

Forest Land Parcelization in Northern Minnesota: A Multicounty Assessment

by

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Forest Land Parcelization in Northern Minnesota: A Multi-County Assessment

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A Report to the Minnesota Forest Resources Council

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Executive Summary

Parcelization, the subdivision of land into smaller ownership parcels, is a phenomenon affecting private forest land across the nation, including Minnesota. Forest land parcelization has been found to have a marked adverse effect on wildlife habitat, timber availability, water quality, and recreational access. In 2005, the Minnesota Forest Resources Council (MFRC) identified forest parcelization as the single most important policy issue affecting the economic and ecological health of the state's forests.

This report describes an assessment of forest land parcelization across a ten county region of northern Minnesota. Using ArcMap as the primary data management and analysis tool, digital files containing the boundaries of all real estate parcels in the ten county study area were analyzed to characterize parcelization activity across private forested landscapes in northern Minnesota. Regression analysis was subsequently used to identify parcel and landscape characteristics that are associated with a parcelized forest landscape. A new metric for characterizing a parcelized forest landscape is proposed to address the deficiencies associated with using average parcel size to describe forest land parcelization. This new metric uses average parcel size, but takes into account the spatial extent of the private forested landscape as well as the distribution of private forest parcel size across this landscape. The study's large spatial scale makes it unique among forest land parcelization studies.

Much of the current literature on forest land parcelization focuses on the consequences of a decrease in the average forest land parcel size. Several studies have examined policy tools and land tenure, such as tax policy and changing reasons for forest land ownership, for their contribution to this forest land parcelization. Still others have examined temporal aspects of forest land parcelization. To our knowledge, no study has attempted to characterize the extent to which a large forest landscapes have become parcelized.

The study's original objectives were to assess the extent of forest land parcelization activity in a 15-county area of northern Minnesota that has occurred since 1999 or to the extent historical records will allow, identify characteristics of parcelized forest land, isolate patterns of forest land parcelization, and assess the relationship between forest land parcelization and development. The intent was to assess the feasibility of replicating the methodology used in a previous study that examined forest land parcelization trends in Itasca County, MN (Mundell et al. 2007) such that it could be applied across a large geographic area of northern Minnesota. The Mundell et al. study used property tax records to examine changes in ownership of forested parcels from 1999-2006.

After considerable consultation with county assessors and their GIS staff, it was concluded that the methods used by individual counties to code, record, and manage parcel-level records are so dissimilar and access (e.g., availability, format) to their parcel-level records so variable, the Itasca County study could not be replicated across the multicounty study area.

Working with MFRC staff, parcel-level GIS ownership data was obtained from the Minnesota Department of Natural Resources (MN DNR) for 10 of the study's 15 counties. Data availability

dictated that the following ten counties could be included in the analysis: Aitkin, Becker, Beltrami, Cass, Clearwater, Crow Wing, Cook, Koochiching, Lake, and Otter Tail. The data obtained included parcel ownership and attribute data that existed in 2008. Consequently, the study focus and methodology was modified from one that tracks parcelization activity over time to one that describes the extent to which a forested landscape is parcelized. Specifically, the study sought to:

- Identify site and proximity characteristics of private forest land in northern MN.
- Evaluate different ways to measure a parcelized forested landscape.
- Identify factors associated with a parcelized forested landscape.
- Identify forest land parcelization patterns in northern MN.

The primary data used in this study is a GIS-based dataset of parcel ownership records across a ten county region of northern Minnesota. For each parcel record, the database contained information such as the owner name, owner address, the parcel's legal description, and the parcel's physical boundaries. Additional GIS layers used were obtained from the MN DNR (<http://deli.dnr.state.mn.us>). Information regarding population, building and land estimated market values, net effective tax rates, and forest productivity index ratings were obtained through Minnesota Land Economics (<http://www.landeconomics.umn.edu>) which is a site maintained by the Department of Applied Economics, University of Minnesota.

Once the primary data set was obtained from the MN DNR, several steps were required to get the data into the proper format required for the analyses to be carried out. These steps were performed in ArcMap version 9.3.1. One of the main tasks was to dissolve common ownership boundaries to create parcels with contiguous owners. Numerous other steps were used to prepare the data, including adding additional information to each parcel record. Once the data was in useable format, a series of maps and histograms were generated to visually portray the state of parcelization across the ten county study area. Modeling work was done using PASW Statistics 17 software (formally SPSS). All ordinary least squares regressions, diagnostic tests, and scatter plots were run using this software.

All individual parcel-level data was aggregated to the survey township, generally consisting of 36 miles. Consequently, all analyses carried out were at the survey township level. Additionally, all survey township-level analyses were carried out at two levels: (1) one that included all private forest land parcels within the township that were at least one acre; and (2) a second that included only those private forest land parcels within the township at least 20 acres. This two-level analysis was used to test whether there is a large effect from shoreland development, which tends to include small parcels.

A number of maps and graphs were generated for the 10-county study area. They include survey township level detail of the following attributes:

- Number of forested parcels.
- Forested acres.
- Average parcel size.
- Percent of parcels adjacent to public water.
- Percent of parcels adjacent to public road.

- Percent of parcels adjacent to public land.
- Percent of parcels within 1 mile of a town.
- Percent change in population.
- Percent change in building value.
- Percent change in forest land value.
- Average net tax rate.
- Total land/bldg. market value.
- Average forest productivity.

All maps and graphs depict analyses of all private forest land within the township as well as only those private forest land parcels at least 20 acres.

The extensive series of maps and graphs created from the data provided depictions of several important physical and economic dimensions of private forest land across the 10-county study area. From these maps, correlations were visually discerned between average parcel size, amount of forest land, and total parcels per township. Townships with small average parcel sizes most often have the highest number of total parcels. The maps and figures illustrate the difference between the analyses carried out using all private, forested parcels and only the private, forested parcels at least 20 acres is generally very minor for most attributes examined.

Several studies use average parcel size to characterize the extent to which a landscape is parcelized. In this study, a new metric was developed to measure the extent to which a forest landscape is parcelized, taking into consideration specific features of a forest landscape. This metric is derived from the formula:

$$\frac{\text{percent of acres} < \text{a specified acre threshold}}{\text{mean parcel size}} \times \text{total private forest land acres}$$

which simplifies to:

$$\text{percent of acres} < \text{a specified acre threshold} \times \text{number of private forest land parcels}$$

This new metric makes two adjustments to average parcel size to better account for the distributional and spatial variability of a parcelized forest landscape.

Ordinary least squares (OLS) regression was used to test this new proposed metric for describing a parcelized landscape. Eight regression models were developed; four using all private forest land at least one acre in a township and four using only private forest land parcels at least 20 acres within a township. For each group, four separate models were run; one using average parcel size and three using the new parcelization metric as the dependent variable. For the three models incorporating the new parcelization metric, 40-, 60-, and 80-acre thresholds were used.

In all eight regression models, the percent change in population, total estimated market value, and percent of forested acres adjacent to public water are significant and positive predictors of a

parcelized forest landscape. Adjacency to public roads is significant in models analyzing parcels 80 acres or less in size and 60 acres or less in size, but not when a threshold level of 40 acres is used. When parcels less than 20 acres in size are removed from the analysis, adjacency to public waters is no longer a significant predictor of a parcelized landscape. This can most likely be attributed to the large amount of development along lakeshores in northern Minnesota.

Figure 1 illustrates the extent to which townships within the 10-county study area are parcelized, using the proposed new parcelization metric with a 40-acre threshold value.

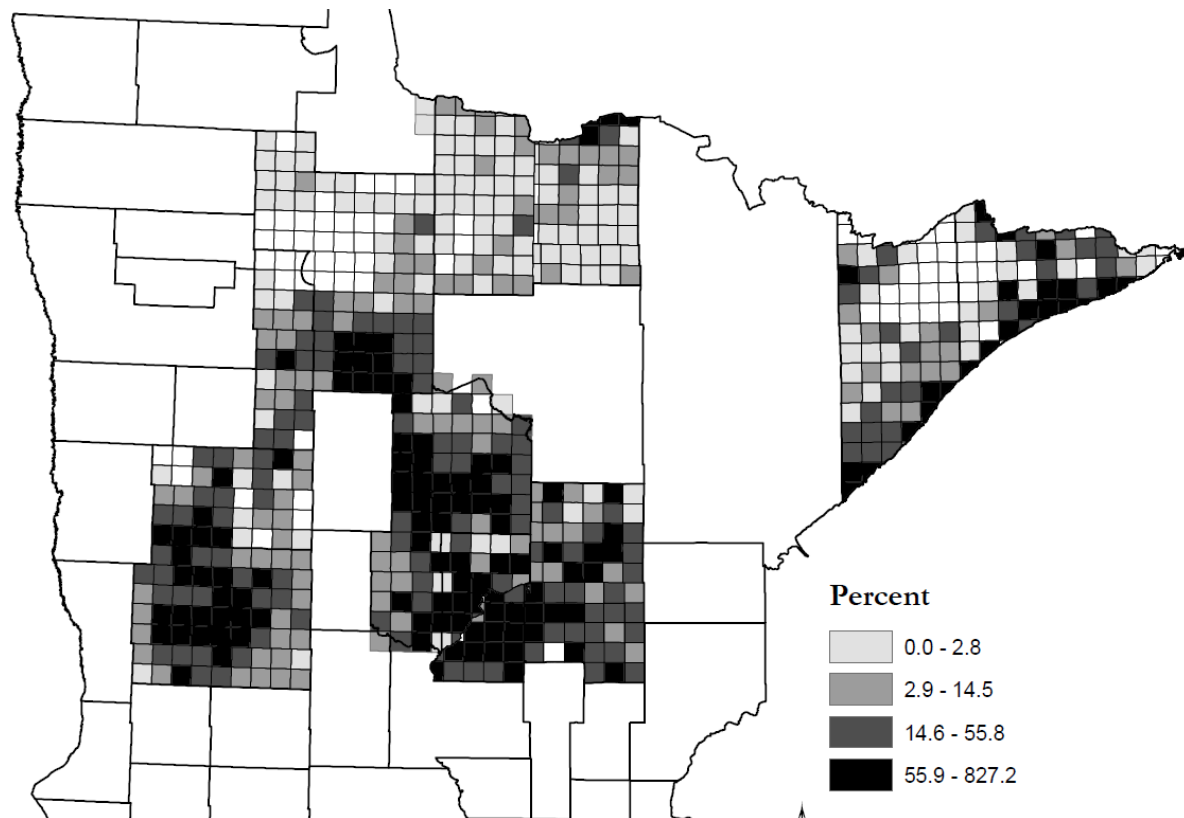


Figure 1. Parcelized forest landscapes (townships) using the new parcelization metric (all forest parcels at least one acre and a 40-acre threshold value). Darker shading indicates a more parcelized landscape.

The results from the analyses illustrate that landscapes experiencing large, positive changes in population tend to be more parcelized. For the data used in this study, this relationship holds regardless of the average parcel size, location of the parcel and amount of forest land in the landscape. Total estimated market value also has a direct and positive relationship to a parcelized landscape; the higher total EMV is for the township, the more parcelized the landscape will be.

This study illustrates the difficulties associated with modeling and assessing parcelization activity across a large forested landscape. It is one of the first to examine parcelization from this point of view; one that looks at the current state of the landscape in an attempt to discern parcelization hotspots. The associations with a parcelized forest landscape identified by this study can be used by

policymakers to developing more targeted strategies for addressing parcelization and its associated impacts. Moreover, the methodology employed by this study provides a framework for evaluating drivers and conditions of a parcelized forest landscape across a large geographic area.

Introduction

Parcelization, the subdivision of land into smaller ownership parcels, is a growing concern for Minnesota's forests. Kilgore and MacKay (2007) define parcelization as the fragmentation of land ownership into smaller ownership blocks. While parcelization may appear to be a natural progression of land development to a higher valued use, it can have several adverse ecological and economic consequences. Forest land parcelization has been found to have a marked adverse effect on wildlife habitat, timber availability, water quality, and recreational access.

Of the nearly 620 million estimated acres of forest land in the United States, approximately 63%, or 393 million acres, is privately owned (Butler and Leatherberry 2004). This means that four out of every ten acres of forest land is owned by nonindustrial private forest owners (NIPF). In the east, roughly 83% of forest land is privately owned, while 67% of forest land in the west is public. This pattern resulted from the way and time each region was originally settled (Butler and Leatherberry 2004). Based on the USDA's Forest Inventory Analysis (FIA) surveys, NIPF ownership in the northeast region of the country has increased from less than 1.7 million owners in the 1970s to more than 2 million owners in 1992. The majority of those NIPF owners own parcels less than 10 acres in size (Brooks 1992).

According to the USDA, between 1982 and 1997, 10 million acres of private forest lands were developed (Germain et al. 2006). In the next few years, NIPF owners are expected to subdivide an additional 5 million acres (Germain et al. 2006). Forest product companies are increasingly divesting their lands. While most of that land will be bought by timber investment management organizations to be managed for timber production, some will be purchased by NIPF owners (Gustafson and Loehle 2006). Across the country, the number of individuals owning forest land is increasing while the average size of NIPF parcels is decreasing.

This report describes an assessment of forest land parcelization across a ten county region of northern Minnesota. Using ArcMap as the primary data management and analysis tool, digital files containing the boundaries of all real estate parcels in the 10-county study area were analyzed to characterize parcelization activity across private forested landscapes in northern Minnesota. Regression analysis was subsequently used to identify parcel and landscape characteristics that are associated with a parcelized forest landscape. A new metric is proposed to address the deficiencies associated with using average parcel size as a measure of a parcelized forest landscape. This new metric uses average parcel size, but takes into account the spatial extent of the private forested landscape and the distribution of private forest parcel size across this landscape. The study's large spatial scale makes it unique among forest land parcelization studies.

Review of Pertinent Literature

Past studies of forest land parcelization have largely focused on four major areas of investigation: parcelization trends over time, parcelization activity across the landscape, impacts of parcelization, and measures of parcelization activity. The following summarizes forest land parcelization studies in each of these four areas.

Temporal Studies

A study of forest land parcelization was carried out using tax records of Itasca County, MN, to examine changes in ownership of forested parcels from 1999-2006. The objective of the Itasca County study was to measure the level of forest parcelization within a defined area over a multiyear period and to relate this parcelization to development activity (Mundell et al. 2007). Minnesota Market Value Files (MVF), which is a database containing a complete record of all real estate in Minnesota, were the primary data used in the study. Within this database, each public and private land parcel is given a parcel identification number (PIN). To track changes in parcelization over time, PINs and deeded acreages were matched in two successive years to track all parcelization activity in the county within this period. This method allowed all parcel splits and combinations to be identified. Parcels were referred to as “parent” and “child” parcels, with the parent being the original parcel that then split into two or more child parcels. The minimum size of parent parcels that were analyzed was 38.5 acres. This allowed for errors in calculation and best fit with Itasca County’s parcel identification scheme.

The Itasca County study found that average parcel size increased by 1.06 acres across the county during the seven year study period, and that an estimated 0.4% of private forest land was parcelized each year. The study found that parcelization activity was fairly constant over the 1999-2006 study period. Of the parcels that split, 11% had the same owner for both the parent and child parcels. The study concluded that forest land parcelization was occurring near water, public land, and cities. Additionally, it found that parcelization was strongly tied to development, with two of every three parcels having buildings erected within six years (Mundell et al. 2007).

A study in New York State tracked the differences in merchantable sawtimber from parcels that remained intact between 1984 and 2005 and those that became parcelized (Germain et al. 2007). The study was done using a multiple analysis of variance procedure and found the only variable with significant differences between the two categories of analysis to be mean percentage of basal area, which is the area of a given section of land that is occupied by the cross-section of tree trunks and stems at their base. The study found that subdivision of land for rural residential development leads to lower basal area and volume of high-value tree species when compared with unorganized parcelization. Other results from the study suggest that as forest parcelization continues, fewer NIPF acres will be available as working forests.

Spatial Studies

A 2009 study by Host and Brown used two spatial analysis categories to measure parcelization: parcelization risk and critical habitat. The parcelization risk analysis used multiple factors to measure a parcels' risk of becoming parcelized—distance to water, wetland density, proportion of public land, land stewardship category, distance to municipality, and distance to major road. All variables were normalized by subtracting the minimum value of a data set from all variables in the set, then dividing the resulting values by the difference between the minimum and maximum value. Mean parcelization risk was calculated for each parcel and mapped based on its risk. The second analysis mapped areas of critical habitat statewide. This was based on positive and negative threats to biodiversity, habitat quality, outdoor recreation, and water quality. Positive features included known occurrences of rare species, biodiversity significance, or abundant game species. Negative drivers included human development, land use, and road density. The study concluded that based on distance to water, roads, and public land, certain parcels are at risk of being subdivided. It also concluded that using critical habitat data did not help identify lands that have a high risk of parcelization.

Donnelly and Evans (2008) developed a digital, spatial dataset of ownership parcels in Indiana based on historical maps from 1928 through 1997. They used a similar parent and child approach that Mundell et al. (2007) used in the Itasca County study to map changes in ownership over time. A transition matrix was used to describe the path of parcelization of parent parcels. The authors found that the most common type of parcel split was where a parent parcel split into two equally sized child parcels. They also concluded that there was not a dominant type of parcelization among parcels that had not split in the previous time interval, the type of parcelization split was partly dependent on the size of the parcel preceding the split, and the aggregation of parcels often precedes a parcelization event.

Drivers

Parcelization studies have attempted to determine what drives parcelization. Mehmood and Zhang (2001) analyzed associations with parcelization according to supply and demand factors. Supply associations include death, taxes, and uncertainty (DeCoster 1998). Conversely, demand associations with parcelization include lifestyle choices and urbanization. The reasons for owning forest land today include a greater interest in aesthetic and amenity values and a decreased emphasis on timber management than in the past (Jones et al. 1995). A study of Virginia private forest landowners found the top three reasons for owning forest land were preserving nature, maintaining scenic beauty, and viewing wildlife (Hodge and Southard 1992). Similarly, interviews with South Carolina forest land owners found that lifestyle enhancement, which includes pride of ownership, stewardship, privacy, recreation/pleasure, and family, was the main reason for forest land ownership (Haymond 1988). Studies of northern Minnesota forest landowners further reinforces that many individuals own forest land for amenity purposes, such as recreation, aesthetics, and water access (Fleury and Blinn 1996; Kilgore et al. 2008). The desire for more open space leads to urbanization. As metropolitan areas expand outwards, suburban fringes

consume a large amount of land—much of which is often forest land (Sampson and DeCoster 2000).

Dennis (1992) evaluated several demographic factors to see if they influenced parcelization in New England forests. He found strong negative correlations between timber harvesting and years of formal education. More highly educated forest landowners were more likely to enlist in voluntary tax programs, even if the programs were restrictive of their timber harvesting. These owners were also more likely to keep their forest land for recreation—but had a higher tendency to post that land as well. Ultimately, this study found that parcel size and owner affluence were significant factors in the behavior of NIPF owners.

A study published in 2009 focused on property taxation and land values as drivers of parcelization (Poudyal and Hodges 2009). They used county-level panel data from counties in Texas and analyzed that data using an Instrumental Variable regression. Results from their study indicated that property tax rates and rural land values had a positive influence on increasing ownership parcelization.

Metrics

Most research on forest land parcelization has characterized “parcelization” according to average parcel size. For example, studies conducted in Wisconsin used a metric called “mean patch size,” which is an area of land with similar land uses (Kennedy and MacFarlane 2009). Mehmood and Zhang (2001) developed a regression model using average parcel size as the dependent variable to evaluate the influence several independent factors have on the average size of a parcel of forest land. The parcelization study in Itasca County, MN, by Mundell et al. (2007) defined parcelization as occurring when a larger parcel split into two or more smaller parcels. A study on logging firms and stumpage prices defined parcelization as parcels becoming smaller and related that to harvest productivity (Rickenbach and Steel 2006). Zhang, Zhang, and Schelhas (2005) related forest utility decreases to an increasing number of NIPF owners. They equated this relationship to parcelization as average parcel size was decreasing.

Reduction in the total acreage of forest land across a landscape most often means reduced opportunities to manage forest land for economic returns (Zhang, Zhang, and Schelhas 2005). This loss of forest land adversely affects several economic sectors that depend on this land base (Sampson and DeCoster 2000). The traditional sources of income from forests, selling timber products, can often be supplemented by leasing hunting lands. However, as parcel size decreases, managing leased lands for recreation can be difficult (Sampson and DeCoster 2000). Subdividing large land parcels with a single owner into smaller parcels with multiple owners significantly reduces the usefulness of management plans dealing with wildlife habitat, gainful agriculture, and timber production (Drzyzga and Brown 1998). Increased development on parcelized forest land can also have negative effects on the surrounding ecosystem. Wildlife habitat and biodiversity are also negatively affected by forest land parcelization.

A study done in Massachusetts using data from 2005 attempted to track parcel ownership (Kittredge et al. 2007). They used parcel tax records and analyzed only undeveloped, forested land. They found that as the study area moved further away from metropolitan Boston, the median ownership size increased from 4.8 to 8.6 acres. The percentage of landowners with larger ownership acreages also increased as the study area moved away from metropolitan cities. The study found the average forest ownership parcel to be 17.9 acres; when parcels less than 10 acres were excluded the average forest ownership parcel size rose to 42.5 acres. The authors also conducted an analysis of parcelization using a proxy variable of the percent of an area's land that is in parcels smaller than 20 acres. They felt that variable was more telling of parcelization than average parcel size.

In summary, the current literature focuses on the consequences of a decrease in the average parcel size of forested land. Myriad factors, such as tax policy and changing reasons for forest land ownership, have been cited as contributing factors to this trend. Previous studies have also examined the temporal aspects of parcelization trends. However, to our knowledge no study has attempted to characterize a landscape as being parcelized based on spatial features of the landscape at a given point in time. The remainder of this report describes my attempt to characterize parcelization across a large forested landscape, as well as better understand those factors that contribute to the parcelization of a forested landscape.

Study Objectives and Approach

The study's original objectives were to:

- Assess the extent of forest land parcelization activity in a multicounty area of northern Minnesota that has occurred since 1999 or to the extent historical records will allow, through 2008.
- Identify characteristics of parcelized forest land.
- Isolate patterns of forest land parcelization.
- Assess the relationship between forest land parcelization and development.

The original intent of this study was to replicate the methodology used in a previous study that examined forest land parcelization trends in Itasca County, MN (Mundell et al. 2007) such that it could be applied across a large geographic area of northern Minnesota. To evaluate the feasibility of replicating this methodology across a multicounty study area, 15 counties in northern Minnesota were contacted to determine if they used similar methods of tax record management as is done in Itasca County. This investigation confirmed that not all counties use Itasca County's methods for recording and managing real estate data and transactions. Further, after considerable consultation with county assessors and their GIS staff, it was concluded that the methods used by individual counties to code, record, and manage parcel-level records are so dissimilar and access (e.g., availability, format) to their parcel-level records so variable, the Itasca County study could not be replicated across the 15 study counties.

Given this finding, the extent and types of spatially explicit, parcel-level real estate data that was available for each county was explored with the intent to assess whether it would be possible to model ownership changes over time using a Geographic Information System (GIS)-based methodology. While some counties had GIS-based parcel-level data, none had these data for multiple time periods. Further, some counties had no digitized parcel data that could be used in a GIS environment.

Working with MFRC staff, we contacted the MN DNR to inquire about the availability of parcel-level data that could be used in the study. From them, we were able to obtain parcel level, GIS ownership data for 10 of the study's 15 counties. While this data allowed the study to proceed, it also presented a unique challenge. Originally, we had planned to conduct a time-series study to assess changes in forest land ownership over time. However, the data we obtained was the parcel ownership data for a single period in time (2008). Consequently, the study focus and methodology was modified from one that tracks parcelization activity over time to one that describes the extent to which a forested landscape is parcelized. Additionally, it was determined the data could be linked to other data (e.g., census data) to identify proximity characteristics (e.g., a parcel's distance to a town) that may be associated with a parcelized forest landscape and forest land parcel size. Given these data limitations, the study objectives were modified to be as follows:

- Identify site and proximity characteristics of private forest land in northern MN.
- Evaluate different ways to measure a parcelized forested landscape.
- Identify factors associated with a parcelized forested landscape.
- Identify forest land parcelization patterns in northern MN.

The nature of this study makes it unique among forest land parcelization research in several important respects. First, nearly all of the previous research has been time-series studies to determine whether or to what extent a landscape becomes parcelized. Our approach involves examining the condition of a private forested landscape at a single point in time. Second, the large spatial scale of my study sets it apart from most previous forest land parcelization studies. We analyzed data across ten counties comprising more than 10,000,000 acres of land using a dataset of over 100,000 parcel ownership records. Another distinction between this and most other parcelization studies is that we attempted to measure and describe a parcelized forest landscape, rather than look at the process of parcelization. Parcelization as a process occurs when a parcel is subdivided into smaller parcels and sold to multiple owners. We were unable to examine the parcel-level data in this manner as it reflects conditions at a single point in time (2008). Rather, our study attempted to identify specific factors that are associated with a parcelized forest landscape.

Study Area

The MFRC identified 15 counties to be examined in the study. These counties were grouped into two tiers; Tier I counties include Aitkin, Cook, Koochiching, Lake and St. Louis. Tier II counties

include Pine, Cass, Crow Wing, Carlton, Beltrami, Hubbard, Clearwater, Becker, and Otter Tail. Per guidance from the MFRC, Tier I counties were to be the primary focus of the study. If a usable study protocol could be developed, then Tier II counties were to be analyzed. Data availability dictated that the following ten counties could be included in the analysis: Aitkin, Becker, Beltrami, Cass, Clearwater, Crow Wing, Cook, Koochiching, Lake, and Otter Tail (see Figure 2). Additional information about the rationale for their selection is outlined in the Data section of this report.

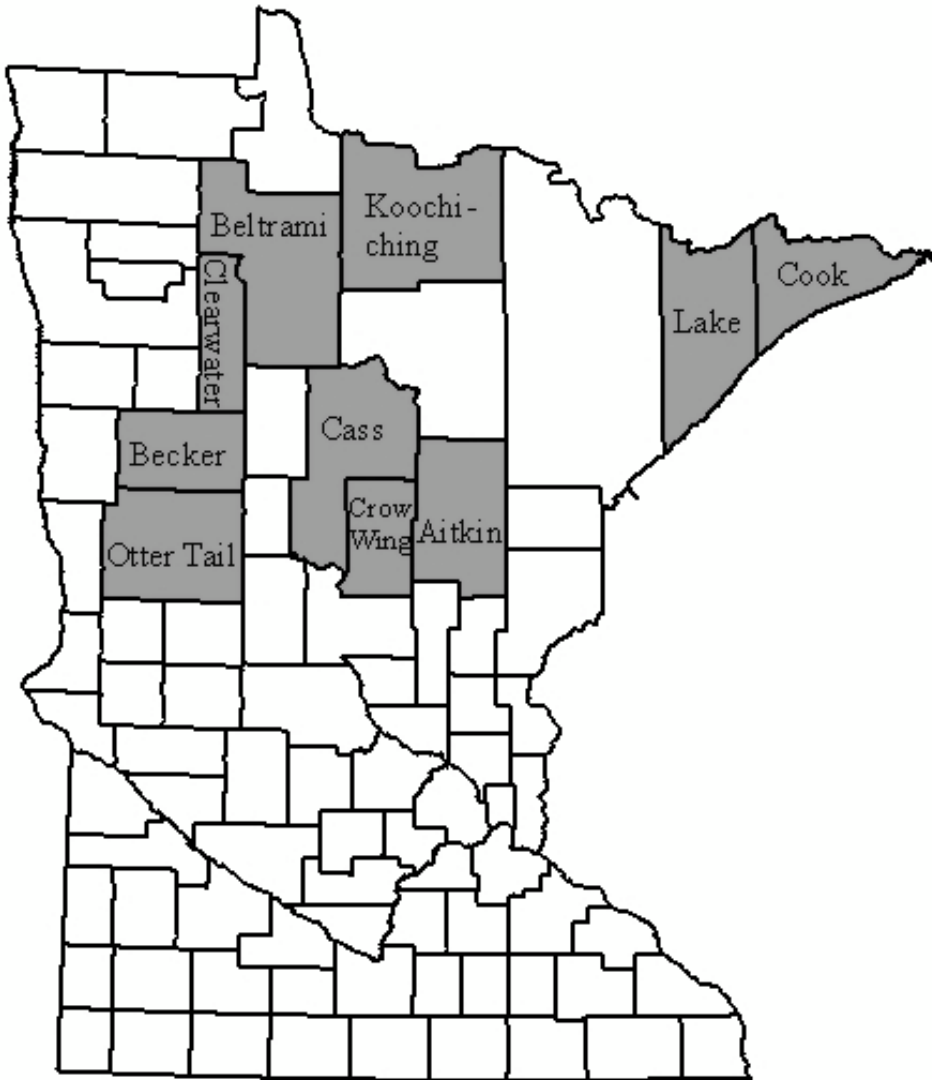


Figure 2. Ten-county study area

The ten counties included in this study vary in land area, physical characteristics, population, and land use. Agriculture is a common land use in the southern and western portion of the study area such as Becker and Otter Tail counties, whereas forest is the predominant land cover in the northern region of the study area. In the northeastern counties such as Lake and Cook, a high

percent of the forest land is publicly owned. Koochiching is the most sparsely populated county and its land cover is predominately forested.

Aitkin County

Aitkin County is located in north central Minnesota. Its population was 15,301 at the 2000 Census and the county spans 1,215,669 acres. Home to more than 300 lakes and 95 miles of the Mississippi River, recreation and tourism are important components of the region's economy. Agriculture and forestry are major economic sectors in the county. There are six incorporated cities in the county ("Aitkin County home" 2009; "Minnesota quickfacts from" 2010).

Becker County

Becker County is located in west central Minnesota and had an estimated 2006 population of approximately 32,000. Total land area is approximately 838,669 acres and contains more than 400 lakes. The county has eight incorporated cities. The main economic sectors in the county include forestry, agriculture, and tourism ("Becker county, Minnesota" 2008; "Minnesota quickfacts from" 2010).

Beltrami County

Beltrami County, located in northern Minnesota, has a total area of 1,604,695 acres with 16,887 acres of lakes and 459,851 acres of public lands. Six cities are incorporated within the county. The 2008 estimated county population was 43,835 ("Beltrami County Minnesota" 2008; "Minnesota quickfacts from" 2010).

Cass County

Cass County is located in central Minnesota and has a land area of 1,291,520 acres. Its 2000 population was 27,150. Twelve cities are incorporated in the county ("Cass County, Minnesota" 2010; "Minnesota quickfacts from" 2010).

Clearwater County

Clearwater County is one of the smaller counties in Minnesota; its total area is 636,800 acres. With an estimated 2008 population of only 8,249 it is also one of the least populous counties in the state. There are six incorporated cities in the county ("Clearwater County, Minnesota" 2007; "Minnesota quickfacts from" 2010).

Cook County

Cook County is located in northeast Minnesota, with its southern border along the north shore of Lake Superior. It is bordered to the north by Canada and to the west by Lake County. The county seat is located in Grand Marais, which is also the county's only incorporated city. The county population is approximately 5,000. Of its roughly 1,000,000 acres of land, 89% is publicly owned ("Cook County, Minnesota" 2009; "Minnesota quickfacts from" 2010).

Crow Wing County

Crow Wing County is located in central Minnesota containing 639,360 acres. Its estimated 2007 county population was 61,390. There are a total of 21 incorporated cities within the county. Crow

Wing County is also home to numerous lakes that provide many recreational opportunities ("Crow Wing County" 2008; "Minnesota quickfacts from" 2010).

Koochiching County

Koochiching County is in northern Minnesota, bordering Canada. Most of its 1,985,510 acres is sparsely populated—there were only 13,281 inhabitants as of 2008. International Falls is the only major city, although there are four other incorporated cities in the county ("Koochiching County, Minnesota" 2010; "Minnesota quickfacts from" 2010).

Lake County

Lake County is located along the North Shore of Lake Superior. As of 2009, an estimated 10,610 people lived in its 2,099 square mile land area. There are three incorporated cities within the county ("Lake County, Minnesota" 2010; "Minnesota quickfacts from" 2010).

Otter Tail County

Otter Tail County is located in west central Minnesota, directly south of Becker County. Its county seat is Fergus Falls and has 19 additional incorporated cities. The estimated 2008 population was 56,786. Of its 1,428,480 acres of area, 173,851 acres are occupied by lakes. There are more than 1,000 lakes in the county, including the large Otter Tail Lake ("Otter Tail County" 2010; "Minnesota quickfacts from" 2010).

Data

The primary data used in this study is a GIS-based dataset of parcel ownership records across a 10-county region of northern Minnesota. This dataset contained parcel data for 10 of the 15 counties originally identified by the MFRC for this study. After consultation with MFRC staff, it was decided to limit the analysis to the ten counties for which GIS-based parcel records were available. The parcel data for the ten counties reflect 2008 ownership conditions. For each parcel record, the database contained information such as the owner name, owner address, the parcel's legal description, and the parcel's physical boundaries. Additional GIS layers used were obtained from the MN DNR (<http://deli.dnr.state.mn.us>). Information regarding population, building and land estimated market values, net effective tax rates, and forest productivity index ratings were obtained through Minnesota Land Economics (<http://www.landeconomics.umn.edu>) which is a site maintained by the Department of Applied Economics, University of Minnesota.

Methods

Once the primary data set containing individual parcel attributes was obtained from the MN DNR, several steps were required to get the data into the proper format required for the analyses to be carried out. These steps were performed in ArcMap version 9.3.1. The initial task was to properly identify the size and boundaries of individual land holdings. Initial inspection of the data indicated that some counties record contiguous parcels owned by the same individual as separate

parcel records. For example, an individual owning 200 contiguous acres of forest land would have five individual 40-acre parcel records. Consequently, prior to conducting any analysis, parcel boundaries between contiguous parcels with the same owner needed to be eliminated. This was achieved through the use of the dissolve function in ArcView, dissolving on owner names. This process erased adjacent property lines between parcels that have the same owner and produced a dataset with a smaller number of parcels. Once this step was complete, the file then had to be changed from a single part file to a multipart file so that parcels owned by the same person could be recorded as separate parcel records.

Public lands were then removed from the data set. This was done using the select by attribute function in ArcView. Once identified, all public lands were manually removed from the dataset and saved as their own shapefile for later use. Public lands were removed from our parcel database, as this study focused on the fragmentation of private forest land ownership.

