amount of LSGA Dedicated Management Boundary lands classified as residential increased from about two percent (345 acres) in 1978 to about six percent (935 acres) in 2006 (Figure 14). During this same time period, the number of residential land use patches increased from 98 to 270 (Figure 13) and the mean patch size remained the same at 3.5 acres (Figure 15). The mean proximity index for residential patches decreased from 1,756.8 to 205.4 (Figure 16). The total class area of lands used for agriculture decreased from 14 percent of the LSGA Dedicated Management Boundary in 1978 (2,091 acres) to four percent (623 acres) in 2006 (Figure 14). The number of agricultural patches decreased from 133 to 62 (Figure 13) and the mean patch size decreased from 15.5 to 10.1 acres (Figure 15). The mean proximity index for agricultural lands increased from 14.3 in 1978 to 66.4 in 2006 (Figure 16).

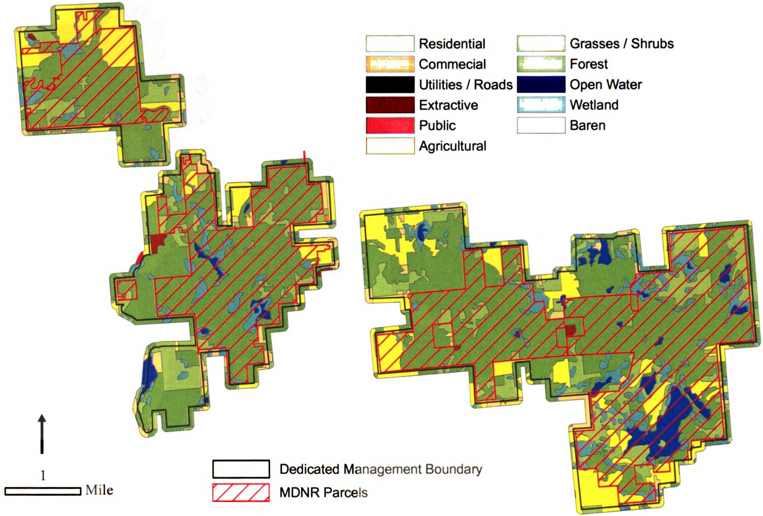



**Figure 9. 1978 Land use map for the Lapeer State Game Area Dedicated Management Boundary.**

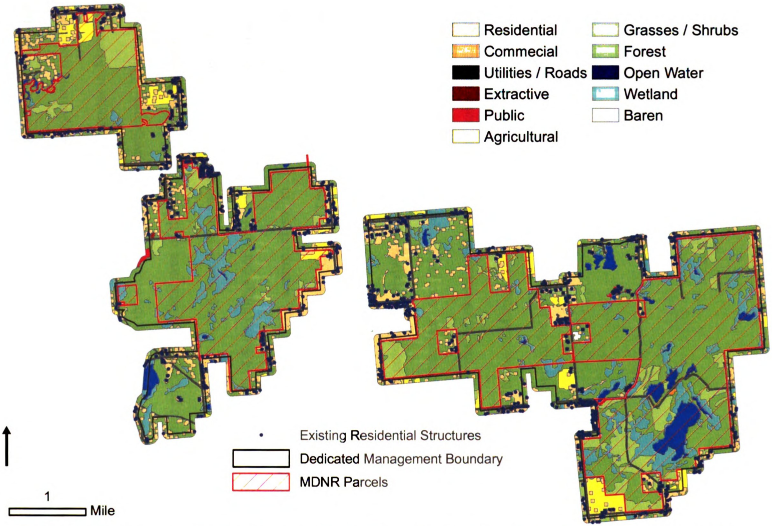



Figure 10. 2006 Land use map for the Lapeer State Game Area Dedicated Management Boundary. Existing residential structures are displayed.

*Full Capacity Alternative Development Scenario*

The full capacity alternative development scenario calculated the potential for 1,929 new residential dwellings within the LSGA Dedicated Management Boundary according to township zoning allowances. The Residential 2 (R2) zoning in Marathon Township accounted for 42% (812) of the projected residential dwellings. This zoning class only occupied three percent of the total area of the LSGA Dedicated Management Boundary; yet, it provided a higher zoning density than any other zoning category in all five townships: approximately 4.5 dwellings per acre or a .22 acre minimum lot size (Table 4). The Residential 1 (R1) zoning class in Mayfield Township, the Agriculture/Residential (AR) zoning class in Oregon Township, and the AR zoning class in Marathon Township were all similar in their contributions to the final build out total, with 350, 340, and 323 potential new dwellings, respectively (Table 4). Of all zoning classes, these three comprised the largest portion of the LSGA Dedicated Management Boundary. With the 1,929 potential new residential units added to the existing 892 in the LSGA Dedicated Management Boundary, the potential for a total of 2,821 residential units exists within the LSGA Dedicated Management Boundary.

**Table 4. Number of potential residential dwellings calculated at full capacity build out per zoning class and minimum lot size expressed in acres.**

| Township | Zoning Class | Minimum Lot Size | Build Out Dwellings |
|---|---|---|---|
| Arcadia | Recreational (REC) | 10 | 0 |
| | Residential 1 (R1) | 0.69 | 0 |
| | Agricultural Residential (AR) | 2 | 94 |
| Deerfield | Residential 1 (R1) | 4 | 0 |
| | Residential 2 (R2) | 1 | 10 |
| Mayfield | Residential 1 (R1) | 4 | 350 |
| | Residential 1 (R2) | 0.22 | 812 |
| Marathon | Agricultural Residential (AR) | 2 | 323 |
| Oregon | Residential 1 (R1) | 0.75 | 0 |
| | Agricultural Residential (AR) | 2.5 | 340 |
| Total | | | 1,929 |

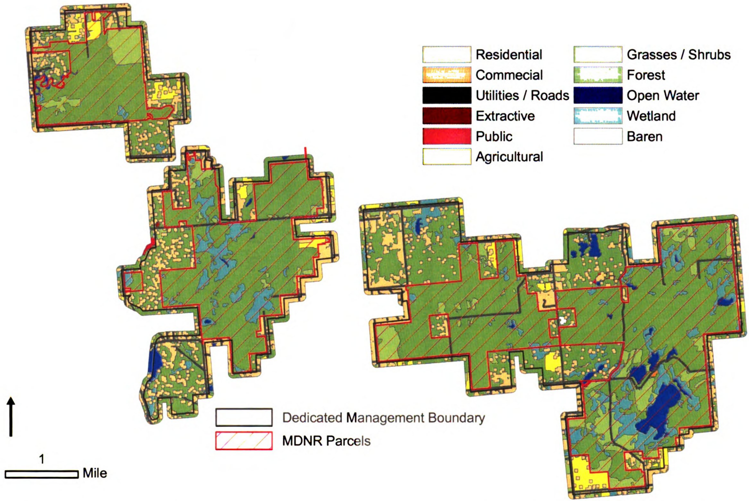



**Figure 11. Full capacity alternative development scenario land use map for the Lapeer State Game Area Dedicated Management Boundary.**

The full capacity alternative development scenario build out analysis produced a potential land use map with 2,359 acres of residential land, based on a buffer of 1.4 acres (Figure 11). The number of residential land patches increased by 316 to total 586 patches (Figure 13) and the mean patch size increased from 0.5 to 4.0 acres (Figure 14). The mean proximity index increased substantially from 205.4 to 4,6531.1 (Figure 16). Agricultural lands within the LSGA Dedicated Management Boundary decreased by 157 acres to 467 acres (Figure 14) while the number of agricultural landcover patches increased from 62 to 95 (Figure 13) and mean 467 patch size decreased from 10.1 to 4.9 acres (Figure 15). The mean proximity index for agricultural landcover patches increased from 66.4 to 91.5 (Figure 16).

*Conservation Alternative Development Scenario*

The conservation alternative development scenario revealed the potential for 1,430 new residential dwellings in the LSGA Dedicated Management Boundary. The R2 zoning class in Mayfield Township accounted for 710 residential dwellings, the largest increase of all zoning classes inside the LSGA Dedicated Management Boundary. The build out analysis in this scenario calculated a potential of 263 new dwellings in the AR zoning class in Marathon Township and 212 new dwellings in the R1 zoning class in Mayfield Township. Other zoning classes revealed less capacity for new dwellings (Table 5). The projected 1,430 new residential units, in addition to the existing 892, create the potential for 2,322 residential units inside the LSGA Dedicated Management Boundary in the conservation alternative development scenario.

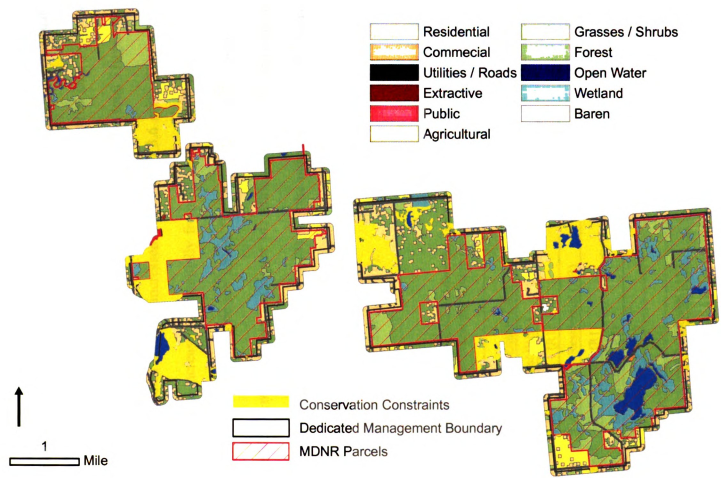



**Figure 12. Conservation alternative development scenario land use map for the Lapeer State Game Area Dedicated Management Boundary**

The conservation alternative development scenario build out analysis produced a potential land use map with 1,946 acres of residential, land based on the one acre square buffer (Figure 12). There was an increase of 1,011 acres of residential land from the 2006 dataset (Figure 14). Residential land patches increased by 300 to total 570 patches (Figure 13) with a mean patch size that increased from 0.01 to 3.6 acres (Figure 15). The mean proximity index increased substantially from 205.4 to 1,385.1 (Figure 16). The amount of agricultural lands inside the LSGA Dedicated Management Boundary decreased by over 159 acres to 464 acres (Figure 14) while the number of agricultural land patches increased from 62 to 99 (Figure 13) and the mean patch size decreased from 10.1 to 4.7 acres (Figure 15). The mean proximity index for agricultural land patches increased from 66.4 to 517.2 (Figure 16).

**Table 5. Number of potential residential dwellings calculated at build out for the conservation development scenario per zoning class and minimum lot size, expressed in acres.**

| | Zoning Class | Minimum Lot Size | Build Out Dwellings |
|---|---|---|---|
| Arcadia | Recreational (REC) | 10 | 0 |
| | Residential 1 (R1) | 0.69 | 0 |
| | Agricultural Residential (AR) | 2 | 83 |
| Deerfield | Residential 1 (R1) | 4 | 0 |
| | Residential 2 (R2) | 1 | 10 |
| Mayfield | Residential 1 (R1) | 4 | 212 |
| | Residential 1 (R2) | 0.22 | 710 |
| Marathon | Agricultural Residential (AR) | 2 | 263 |
| Oregon | Residential 1 (R1) | 0.75 | 0 |
| | Agricultural Residential (AR) | 2.5 | 90 |
| Total | | | 1,430 |

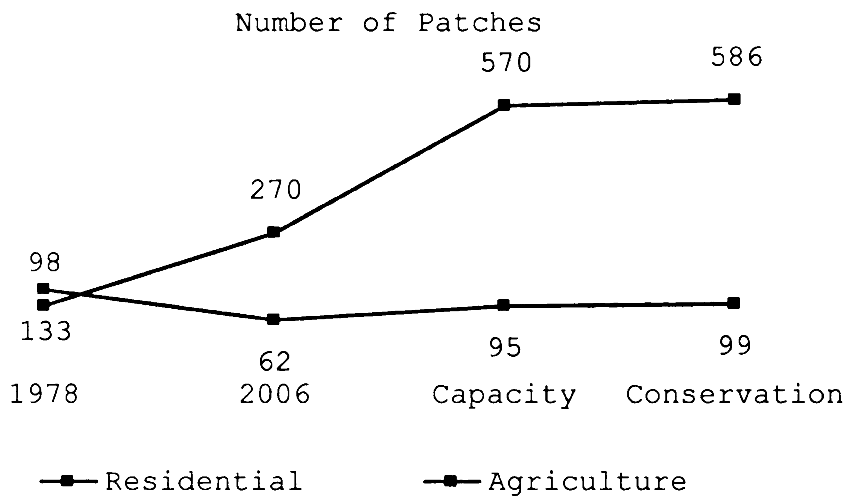



**Figure 13. Change in the number of patches for built land use classes inside the Lapeer State Game Area Dedicated Management Boundary from 1978 to 2006 and for the full Capacity and Conservation alternative development scenarios.**