The Department of Revenue Identification Number (DORID) file was then added and used to crop the boundaries of the parcel shapefile into individual counties. This step was done in order to identify each city or town by code. That code consists of a unique county code, followed by a unique city code. For example, the DORID number 2030 refers to one city (coded 30) in Aitkin County (coded 20), while the number 2050 refers to another city (coded 50) in Aitkin County. The DORID file was also used to remove all parcels located within city boundaries. Parcels within cities were removed because of the uncertainty whether these parcels were truly “forested,” meaning they were over one acre in size and contained at least 50% forest cover. To remove these parcels, the attribute “cities” was selected in the DORID file and exported as a new shapefile. This newly created cities shapefile was then spatially joined to the parcel file. The “select by attributes” function was then used to select all parcels within a city boundary, which were subsequently deleted from the dataset.

Next, shapefiles from the MN DNR Data Deli website were then loaded into the ArcView file. These layers include Public Land Survey System (PLSS) township boundaries, Minnesota lakes, ponds, and rivers, and the DOT master road map. The PLSS township file was for the whole state; consequently it was clipped using the previously created county DORID outline. During the clipping process, negligent “slivers” of townships are created and must be removed in order for the file to function properly. These slivers are created because of the syntax used by ArcView when clipping one shapefile based on another shapefile. If they are left in the shapefile, they cause functions to not work properly and to give false results. In the PLSS township file, total acreage was calculated for each township in the attribute table. Any “township” with negligible area (less than one acre) was then deleted from the township shapefile. The PLSS township file was added because individual parcel attributes were aggregated to the township level to facilitate analysis and characterization across a large forested landscape.

A forested parcel consisted of all parcels containing at least 50% forest land cover. Using data from the National Land Cover Database, a raster file was created which converted more than 100 different land use categories into five at the 30 x 30 meter raster scale. The National Land Cover

Database is a GIS created by the US Geological Survey that classifies the land cover of the United States. Other federal agencies also collaborate to maintain and update the GIS database, including the US Environmental Protection Agency, the National Oceanic and Atmospheric Association, and the USDA-Forest Service. A raster file stores information in a rectangular grid. Each cell has information that is used to make up the whole file or image. For example, a raster file may simply be a 4 x 4 grid, with each cell either being designated as “on” or “off.” The five land use categories into which each private land parcel was reclassified were: (1) annual crops/orchard; (2) grass; (3) trees; (4) water/wetlands; and (5) urban/other. Once this classification was complete, a separate binary indicator was used to classify the land into forest or nonforest using the Spatial Analyst tool, which totals the associated values within each raster cell. In order to interpret this data, all assigned values needed to be reclassified as either zero or one.

The spatial analyst tool within ArcView was utilized to calculate a zonal statistics table. The zonal statistics table creates a data table with a variety of useful metrics regarding the raster data it is analyzing, including mean, median, mode, and count. The zonal statistics table was subsequently joined to the file containing all of the individual parcel records. Two metrics in the zonal statistics table were used to determine if a parcel was forested. The first, the sum statistic, sums all the “1” values in the forest/nonforest column for each parcel. The second statistic, count, sums all raster squares for the same parcel. By dividing the sum statistic by the count statistic, a percentage of forested land for each parcel is created. All parcels whose sum/count value was less than 0.51 were deleted from the data set. The resulting data set was a file containing all private forest land parcels.

Certain counties’ designate “undivided ownership interests” when classifying taxable property. Undivided ownership interest occurs when two or more individuals each have equal ownership in a single parcel. In several counties, each owner of an undivided interest in land is recorded as a separate parcel record. This resulted in a situation in which the same parcel is listed multiple times in the data set—one for each owner of the undivided interest. The zonal statistics function does not work properly when undivided interests exist. To remove the multiple listings, a manual inspection of acreages of the parcels was done. When a specific acreage was repeated multiple times, the parcel records were checked to see if the same parcel was listed for each undivided interest. When this situation was encountered, all but one of the entries was deleted. Zonal statistics were subsequently run on the resulting file to identify the private forested parcels in each county.

The new parcel file was then spatially joined with the PLSS township file (a file containing the boundaries of each township) to facilitate analysis at the township level. The resulting parcel/PLSS township file was spatially joined with the DORID file to associate each PLSS township with a civil township. This was done because much of the data used was based on civil townships, which are different than PLSS townships in that civil townships are jurisdictional

boundaries and PLSS townships were established through the National Land Survey. The final joined file was exported as a new file.

The National Land Cover Database data was also used to calculate the percent of private forest land as compared to all land for each township. To do so, the National Land Cover Database file was reclassified into “land” and “water” categories. Much like the determination of forested land, the zonal statistics function was used to determine the percent area of each township that was land. This percent was then multiplied by the total township acreage (land and water) to determine the township’s total land acres. That figure was then used to calculate the percent of private forest land per township. This calculation was important, as we wanted to limit our analysis only to land cover.

Based on their prevalence in the literature, a number of proximity variables thought to be helpful in explaining a parcelized landscape were identified. The variables that were most often mentioned in the literature, however, were not all replicable given the data or the method of analysis employed. Variables that could not be represented spatially, for example a landowner’s need to sell their land to pay medical bills, were not included in this analysis. The proximity variables selected as having possible associations of parcelization included adjacency to: water⁴, public land, roads, and cities. Estimating these attributes for each private forest land parcel was accomplished using a binary indicator column in the attribute table. The “select by location” function in ArcView was used to determine each adjacency feature. For example, if a parcel was adjacent to public waters, it received a “1” value in the corresponding column.

Identifying how population and development affected the parcelized condition of a forested landscape was also of interest. While a variable depicting population change within the township already existed, estimated building market value within the township was used as a proxy variable to represent development. This value is further discussed in the Maps and Descriptions section.

The preceding file was then joined to a five other data tables: population data, timber value data, property tax data, crop and forest productivity data, and agricultural production data. The population data was obtained from the Minnesota Department of Revenue’s (DOR) annual Abstract of Tax Lists. This is a database compiled by the DOR from tax data each county is required to submit, including population information and how much was paid in taxes for various categories of taxation. This large database was then aggregated using Pivot Tables in Microsoft Excel and brought back into ArcMap. Maps and histograms were then created from this database in ArcMap and Excel. The database was also used for modeling the associations of parcelization.

Modeling work was done using PASW Statistics 17 software (formally SPSS). All ordinary least squares regressions, diagnostic tests, and scatter plots were run using this software. Data to be used in the modeling work was selected by choosing only those records with at least 10% forest cover and less than 100% forest cover. It was felt that a parcel with less than 10% forest cover

⁴ As defined by Minnesota Statutes section 103G.005, subdivision 15.

could not be managed as forest land and therefore should not be included in the forested category. Because of calculating errors when using ArcMap, a few townships were recorded as having more than 100% forest cover; these were not included in the modeling to maintain accuracy.

Each township's private forest land data was defined in two ways. The first included all private, forested parcels with no minimum individual parcel acreage limit. The second definition included only those private, forested parcels that were greater than 20 acres in size. The parcels less than 20 acres in size were eliminated from the second screen to account for the pattern of development around lakeshore, where parcels tend to be very small. By removing only parcels less than 20 acres in size instead of parcels touching the boundary of a lake, large parcels that may have minimal shoreline were retained in both screens. Those larger parcels play an important role in telling the story of parcelization. Forest management plans are more feasible on larger forest parcels. Larger forest parcels also provide more area for recreation and wildlife habitat.

Maps and Descriptions

This study was conducted over a 10-county region in northern Minnesota. Any township depicted on a map that is clear is a township for which data was not available for the variable being analyzed. The shading for all townships for which data existed is broken into quartiles. For each variable that is mapped, the two definitions of private forest land were analyzed. The first includes all private, forested parcels regardless of acreage. The second includes only private, forested parcels greater than 20 acres in size.

A standard PLSS township is made up of 36 sections and covers 36 square miles of area, or approximately 23,040 acres. Individual townships in the study region range from roughly 400 acres to 25,000 acres. The variability in township area is due to the way the original public land survey was carried out. Townships would often end at major terrain events, such as a river or bluff. Townships are also truncated at county boundary lines. In this study, 555 townships are contained within the 10-county study area. Figure 3 illustrates a group of standard townships whose sizes are approximately six square miles. Figure 4 shows smaller townships along the border between counties. Figure 5 illustrates irregular townships bordering a river.

Figure 6 illustrates the total forested acres per township across the ten county study region. A majority of townships contain between 3,700 to 24,000 forested acres. Southern counties tend to have smaller amounts of private forest land due to the large amount of land that is agricultural. Cook and Lake counties also have several townships containing only a small amount of private forest land, but for a different reason. In these counties, while forest is the predominant land use, most of the forest land is publicly owned.

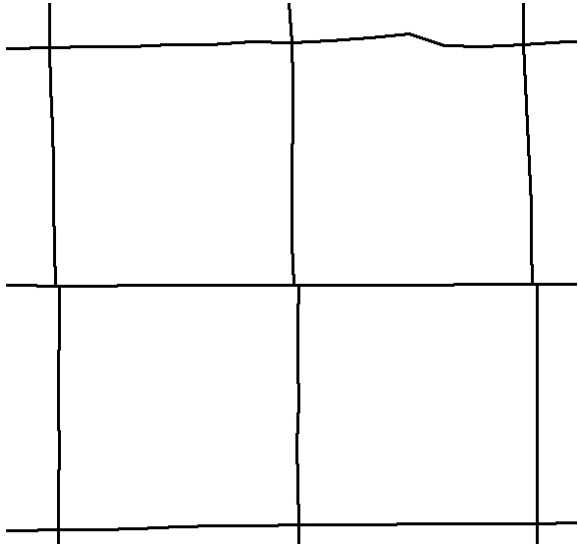


Figure 3. Standard township boundaries.

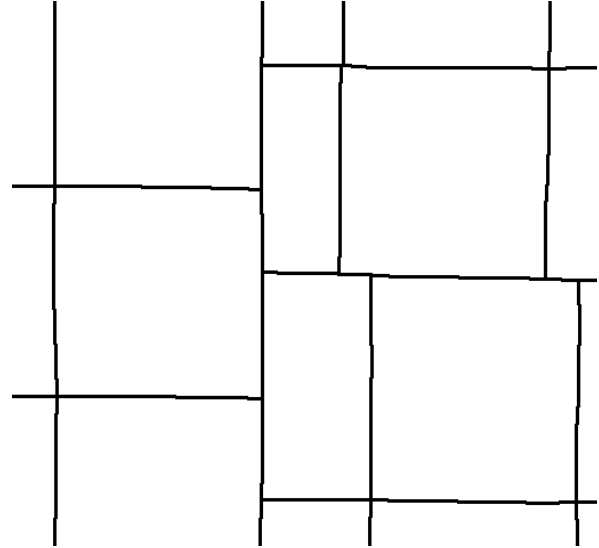


Figure 4. Irregular township boundaries.

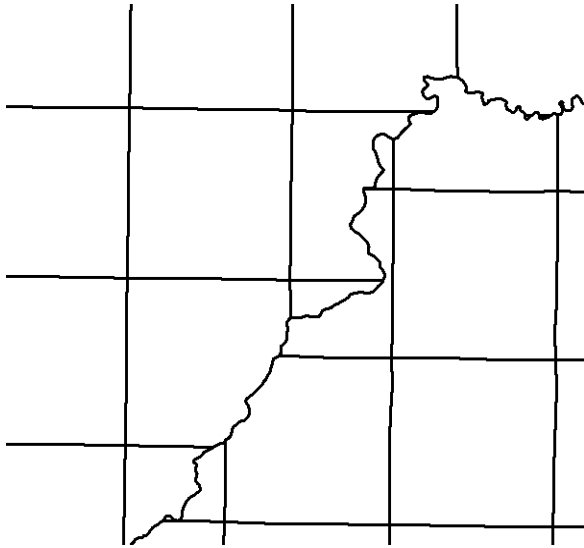


Figure 5. Boundaries between adjacent townships.

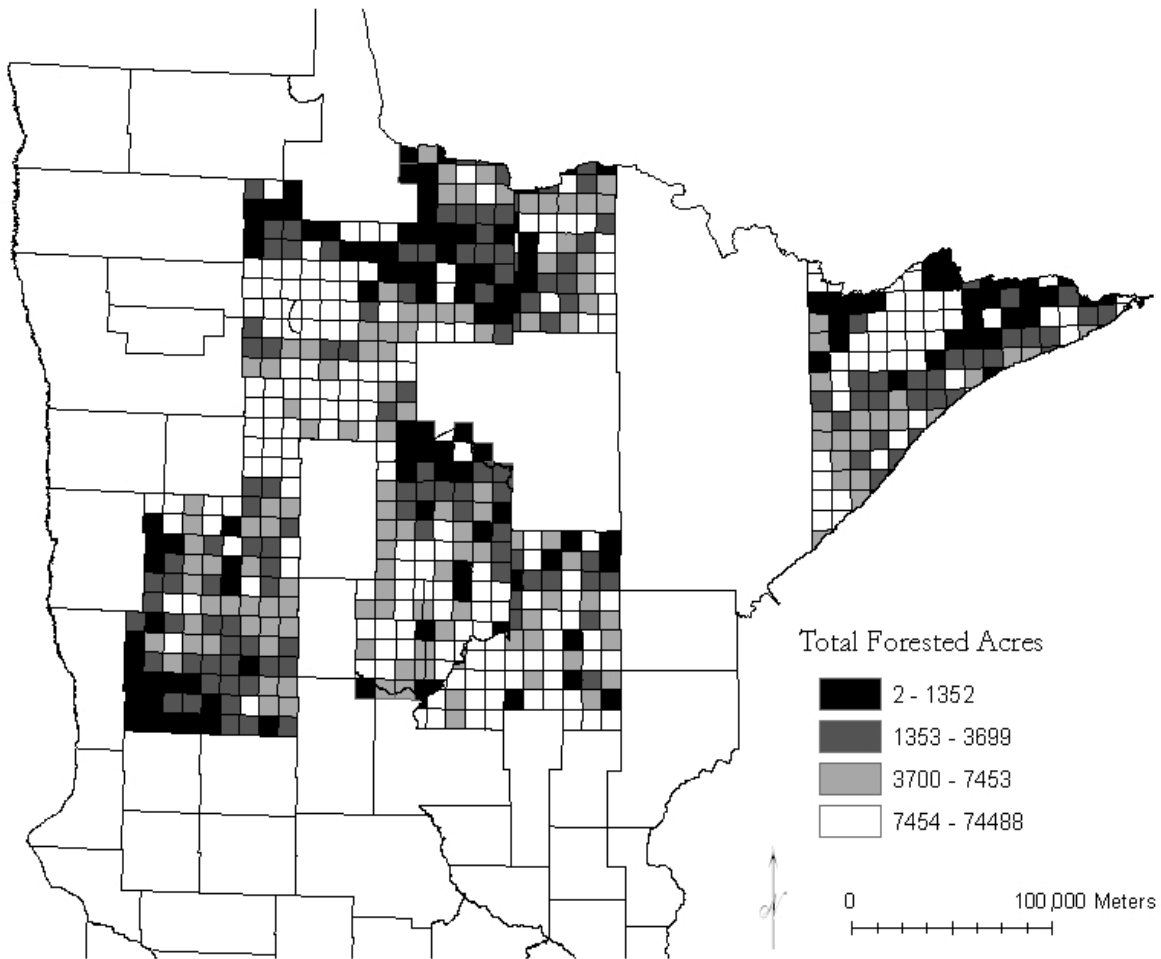


Figure 6. Total forested acres per township.

Figure 7 shows the total forested acres per township for all forested parcels greater than 20 acres in size. As expected, there is a noticeable decrease in total forested acres per township across the entire study area as compared to Figure 6 which includes all forested parcels. This finding indicates a large amount of forest land is in parcels less than 20 acres. The average amount of forested land remains high in Becker, Clearwater and southern Lake counties, as well as in parts of Koochiching County.

Correlations can be seen between average parcel size and the total forested acres in a township. If a township has a large amount of forested acres available for private ownership, there is greater opportunity for larger parcels to exist. Alternatively, when a township has few forested acres, parcel size tends to be smaller.

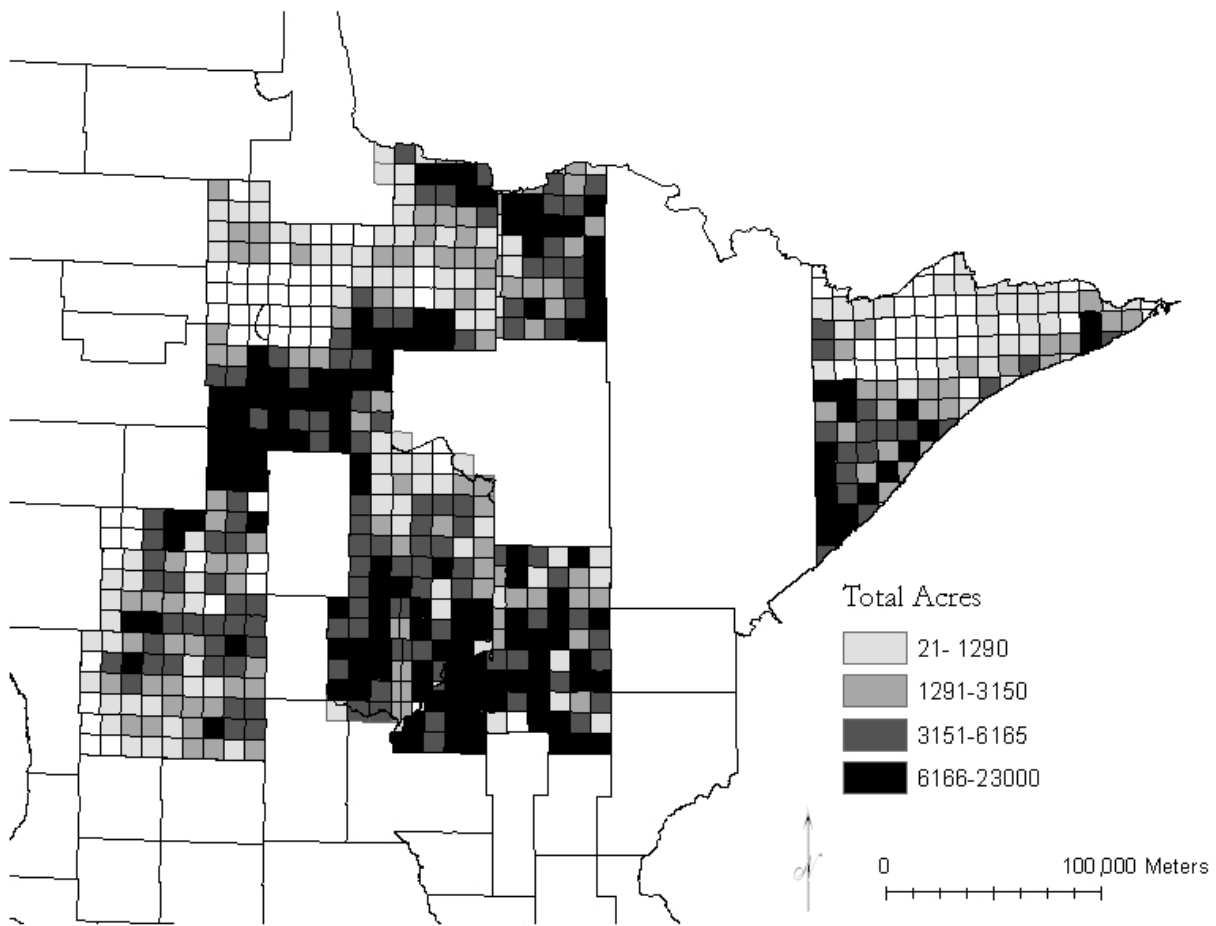


Figure 7. Total forested acres in parcels more than 20 acres per township.

Figures 8 and 9 correspond to the maps depicting total forested acres per township (Figures 6 and 7). These graphs are fairly similar in that the largest frequency of townships contain between 1 and 500 acres of forest land. The number of townships in each frequency bin following the 1 to 500 acres category gradually decreases.

Figure 10 depicts the average parcel size of all forested parcels per township across the 10-county study region. A forested parcel is defined as a parcel that has at least 50% of its land classified as forest, based on the study's reclassification of the National Land Cover Database. By looking at the map, one can see that average parcel size is generally higher in the northern part of the study area. The southern counties, such as Otter Tail and Becker, have more agricultural land rather than forest land, which could contribute to the smaller average parcel size. The southern areas also tend to have more population and development, leading to smaller parcel sizes. The average parcel size in Cook County is smaller than might be expected, given the county's extensive area of forest cover. This can be attributed to the fact that a majority of the forest land in Cook County is public land.

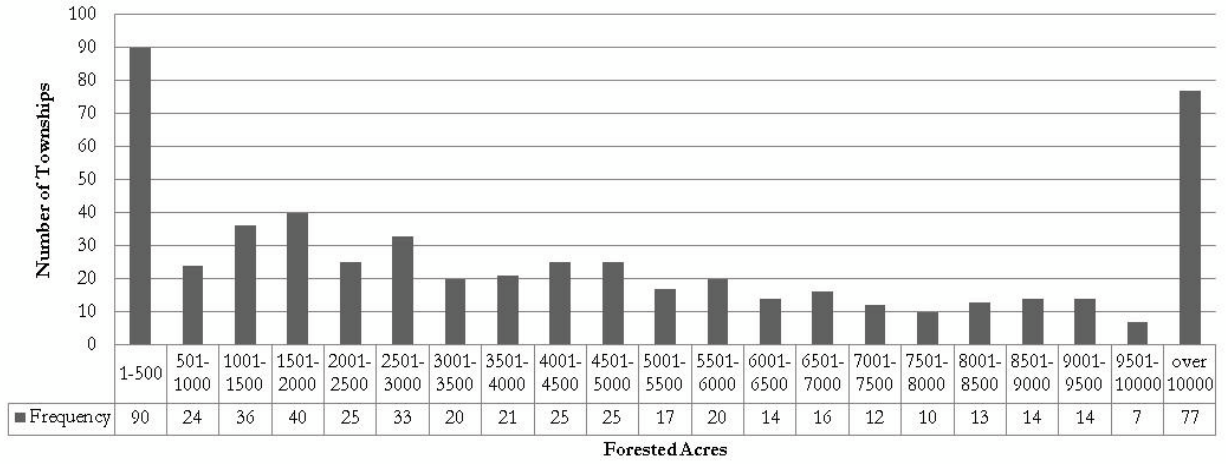


Figure 8. Frequency distribution of total forested acres per township for forested parcels.

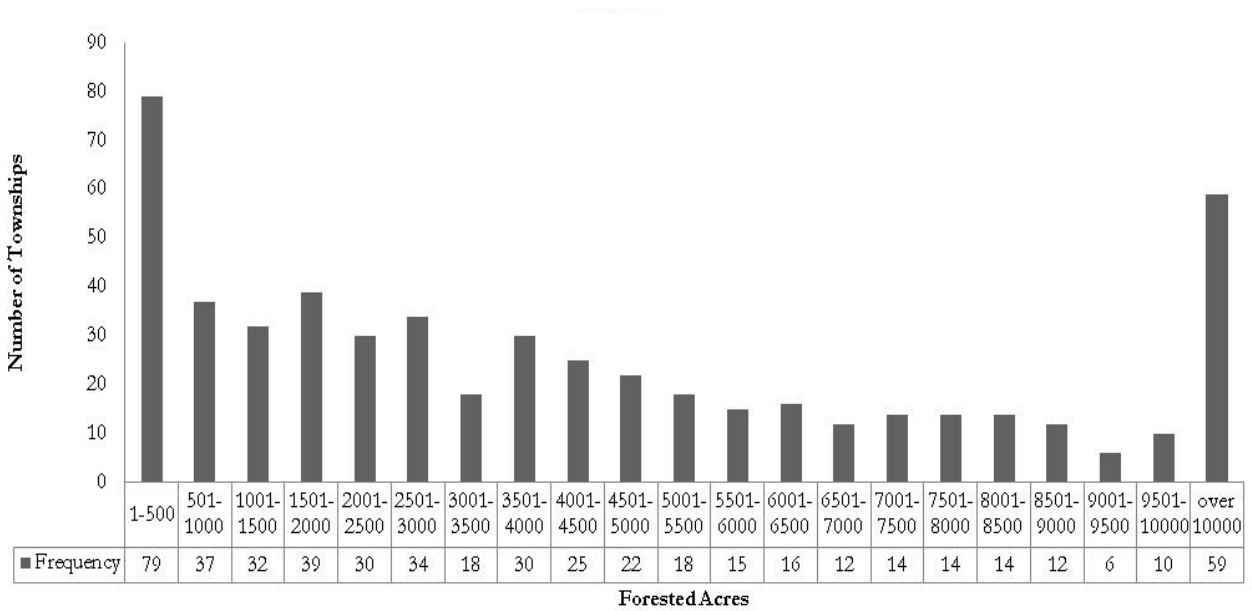


Figure 9. Frequency distribution of total forested acres per township for forested parcels more than 20 acres.

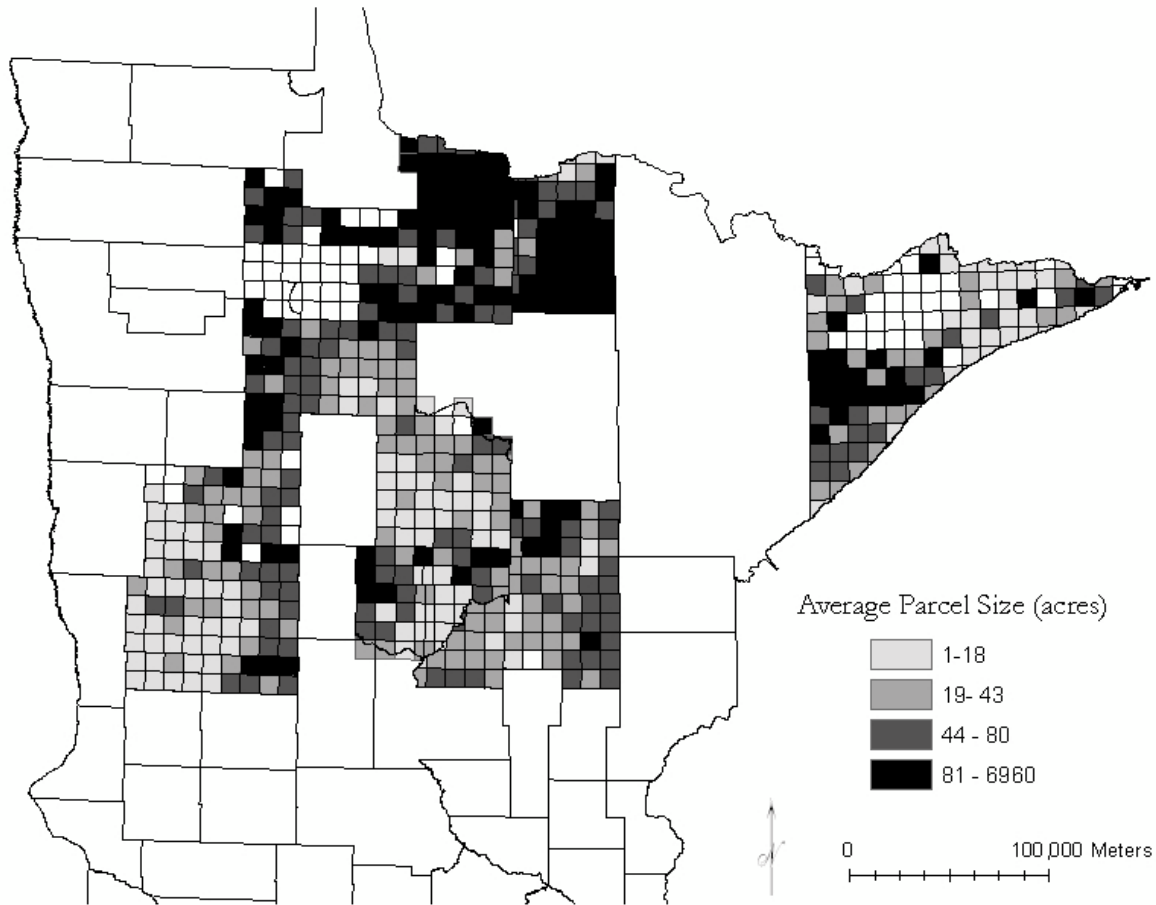


Figure 10. Average forested parcel size per township.

Figure 11 depicts the average parcel size for all forested parcels greater than 20 acres per township. The patterns between this and Figure 8 are essentially identical; parcel size tends to be the largest in the northern portion of the study area. The southern counties have a slightly higher average parcel size with the parcels less than 20 acres removed. This was expected; when calculating average parcel size the average will increase when the smallest parcels are removed.

Figure 12 illustrates the frequency of townships' average parcel size. It shows that the majority of townships have an average parcel size between 1 to 40 acres. Out of 554 townships included in this category, only 92 have an average parcel size greater than 100 acres, which represents only 16% of the study area's 555 townships.

Figure 13 illustrates the frequency distribution of the average parcel size for forested parcels greater than 20 acres per township. Again, the majority of townships have an average parcel size less than 100 acres; more specifically 362 out of 536 townships or approximately 68%. The total townships in this screen is not 555, as some townships do not have an average parcel size of 20 or

more acres; consequently those townships are not included in this analysis. By comparing the preceding two histograms, one can see the resemblance in their shapes.

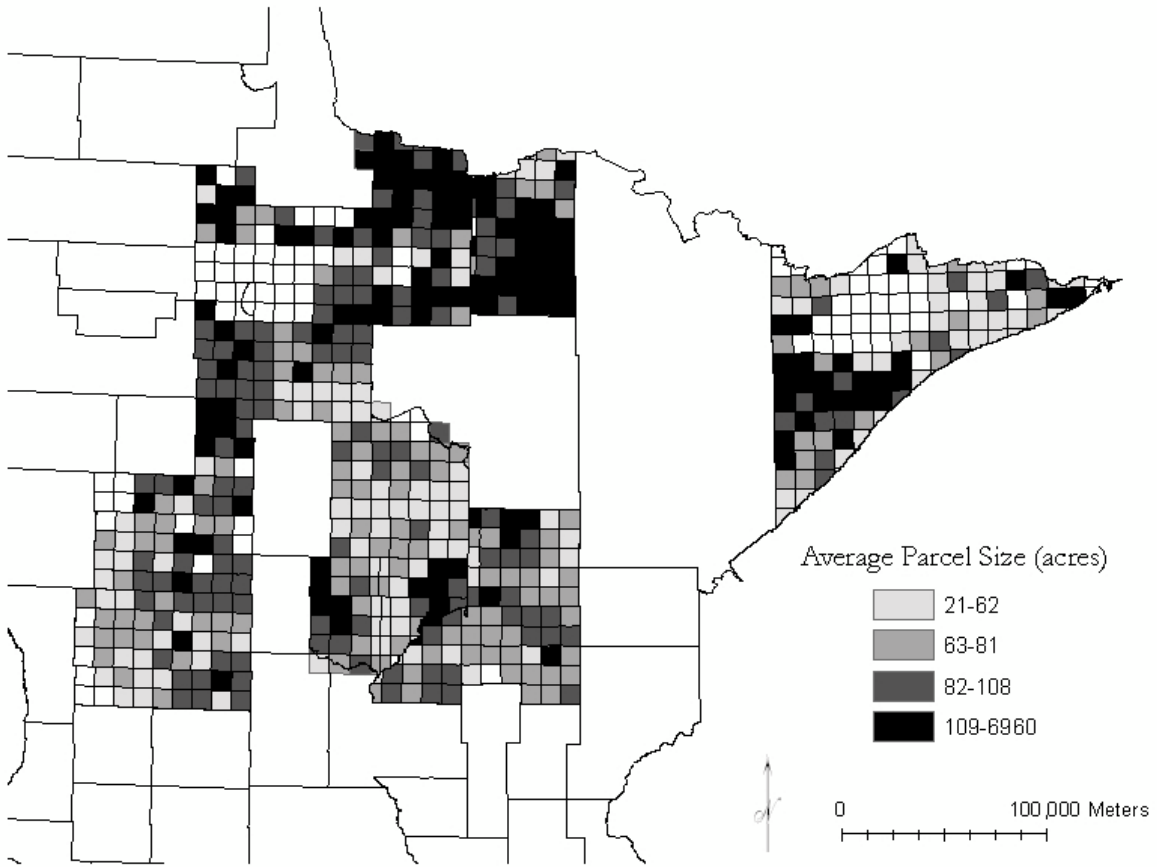


Figure 11. Average parcel size per township in parcels more than 20 acres.

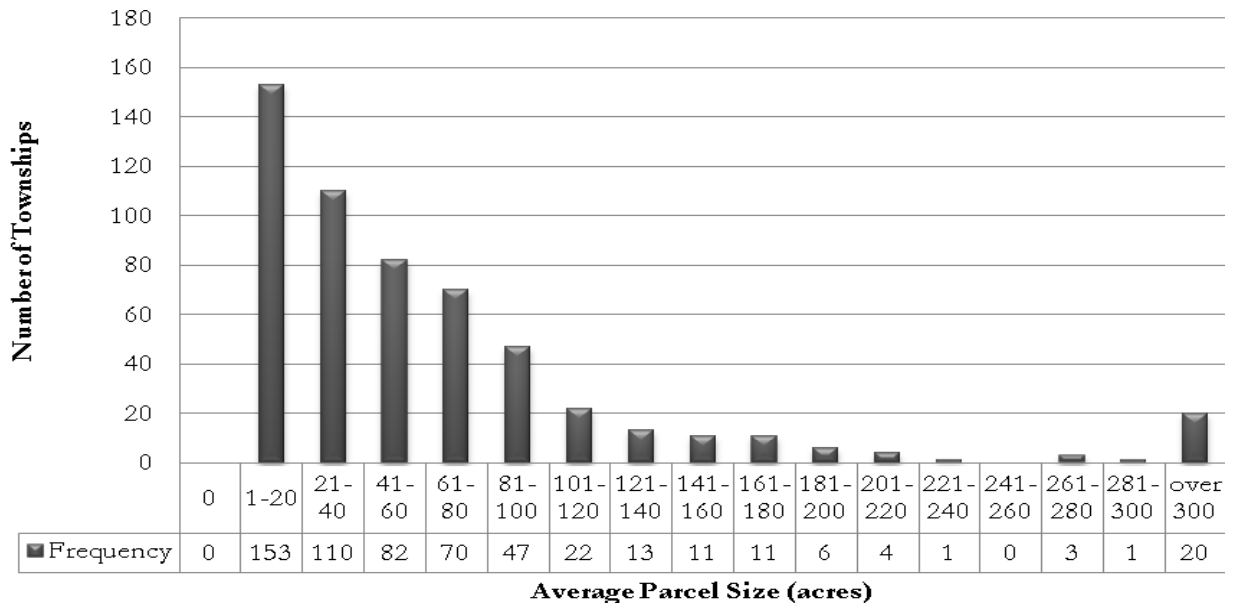


Figure 12. Frequency distribution of average forest parcel size per township.