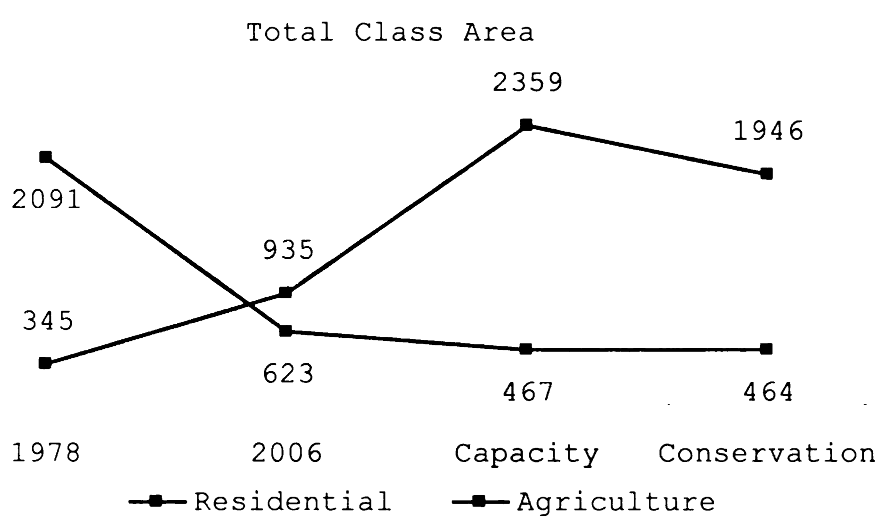



**Figure 14. Change in the total class area for built land use classes inside the Lapeer State Game Area Dedicated Management Boundary from 1978 to 2006 and for the Capacity and Conservation alternative development scenarios.**

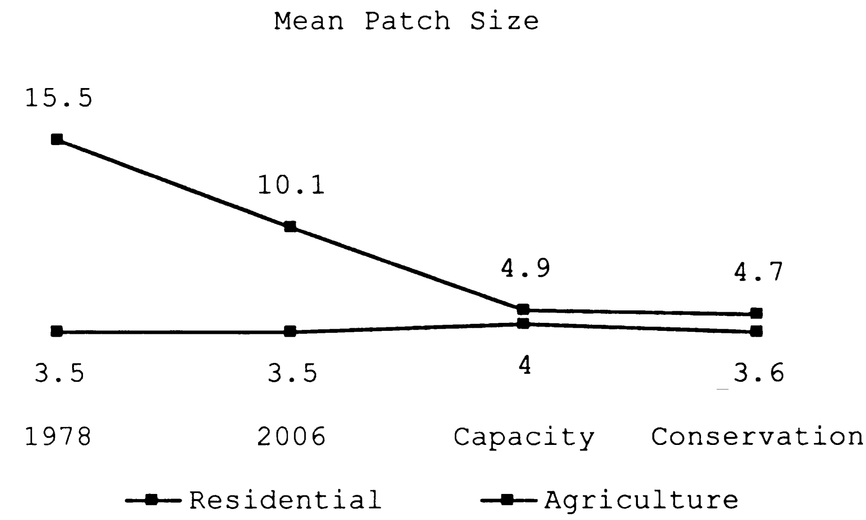



**Figure 15. Change in the mean patch size for built land use classes inside the Lapeer State Game Area Dedicated Management Boundary for 1978 to 2006 and for the full Capacity and Conservation alternative development scenarios.**

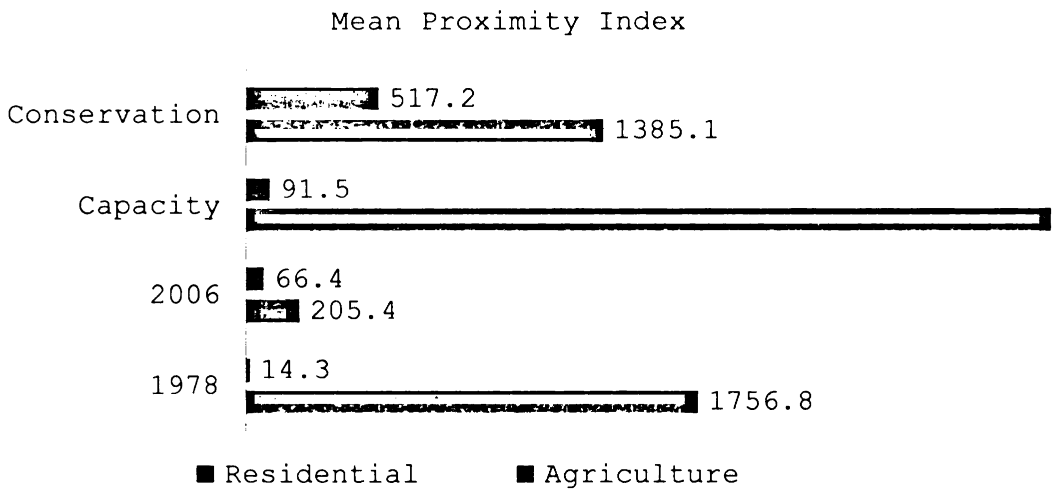
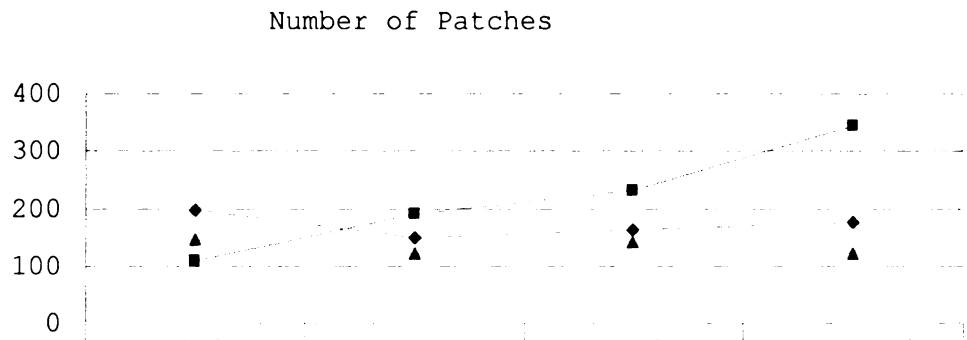