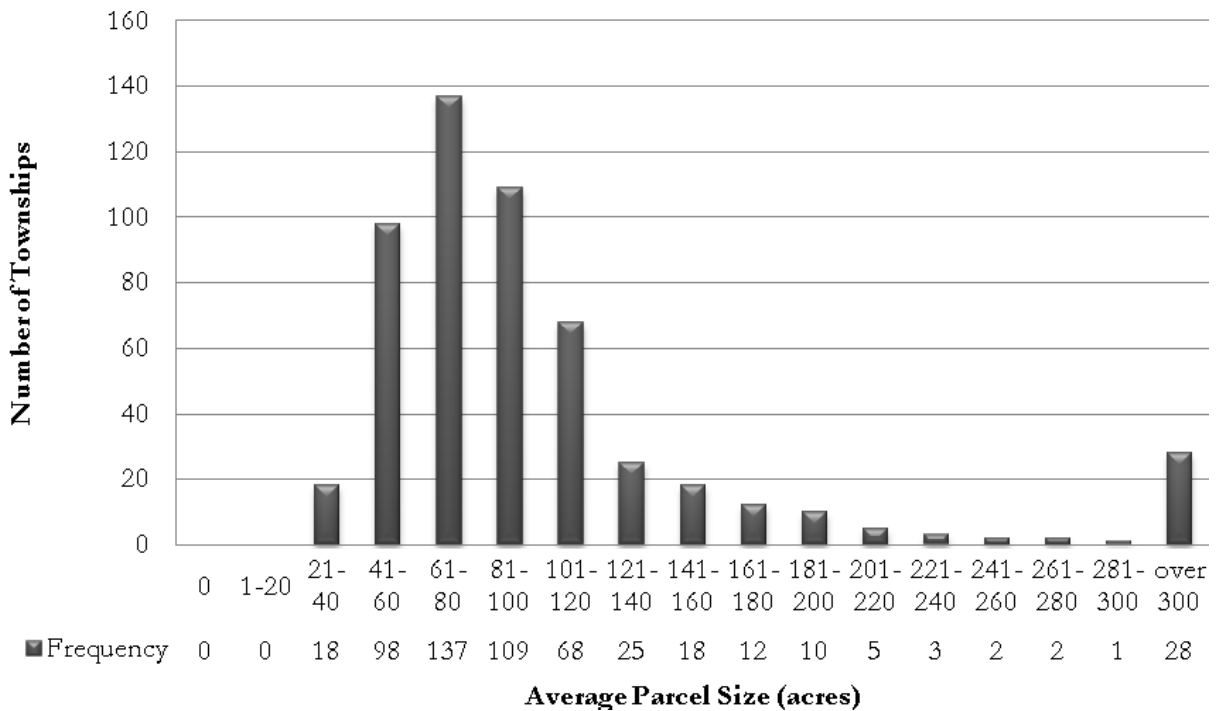


Figure 13. Frequency distribution of average parcel size per township for forested parcels more than 20 acres.

Figure 14 shows the number of forested parcels per township for the ten county study region. The total number of parcels is highest in the southern counties and lowest in the northern part of the study area. Crow Wing County has a very high number of forested parcels per township. This may be due, in part, to the large number of water front lots and their associated small acreage per parcel. Total parcel numbers are also high in Cook and Lake Counties, especially along the boundary of Lake Superior, but then the number of forested parcels quickly decreases as the distance from lakeshore increases.

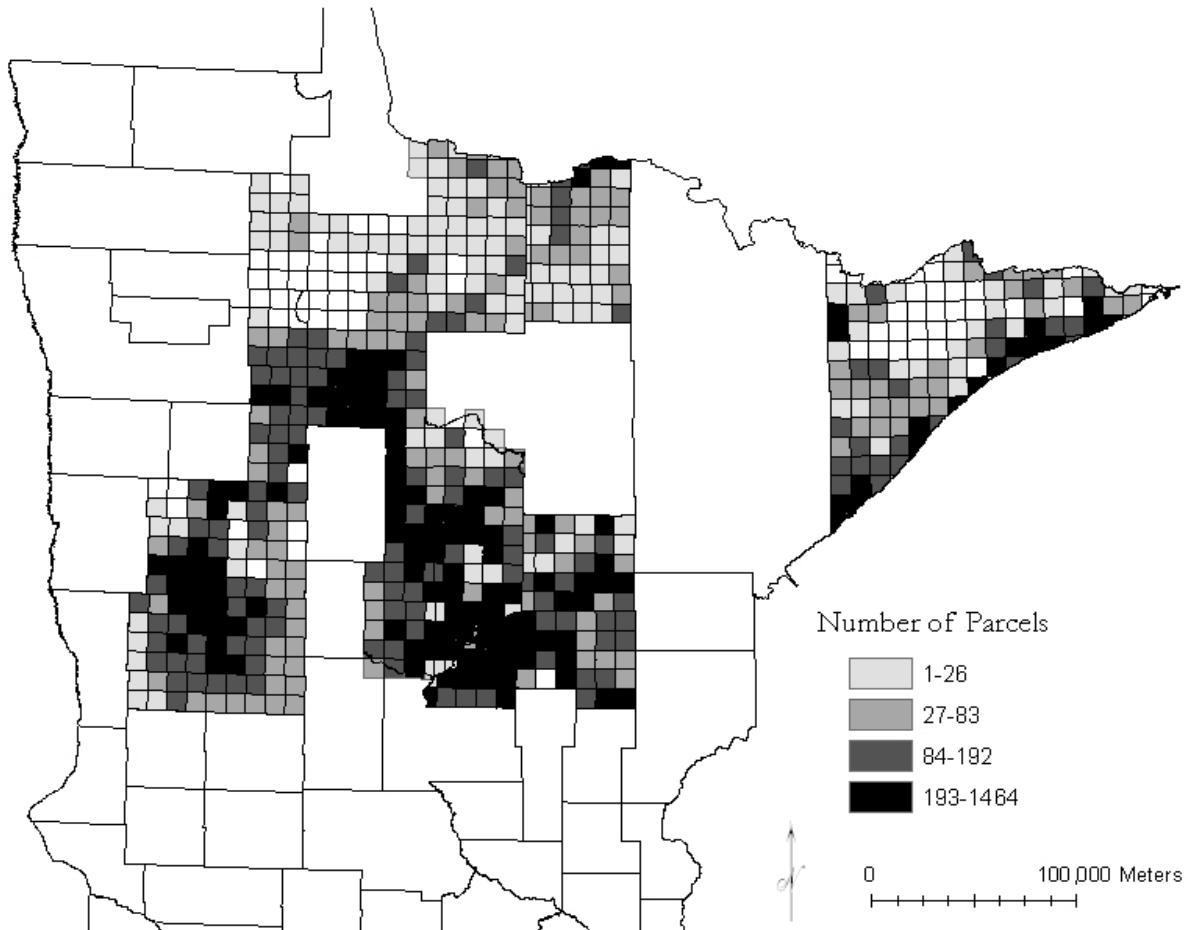


Figure 14. Number of forested parcels per township.

Figure 15 illustrates the number of forested parcels of 20 or more acres in size in each township. The pattern of southern counties having a larger total number of parcels per township than northern counties is similar to the patterns seen in Figure 14 (where all forest land parcels greater than one acre are included). Similarly, the number of forest land parcels is still high in those Cook and Lake county townships that border Lake Superior.

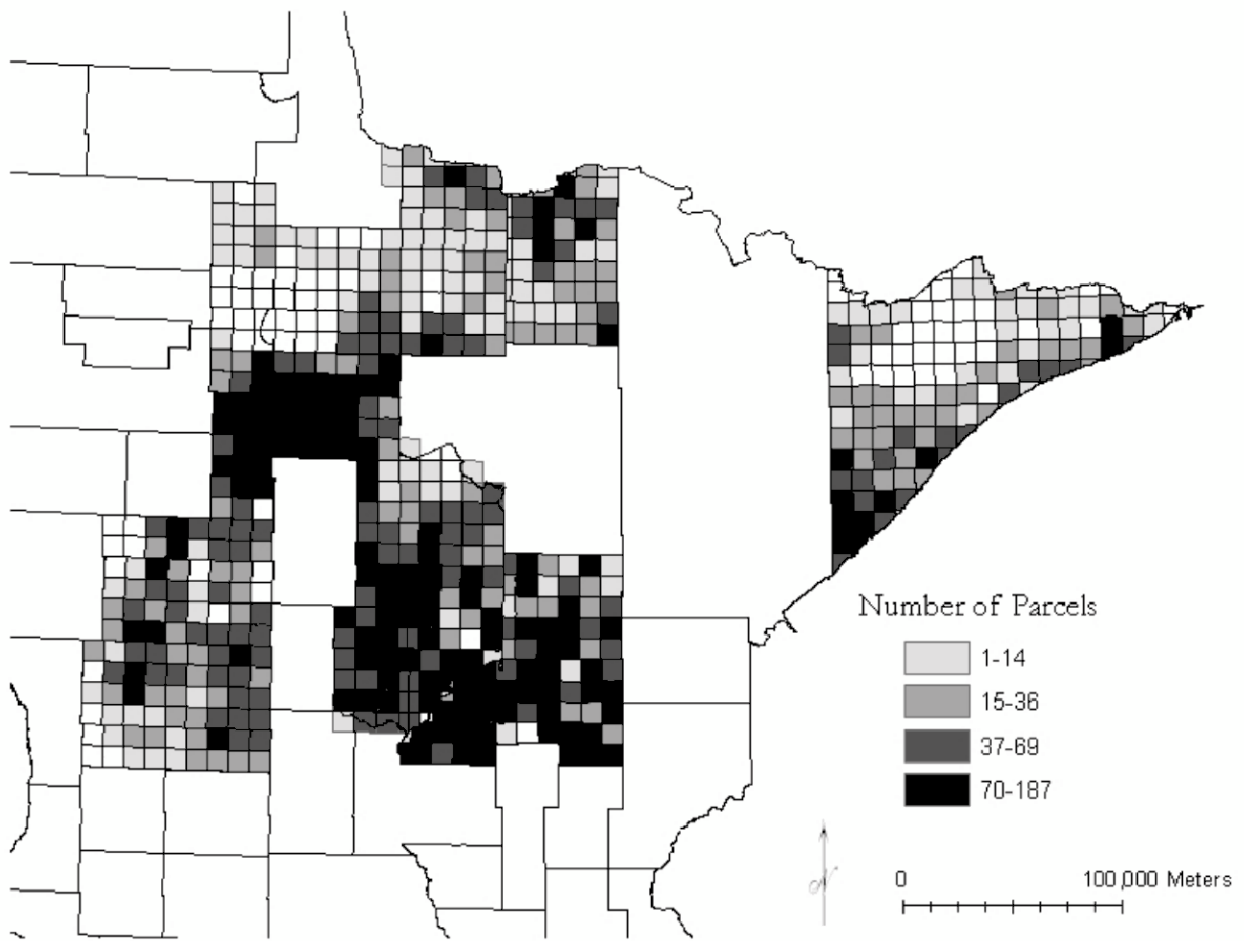


Figure 15. Number of forested parcels more than 20 acres per township.

Across the study area, the total number of parcels per township is inversely correlated to average parcel size. When a township has a large number of parcels, the average parcel size tends to be small. This suggests a township containing small amount of private forest land and a large number of parcels tends to have the smallest average forested parcel size. Areas of the maps showing total forested acres and total number of forested parcels to pay particular attention to are those that are the darkest. If a township has a large amount of forest land and a large number of forest parcels this may indicate the presence of a parcelized landscape.

Figure 16 shows the number of forested parcels per township in a histogram format. The majority of townships have between 1 to 100 forested parcels.

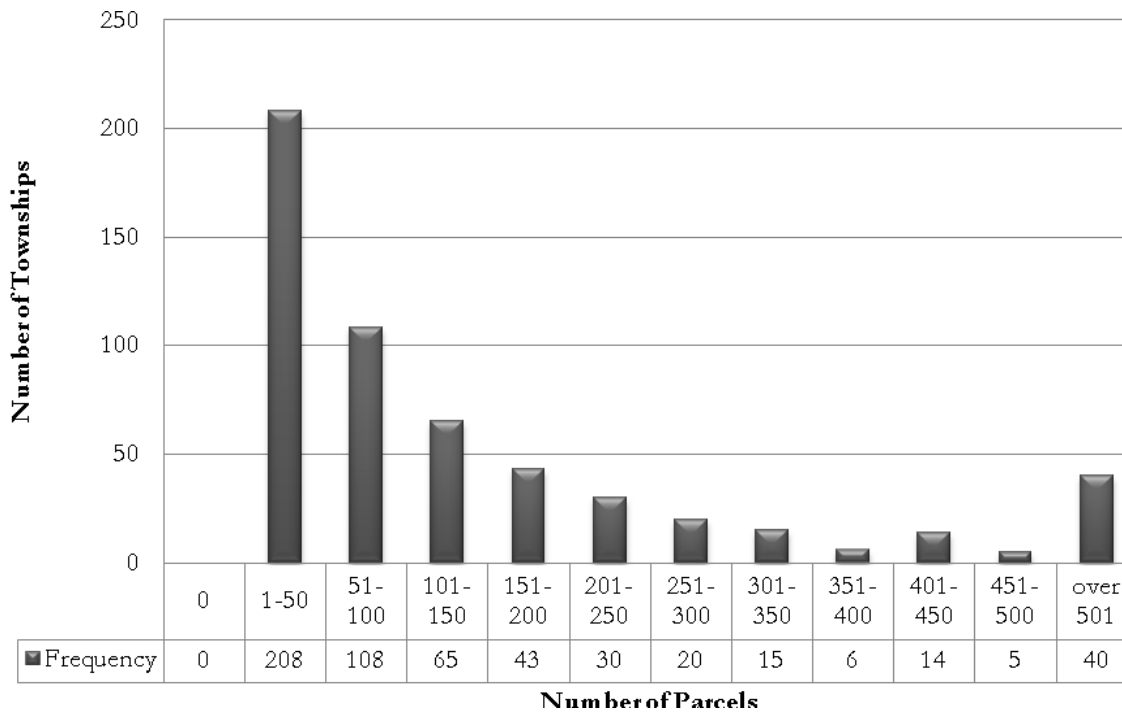


Figure 16. Frequency distribution of number of forested parcels per township.

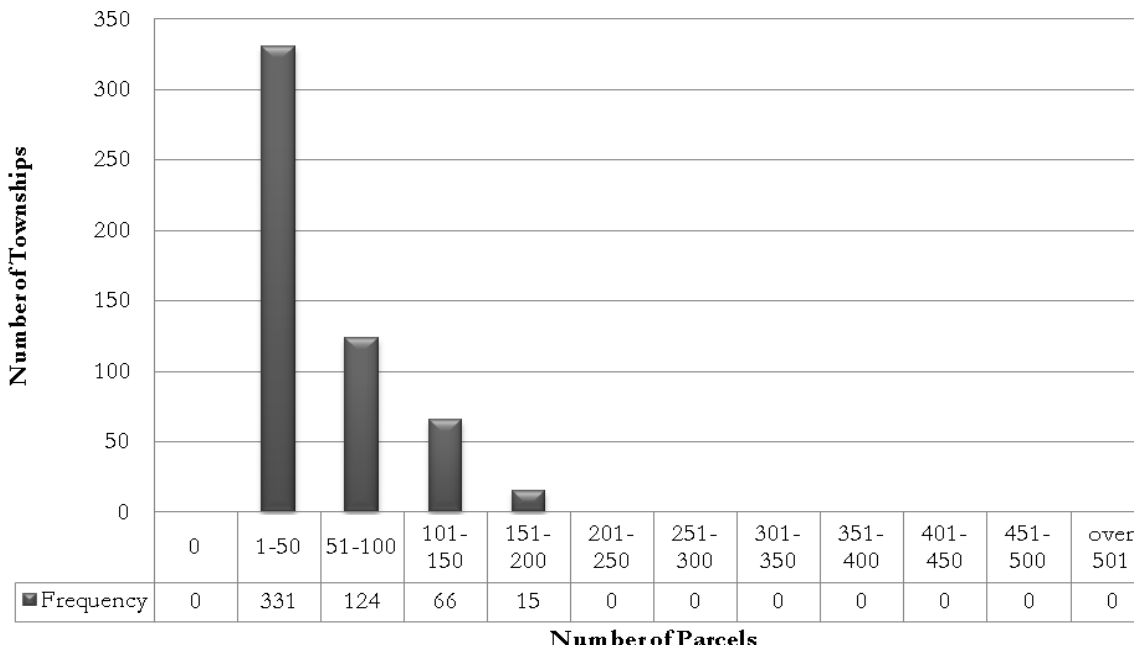


Figure 17. Frequency distribution of number of forested parcels more than 20 acres per township.

Figure 17 illustrates the distribution of the forest parcel numbers of 20 acres or more in size per township. As with the previous histogram, the majority of townships have between 1 to 100 forested parcels. Note that in contrast to Figure 16 (no minimum parcel size), no townships have more than 200 forested parcels. This comparison illustrates the large number of forested parcels that are less than 20 acres in size.

The next series of maps portrays information on proximity of forested parcels to features that may have an effect on parcelization. They include adjacency to water, public land, and roads and the parcel's proximity to an incorporated municipality. Maps illustrating the percent of forested parcels containing these adjacency or proximity characteristics were included to illustrate possible associations with average parcel size or number of parcels per township.

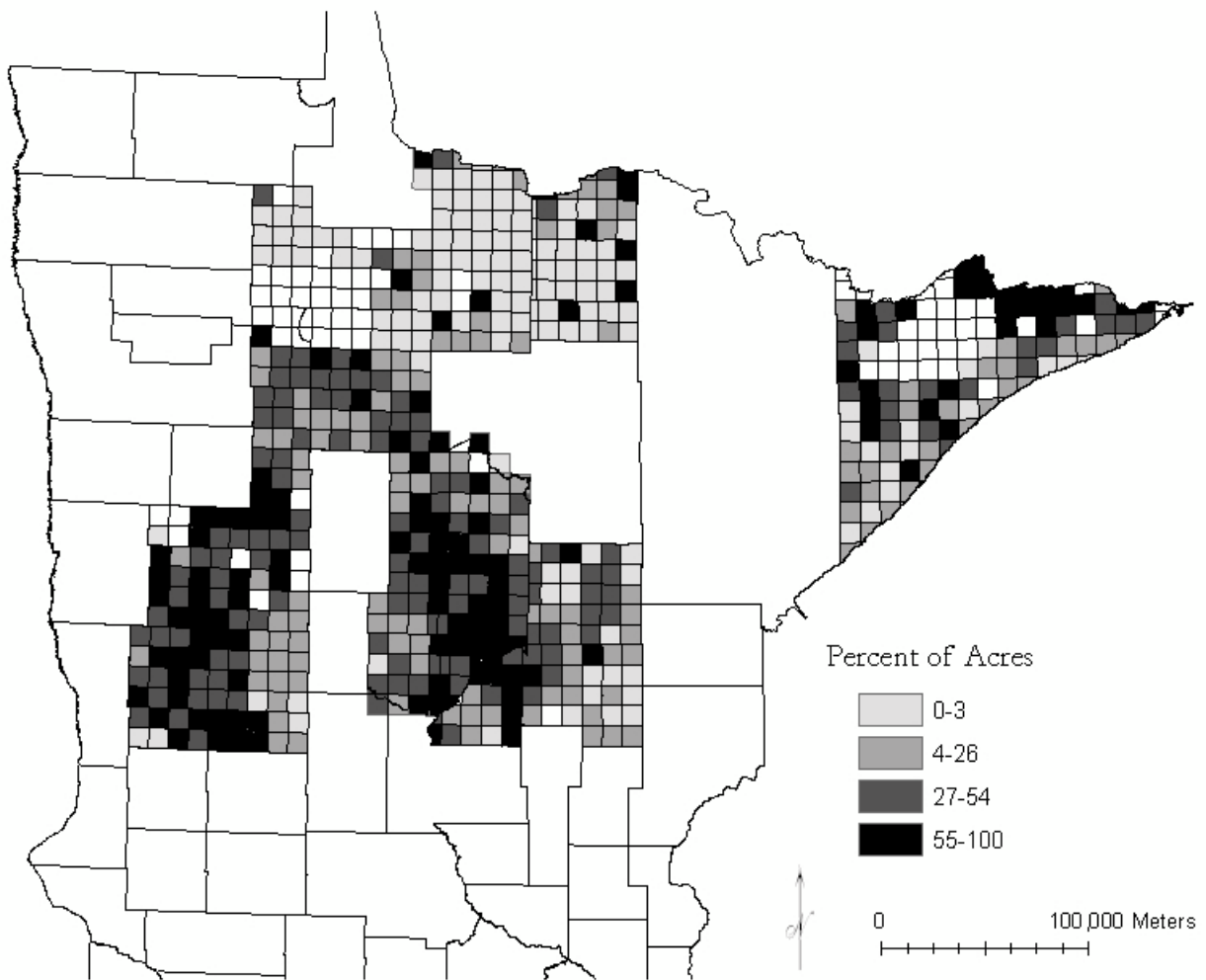


Figure 18. Percent of forested acres per township adjacent to public water.

Figure 18 shows the percent of forested acres per township that are adjacent to public waters. This statistic was calculated by dividing the total forested acreage that is adjacent to water by the entire sum of forested acres per township. As with other descriptions of the study area, the

number of forest parcels adjacent to water are generally highest in southern counties and lowest in the north. There are also high portions of Otter Tail County where the percent of forest land adjacent to water is high due to the large number of lakes. Nearly all of the townships in Koochiching County contain little to no forest land that is adjacent to water. Across the study area, half of the townships in the study area have between 27 to 100% of their private forest land adjacent to water.

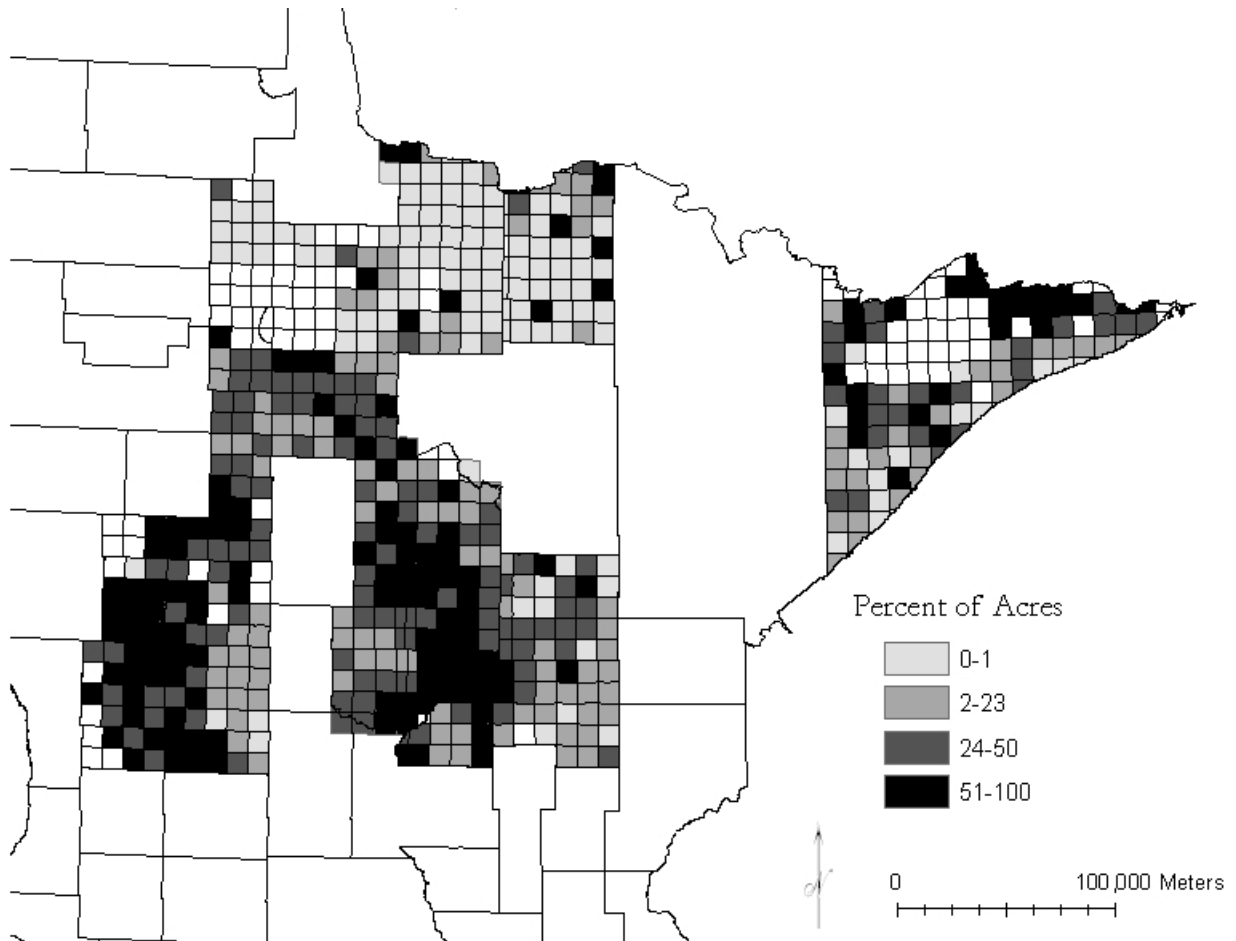


Figure 19. Percent of forested acres in parcels more than 20 acres per township adjacent to public water.

Figure 19 illustrates the percent of forested acres of parcels 20 acres or more in size that are adjacent to public waters. Basically the same patterns are evident in this map as in the map that includes all forested parcels. When compared to the analysis that includes all forest land (Figure 18), Otter Tail County has more townships with the majority of its private forest land adjacent to water, while Koochiching County has an even lower percent of its forest land containing water frontage.

Figures 20 and 21 correspond to the maps showing forest acres per township adjacent to public waters. The number of townships in each bin is fairly evenly distributed, with an increase in

townships having no forest land adjacent to public waters. These two figures are nearly identical, with Figure 21 illustrating a smaller number of forest land adjacent to public waters, which was expected given that all parcels less than 20 acres are not included.

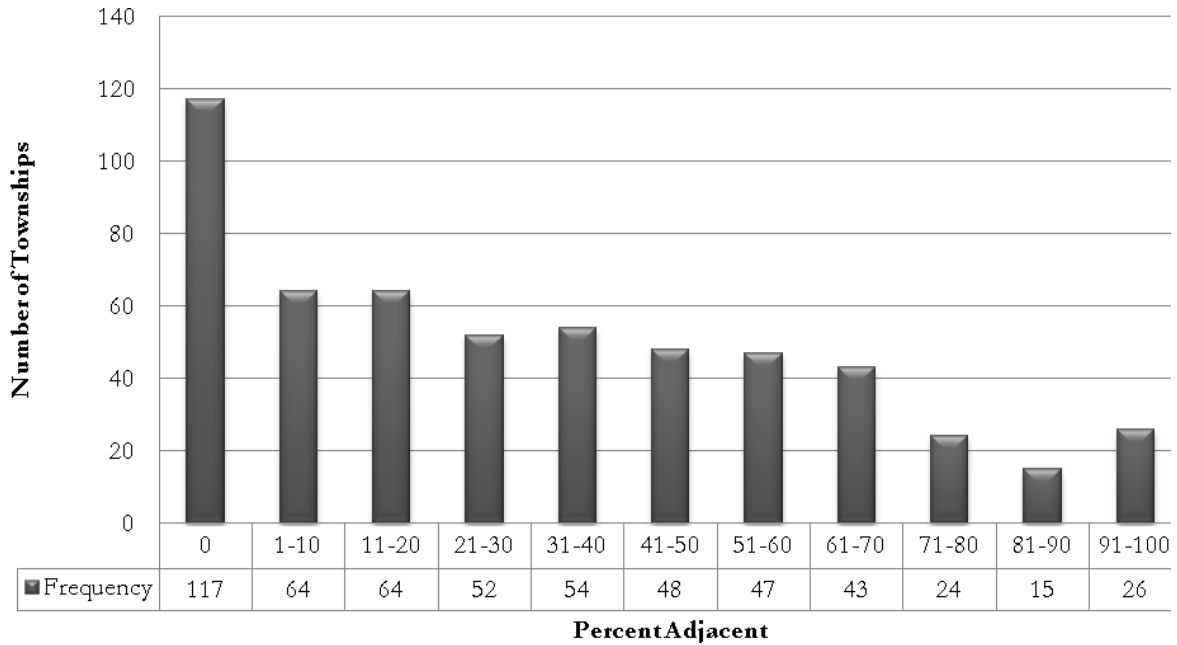


Figure 20. Frequency distribution of percent of forested acres per township adjacent to public water.

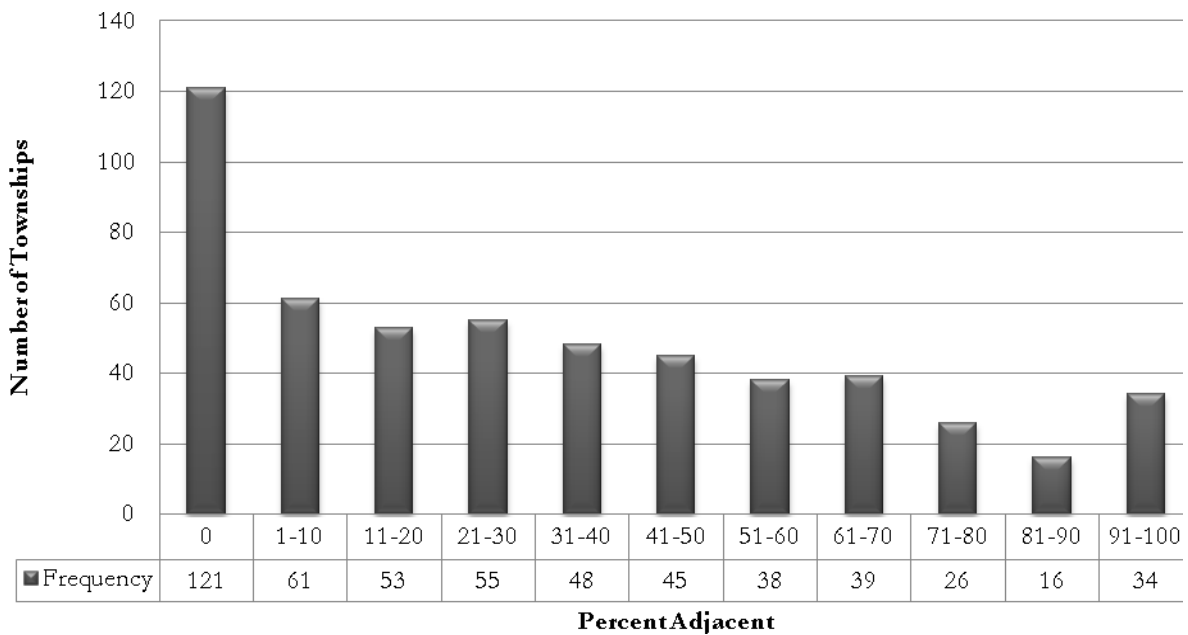


Figure 21. Frequency distribution of percent of acres in forested parcels more than 20 acres per township adjacent to public water.

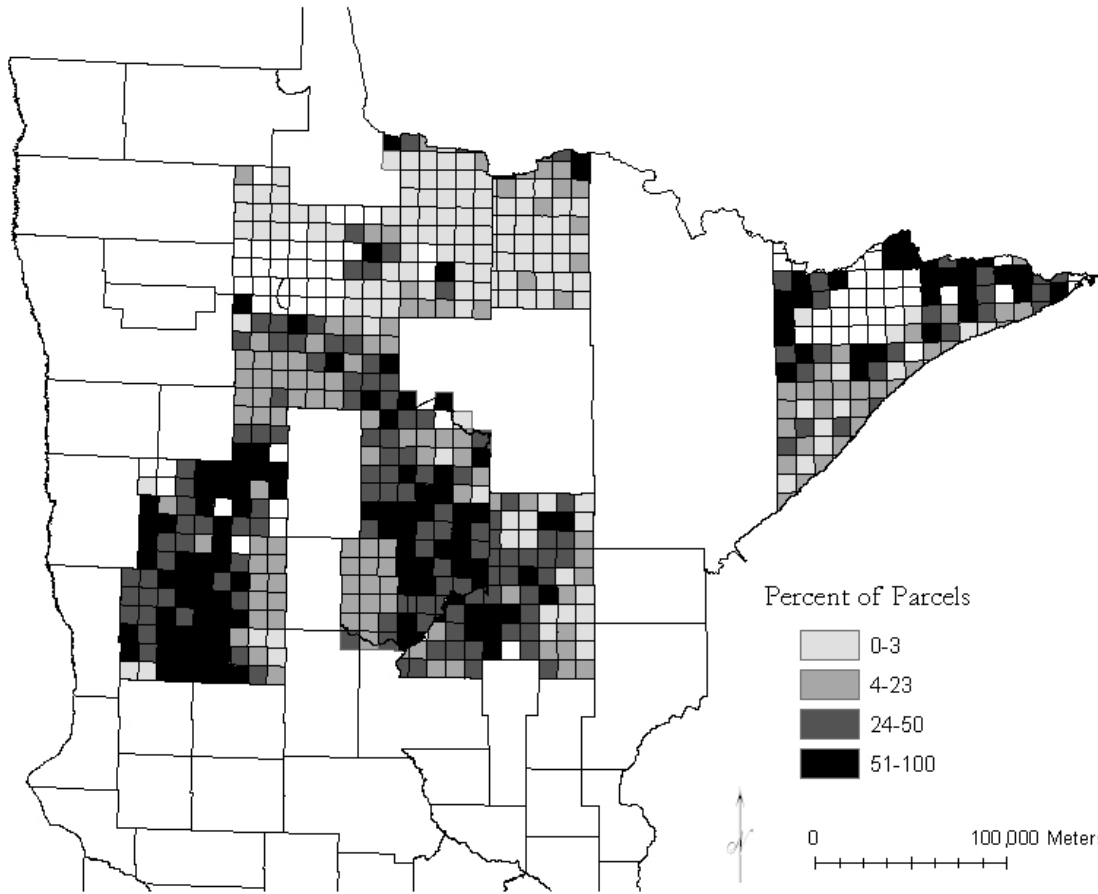
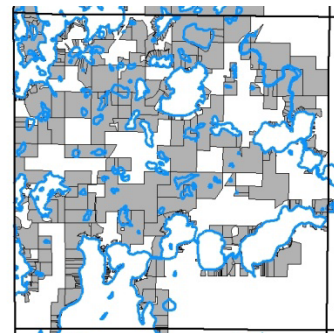


Figure 22. Percent of forested parcels per township adjacent to public water.