**Figure 16. Change in the mean proximity index for built land use classes inside the Lapeer State Game Area Dedicated Management Boundary for 1978 to 2006 and for the full Capacity and Conservation alternative development scenarios. The bar representing the mean proximity index for the residential land use class is not to scale.**

### ***Change in the Landscape Metrics for Non-Built Land Cover Classes***

*Number of Patches*

The number of patches is the count of all patches of a corresponding patch type. From 1978 to 2006, the number of grassland patches decreased by 48: from 198 to 150 patches, respectively. From the 150 grassland patches identified for 2006, the full capacity alternative development scenario produced an increase of 15 grassland patches while the conservation alternative development scenario produced an increase of 2 grassland patches (Figure 17). Between 1978 and 2006, the number of forest landcover patches increased by 79 to total 190 forest patches. From the 190 forest patches identified for 2006, the full capacity alternative development scenario produced an increase in the number of forest patches of 41. From the 2006 landcover dataset, the conservation alternative development scenario produced a larger increase in the number of forest patches, with 157 additional forest patches (Figure 17). From 1978 to 2006, the number of wetland patches decreased by 23 to total 124 patches. From the 124 wetland patches identified for 2006, the full capacity alternative development scenario produced an increase in the number of wetland patches of 20 patches. There was no change in the number of wetland patches resulting from the conservation alternative development scenario (Figure 17).

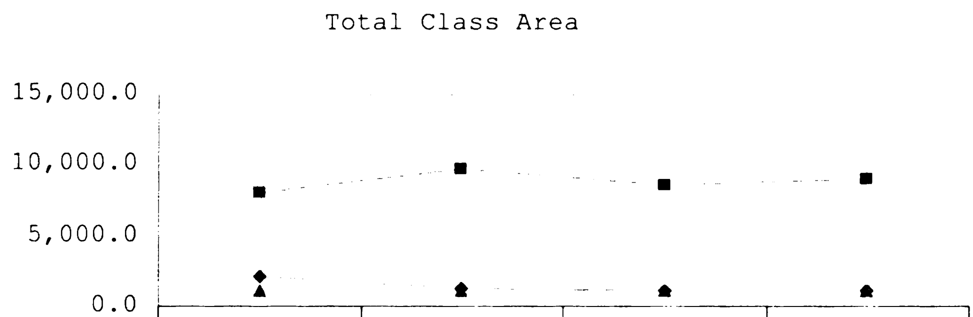



| | 1978 | 2006 | Capacity | Conservation |
|---|---|---|---|---|
| ◆ Grassland | 198 | 150 | 165 | 177 |
| ■ Forest | 111 | 190 | 231 | 347 |
| ▲ Wetland | 147 | 124 | 144 | 124 |

**Figure 17. Change in the number of patches for non-built landcover types inside the Lapeer State Game Area Dedicated Management Boundary for 1978, 2006, and the full Capacity and Conservation alternative development scenarios.**

*Total Class Area*

The Total Class Area (TClA) is a measurement of the total area of all patches of a corresponding patch type in acres. From 1978 to 2006, the TClA of grassland landcover patches decreased by 799 acres, to total 1,293.8 acres of grassland. From the 2006 TClA, the full capacity alternative development scenario decreased the grassland TClA by 122 acres and the conservation alternative development scenario decreased the grassland TClA by 108 acres (Figure 18). Between 1978 and 2006, the TClA for forest landcover patches increased by 1,652 acres to total 9,737.0 forested acres. The full capacity alternative development scenario reduced the 2006 forest TClA by 1,041 acres. The conservation scenario reduced the 2006 forest TClA by 717 acres (Figure 18). From 1978 to 2006, the TClA of wetland patches increased by 105 acres to total 1,168.1 acres. The full capacity alternative development scenario reduced the 2006 TClA for wetland patches by 76 acres while the conservation alternative development scenario produced no change in the TClA of wetland patches (Figure 18).



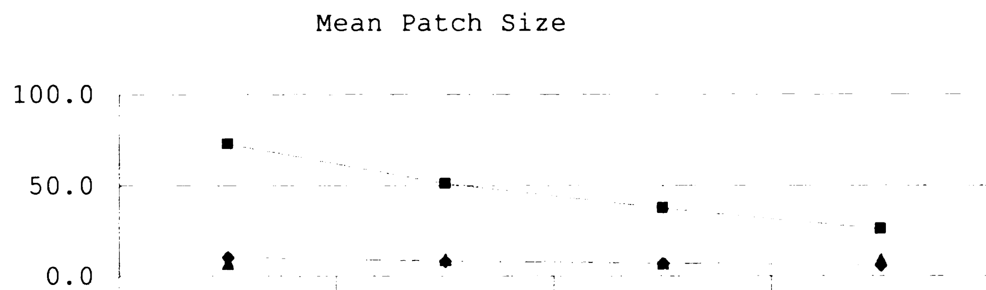

| | 1978 | 2006 | Capacity | Conservation |
|---|---|---|---|---|
| ◆ Grassland | 2,092.5 | 1,293.8 | 1,172.0 | 1,186.1 |
| ■ Forest | 8,084.9 | 9,737.0 | 8,695.7 | 9,020.3 |
| ▲ Wetland | 1,063.3 | 1,168.1 | 1,091.9 | 1,163.6 |

**Figure 18. Change in the total class area for non-built landcover classes inside the Lapeer State Game Area Dedicated Management Boundary for 1978, 2006, and the full Capacity and Conservation alternative development scenarios.**

*Mean Patch Size*

Mean Patch Size (MPS) is the average size of all the patches of a corresponding patch type. From 1978 to 2006, the MPS for grassland patches decreased by 1.9 acres to produce a MPS of 8.6 acres (Figure 19). From the 2006 landcover data, the full capacity alternative development scenario decreased the MPS for grassland patches by 1.5 acres while the conservation alternative development scenario decreased the MPS for grassland patches by 1.9 acres (Figure 19). From 1978 to 2006, the MPS of forest landcover patches decreased by 21.6 acres. From 2006, the full capacity alternative development scenario decreased the MPS for forest landcover patches by 13.6 acres while the conservation alternative development scenario decreased the MPS for forest patches by 24.2 acres (Figure 19). The MPS for wetland landcover patches increased by 2.2 acres from 1978 to 2006. From 2006, the full capacity alternative development scenario decreased the MPS for wetland patches by 1.8 acres while the conservation alternative development scenario produced no change in the MPS for wetland patches

(Figure 19).