At the right, a township from Aitkin County showing all private, forested parcels adjacent to public waters.



Figures 22 and 23 illustrate the same proximity variable, adjacency to public waters, as is presented in Figures 18 to 21. In these figures, adjacency to public waters is presented as a percent of the number of forested parcels rather than number of forested acres in a township. The patterns that emerged are strikingly similar to the maps based on acreage, suggesting there may be a correlation between average parcel size and number of parcels.

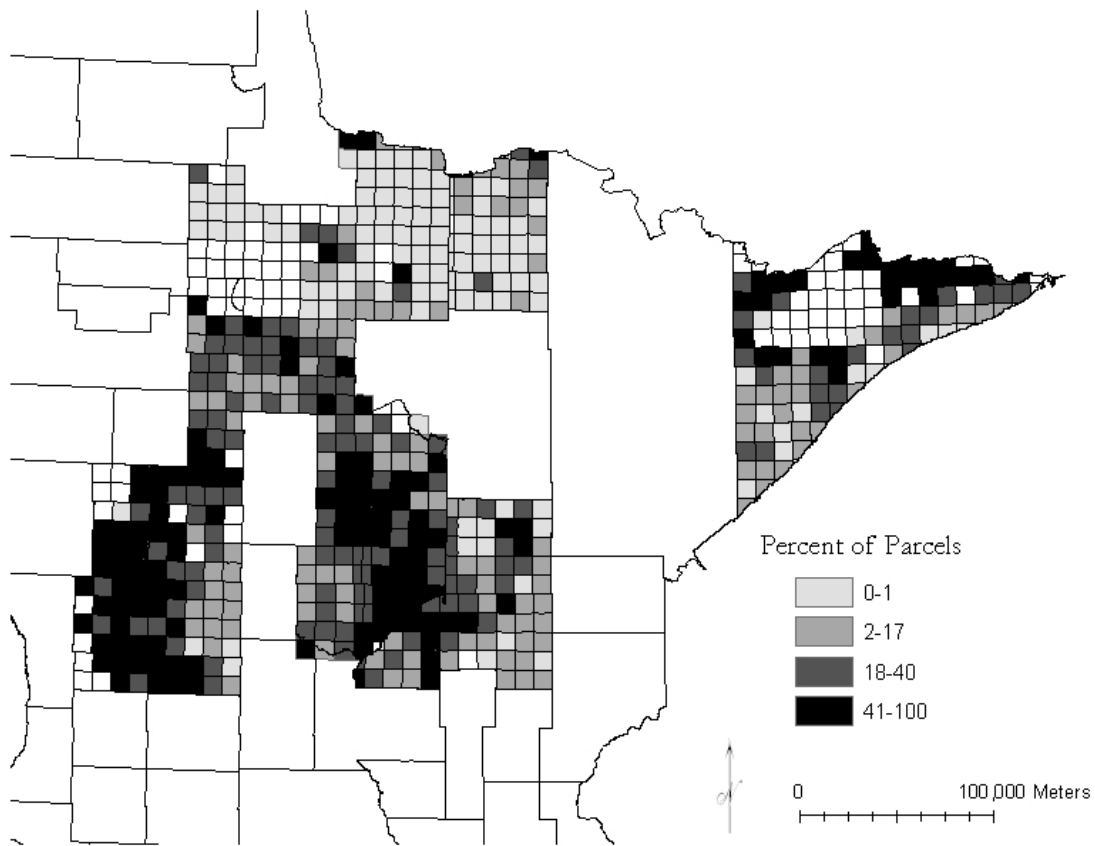


Figure 23. Percent of forested parcels more than 20 acres per township adjacent to public water.

Figures 24 and 25 correspond to the previous set of maps (Figures 22 and 23) showing the percent of forested parcels per township that are adjacent to public waters. Note the similarity between the two graphs. For both all private forest land in a township as well as only those parcels 20 acres or more in size, the majority of townships did not have any forest land adjacent to public waters. However, unlike the graphs showing percent of forest acres adjacent to public waters, these graphs have a slightly wider distribution with less concentration in the low percentage categories and more townships falling into some of the middle categories.

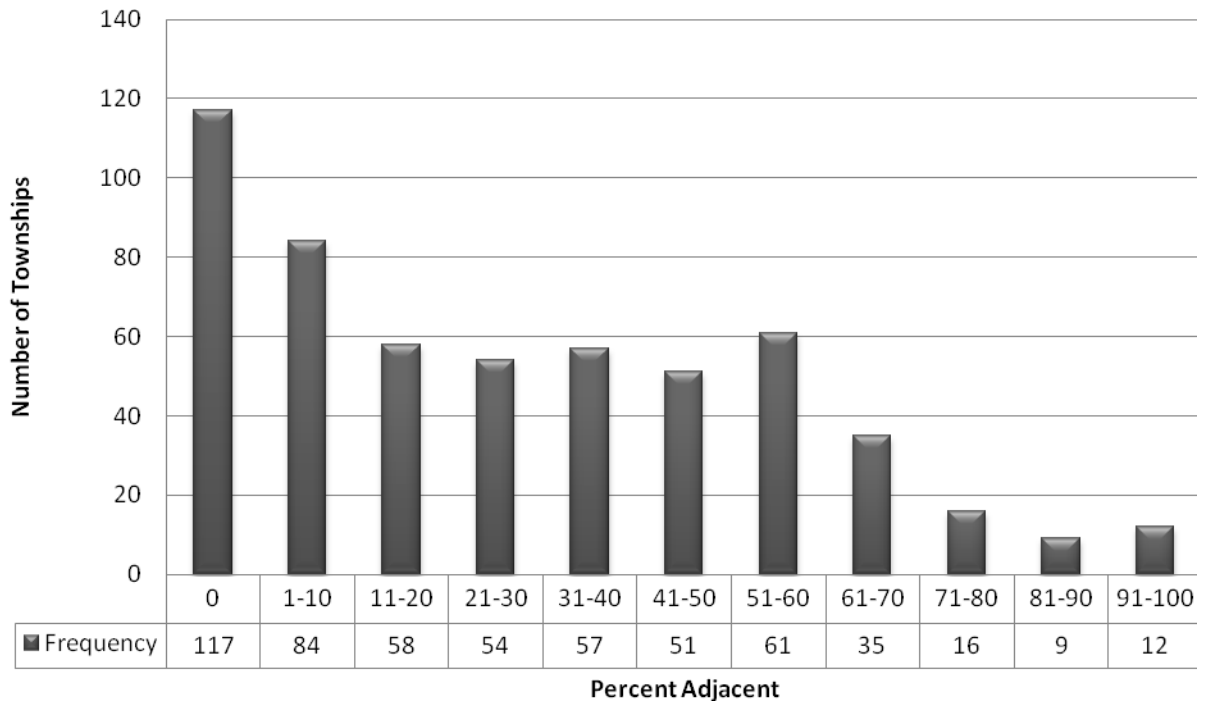


Figure 24. Frequency distribution of percent of forested parcels per township adjacent to public waters.

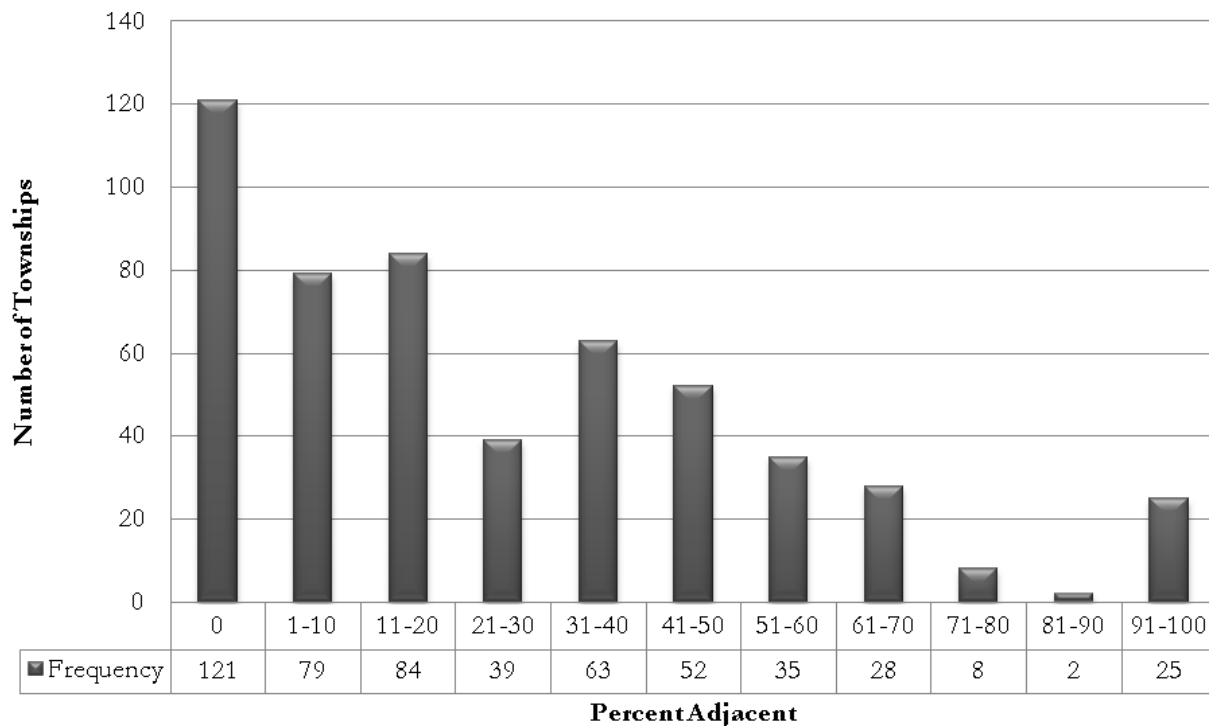


Figure 25. Frequency distribution of percent of forested parcels more than 20 acres per township adjacent to public water.

Figure 26 depicts the percent of forested acres per township that are adjacent to public land. Public land is defined as forest land owned and/or managed by federal, state, or local units of government. This statistic was calculated by dividing the total forested acreage that is adjacent to public land by the sum of forested acres per township. Cook and Lake counties have the highest overall percentages throughout the county—almost all townships have between 87 to 100% of their forest land adjacent to public land. In contrast, Koochiching County has low percentages in all townships, in the 0 to 14% range, likely due to the large blocks of contiguous private forest land that exist in the county. The large blocks of private forest land exist because of the high amount of public forest land in Koochiching County, indicating that private forest land is concentrated into those large blocks. Several townships in Otter Tail County also contain a relatively low portion of their forest land that is adjacent to public lands. The central region of the study area has most of its townships containing 15 to 52% of its private forest land adjacent to public forest land.

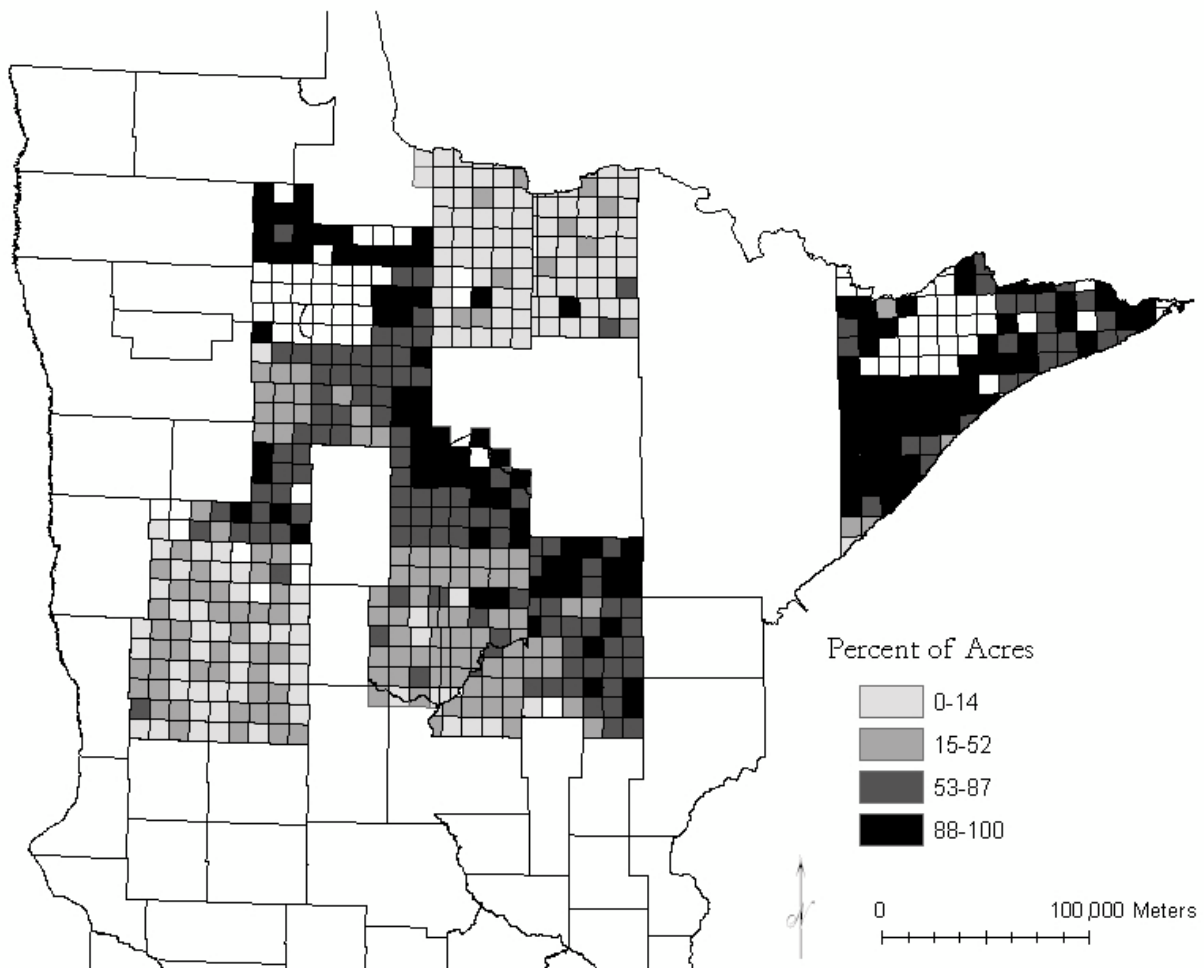


Figure 26. Percent of forested acres per township adjacent to public land.

Figure 27 depicts the percent of forested acres of parcels 20 acres or more in size that are adjacent to public forest land. Patterns between this and the previous figure are nearly identical. One difference can be seen in Cook and Lake counties where the percent of private forest land parcels adjacent to public land is higher when only larger forest parcels (>20 acres) are considered, compared to the percent of all forest land parcels that are adjacent to public forest land.

Interestingly, in the southern part of the study area where many townships had high number of forested acres and total parcels, there seems to be low adjacency to public land rates. This may indicate that adjacency to public land is not a significant driver of parcelization.

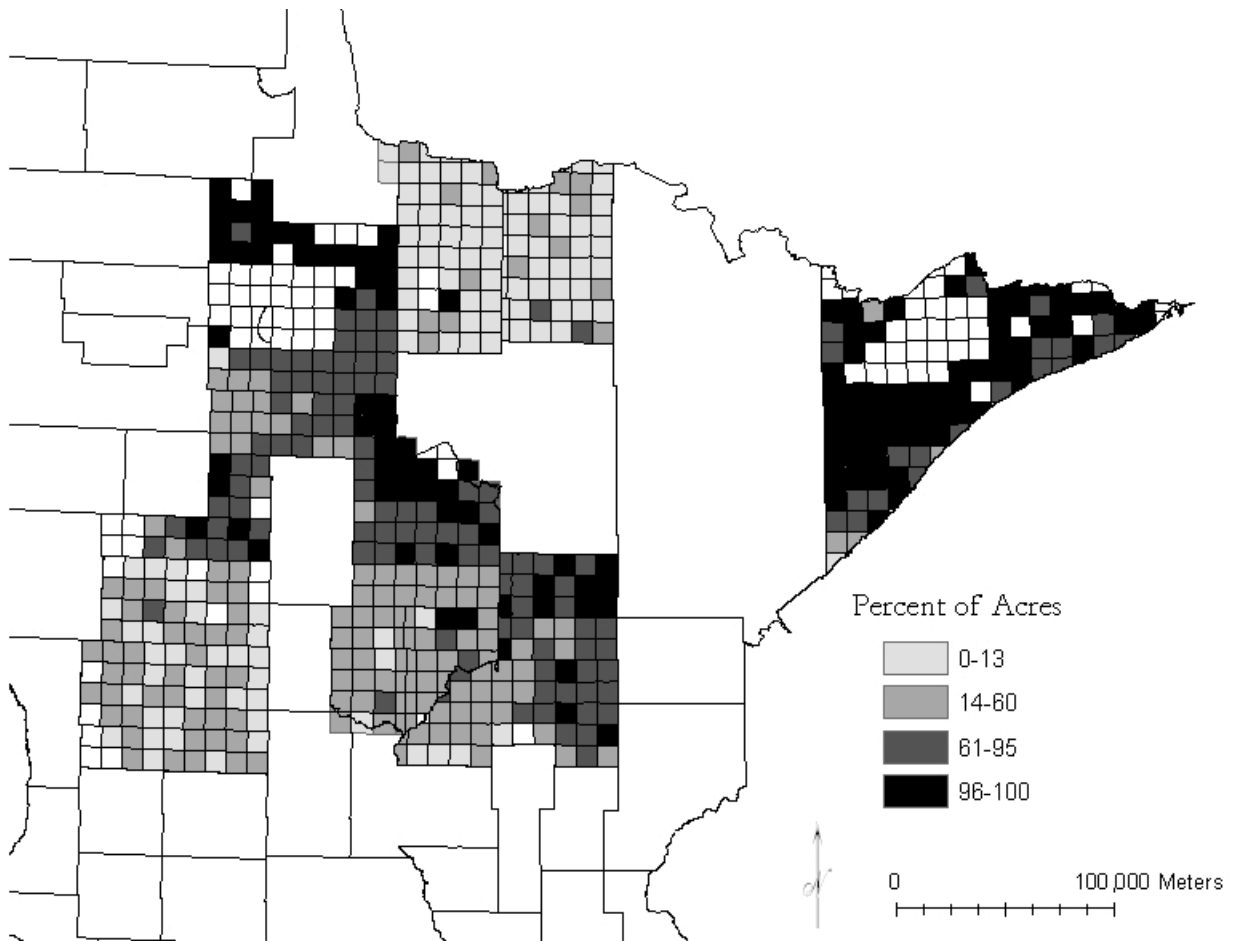


Figure 27. Percent of forested acres in parcels more than 20 acres in size per township adjacent to public land.

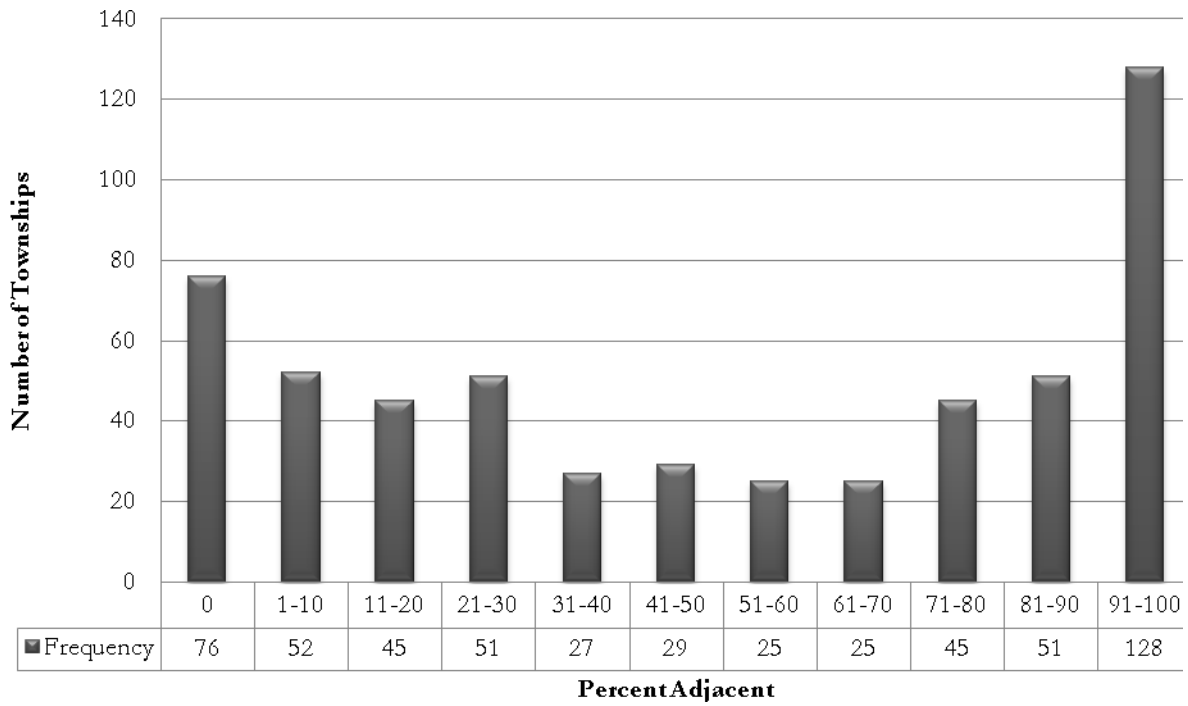


Figure 28. Frequency distribution of percent of forested acres per township adjacent to public land.

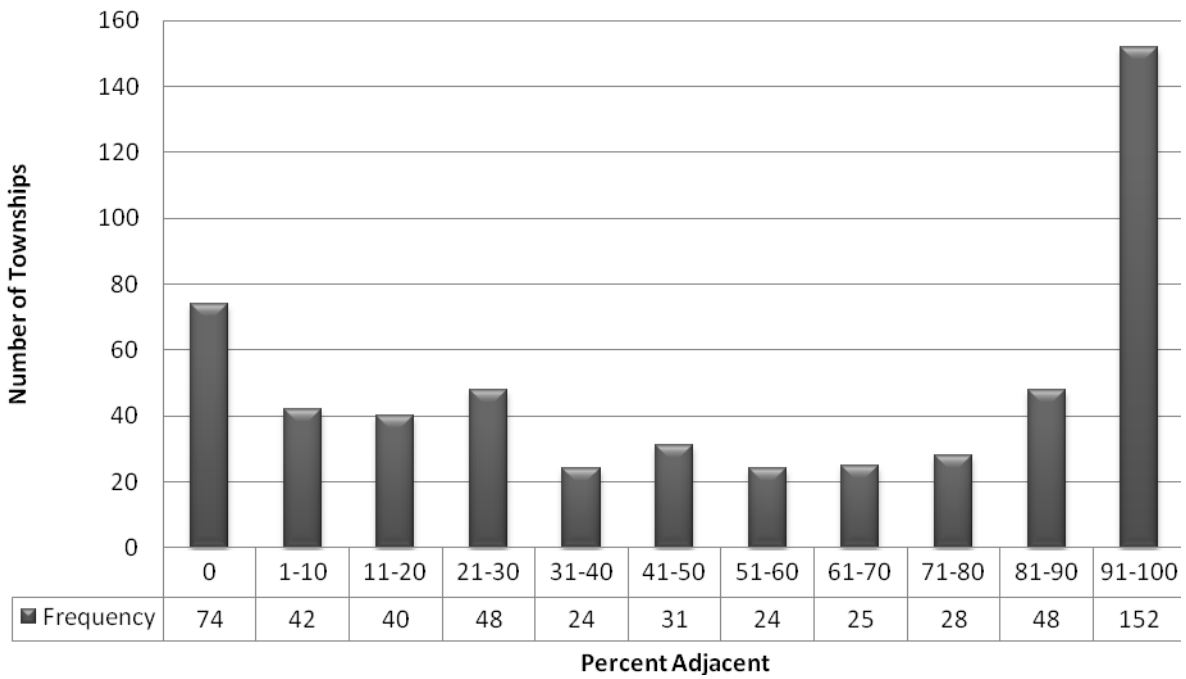


Figure 29. Frequency distribution of percent of acres in forested parcels more than 20 acres per township adjacent to public land.

Figures 28 and 29 illustrate the frequency distribution of the percent of private forest acres per township that are adjacent to public land. These two figures have roughly the same frequency distribution, indicating that, on a percentage basis, only a small portion of forest parcels less than 20 acres are adjacent to public land. Interestingly, there is a large spike in the number of townships having 91 to 100% of their forested acres adjacent to public land when only parcels that are 20 acres or more in size are considered. This may be due to landowners with property adjacent to public land that value the recreational value of public land and keep their land forested to increase this recreational value. Note that a considerable number of townships (i.e., nearly 80) have no forest land adjacent to public land.

Figures 30 and 31 depict private forest land adjacency to public forests, expressed as a percent of private forest land parcels, rather than a percent of all private forest land acres, that are adjacent. The similarities between the maps featuring percent of acres adjacent and maps featuring percent of parcels adjacent are evident, reaffirming the likely correlation between parcel size and number of parcels. The distribution of percent adjacent townships only slightly changes between the analysis of acres adjacent and parcels adjacent, it shows that the number of parcels and parcel size are correlated.

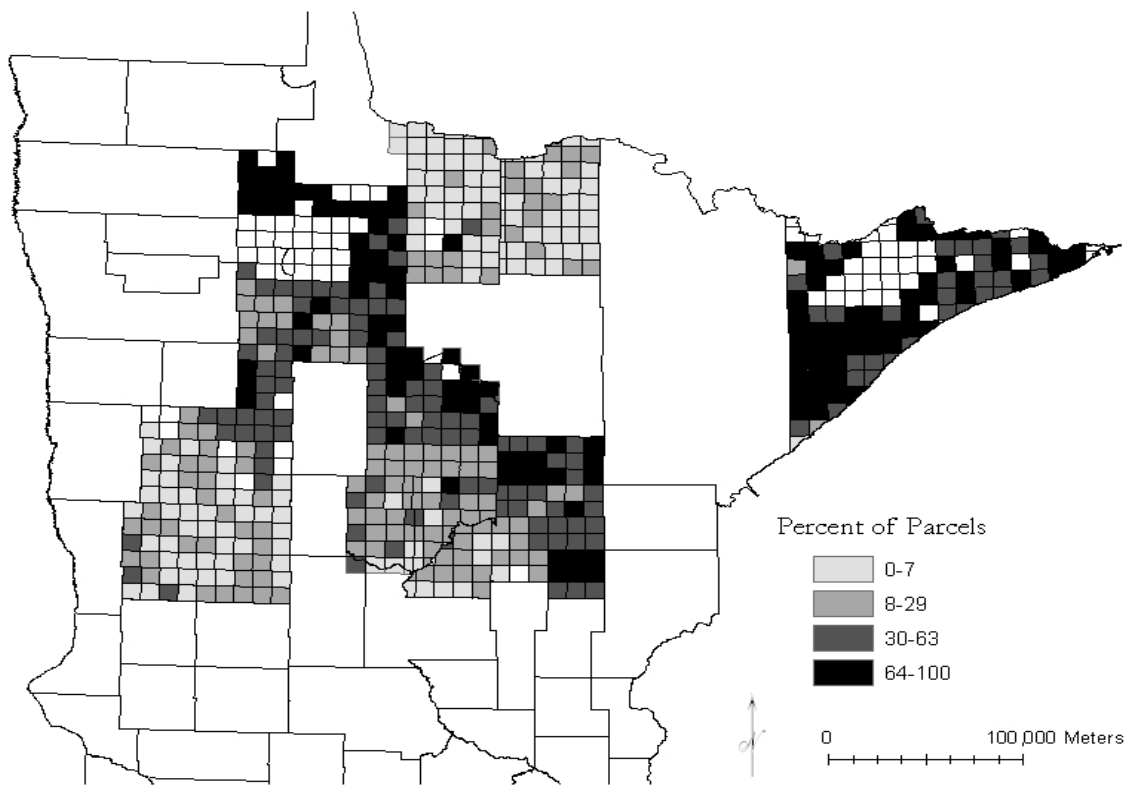


Figure 30. Percent of forested parcels per township adjacent to public land.

At the right, a township from Cook County illustrating parcels adjacent to public lands. Public lands are designated by the dotted pattern.



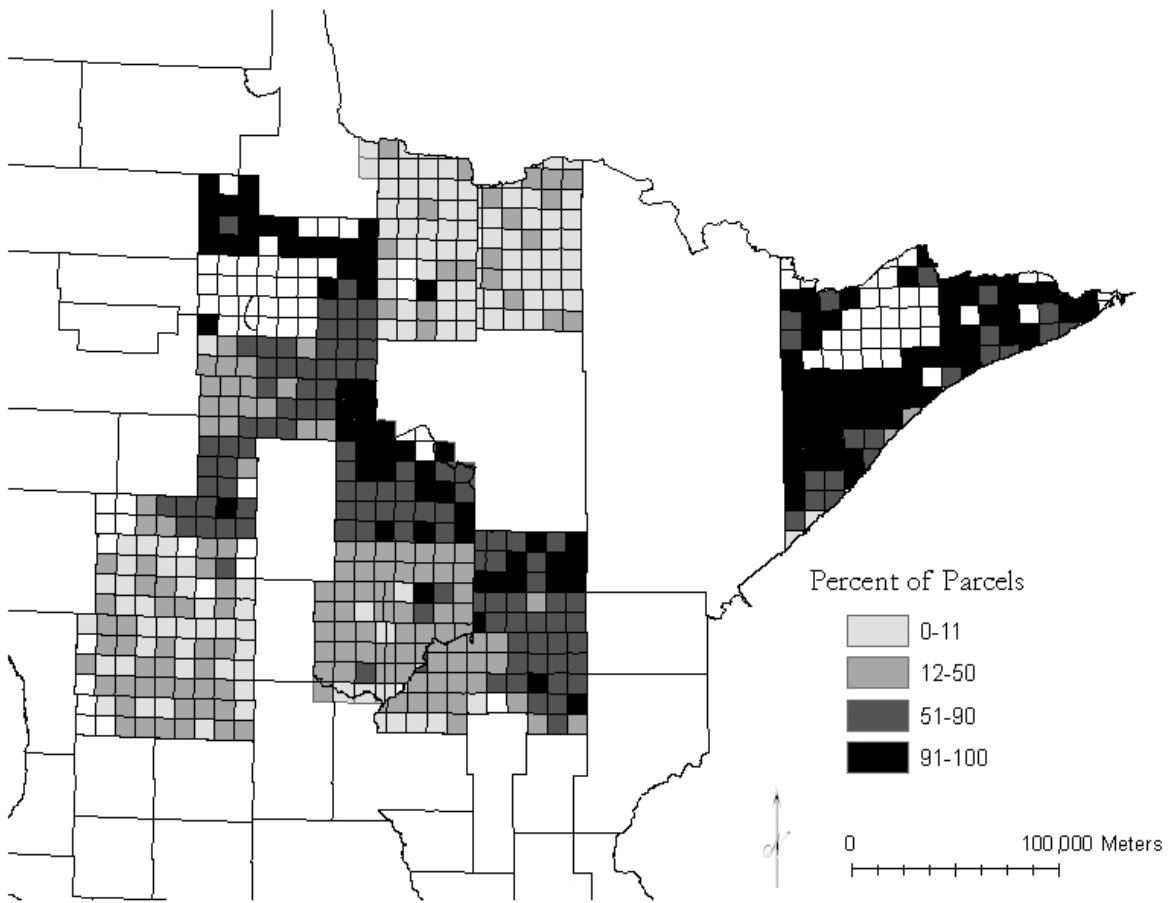


Figure 31. Percent of forested parcels more than 20 acres in size per township adjacent to public land.

Figures 32 and 33 graphically illustrate the distribution of the percent of forested parcels per township that are adjacent to public land with and without the 20-acre cutoff value. Townships having up to 20% of their private forest land parcels adjacent to public land or having 91 to 100% of the parcels adjacent to public land are the most common categories. The differences when all versus only parcels 20 acres or more in size are considered appears to indicate there are many smaller acreage parcels adjacent to public land that collectively do not amount to a large number of forested acres.

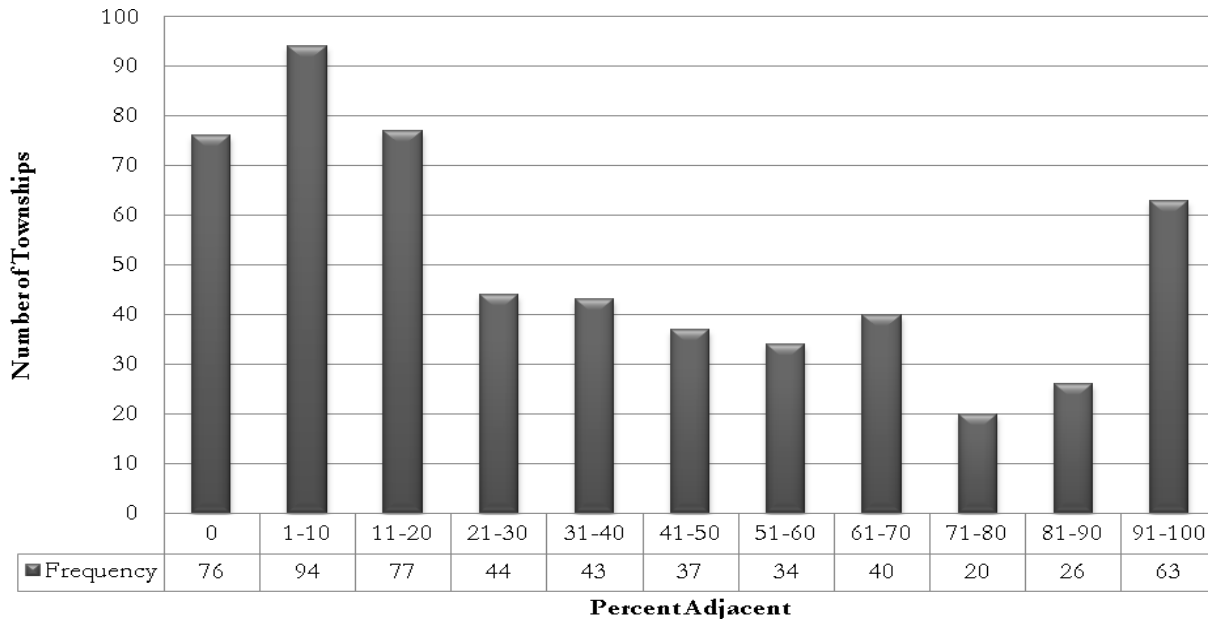


Figure 32. Frequency distribution of percent of forested parcels per township adjacent to public land.

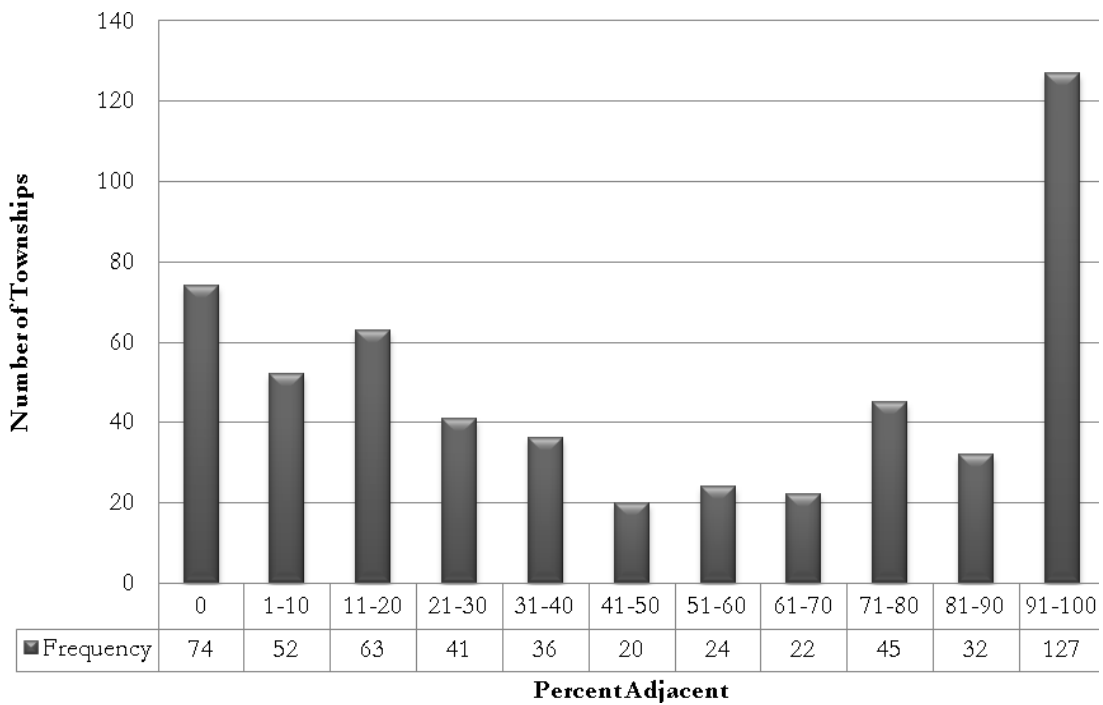


Figure 33. Frequency distribution of percent of forested parcels more than 20 acres per township adjacent to public land.

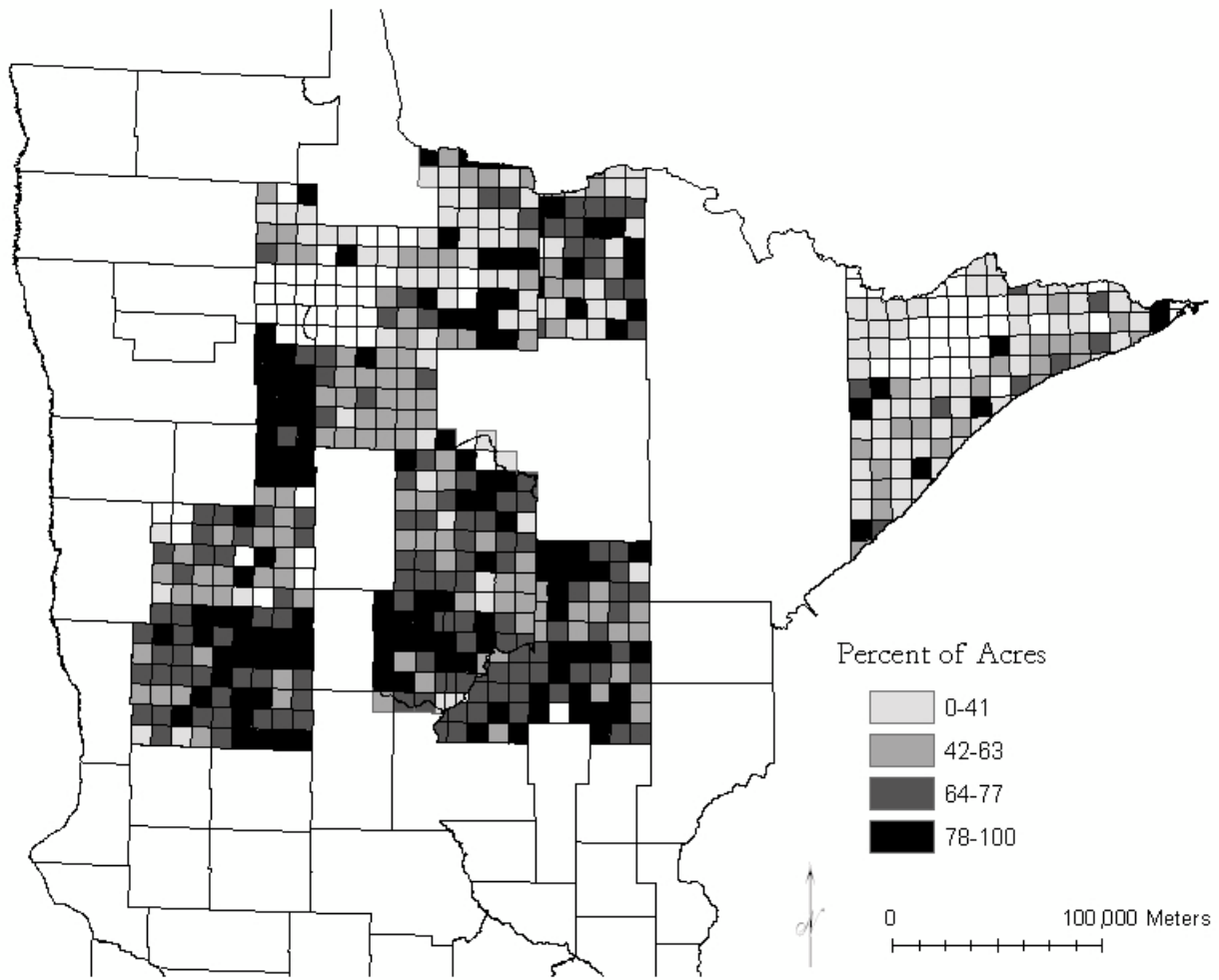


Figure 34. Percent of forested acres per township adjacent to public roads.

Figure 34 illustrates the percent of forested acres per township that is adjacent to public roads. This statistic was calculated by dividing the total forested acreage adjacent to public roads by the total forested acres per township. Southern counties have higher adjacency rates to public roads than northern counties. This can be attributed to the fact that southern counties are more populated and consequently, have more development including all-weather roads. Adjacency rates are lowest in Cook and Lake counties, where a large amount of the land base is public and few roads exist. Clearwater County has very high overall adjacency rates; 77 to 100%. Some townships in Otter Tail County also have high adjacency rates.

Figure 35 depicts the percent of forested acres for parcels 20 acres or more in size per township that is adjacent to public roads. As expected, there is an overall decrease in the percent of larger private forest land parcels that are adjacent to public roads, with more townships falling under the 67% adjacency rate. Cook and Lake counties have the lowest overall adjacency rates of the study's ten counties.

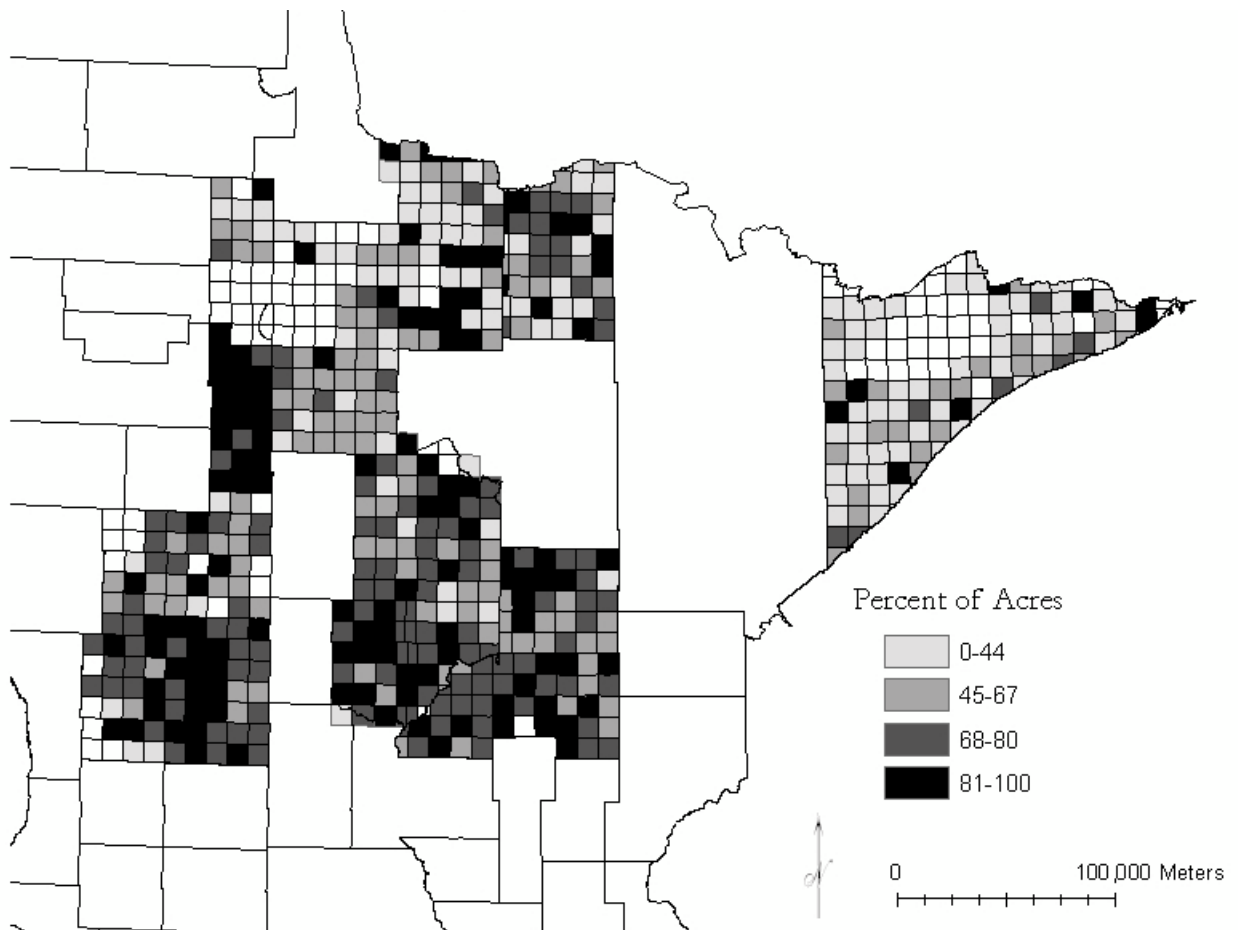


Figure 35. Percent of forested acres in parcels more than 20 acres in size per township adjacent to public roads.

Figures 36 and 37, depicting the percent of all private forest land and only forested parcels 20 acres or more in size per township that are adjacent to public roads, respectively, are very similar. This similarity illustrates that smaller parcels (less than 20 acres) do not have much of an effect on overall percent of forested acres adjacent to public roads. Interestingly, the curve is skewed toward the right, with more townships having higher adjacency rates; the most in the 71 to 80% category. This is likely due to the fact that as our landscape in general becomes more developed, more roads are built. There are also more than 40 townships with less than 1% of its private forest land (both all and only 20+ acre parcels) adjacent to public roads.

Figures 38 and 39 are similar to Figures 34 and 35, with the difference being the former are the percent of forest land parcels adjacent to public roads instead of percent of forest acres.

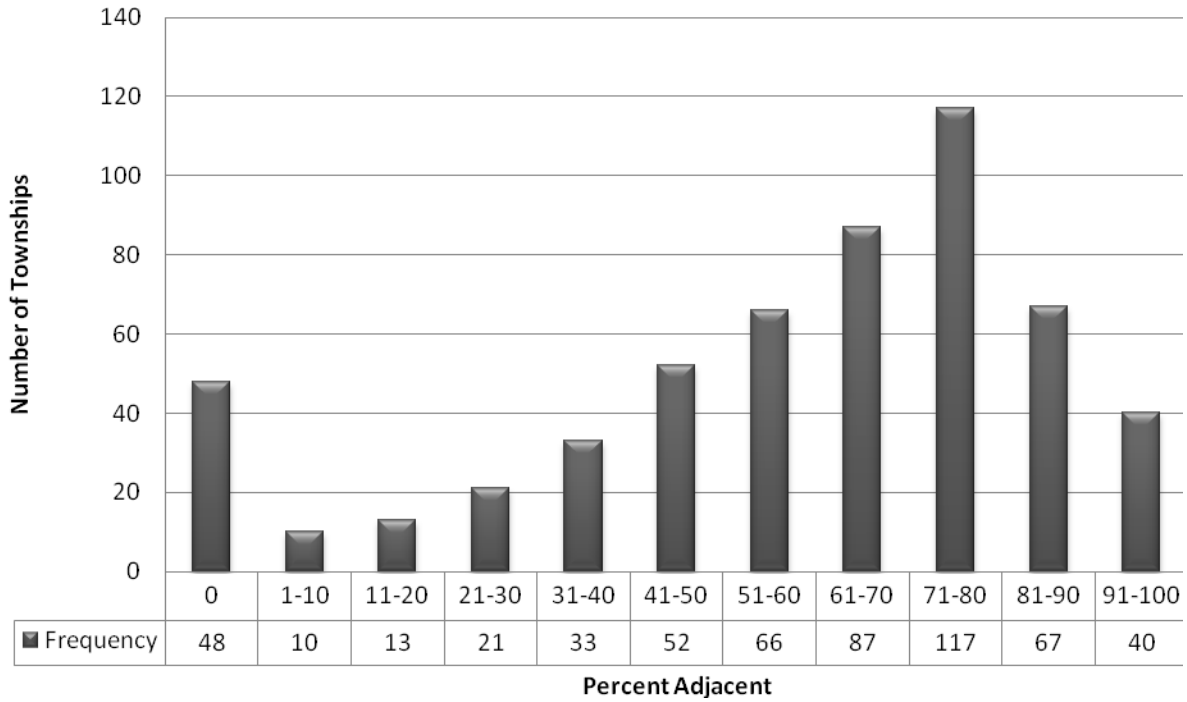


Figure 36. Frequency distribution of percent of forested acres per township adjacent to public roads.

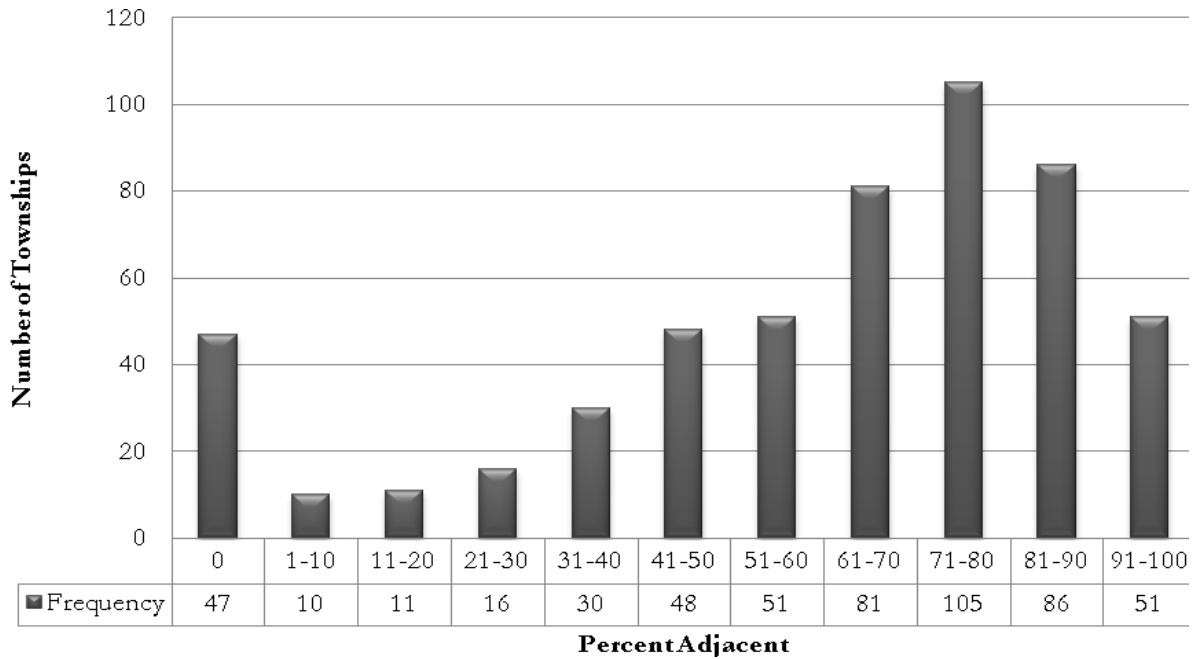


Figure 37. Frequency distribution of percent of acres in forested parcels more than 20 acres in size per township adjacent to public roads.

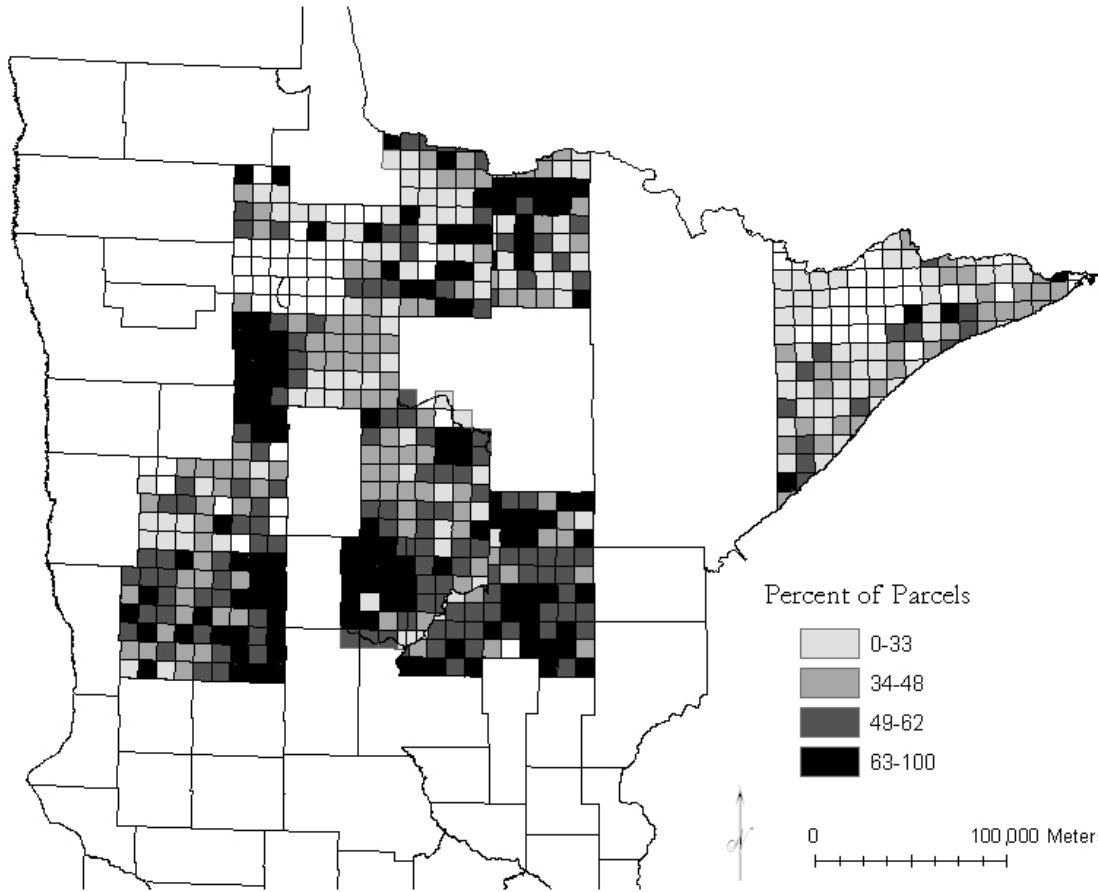
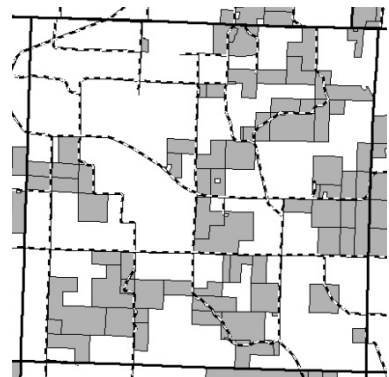


Figure 38. Percent of forested parcels per township adjacent to public roads.

At the right, a township from Ottertail County illustrating private, forested parcels adjacent to public roads.



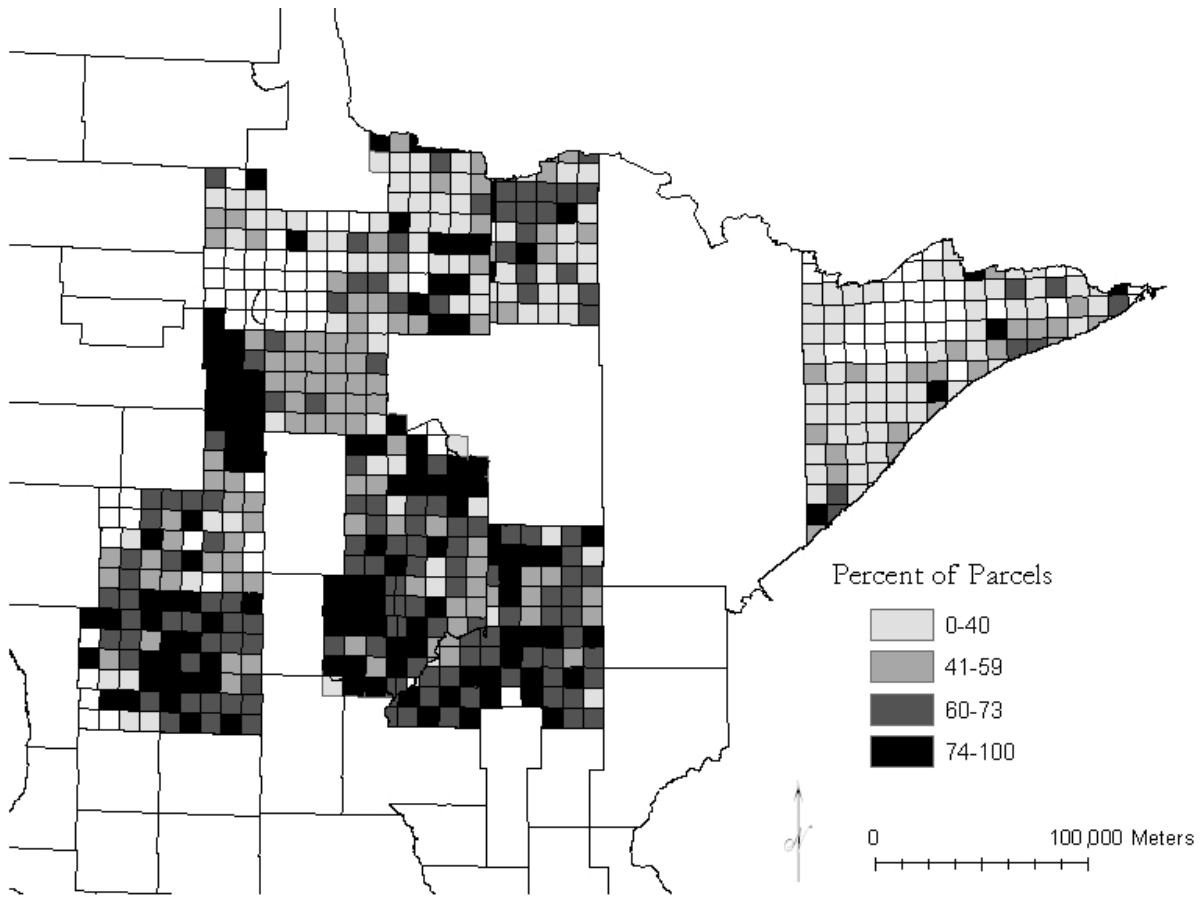


Figure 39. Percent of forested parcels more than 20 acres per township adjacent to public roads.

Figures 40 and 41 are also quite similar to the histograms depicting percent of forested acres adjacent to public roads (Figures 36 and 37). However, there is a slight shift in distribution with more being distributed in the middle categories. This could indicate that some of the large-acreage parcels are adjacent to public roads. Again, a considerable number of townships have less than 1% of their private forest land adjacent to roads; most likely due to the remoteness of these townships.

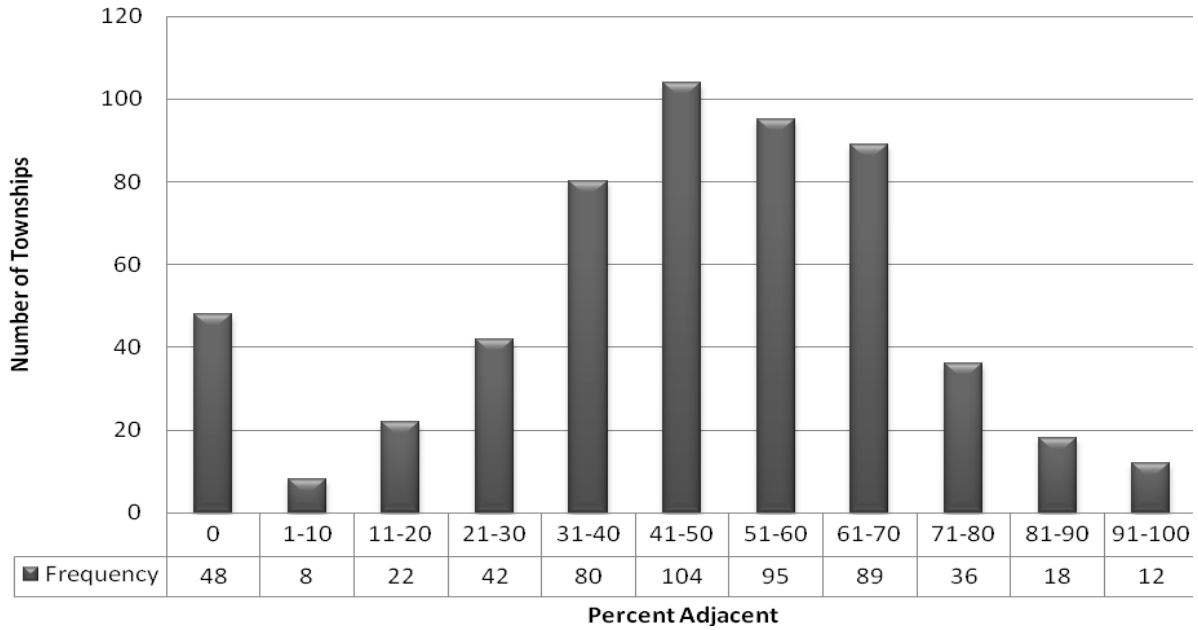


Figure 40. Frequency distribution of percent of forested parcels per township adjacent to public roads.

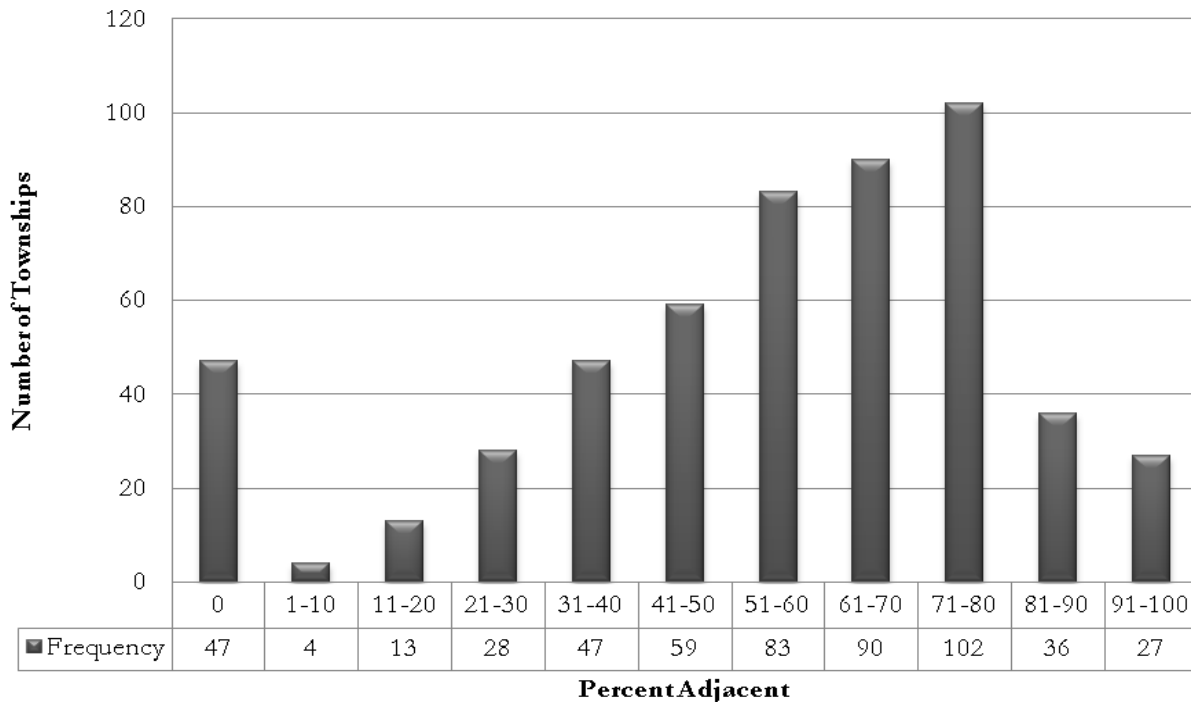


Figure 41. Frequency distribution of percent of forested parcels more than 20 acres per township adjacent to public roads.

Figure 42 depicts the percent of forested acres per township that is within 1,600 meters of a city, which is roughly equal to one mile. A city was defined as an incorporated municipality based on the DORID files. The percent of forested acres per township within 1,600 meters of a city was calculated by dividing the total forested acreage that is within 1,600 meters of a city by the entire sum of forested acres per township. As shown in Figure 42, the majority of townships have less than 1% of parcels within 1,600 meters of a city. Crow Wing County has the largest percentage of its townships in close proximity to an incorporated municipality, with a number of its townships falling in the 36 to 100% range. Some townships in southern Otter Tail County also fall into that higher range of 36 to 100%. The overall low percentages are most likely due to the paucity of incorporated municipalities in the study counties.

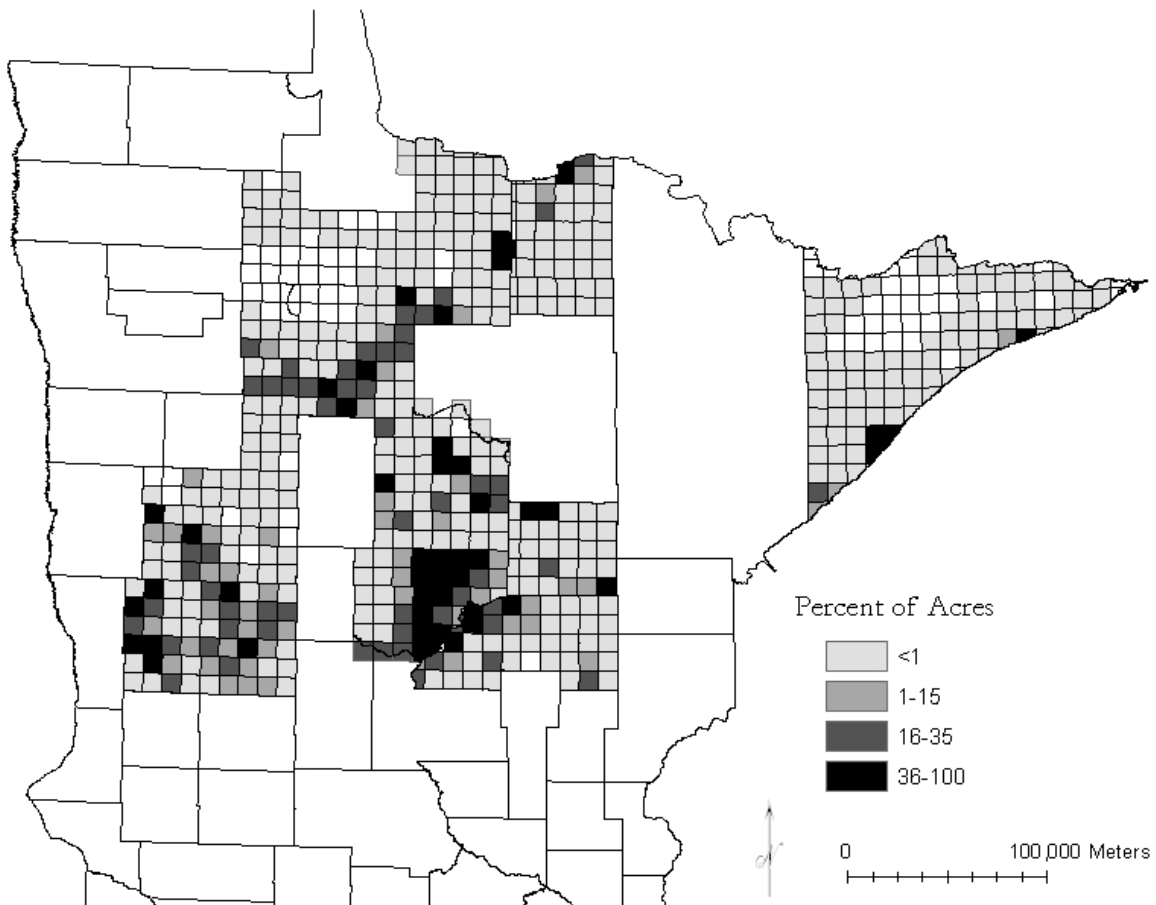


Figure 42. Percent of forested acres per township within 1,600 meters of a city.

Figure 43 illustrates the percent of forested acres for parcels 20 acres or more per township that is within 1,600 meters of a city. As with Figure 42 that included all private forest land, the majority of townships do not contain 20+ acreage forest land within the specified distance of a city. Exceptions include southern Beltrami and Otter Tail counties. In general, the northern

counties of the study area tend to be very rural, resulting in very few townships having any significant amount of private forest land within 1,600 meters of a city.