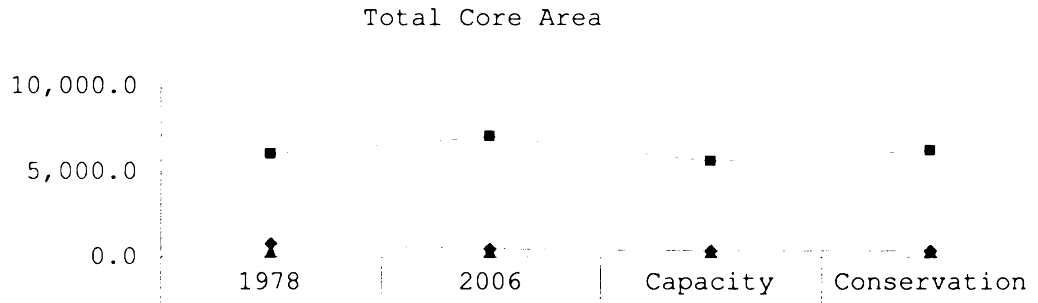



| | 1978 | 2006 | Capacity | Conservation |
|---|---|---|---|---|
| ◆ Grassland | 10.6 | 8.6 | 7.1 | 6.7 |
| ■ Forest | 72.8 | 51.2 | 37.6 | 26.0 |
| ▲ Wetland | 7.2 | 9.4 | 7.6 | 9.2 |

**Figure 19. Change in the mean patch size for non-built landcover types inside the Lapeer State Game Area Dedicated Management Boundary for 1978, 2006, and the full Capacity and Conservation alternative development scenarios.**

*Total Core Area*

The Total Core Area (TCA) is area greater than 100 meters from the edge of all patches of a corresponding patch type. From 1978 to 2006, the TCA for grassland patches inside the LSGA Dedicated Management Boundary decreased by 350 acres, from 859.5 to 510.5, respectively. From the 2006 landcover data, the full capacity alternative development scenario decreased the TCA by 61 acres and the conservation alternative development scenarios decreased the TCA for grassland patches by 52 acres (Figure 20). Between 1978 and 2006, the TCA for forest landcover patches increased by over 1,444 acres, from 6,070.7 to 7,114.6 acres, respectively. From 2006, the full capacity alternative development scenario decreased the TCA for forest patches by 1,444 acres and the conservation alternative development scenario decreased the TCA for forest patches by 825 acres (Figure 20). From 1978 to 2006, the TCA for wetland patches increased by 77 acres, from 274.5 to 352.3 acres, respectively. From the 2006 landcover data, the full capacity alternative development scenario decreased the TCA for wetland patches by 39 acres and the conservation alternative development scenario produced no change in TCA for wetland patches (Figure 20).



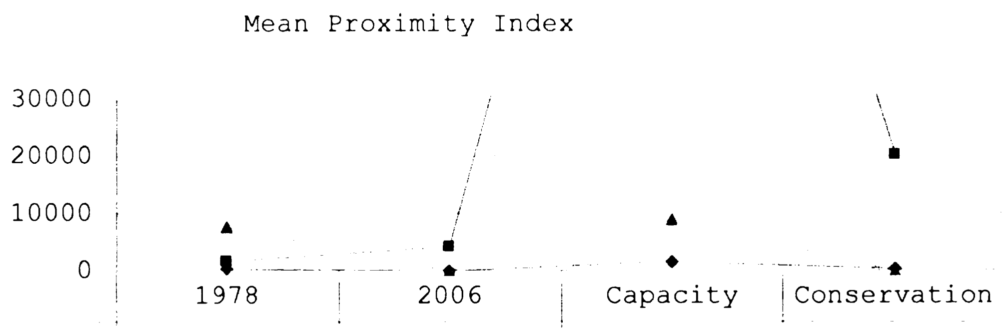

| | 1978 | 2006 | Capacity | Conservation |
|---|---|---|---|---|
| ◆ Grassland | 859.5 | 510.5 | 449.5 | 458.5 |
| ■ Forest | 6,070.7 | 7,114.6 | 5,670.3 | 6,289.3 |
| ▲ Wetland | 274.5 | 352.3 | 312.8 | 352.3 |

**Figure 20. Change in the total core area for non-built landcover types inside the Lapeer State Game Area's Dedicated Management Boundary for 1978, 2006, and the full Capacity and Conservation alternative development scenarios.**

*Mean Proximity Index*

The Mean Proximity Index (MPI) measures the degree of isolation and fragmentation of the corresponding patch type. It equals zero when there are no patches of corresponding patch type within the specified search radius (15,960 meters) and increases as the number of patches within that specified radius increases. From 1978 to 2006, the MPI for grassland landcover patches decreased from 203.4 to 106.1, respectively. From the 2006 landcover data, the MPI for grassland patches increased to 1,721.36 in the full capacity alternative development scenario. In the conservation alternative development scenario, the MPI for grassland patches increased to 255.51 from the 2006 landcover dataset (Figure 21). From 1978 to 2006, the MPI for forested landcover patches increased from 1,577.6 to 4,143.2, respectively. In the full capacity alternative development scenario, MPI for forest patches increased to 145,703.6 and the conservation alternative development scenario increased the MPI for forest patches to 20,207.8 (Figure 21). From 1978 to 2006, the MPI for wetland patches decreased from

7,835.8 to 50.4, respectively. From 2006, the full capacity alternative development scenario increased the MPI for wetland patches to 9,062.8 while the conservation alternative development scenario produced no change in the MPI for wetland landcover patches (Figure 21).