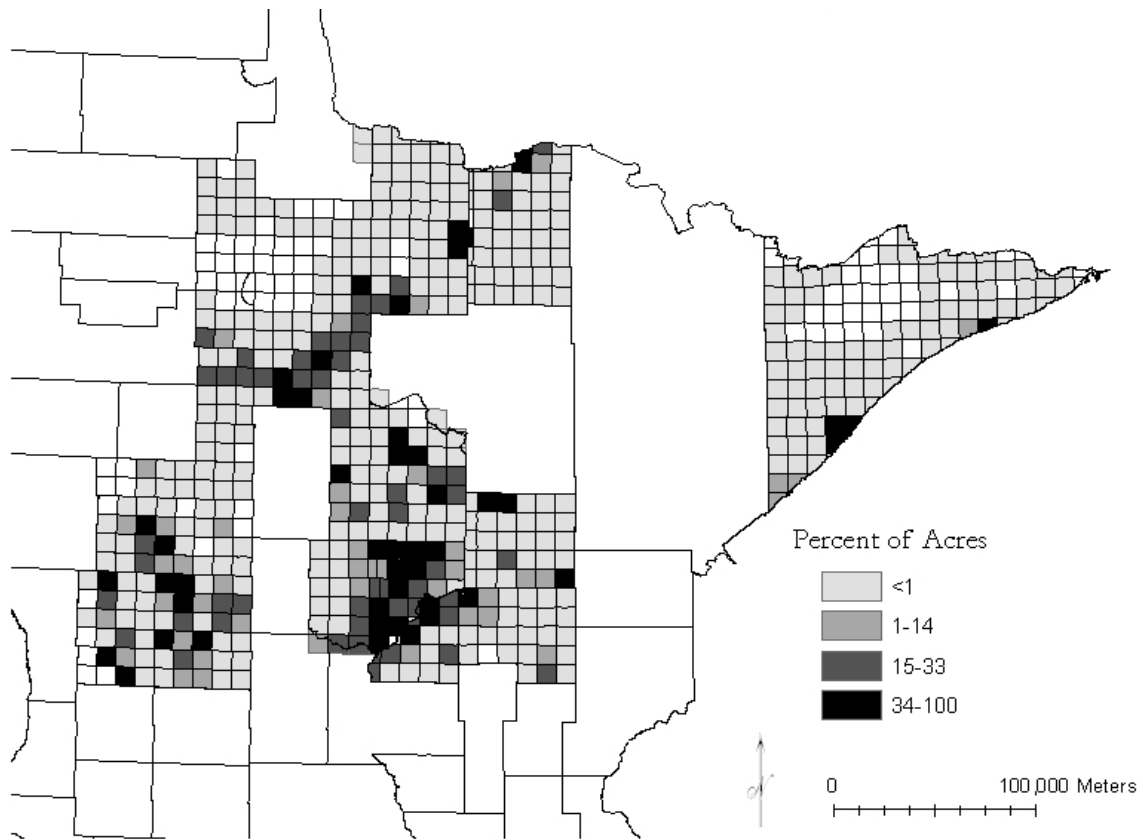


Figure 43. Percent of forested acres in parcels more than 20 acres per township within 1,600 meters of a city.

Figures 44 and 45 show the percent of acres in forested parcels, and forested parcels 20 acres or more in size per township, respectively, that are within 1,600 meters of an incorporated municipality. These graphs reiterate what the maps (Figures 42 and 43) depicted—that in most townships the forested parcels are not within 1,600 meters of a city. There is not a large difference between the two histograms, indicating that parcels under 20 acres in size are not any more likely to be within 1,600 meters of a city than larger forested parcels.

Figures 46 and 47 illustrate the percent of forested parcels that are within 1,600 meters of a city rather than the percent of forested acres.

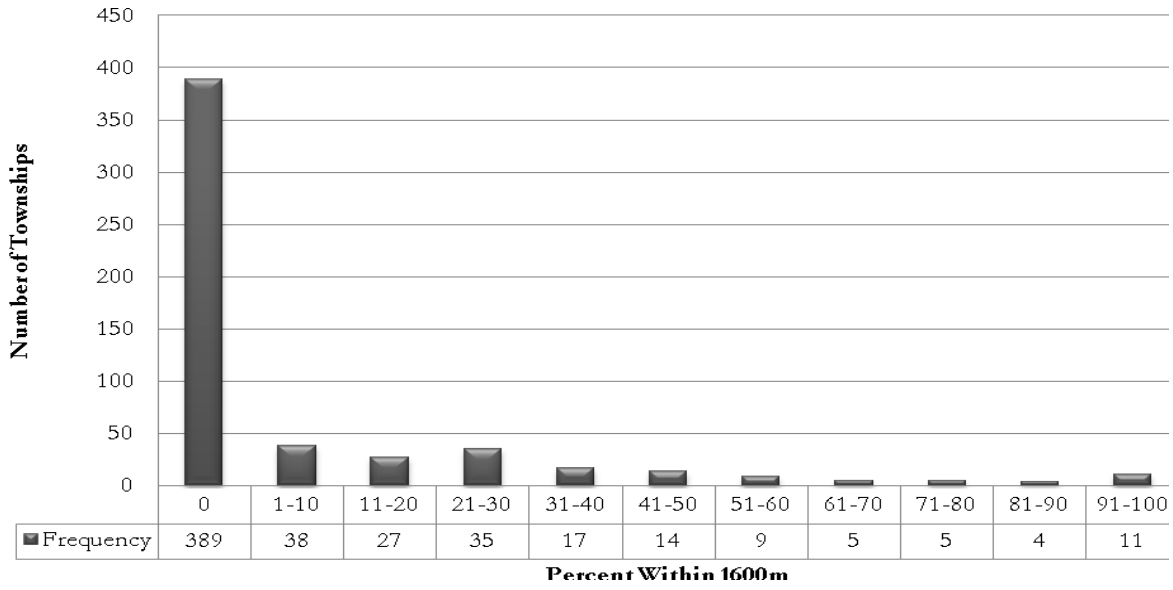


Figure 44. Frequency distribution of percent of forested acres per township within 1,600 meters of a city.

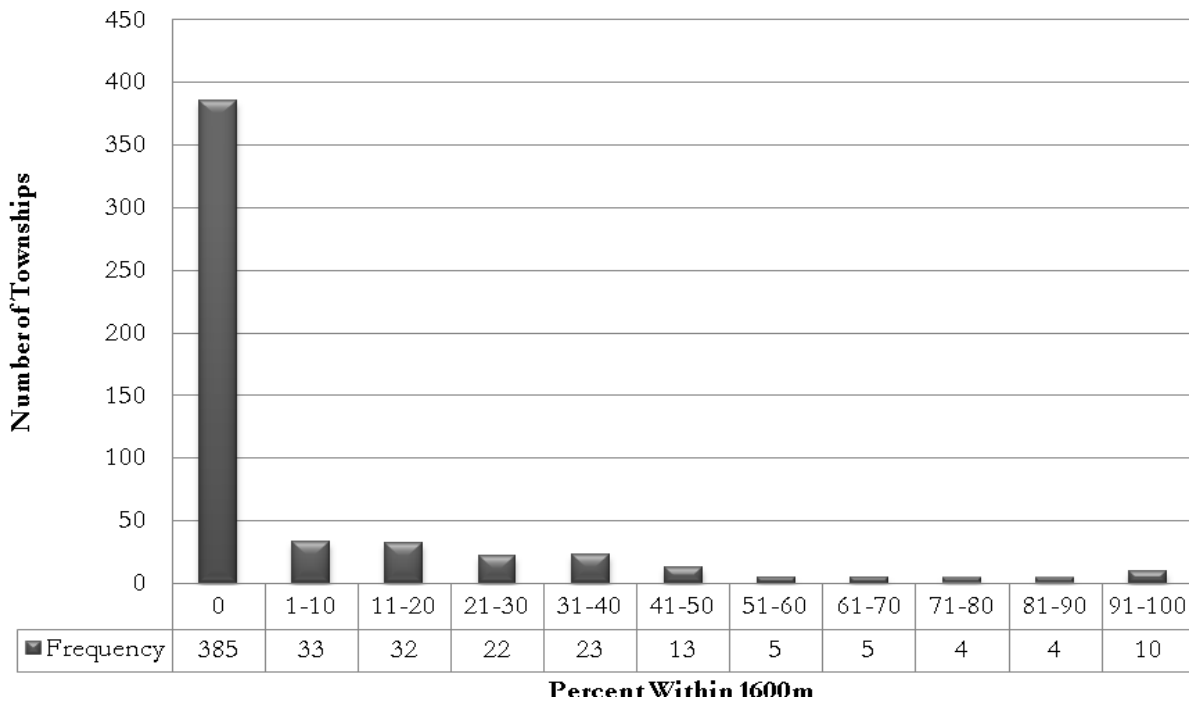


Figure 45. Frequency distribution of percent of acres in forested parcels more than 20 acres per township within 1,600 meters of a city.

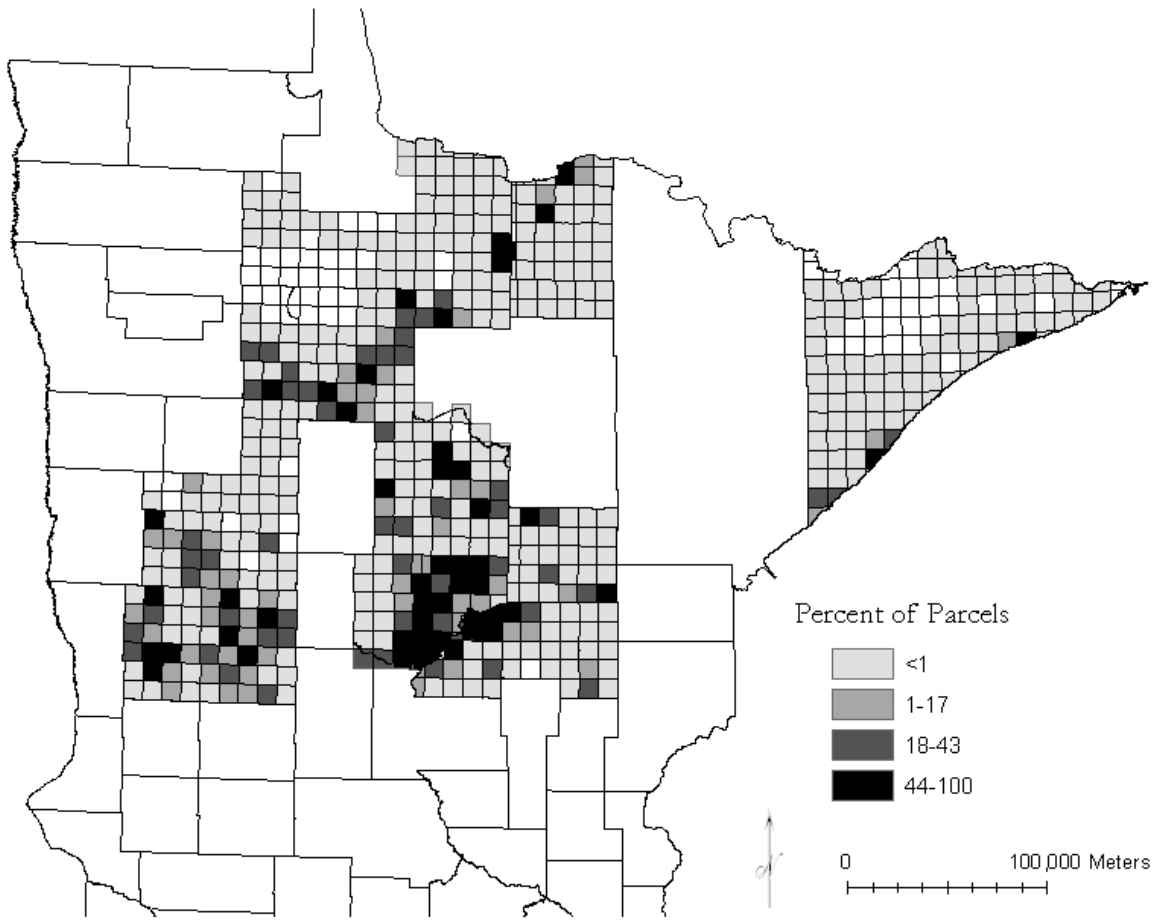
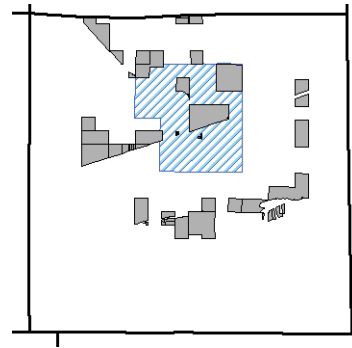


Figure 46. Percent of forested parcels per township within 1,600 meters of a city.

At the right, a township in Aitkin County illustrating parcels within 1,600 meters of a city. The city boundaries are shown with a diagonal hatch.



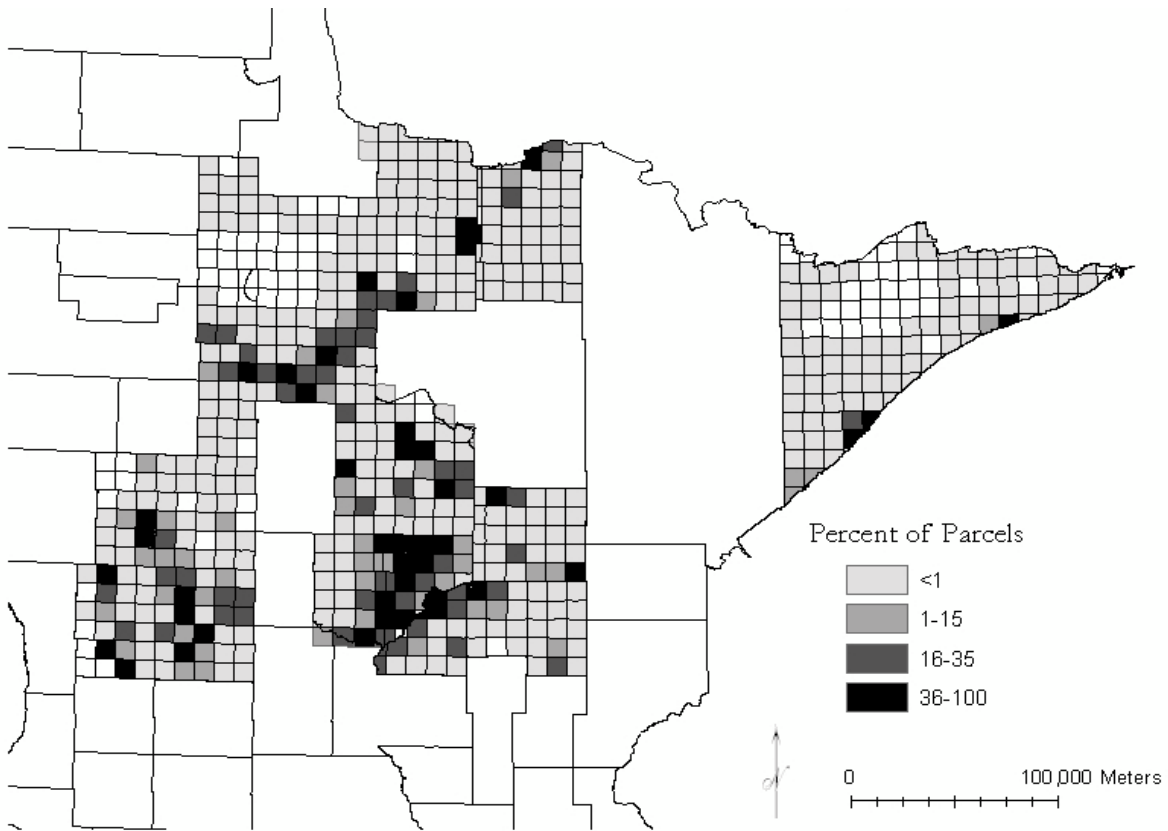


Figure 47. Percent of forested acres in parcels more than 20 acres per township within 1,600 meters of a city.

Figures 48 and 49, depicting the frequency distribution of percent of forested parcels within 1,600 meters of a city, do not show much of a difference from their counterparts depicting percent of forested acres within 1,600 meters of a city (Figures 44 and 45). The fact that Figures 48 and 49 are very similar indicates that forested parcels less than 20 acres in size are no more likely to be within 1,600 meters of an incorporated municipality than larger forested parcels. Overall, the majority of townships have less than 1% of their forested parcels within 1,600 meters of a municipality.

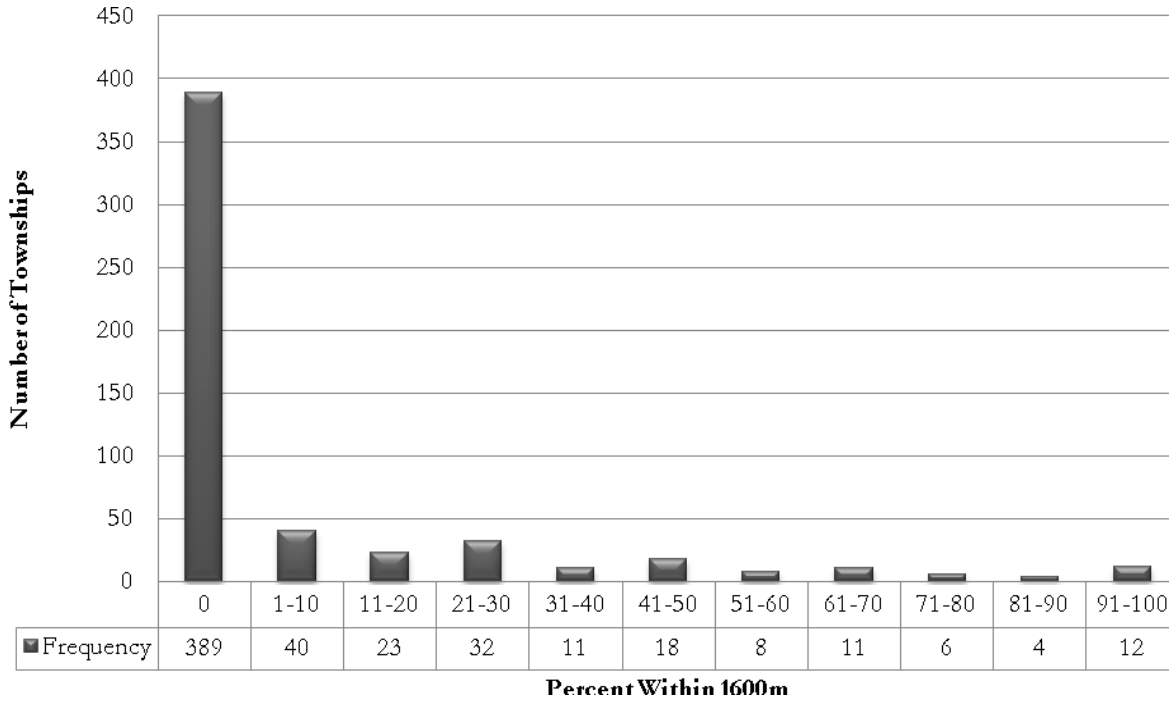


Figure 48. Frequency distribution of percent of forested parcels per township within 1,600 meters of a city.

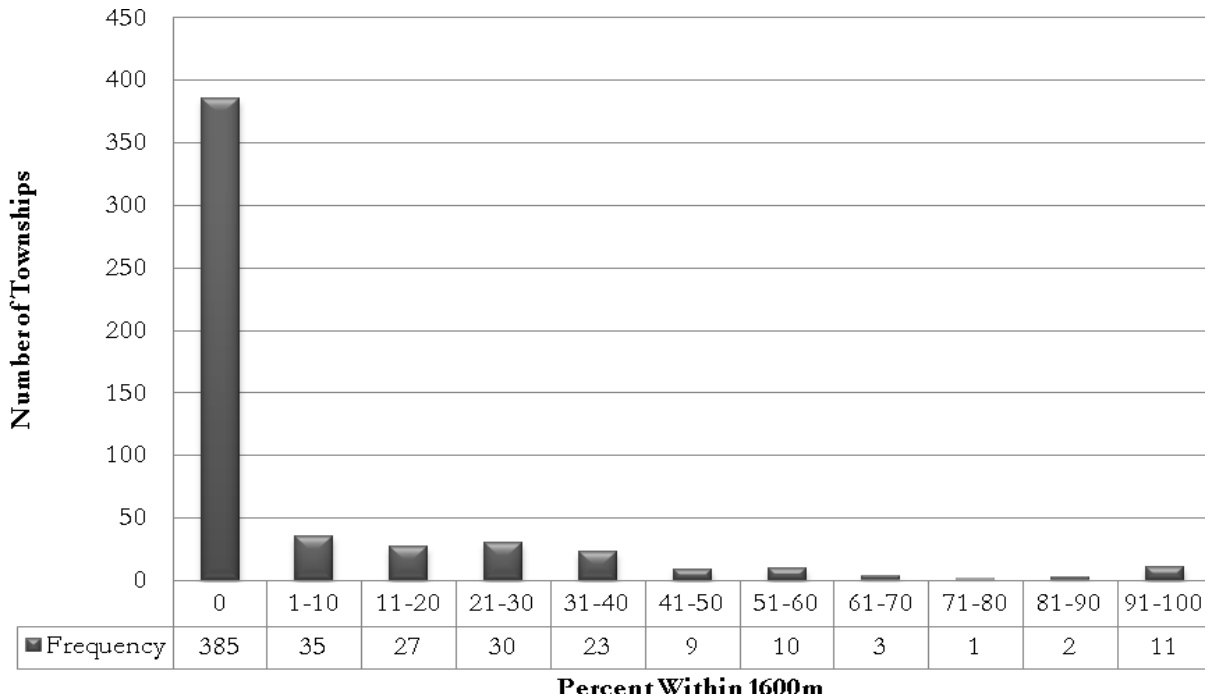


Figure 49. Frequency distribution of percent of forested parcels more than 20 acres per township within 1,600 meters of a city.

Figure 50 indicates the percent change in population from 1996 to 2006 per township. Population figures came from data collected by the Minnesota Land Economics. Larger increases in population are seen in the townships located in the southern counties than in northern ones. Some townships experienced decreases in population over this period, such as Koochiching and Lake counties. Overall, the highest population increases occurred in the central area of the study region. Large population increases were also evident in certain parts of southern Cook and Lake counties, likely illustrating the demand for amenities such as Lake Superior. The large increases in the southern/central counties, however, are more likely attributable to an increase in employment opportunities and the rural character of that area when compared the area surrounding the Twin Cities Metropolitan Area.

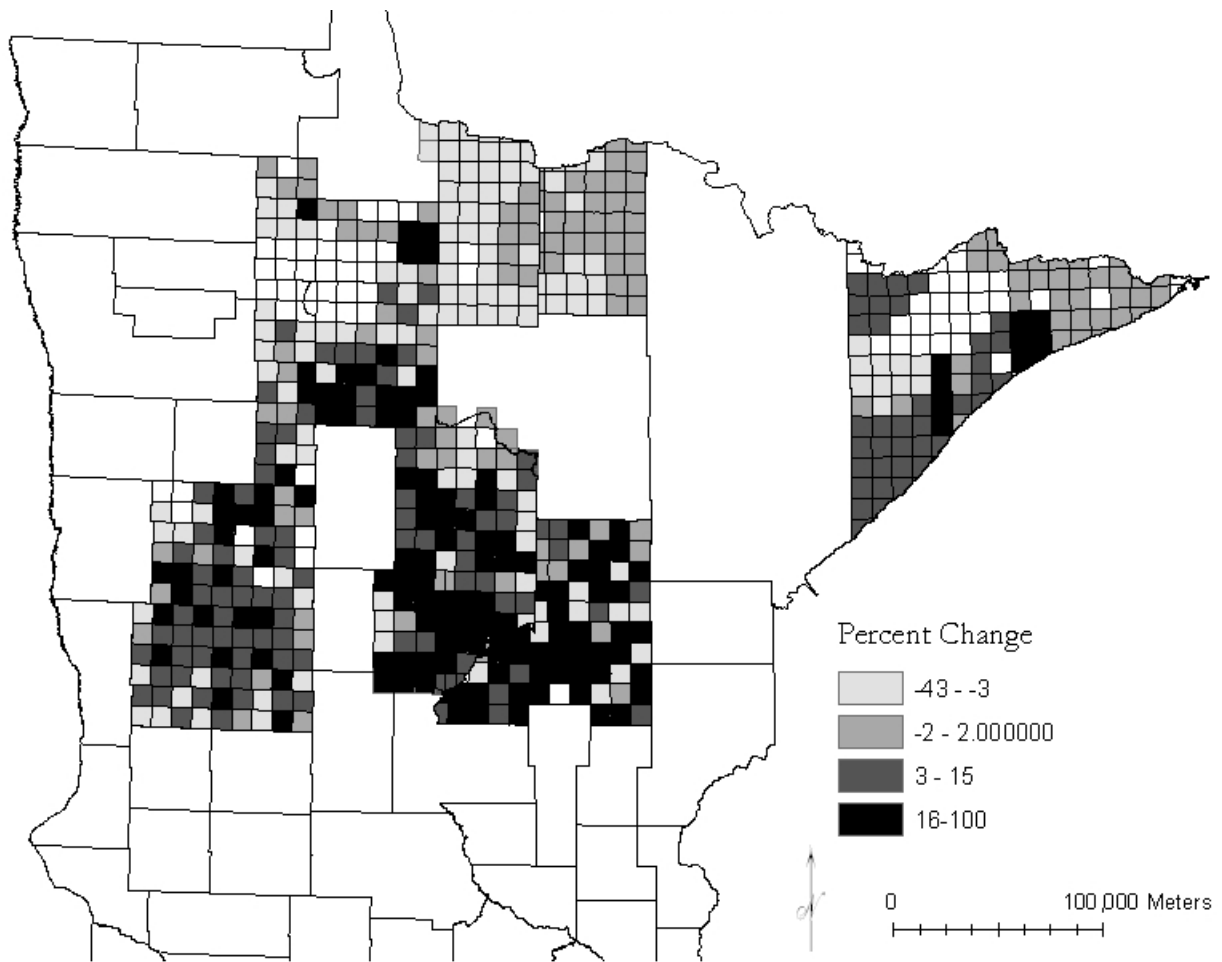


Figure 50. Percent change in population in forested parcels per township from 1996 to 2006.

Figure 51 illustrates the percent change in population from 1996 to 2006 per township for all forested parcels more than 20 acres. The patterns in this map are basically the same as those shown in Figure 50, which includes all private forest land. Otter Tail County shows fewer townships with decreases in population during this period, while southern Cass County shows the area with the largest increase in population.

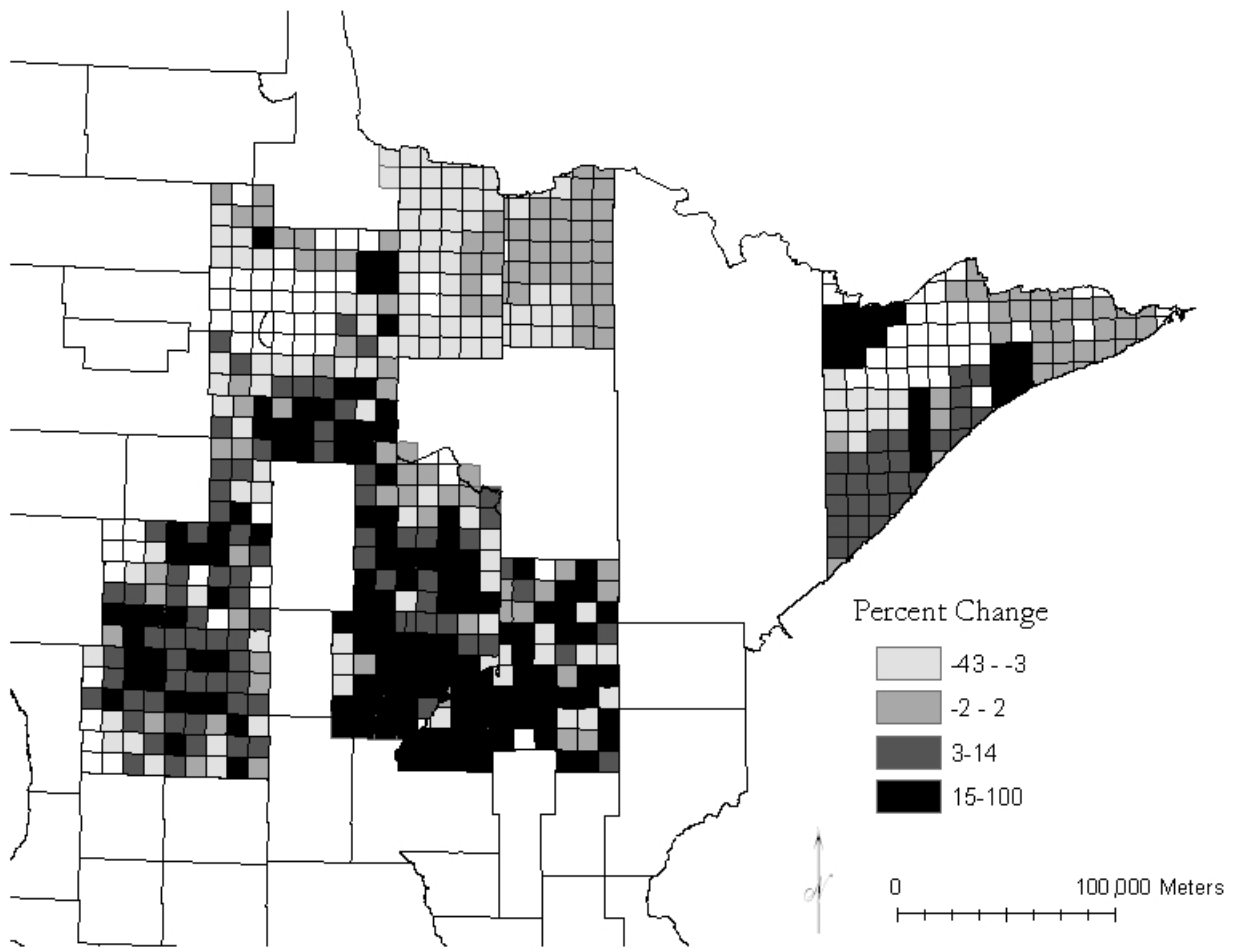


Figure 51. Percent change in population in forested parcels more than 20 acres per township from 1996 to 2006.

Figures 52 and 53, graphing the percent change in population for all forest land and parcels 20 or more acres in size, are very similar to each other. While some townships in both screens had slight decreases in population, the largest percent of townships had no change in population over this period.

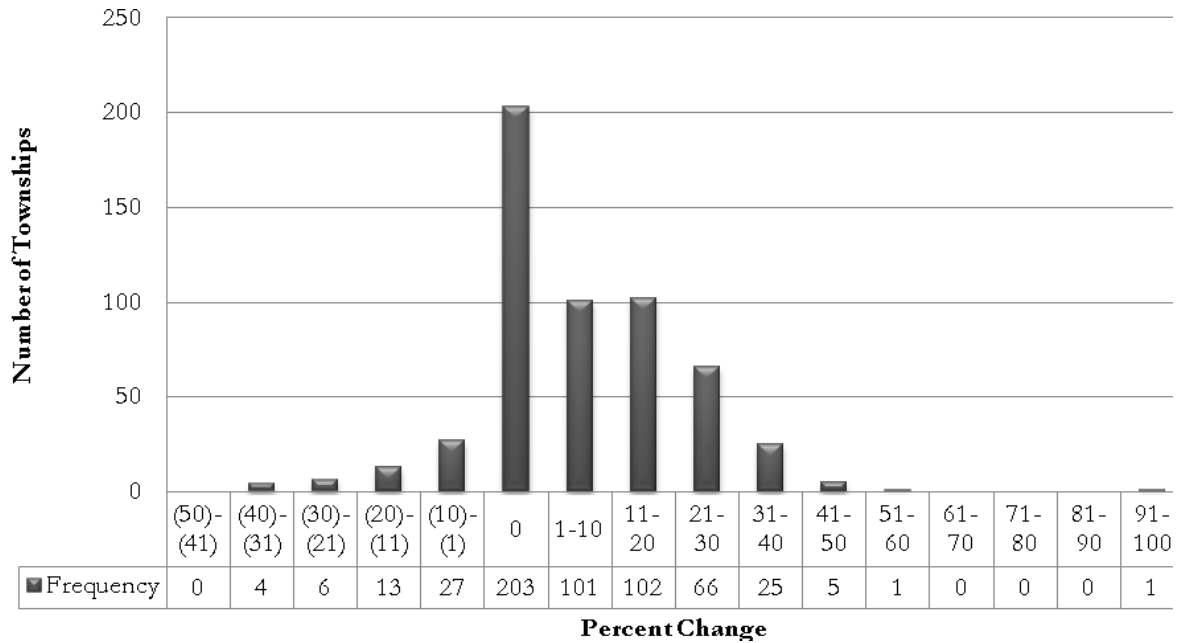


Figure 52. Frequency distribution of percent change in population for forested parcels per township from 1996 to 2006.

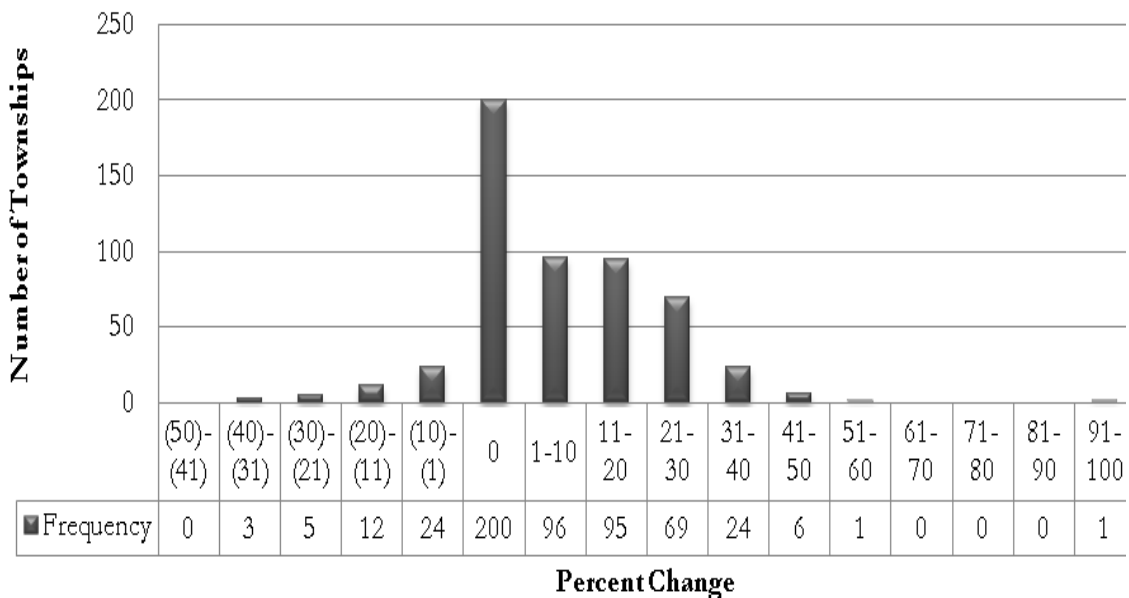


Figure 53. Frequency distribution of percent change in population per township for forested parcels more than 20 acres from 1996 to 2006.

Figure 54 illustrates the percent change in the county assessor’s estimate of building market value (EMV) from 2002 to 2008 per township for all forested parcels. Building estimated market value is the market value for any buildings on a parcel estimated by the county assessor the previous fall before the reporting year. For example, the market value for a building that is reported in 2003 is actually from an assessment made in 2002. These assessed values serve as the basis for property tax assessments. Substantial increases in building EMV can indicate a large increase the number of buildings located on forest land, which also signals an increase in development.

Much of Koochiching and Clearwater Counties experienced a very large increase in building EMV, as did certain portions of Aitkin County and a group of townships in Lake County. The rest of the study region experienced only marginal changes, both increases and decreases, with few exceptions. Substantial increases in building EMV can indicate a large increase the number of buildings located on forest land, which also signals an increase in development.

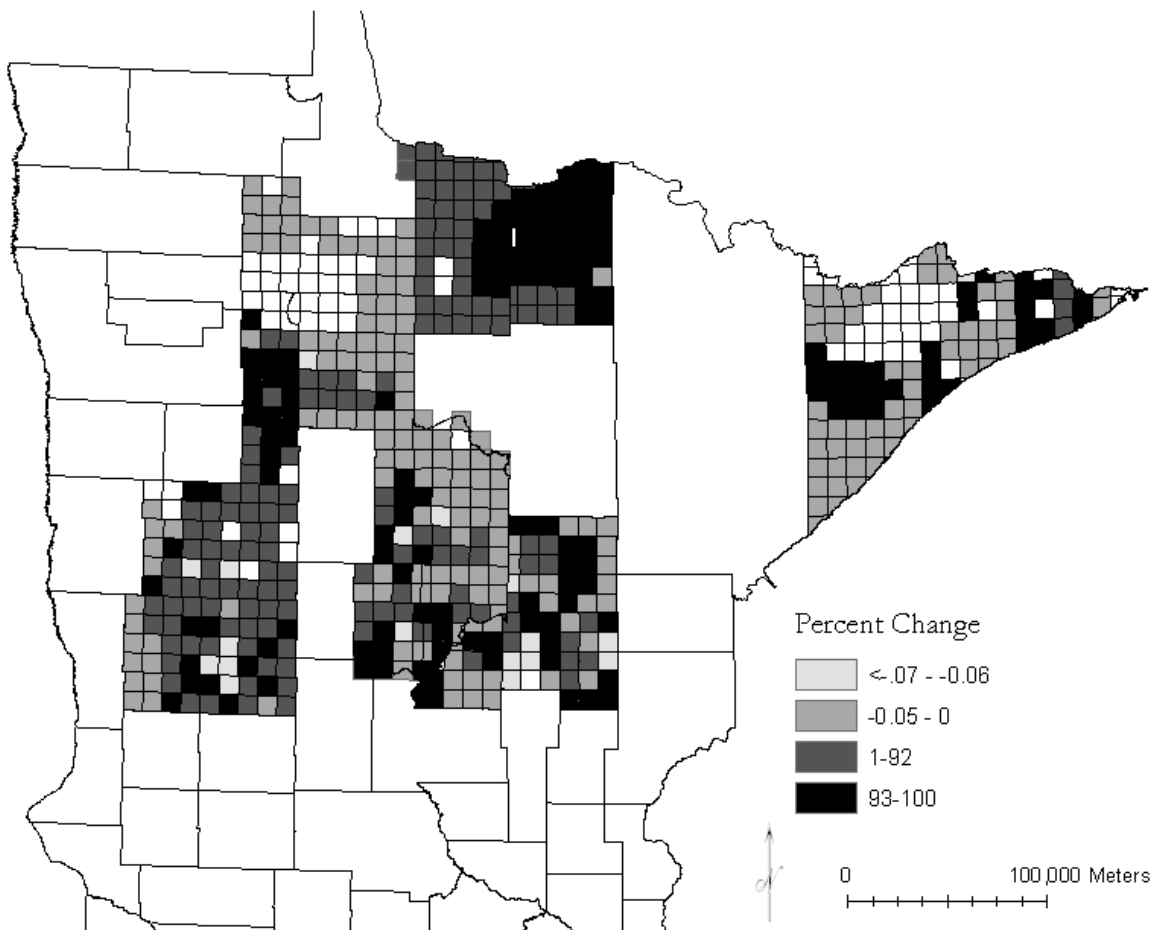


Figure 54. Percent change in building estimated market value per township from 2002 to 2008

Figure 55 shows the percent change in building EMV per township from 2002 to 2008 for all forested parcels 20 acres or greater. Koochiching County still shows a large increase in building EMV. The cluster of townships in Lake County with a large increase when all forest land is

considered (Figure 54) is reduced in size when only parcels 20 acres or more in size are considered. Overall, the entire study range has more townships in the -4 to -0% change range than in the previous map. This could indicate that more building development happens on forested parcels that are less than 20 acres.

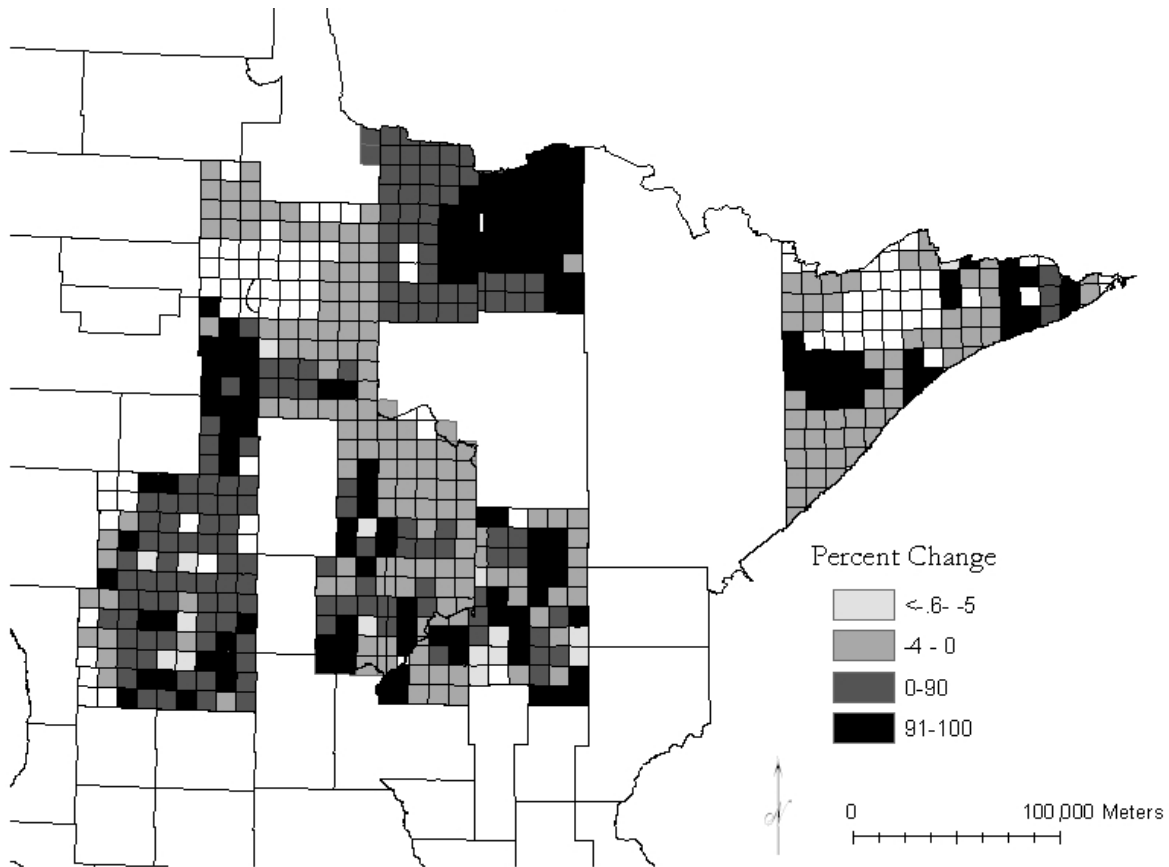


Figure 55. Percent change in building estimated market value in forested parcels more than 20 acres per township from 2002 to 2008.

Figure 56 depicts the building EMV on all seasonal recreation land in the ten county study region. Seasonal recreation land is a property tax classification used in Minnesota for land whose primary purpose is recreation. Seasonal recreation land can include land with and without buildings (e.g., cabins). This study chose to look at changes in building value as a surrogate for measuring development activity. Often, new buildings on property signify growth and development. This map is very different from the maps illustrating building EMV on forested lands (Figures 54 and 55). Across the 10-county study area, the northern counties have the smallest increases in building EMV, with some even having a large decrease in building EMV. Building EMV increase on a north-to-south gradient across the study region.

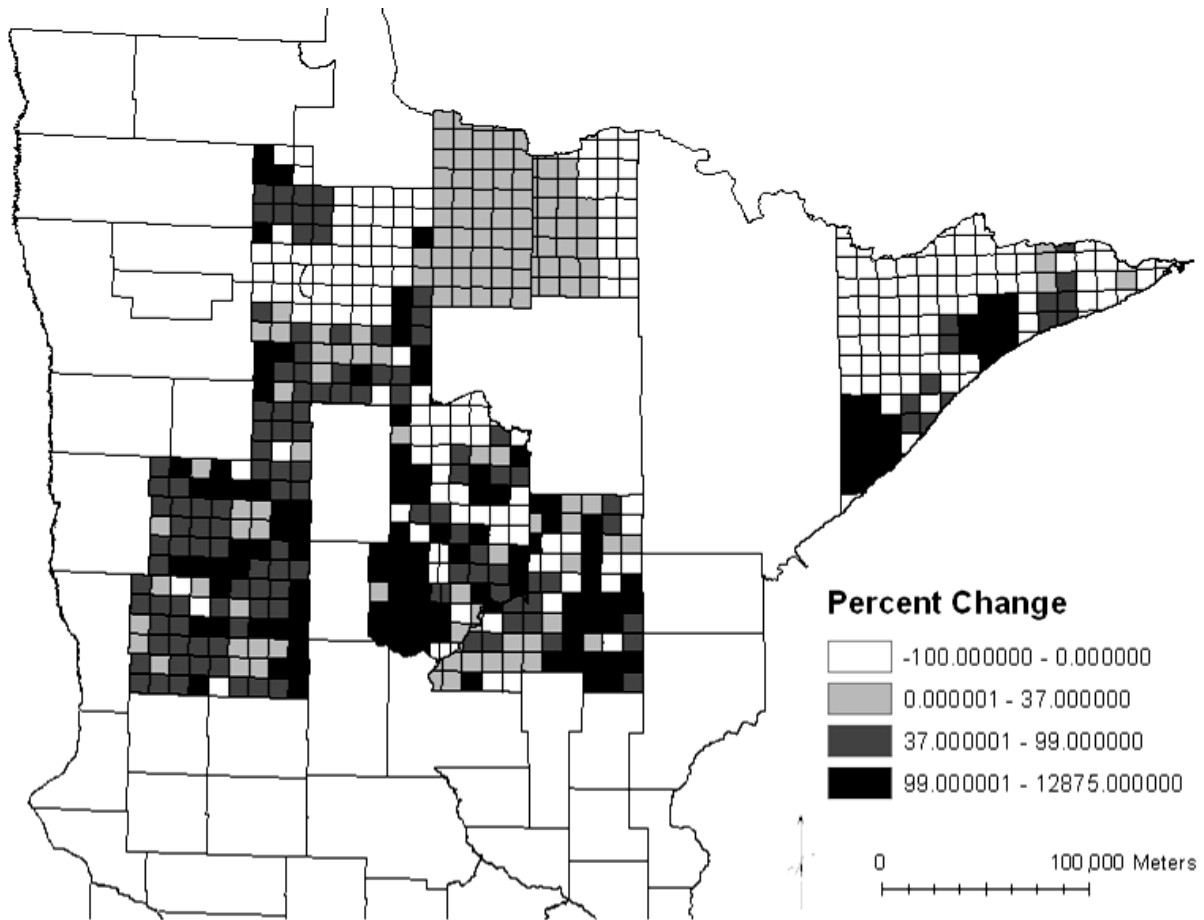


Figure 56. Percent change per township of building estimated market values on seasonal recreational land from 2002 to 2008.

Figures 57 and 58, depicting the percent change in building EMVs per township, are very similar to one another. In comparing the data presented in these two histograms, there are huge spikes in the less than 1% change and the 91 to 100% increase categories, yet hardly any activity in the categories in between. This seems to indicate that for most of the forested land in the study area there was either no increase in building value or a very large increase. This seems to indicate that any development that did occur was major. Rather than a small shed being built on a parcel, it seems likely that a commercial business or large house was built.

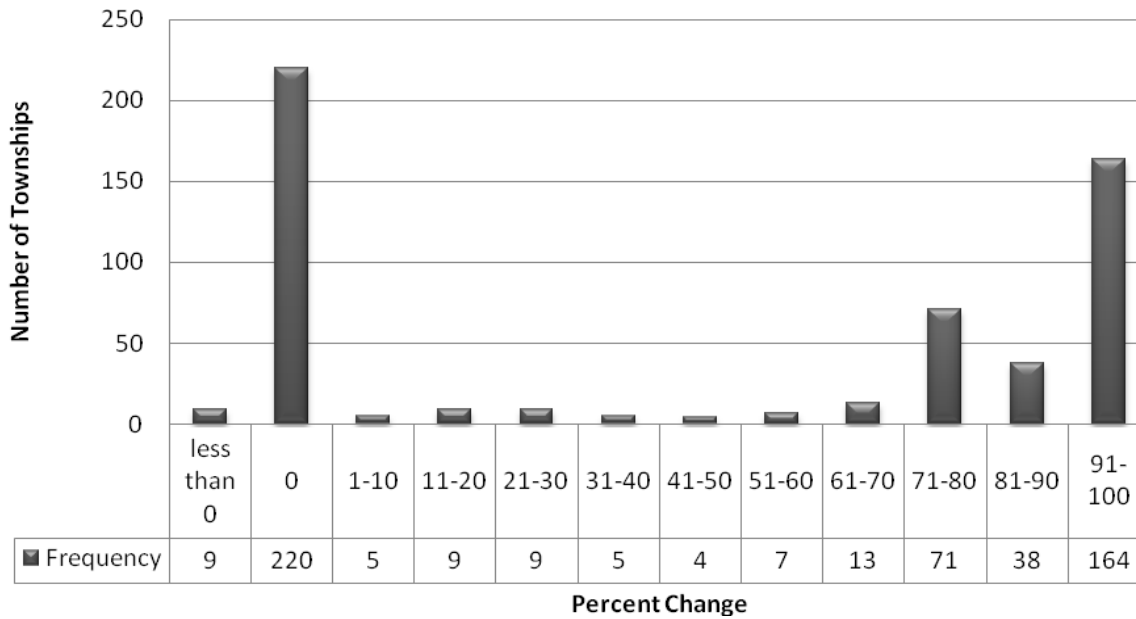


Figure 57. Frequency distribution of percent change in building estimated market value per township for all forested parcels from 2002 to 2008.

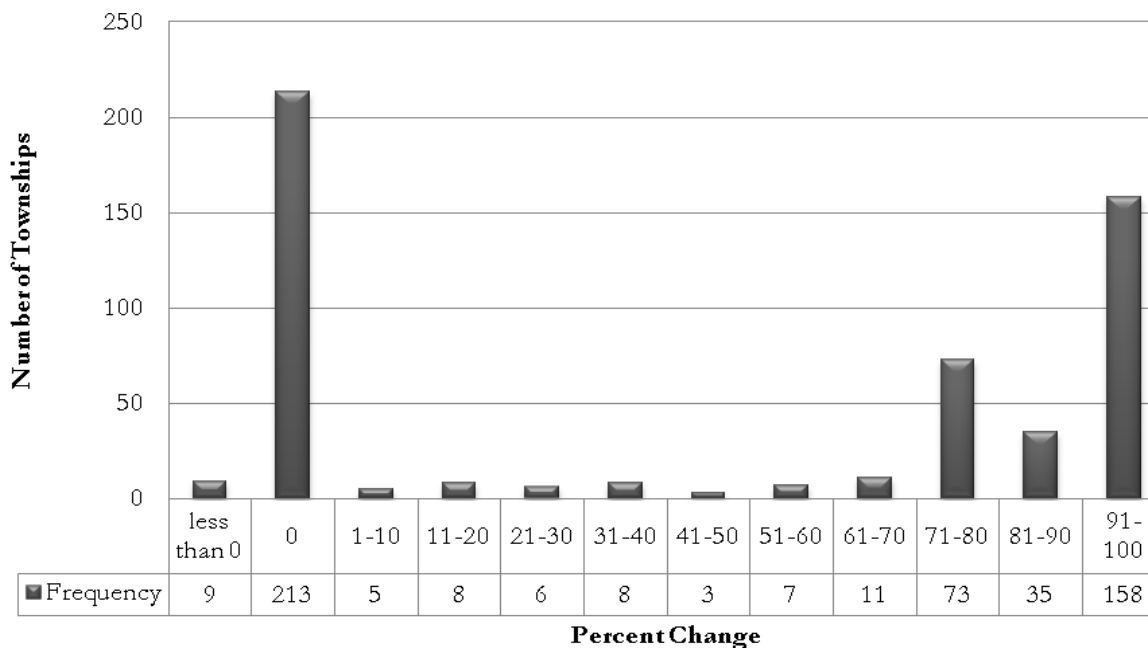


Figure 58. Frequency distribution of percent change in building estimated market value per township for forested parcels more than 20 acres from 2002 to 2008.

Figure 59, illustrating the percent change in building estimated market value per township for seasonal recreational land, is similar to those regarding building estimated market value on forested land in that there is a large number of townships with no change in building EMV from 2002-2008. This graph, however, shows much more variation between bins (i.e., categories in a histogram) than the preceding two. More townships in the seasonal recreation land category had large increases in building estimated market value compared to the forested land category, with 78 townships registering an increase of more than 200%. Additionally, more townships in this division of land classification had decreases in building estimated market value.

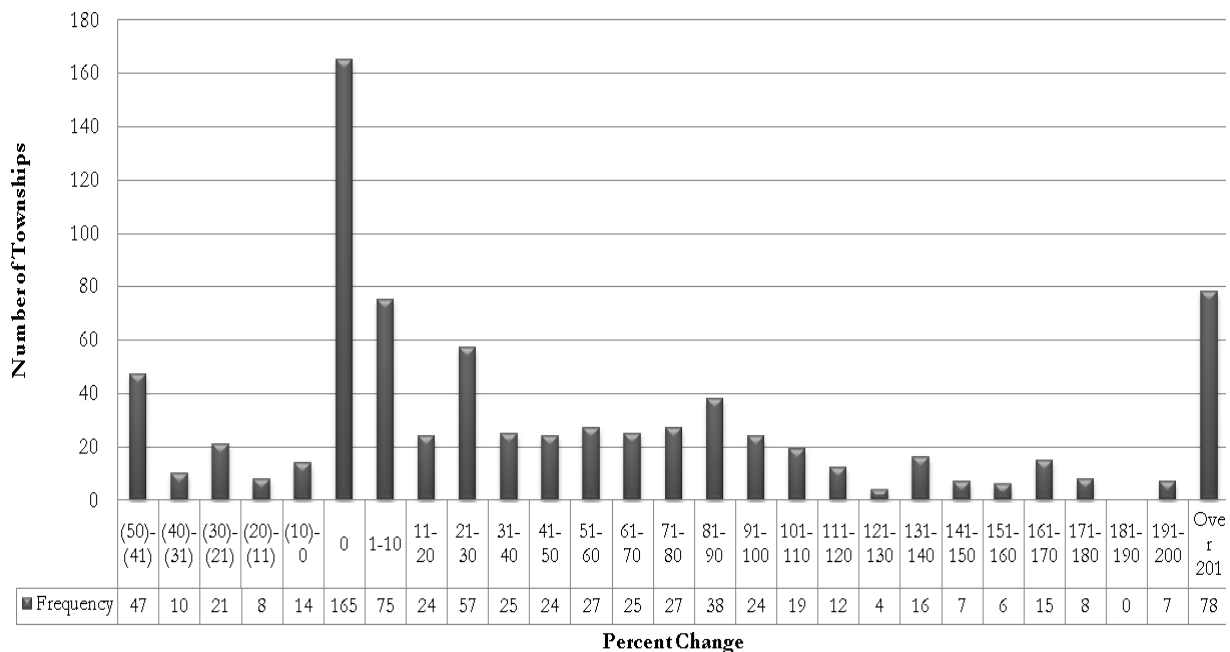


Figure 59. Frequency distribution of percent change in building estimated market value per township for seasonal recreational land from 2002 to 2008.

Figure 60 illustrates the percent change in land EMV from 2002 to 2008 per township for all forested parcels. Land EMV is the market value for certain classification of land as estimated by the county assessor for property tax purposes. This data comes from the Minnesota market value files, which are compiled from the data that county assessors record. This map shows that more townships experienced an increase in land EMV (on a percentage basis), rather than a decrease. Increases were often dramatic, more than 100%. Townships in northern Lake, Beltrami, northern Aitkin, and portions of Otter Tail County experienced the greatest percent increase in forest land EMV over this seven-year period. Koochiching County townships surprisingly almost all fall into the same category of increase, from 204 to 269%. No distinctive regional patterns of township EMV change are apparent

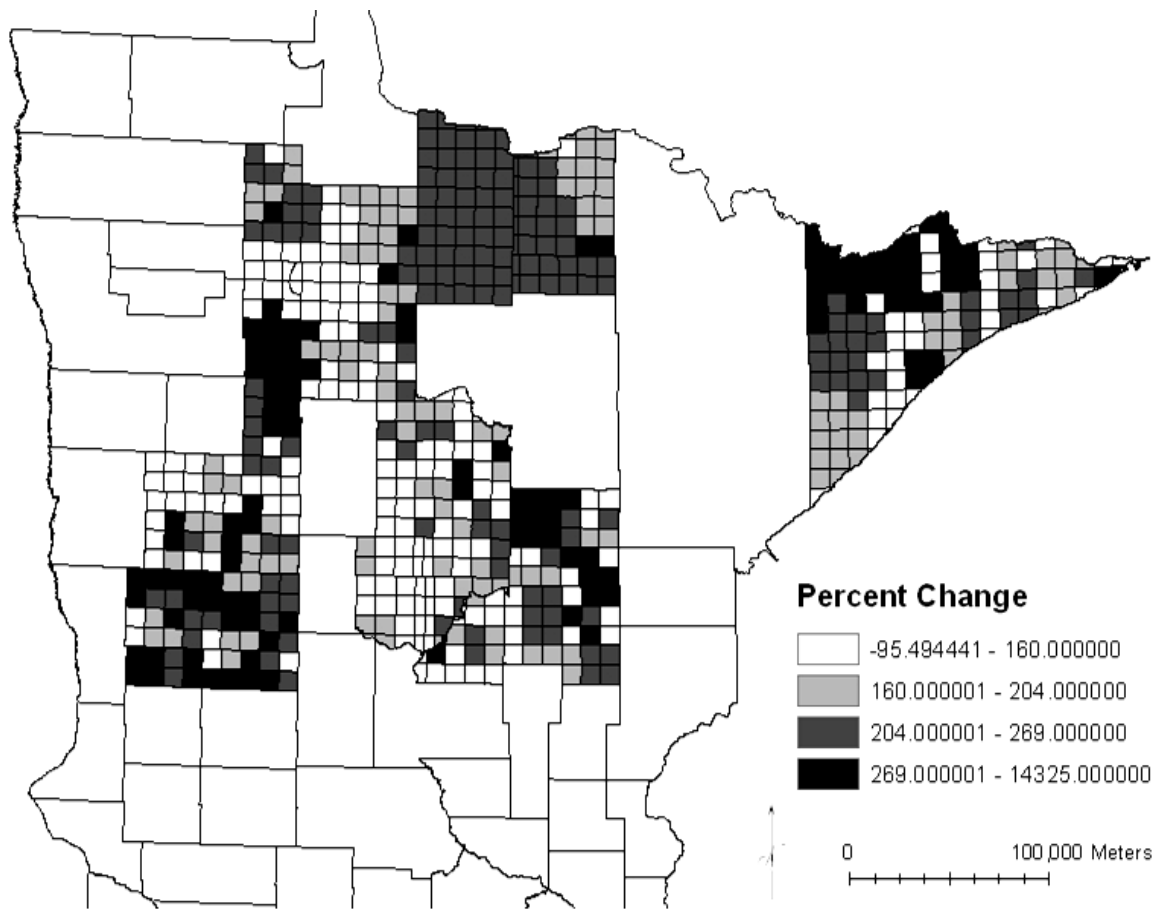


Figure 60. Percent change per township of land estimated market values on forested parcels from 2002 to 2008.

Figure 61 shows the average total net effective tax rate (NER) per township for all forested parcels. NER is the calculated tax rate for the different property tax classifications in Minnesota and was chosen as the variable that best represents overall property tax liability. We wanted to test if higher tax rates cause people to subdivide and sell their land or, conversely, if lower tax rates across a landscape correspond to less parcelization. Total NER generally tend to be higher in northern counties than in southern counties, with Beltrami, Clearwater, and Southern Lake counties having the highest NER. A cluster of townships in the middle of Koochiching County also had a high average NER. Additionally, some townships in Cook and Cass counties had an average total NER of zero. This is most likely due to the fact that data for this variable was not available for every township in every county.

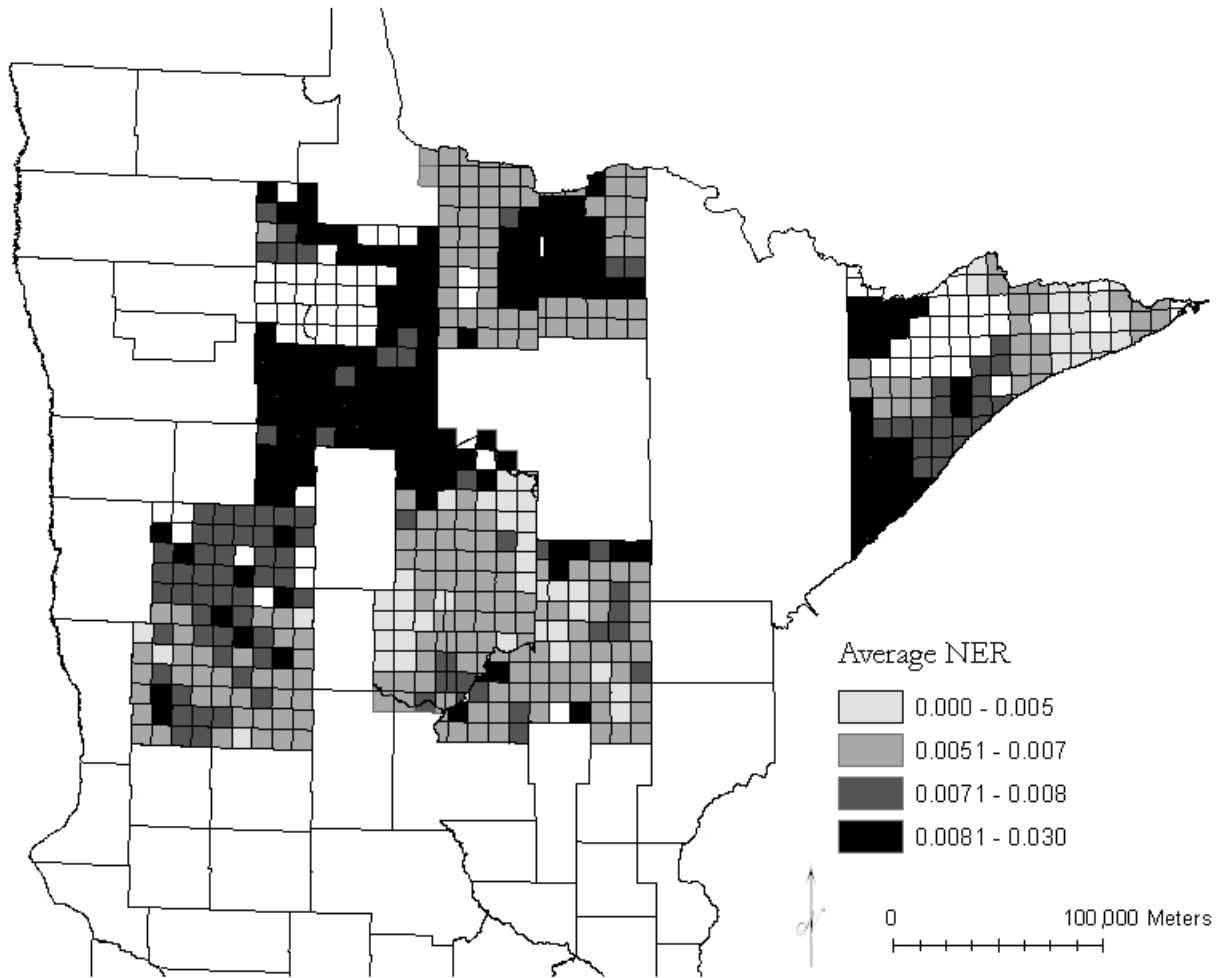


Figure 61. Average net effective tax rate per township.

Figure 62 shows the average total NER per township for all forested parcels at least 20 acres. Patterns in this map are consistent with the patterns in the previous map (Figure 61) that includes all forested parcels. However, more townships throughout the study area are in the 0 to 0.005 NER category in Figure 62 than Figure 61.

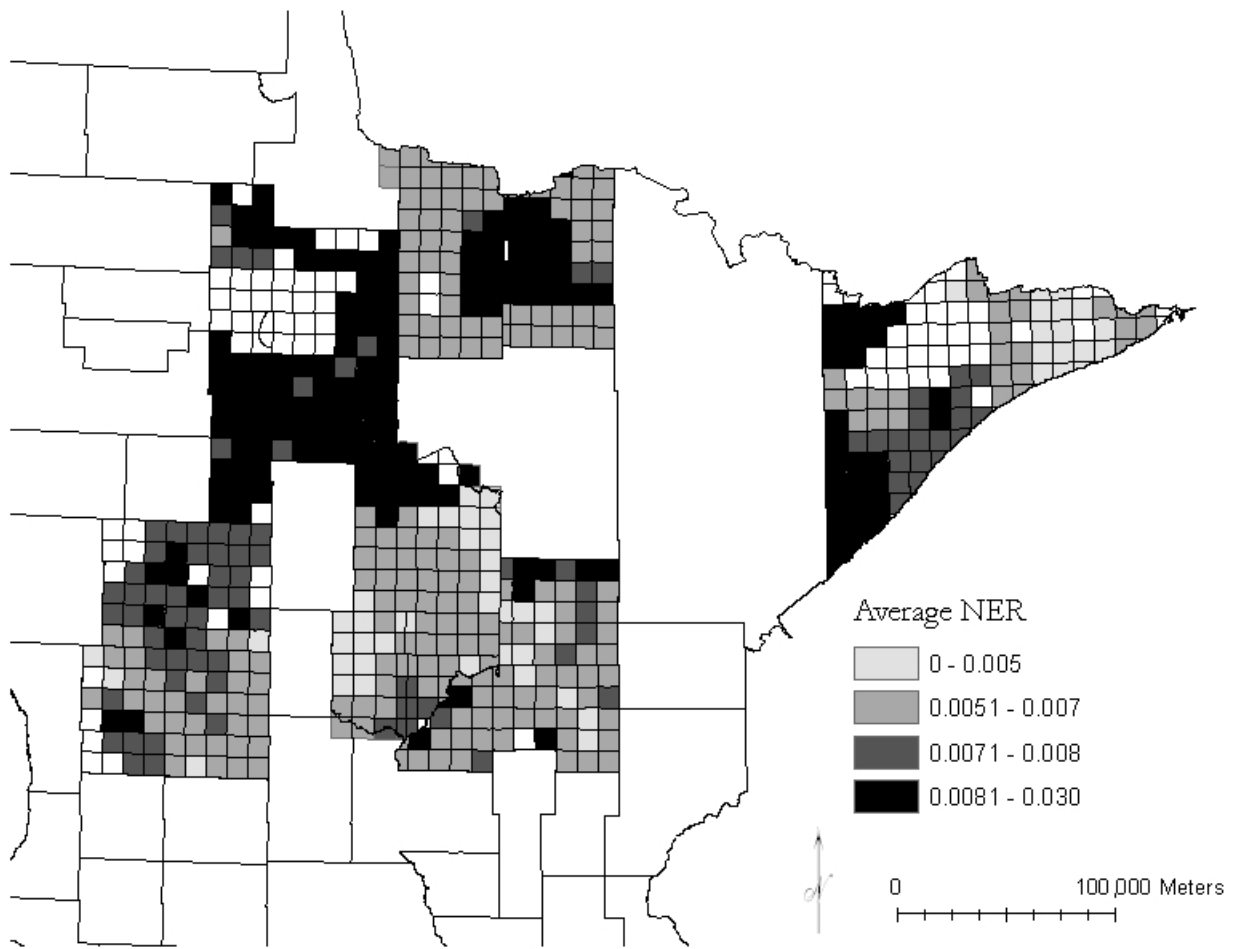


Figure 62. Average net effective tax rate per township in parcels more than 20 acres.

The histograms presented in Figures 63 and 64 correspond with the preceding two maps (Figures 61 and 62) and illustrate the frequency distribution of average net effective tax rate per township across the ten county study area. The two histograms are nearly identical, indicating the smaller forested parcels are not correlated with a lower or higher township net effective tax rate.