| | 1978 | 2006 | Capacity | Conservation |
|---|---|---|---|---|
| ◆ Grassland | 203.38 | 106.07 | 1721.36 | 255.51 |
| ■ Forest | 1577.6 | 4143.22 | 145703.59 | 20207.75 |
| ▲ Wetland | 7835.82 | 50.43 | 9062.08 | 50.43 |

**Figure 21. Change in the mean proximity index for non-built landcover types inside the Lapeer State Game Area's Dedicated Management Boundary for 1978, 2006, and the full Capacity and Conservation alternative development scenarios. Data point for the Capacity Scenario is not shown**

## DISCUSSION

### *Urbanization and Landcover Change from 1978 to 2006*

From 1978 to 2006, the predominant land use change within the Lapeer State Game Area Dedicated Management Boundary was the conversion of agricultural lands to residential lands. This land use change not only altered the proportion of the LSGA Dedicated Management Boundary occupied by these two landcover types; it changed the spatial patterns exhibited by both land use classes. The drastic difference in the mean proximity index for both of these classes indicates that there was a shift in the type of residential development taking place. In 1978, there were 98 patches of residential land in a dense pattern, indicated by the high mean proximity index (1,756.8). As the number of residential land patches increased to 270 in 2006, the residential foot print on the landscape increased and the pattern of residential land use became more dispersed, indicated by the mean proximity index of 205.4. The increase in residential area was not a result of large subdivision development; it was a result of the development of individual homes.

Urbanization has produced marked changes in the built landscape patterns inside the LSGA Dedicated Management Boundary. The first hypothesis of this research was aimed at evaluating whether these changes affected the non-built landcover classes by decreasing the numbers of grassland and wetland patches and increasing the number of forest patches. The pattern of grassland patches inside the LSGA Dedicated Management Boundary changed ways indicative of attrition and shrinkage. The grassland landcover class exhibited a decrease in the number of patches, total class area, mean patch size, and total core area (table 7). As Forman (1995a) suggests, attrition and shrinkage are most important when there is less than half the original landcover type remaining. In this case, the grassland patches on the periphery of the LSGA are experiencing attrition as a result of residential development and forest succession. Shrinkage is most often experienced by grassland patches in the interior of the LSGA as forest succession occurs at their outer edges due to lack of management.

**Table 6. Generalized behavior of landscape metrics from 1978 to 2006 for non-built landcover classes inside the Lapeer State Game Area Dedicated Management Boundary.**

| Class | Number of Patches | Total Class Area | Mean Patch Size | Total Core Area | Mean Proximity Index |
|---|---|---|---|---|---|
| Grassland | - | - | - | - | - |
| Forest | + | + | - | + | + |
| Wetland | - | + | + | + | + |

From 1978 to 2006, the patterns of forest and wetland landcover patches changed, also: the numbers and extent of wetland and forest patches increased inside the LSGA Dedicated Management Boundary. Forest patches increased by over 1,600 acres with the addition of 76 new patches. The increases in forest and wetland patches were coupled with decreases in mean patch size, which suggests that relatively small patches were added. The expansion of forest landcover is related, in part, to the succession of grassland patches to forest. Also, in agricultural areas being converted to residential developments, portions of the residential lot not maintained as lawn typically succeed to forest. The increase in wetland landcover patches may be related to wetland hydrology returning to areas previously drained for agriculture. According to the MDNR Management Plan for the LSGA, some increases in wetland area were the result of management actions. A portion of this change may also be due to differences in data interpretation and quality between land use datasets.

The gains in forest landcover create habitat for species that are not sensitive to edge conditions and species with small area requirements. The landscape was simplified and many patches of forest were perforated. Forest patch perforation alters the patch structure by reducing the total area, increasing the edge effects and it also introduces new disturbances. Many game species (i.e. white tail deer, ruffed grouse, and pheasant) use edge habitats between forest and grassland. The edges between residential lots and forest do not necessarily function as habitat for these game species. From this study, it is difficult to quantify how much of the increase in forest landcover actually occurred within the boundaries of the MDNR property and to what extent MDNR management actions facilitated this increase in forest landcover. Based on visual inspection of the maps depicting land use change, the majority of the landcover change appears to have taken place outside of the LSGA State owned parcel boundaries. Also, agricultural land has some habitat value for many of these game species. This habitat value is significantly decreased or lost with the conversion of agricultural lands to residential lands.

### *Alternative Development Scenarios*

The two alternative development scenarios were intended to facilitate discussion on the possible futures of the LSGA. Alternative scenarios can help land managers deal with uncertainty in real-world natural resource management issues. The intent of this section was to evaluate the usefulness of employing landscape metrics to understand and compare differences in landscape structure as a result of potential development scenarios. The full capacity alternative development scenario was based on actual planning documentation from the five townships surrounding the LSGA. The conservation alternative development scenario was intended to demonstrate a future where conservation measures are implemented.

The use of landscape metrics in the planning process is one way to incorporate biological information into the planning processes of the MDNR and the local municipalities. There were two objectives for this section. The first objective was to test the hypothesis that projected increases in residential land use inside the LSGA Dedicated Management Boundary under the full capacity alternative development scenario would produce changes in the structure of non-built landcover patches associated with decreasing non-built landcover. The second objective was to test the hypothesis that implementing strategic conservation measures to limit increased residential use on ecologically significant non-built landcover patches under the conservation alternative development scenario would mitigate the impact of urbanization on the landscape structure. The author will discuss each of the two alternative development scenarios followed by a comparison of the two.

*Capacity Scenario Potential Land Use Change and Impacts to Non-built Landcover*

The full capacity alternative development scenario calculated over a 216% increase in the number of residential dwellings within the Lapeer State Game Area Dedicated Management Boundary, using the full capacity of adjacent township zoning allowances. Assuming a standard area of residential dwellings to be one acre actively maintained as a yard, there would be a 150% increase in the total area and 117% increase in the number of patches of residential landcover in the full capacity development scenario. The pattern of this projected development is more dispersed than the pattern of residential use in 2006, indicated by an increase in the mean proximity index. Under the full capacity alternative development scenario, agricultural lands within the LSGA Dedicated Management Boundary would be effectively eliminated with mean patch sizes dropping from 10.1 to 4.9 acres of agricultural lands. The projected mean patch size of agricultural land is less than one acre larger than the mean patch size of residential landcover patches. The projected pattern of residential landcover patches does alter the structure of the non-built landcover patches within the LSGA Dedicated Management Boundary.

**Table 7 Generalized behavior of landscape metrics from 2006 to full capacity alternative development scenario for non-built landcover types within the Lapeer State Game Area Dedicated Management Boundary.**

| Class | Number of Patches | Total Class Area | Mean Patch Size | Total Core Area | Mean Proximity Index |
|---|---|---|---|---|---|
| Grassland | + | - | - | - | + |
| Forest | + | - | - | - | + |
| Wetland | + | - | - | - | + |

The first stated objective of this section was proven: projected increases in residential land use based on build out at full capacity do alter the structure of grassland, forest, and wetland landcover. Projected changes in grassland patches exhibit the characteristics of fragmentation, including an increase in the number of patches and mean proximity index, and decrease in the mean patch size and core area (Table 7). The number of grassland patches increased by 15, producing a loss in total area of 122 acres, a decrease in patch size of 1.5 acres, and a loss of 61 acres of core area. The decrease in total area is equal to almost 10% of the total grassland area within the LSGA Dedicated Management Boundary. Over 75% of the remaining grassland patches lay within the LSGA parcel boundaries; those within the surrounding LSGA Dedicated Management Boundary would be small and fragmented. These changes in spatial patterns have serious implications for many species that use large patches of grassland. Such decreases in suitable habitat in the landscape surrounding the LSGA could thwart restoration efforts within the Lapeer State Game Area.

Forest patches also exhibited fragmentation in the full capacity alternative development scenario. The scenario projected decreases in total class area, mean patch size, and core area, along with increases in the number of patches, total edge, and mean proximity index (Table 7). The majority of the land use change in the full capacity development scenario was from forested landcover to residential landcover. There was a 1,041 acre decline in total forest area and a 25% decrease (over 1,444 acres) in core habitat. The mean proximity index for forest patches increased from 4,143.2 to 14,570.6, indicating that the degree of isolation decreased with the increase in number of small patches. These changes in landcover patterns can impact both game and non-game wildlife species.

Fragmentation was the predominant spatial process occurring on the wetland patches within the LSGA Dedicated Management Boundary in the full capacity alternative development scenario. Land use change associated with wetland landcover was similar to that exhibited by the grassland patches in the full capacity development scenario. This similarity is most likely related to the small percentage of the actual landscape occupied by both landcover classes.

***Conservation Scenario Potential Land Use Change and Impacts to Non-Built Landcover***

The conservation alternative development scenario calculated the potential for a 116% increase in the number of residential dwellings within the Lapeer State Game Area Dedicated Management Boundary, if large areas of ecological value were conserved. The increase in number of residential dwellings would allow a 107% increase in the total area and 111% increase in the number of patches of residential landcover, assuming a standard residential dwelling area of one acre actively maintained as yard. The pattern of this projected development is dispersed, as indicated by the increase in the mean proximity index. Agricultural lands within the LSGA Dedicated Management Boundary would be effectively eliminated under the conservation alternative development scenario, with mean patch sizes dropping from 10.1 to 4.7 acres of agricultural landcover. In the conservation alternative development scenario, the projected pattern of residential land use alters the structure of the grassland, forest, and wetland patches inside the LSGA Dedicated Management Boundary.

**Table 8. Generalized behavior of landscape metrics from 2006 to conservation development scenario for non-built landcover classes within the Lapeer State Game Area Dedicated Management Boundary**

| Class | Number of Patches | Total Class Area | Mean Patch Size | Total Core Area | Mean Proximity Index |
|---|---|---|---|---|---|
| Grassland | + | - | - | - | + |
| Forest | + | - | - | - | + |
| Wetland | + | - | - | - | + |

The second objective of this section was to test whether targeted conservation measures could mitigate potential alterations to the structure of grassland, forest, and wetland patches. Clearly, based on the changes in the landscape metrics, this targeted conservation scenario did not eliminate the projected impacts of residential development. However, targeting wetland patches and non built landcover patches with high total and core area did mitigate some impacts of residential development. Projected changes in grassland patches exhibited the characteristics of fragmentation under the conservation alternative development scenario, with increases in the number of patches and total edge, and decreases in the mean patch size and core area. The number of grassland patches increased by 27 with a loss in total area of 108 acres, a decrease in patch size of 1.9 acres, and a loss of 52 acres of core area.

Forest landcover was also fragmented in the conservation alternative development scenario, with projected decreases in total class area, mean patch size, and core area along with increases in the number of patches, total edge, and mean proximity index (Table 8). As with the full capacity alternative development scenario, the majority of the land use change in the conservation alternative development scenario was from forested to residential landcover. As a result of the conservation constraints in this scenario, the decline in total forest area was 717 acres and the decline in core area was 825 acres. Forest patches were less isolated in this scenario due to the fragmentation of large patches. The mean proximity index increased from 4,143.2 to 20,207.7. The conservation alternative development scenario produced no change in wetland metrics because they were constrained from the build out.

***Alternative Development Scenario Comparison***

In order to demonstrate the impacts that conservation efforts could have within the Lapeer State Game Area Dedicated Management Boundary, this section will compare patterns of grassland, forest, and wetland patches produced by the two alternative development scenarios along with those from 1978 and 2006. Conservation efforts cannot wholly negate the impacts of land use change on grassland, forest, and wetland patches. However, this comparison reveals how targeting specific attributes of the landscape with conservation measures (i.e. preservation of large patches, large core areas, and wetlands) can reduce the impacts of increased residential use. This section will first compare the composition, then the configuration, of grassland, forest, and wetland patches inside the Lapeer State Game Area Dedicated Management Boundary.

The composition of forest patches changed greatly from 1978 to 2006. The number of patches, total class area, and total core area exhibited substantial increases. While there was a 17% increase in the amount of forest landcover, there was a 160% increase in the amount of residential landcover. This trend of rapid expansion in residential land has serious consequences for the non-built landscape in and around the LSGA. The conservation alternative development scenario displayed noticeable improvements in non-built landscape composition amidst residential development. In the conservation alternative development scenario, the number of forest and grassland patches remaining on the landscape increased. (Figure 15). The increases total forest area and total forest core areas were not surprising, due to the implementation of measures that targeted larger non-built patches for conservation (Figure 16 and Figure 18). The mean patch size for forest and grassland patches was less in the conservation alternative development scenario than in the full capacity alternative development scenario. This is because the conservation scenario constrained residential land use on relatively small grassland and forest patches outside the parcel boundaries of the LSGA, compared to the patches found and protected inside the LSGA parcels. In the full capacity alternative development scenario, attrition takes place on the relatively small grassland and forest patches found outside the LSGA parcels, which results in a higher mean patch size (Figure 19).

While the composition attributes of grassland and forest patches were targeted with conservation measures in the conservation alternative development scenario, the conservation measures also impacted the configuration of grassland and forest patches. The conservation alternative development scenario showed that by conserving large habitat patches outside of the boundaries of the LSGA, the landscape-wide mean proximity index was greatly decreased (Figure 19). The decrease in mean proximity index resulted from the preservation of several large blocks of forest and grassland.

Through this study, the author has demonstrated that landscape ecology can provide a useful set of metrics to evaluate alternative development scenarios for the purpose of land use and management planning. Landscape metrics can also provide an effective means of linking and incorporating biological and ecological information into the MDNR and local municipalities' planning processes.

## MANAGEMENT CONSIDERATIONS AND FUTURE RESEARCH

This research demonstrates some of the incentives for guiding residential development around areas of ecological significance in and around the Lapeer State Game Area. This research also shows that if targeted conservation measures based on ecologic criteria are implemented they can be an effective method to guide residential growth patterns around ecologically important areas. The MDNR and surrounding municipalities have tools in place that can be used to guide and control residential growth patterns. There are opportunities for these two entities to collaborate and engage in innovative conservation efforts. This section includes a discussion of the tools and opportunities available for managing residential growth in the LSGA Dedicated Management Boundary.

The MDNR has a set of tools specializing in interactions with individual land owners. These tools can provide interesting opportunities for the MDNR inside the LSGA Dedicated Management Boundary. As this study has shown, high quality forest lands surround the LSGA. Almost 13% of the land that is adjacent to the LSGA is vacant and 12% is used for agriculture (Nelson et. al., 2007). In areas adjacent to State Game Areas across southern Michigan, over 23% of landowner respondents indicated that they had an even chance or were very likely to sell their properties in the next five years (Nelson et. al., 2007). The presence of vacant and agricultural lands adjacent to State Game Areas, along with adjacent landowner willingness to sell their properties, creates opportunities and a sense of urgency for innovative land use planning. With increased residential development likely to continue on the lands surrounding the LSGA, the price of land is likely to increase while the availability decreases.

One tool available to the MDNR is the fee-simple acquisition of land parcels inside the LSGA Dedicated Management Boundary. Fee-simple acquisition of lands can be accomplished using funds that are currently available, such as the Michigan Natural Resource Trust Fund (MNRTF). The MNRTF pay for over 20 million dollars worth of land purchases each year for the purposes of conservation and recreation in the State of Michigan. Another tool available to the MDNR is the Land Owner Incentive Program. This program compensates land owners for the conservation of private property. The fee-simple acquisition of lands and Land Owner Incentive Program are often limited to opportunistic application. This thesis demonstrates one possible method for the MDNR to prioritize available lands by targeting landcover patches of high ecologic importance and patches at high risk of being developed. Such land prioritization could allow the MDNR to use these tools in a strategic conservation design.

The tools available to local municipalities are focused on guiding broader patterns of development. Local municipalities have regulatory tools, including the master planning and zoning processes, which dictate land management within their jurisdictions. Local municipalities also have the Park, Recreation, and Greenspace planning processes, which can be incorporated into their land management system to guide residential development. The cost of rapid residential development can be destabilizing to the fiscal resources of local municipalities; herein lies the incentive for managing land use change. The long term costs associated with providing services to residential areas can quickly outpace the tax revenues created by those residential areas. Municipalities often attempt to control the amount of residential development through zoning measures, such as agricultural zoning with the oft stated goal of preserving rural character. These measures tend to be ineffective at controlling growth. Part of the difficulty in controlling growth is the lack of technical resources for incorporating biological criteria into rural community zoning ordinances.

There are potential benefits for local municipalities and the MDNR to collaborate in innovative ways to control growth inside the LSGA Dedicated Management Boundary. By utilizing the resources that both entities have at their disposal, strong growth control measures can be developed. With the expertise of the MDNR, local municipalities could develop conservation based zoning ordinances that target specific species and ecologic communities of importance. Also with the expertise of the MDNR, local park, recreation, and greenspace plans could reflect the ecosystem management goals for the LSGA. This would provide the opportunity for increased leverage among both entities for funding sources such as the MNRTF. The development of easy to use tools such as the Potential Conservation Areas Assessment by the Michigan Natural Features Inventory can serve as the vehicle to include biological information into the planning process. By engaging municipalities with conservation based zoning ordinances and local non-profit groups (e.g. land trusts), the MDNR could help in identifying ecologically important pieces of the landscape and ensure that they remain intact.

Third party non-profits such as land trusts, resource advocacy groups, and science-based conservation organizations can serve as helpful intermediaries to work between MDNR biologists and land managers and local municipalities. In Lapeer County, there are several groups that could act as intermediaries. For instance, the conservation alternative development scenario used the GLS Greenlinks green infrastructure network boundaries to identify the areas considered for conservation. The GLS Greenlinks green infrastructure network could contribute to the facilitation of conservation measures within the LSGA Dedicated Management Boundary because it considers social preferences for conservation as well as biological criteria.

Considerations for future research should include alternative development scenarios that account for landscape change within the LSGA boundary based on forest and old field succession, natural disturbance, and future management action. Research that seeks to understand threshold responses to changes in landcover for game and nongame species important to the LSGA would also be useful. Such research would allow managers to further their understanding of the potential impacts of future development. Future research could better address the types of development that are actually occurring. This study assumed that all areas would be built-out at 100% and that all lot sizes were one acre. Both of these assumptions vary greatly in their accuracy based on the zoning class. Similar studies at coarser scales would also be important in understanding broad development patterns and the impacts of these patterns on the structure of forest, grassland, and wetland landcover.

It would be useful to develop a landcover dataset for 1978 using the same methods used to develop the 2006 landcover dataset. This would allow for a more reliable change comparison. The author notes that the change comparison is not essential to the planning process, as currently implemented, however, it is the author's opinion that using landscape metrics to evaluate the alternative scenarios is a good way to incorporate biological information into the planning process.

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