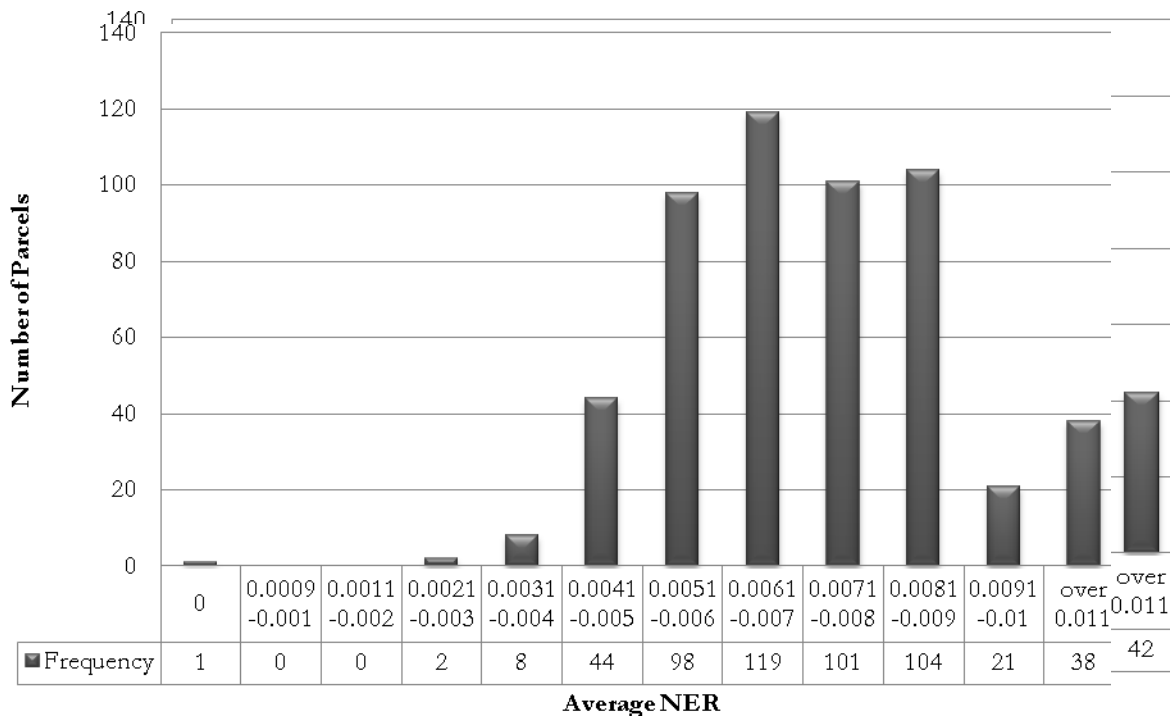


Figure 63. Frequency distribution of average net effective tax rate per township.

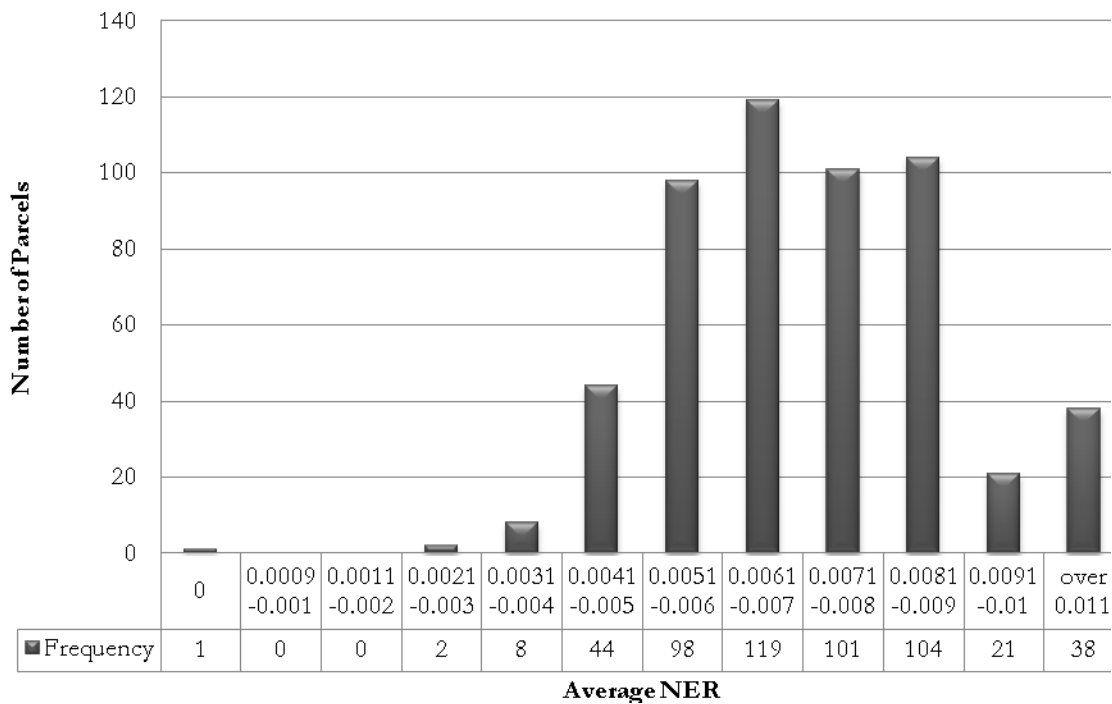


Figure 64. Frequency distribution of average net effective tax rate for forested parcels more than 20 acres per township.

Figure 65 indicates the average forest productivity index rating (FPI) per township for all private forested parcels. The Minnesota FPI is a rating system that ranks soils based on their ability to grow quaking aspen. The index can be used to compare the growth potential of one soil to another. Ratings are on a 0 to 100 scale, with high rates indicating better forest growth potential. Ratings are based on physical and chemical properties of the soil. Three categories were used to rate the soils: (1) their effects on water availability (including soil drainage class, depth to water table, and available water storage); (2) nutrient availability (including organic matter and exchangeable bases); and (3) other (site) factors such as the bulk density of the rooting zone and stone content. The FPI information can be used to target those areas that have the greatest opportunity to impact forest productivity, as increased parcelization often leads to reduced forest productivity.

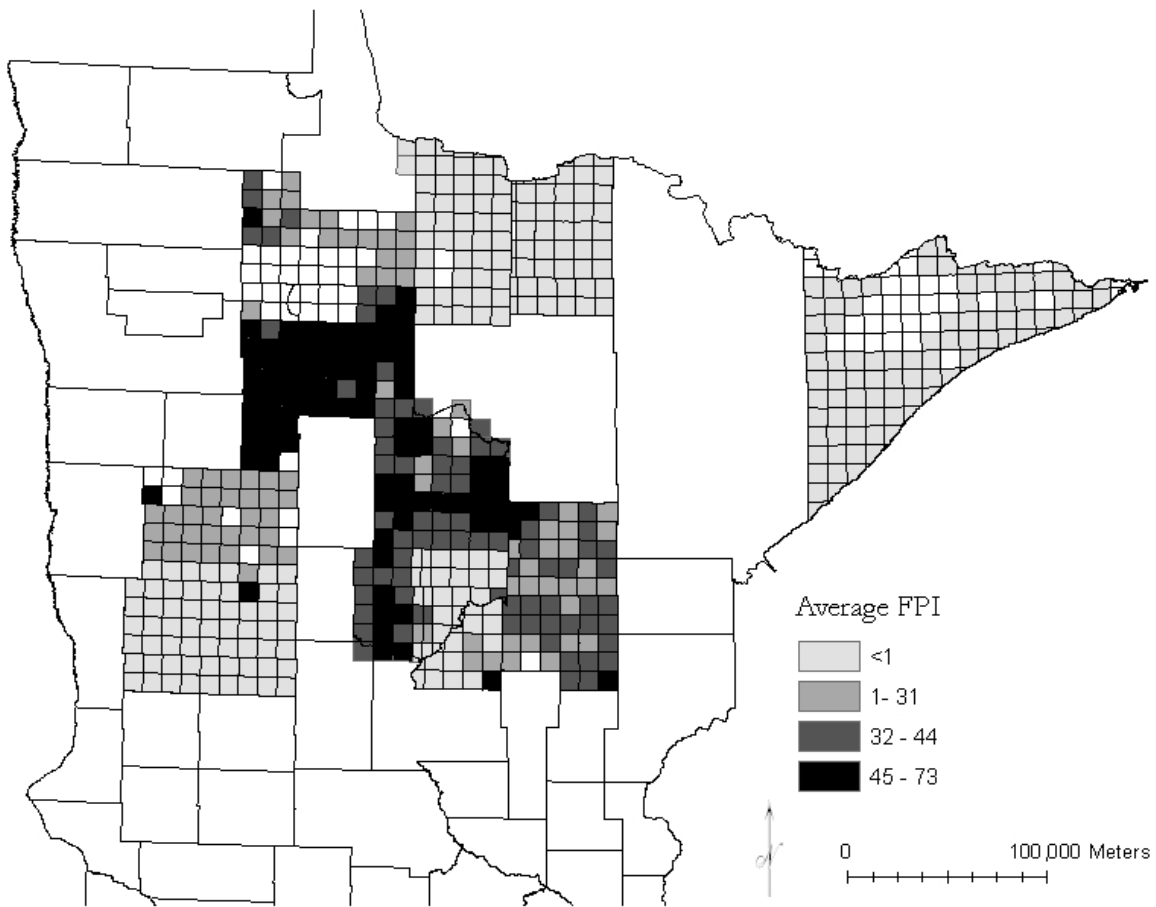


Figure 65. Average forest productivity index rating per township.

FPI ratings are highest in Clearwater and southern Beltrami counties. Cass County has the second highest overall rating. Cook, Koochiching, Lake, and Otter Tail counties all have an average rating of zero, as FPI rating data was not available for those counties.

Figure 66 indicates the average FPI per township for all forested parcels 20 acres or more. The same patterns are evident in this map as in the map that included all forested parcels (Figure 65), with Clearwater and southern Beltrami counties having the highest FPI ratings.

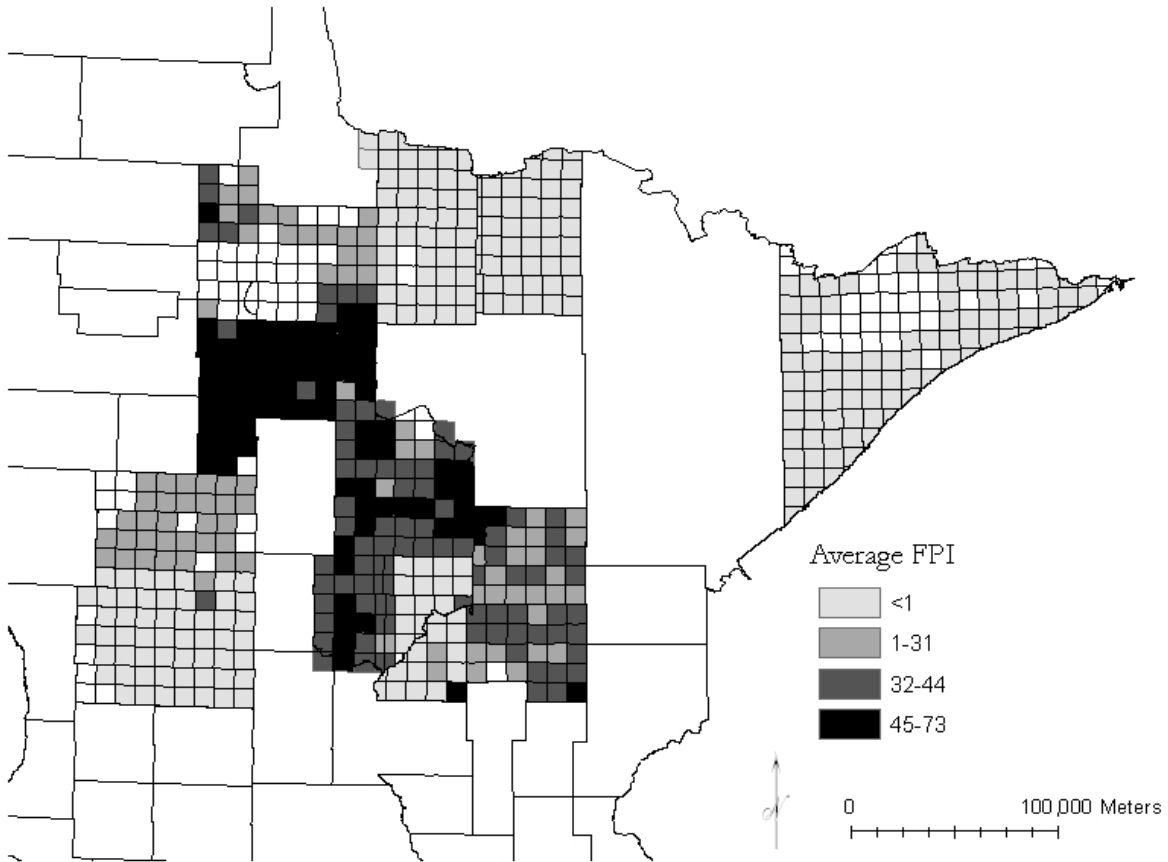


Figure 66. Average forest productivity index rating per township for parcels more than 20 acres.

Figures 67 and 68, illustrating average forest productivity index rating per township, and are very similar. Considering only forested parcels 20 acres or more in size (versus all forest land regardless of parcel size) does not have a significant impact on a township's overall FPI index. Most townships have a rating of zero, again because FPI rating data was not available. There are a few townships distributed across the ratings from 1 to 80.

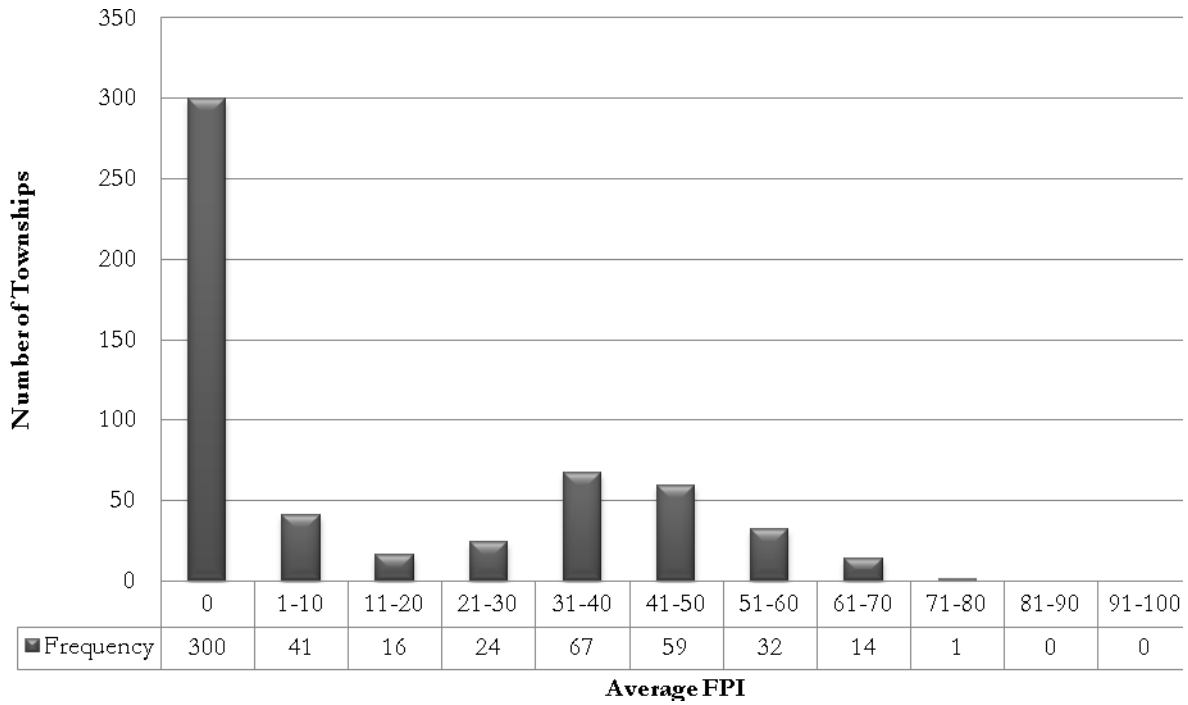


Figure 67. Frequency distribution of average forest productivity index rating for forested parcels per township.

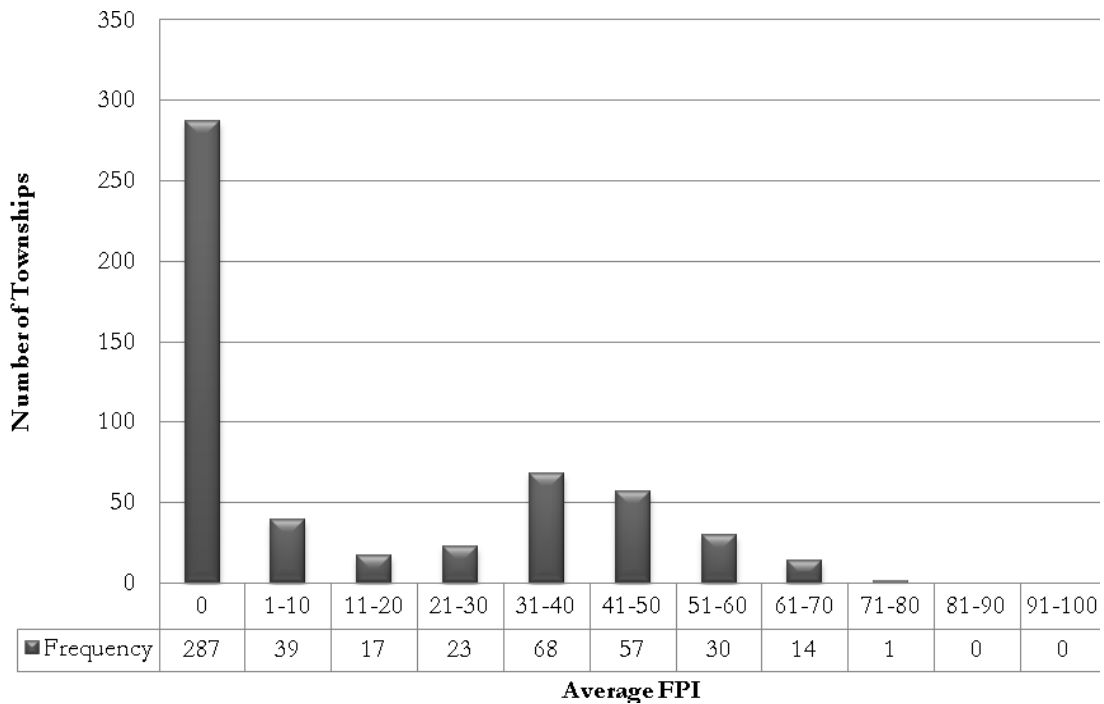


Figure 68. Frequency distribution of average forest productivity index rating for forested parcels more than 20 acres per township.

Summary Observations of the Multicounty Analysis

The extensive series of maps and graphs created from the data allowed us to visually display and examine several important physical and economic dimensions of private forest land across the 10-county study area. From these maps, relationships were visually discerned between average parcel size, amount of forest land, and total parcels per township. Recognizing the disadvantages associated with average parcel size as an indicator of parcelization, this metric can visually represent important changes that are occurring across a large landscape. From the data, it appears that townships with smaller average parcel sizes most often have the highest numbers of total parcels. Interesting patterns also emerge when analyzing parcels' adjacency to water, roads, and public lands. Surprisingly, the rate of adjacency to water does not drastically change when parcels less than 20 acres in size are removed from the analysis. We had expected the effects of small parcels next to lakes to have a more pronounced effect on the level of parcelization within a forested landscape. Moreover, the histograms show that the difference between the analysis done using all private, forested parcels and that done using private, forested parcels 20 acres or more is minor regardless of the driver that was being graphed. These observations suggest that there are specific drivers of parcelization, regardless of the size of a parcel. The statistical analysis that follows is able to lend itself to more conclusive determinations than the visual analysis alone.

Characterizing a Parcelized Landscape

One of the main goals of this study was to describe a parcelized landscape, as well as site and proximity factors associated with a parcelized landscape. Most research has characterized forest parcelization according to average parcel size. However, results from the preceding analysis indicate the use of average parcel size as a measure of parcelization may not accurately portray the distribution of parcel sizes and number of parcels across a landscape. For example, Figure 69 illustrates how using mean parcel size can present very different characterizations of forest land parcelization. The acreage of private forest land represented in these two figures is very different, even though both townships have nearly identical average parcel size. The Crow Wing township in Figure 69 contains 157 private forest land parcels—133 more than is contained in the Cook County township. Yet, if average parcel size is used to characterize a parcelized landscape, these two townships would be considered nearly equivalent (mean parcel size of 83.46 and 83.05, respectively). As is obvious from these two figures, the two townships are quite distinct in terms of the degree to which each is parcelized. In the Crow Wing County township, nearly three-quarters of its land covered in private forest land, while private forests contained in the Cook County township covers only 9% of the township's land area.

Another problem with using average parcel size as a measure of a parcelized landscape is its inability to account for the distribution of individual parcel size. The two hypothetical landscapes portrayed in Figure 70, contain the same land area, number of parcels, and average parcel size. Using average parcel size as a metric to describe a parcelized landscape would have described

these two hypothetical landscapes as identical, yet they illustrate very different pictures of parcelization. With its entire area covered by small parcels, by most measures, landscape B would be considered to be more parcelized than landscape A where small acreage parcels only cover a small portion of its land area.

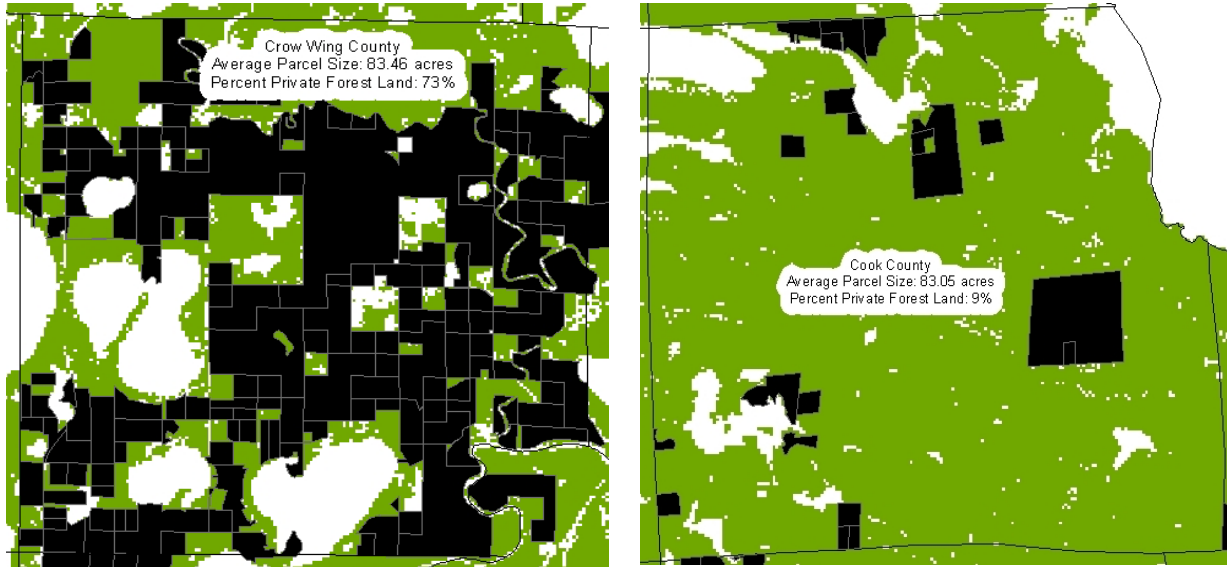


Figure 69. Townships in Crow Wing and Cook counties with nearly equal average parcel size.

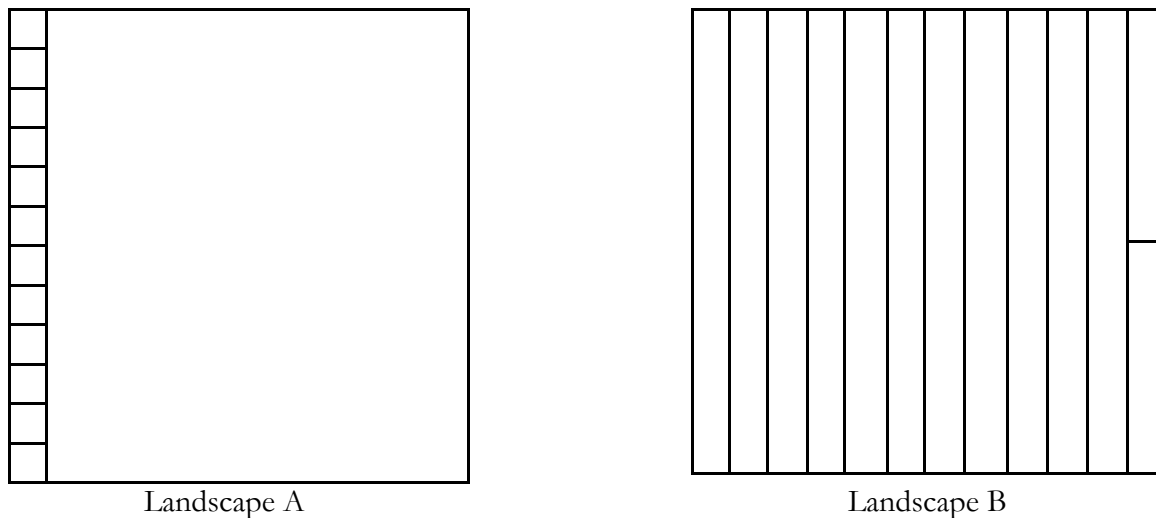


Figure 70. Two landscapes with the same area, number of parcels, and average parcel size.

A few researchers have used metrics other than mean parcel size to describe forest land parcelization. Pan, Zhang, and Majumdar (2009) used a Gini-coefficient to model county timberland distribution, plotting the cumulative percent of forestland against the cumulative percent of forest land owners to create their Gini-index. This index measures the statistical

dispersion of forested land across a geographic area. We felt using a Gini-coefficient could result in a misleading characterization of parcelization, as this metric focuses more on the area in the tail of the dispersion graph, rather than on the majority of the area. Focusing only on the area in the tail of the graph skews the meaning of what is attempting to be explained—the extent of parcelization in forestland parcels. A township with a very large distribution of parcel sizes could have the same Gini-coefficient number as a township with a very narrow distribution in parcel size.

Proposed New Measure of a Parcelized Landscape

To account for the distributional and spatial problems associated with using average parcel size, a new metric was developed to measure the extent to which a forest landscape is parcelized, taking into consideration specific features of a forest landscape. This metric can be expressed as follows:

$$\frac{\text{percent of acres} < \text{a specified acre threshold}}{\text{mean parcel size}} \times \text{total private forest land acres}$$

which simplifies to:

$$\text{percent of acres} < \text{a specified acre threshold} \times \text{number of private forest land parcels}$$

This metric makes two adjustments to average parcel size to better account for the distributional and spatial variability of a parcelized landscape, as illustrated in Figures 69 and 70. To address the acreage distributional problem, the percent of acres attributed to parcels within a forested landscape (e.g., township) that are less than a threshold acreage value is included. Although the selection of a threshold acreage value is arbitrary, the threshold value suggests the size of parcels that could be associated with a parcelized landscape. To illustrate, assume two landscapes have an average parcel size of 15 acres, yet 90% of the area in one landscape contains parcels less than 20 acres in size (the threshold value used in this case) while only 20% of the other landscape’s area has parcels less than 20 acres in size. By adjusting each township’s average parcel size to account for the percent of acres in parcels less than 20 acres produces very different measures of a parcelization (i.e., 0.06 for the township with 90% of its land in parcels less than 20 acres versus 0.013 for the township with 20% of its land area containing parcels less than 20 acres in size).

Similarly, the new metric accounts for the spatial extent of a forested landscape by multiplying by the total forest acres per township. The formula accounts for the areal extent of forested landscapes, as the value of the proposed new parcelization metric increases with the size (area) of the forested landscape.

Using the formula described above, a higher value represents a higher level of parcelization (i.e., decreasing the average parcel size, increasing the percent of the landscape in smaller parcels, or increasing the area of the landscape will all increase the value of this new parcelization metric).

While we suggest this metric is an improvement over using average parcel size to describe a parcelized landscape, it has its shortcomings. One is that the specific threshold acreage value selected can impact the value of the parcelization metric. For example, assume each of the two landscapes illustrated in Figure 70 is 144 acres. Each has 13 parcels and an average parcel size of 11.08 acres. Landscape A contains one 132-acre parcel, and twelve 1-acre parcels. Landscape B has eleven 12-acre parcels, and two 6-acre parcels. For most reasonable acreage threshold values (i.e., those that are not extremely small), the proposed new metric characterizes landscape A as being less parcelized than landscape B (i.e., the calculated metric for landscape A is smaller than for landscape B). However, using any threshold acreage value smaller than 6 acres will characterize landscape A as a more parcelized landscape than landscape B. This points to the somewhat subjective nature of selecting a parcel size below which a landscape is considered parcelized.

Characterizing what constitutes a parcelized landscape is also dependent on the spatial arrangement and associated amenity features of the landscape. For example, landscape A in Figure 70 may be considered more parcelized if the row of small parcels is on a lake shore and one is concerned with runoff issues. Conversely, landscape B may be considered more parcelized if focusing on wildlife habitat fragmentation. This limitation notwithstanding, we suggest the proposed metric is a substantial improvement over average parcel size to characterize a parcelized landscape.

Applying the Parcelization Metric to the Study Data

Ordinary least squares (OLS) regression was used to test this new proposed metric for describing a parcelized landscape. Using the percent change in population, net effective tax rate, estimated market value, adjacency to public water, adjacency to public land, adjacency to public roads, and adjacency to a city as independent variables, both mean parcel size within a township and the proposed new parcelization metric were tested as dependent variables.

Diagnostic tests of the data indicated OLS model assumptions (e.g., linearity, constant variance, independence and normal distribution of error terms) were not substantially compromised.

Other important aspects of the models used to test the new parcelization metric:

- Townships are the unit of analysis. The PivotTable function in Microsoft Excel 2007 was used to aggregate individual parcel data up to the township level.
- The independent variables were chosen based on findings from previous research suggesting they are associated with parcelization. When reviewing previous studies of parcelization, several characteristics were consistently used to identify associations of parcelization: proximity to water, public land, metropolitan areas, access availability (roads), population, tax rates, and development. Limited by data availability, we incorporated those proxy variables for the associations thought to be most influential.

- Two analyses of the data were conducted depending on whether private forest land was considered to be: (1) at least one acre; and (2) at least 20 acres. These two levels of analysis were used to test whether there is a large effect from shoreland development, which tends to include small parcels.
- All analyses were conducted using PASW 17.0.3 software (SPSS).

Table 1 identifies the independent variables used in the regressions. Table 4, located in Appendix A, contains descriptive statistics for all independent variables from data including all private, forested parcels. Table 5, also located in Appendix A, contains descriptive statistics for all independent variables from data including all private, forested parcels 20 acres or more in size.

Table 1. Variables from dataset hypothesized to be associated with a parcelized landscape.

Variable	Description	Hypothesized Effect on Parcelization
% Change in population 96-06	Percent change in population per township from 1996-2006	Positive
Average of totalner	Average total net effective tax rate per township	Positive
Totemv08	Average total estimated market value per township	Positive
% of adj_lakeacre	Percent of private, forested acres adjacent to public waters	Positive
% of adj_pblclnacre	Percent of private, forested acres adjacent to public land	Positive
% of adj_roadacre	Percent of private, forested acres adjacent to public roads	Positive
% of 1600macres	Percent of private, forested acres within 1,600 meters of a city	Positive

OLS Models Developed – All Forest Land

The following describes the four OLS models that were developed to identify associations between different measures of a parcelized forested landscape and various parcel-level data (e.g., value, proximity characteristics), aggregated to the township. All four models included all private forest land in the analysis. The left-hand side (LHS) variables for these four models include mean parcel size and three new parcelized landscape metrics (incorporating 80, 60, and 40 acre threshold levels) and are described as follows:

Average parcel size = $f(\text{change in population from 1996-2006, net effective tax rate, total estimated market value, adjacency to public waters, adjacency to public lands, adjacency to public roads, within 1600m of a city})$.

(percent of acres in parcels under 80 acres / average parcel size)*total forest acres
= $f(\text{change in population from 1996-2006, net effective tax rate, total estimated market value, adjacency to public waters, adjacency to public lands, adjacency to public roads, within 1600m of a city})$.

(percent of acres in parcels under 60 acres /average parcel size)*total forest acres
 =f(change in population from 1996-2006, net effective tax rate, total estimated market value, adjacency to public waters, adjacency to public lands, adjacency to public roads, within 1600m of a city).

(percent of acres in parcels under 40 acres /average parcel size)*total forest acres =f(change in population from 1996-2006, net effective tax rate, total estimated market value, adjacency to public waters, adjacency to public lands, adjacency to public roads, within 1600m of a city).

Table 2 contains the results of these four models. Independent variables with a p-value ≤ 0.05 are considered statistically significant. A positive coefficient that is statistically significant means that as that variable increases in value, the dependent variable increases (meaning a more parcelized landscape). Conversely, a negative coefficient that is statistically significant means that as that variable decreases in value, the dependent variable decreases (meaning a less parcelized landscape).

In Table 2, only percent change in population from 1996 to 2006 is statistically significant for Model I, using average parcel size as the dependent variable. In Models II-IV, percent change in population is also statistically significant. This indicates that as population increases, so does parcelization, as the sign on the independent variable is positive. Percent of acreage adjacent to public water is also significant in Models II-IV. Again, the sign on all three models is positive, indicating that as more acreage is adjacent to water, the landscape becomes more parcelized.

Table 2. Regression results using all forested parcels at least one acre.

Model	I			II			III			IV		
Variable	Average parcel size			80 acres			60 acres			40 acres		
	Coeff.	SE	p-Val	Coeff.	SE	p-Val	Coeff.	SE	p-Val	Coeff.	SE	p-Val
% Change in population 96-06	-1.481	0.344	0.000	2.250	0.436	0.000	1.872	0.379	0.000	1.386	0.311	0.000
Average of totalner	-417.890	2632.184	0.874	1441.597	3336.486	0.666	1028.427	2896.654	0.723	1061.409	2367.562	0.654
totemv08	0.000	0.000	0.512	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% of adj_lakeacre	-0.127	0.229	0.581	0.826	0.290	0.005	0.730	0.252	0.004	0.548	0.208	0.009
% of adj_pblndnacre	-0.046	0.169	0.783	-0.055	0.214	0.799	-0.024	0.186	0.898	-0.026	0.153	0.867
% of adj_roadacre	0.061	0.301	0.839	0.382	0.382	0.318	0.265	0.332	0.425	0.210	0.275	0.446
% of 1600macre	-0.313	0.311	0.316	0.595	0.395	0.132	0.541	0.343	0.115	0.389	0.280	0.166
(Constant)	87.566	31.233	0.005	-35.320	39.590	0.373	-32.204	34.371	0.349	-31.977	28.353	0.260
R ²	0.060			0.370			0.375			0.376		
Adjusted R ²	0.042			0.357			0.363			0.364		
F-Statistic	3.260			29.913			30.633			30.274		
Model p-Val-value	0.002			0.000			0.000			0.000		
n	364.000			364.000			364.000			358.000		

Figures 71 to 73 illustrate various characterizations of parcelized forest landscapes across the ten county study area using the proposed new metric of a parcelized landscape.

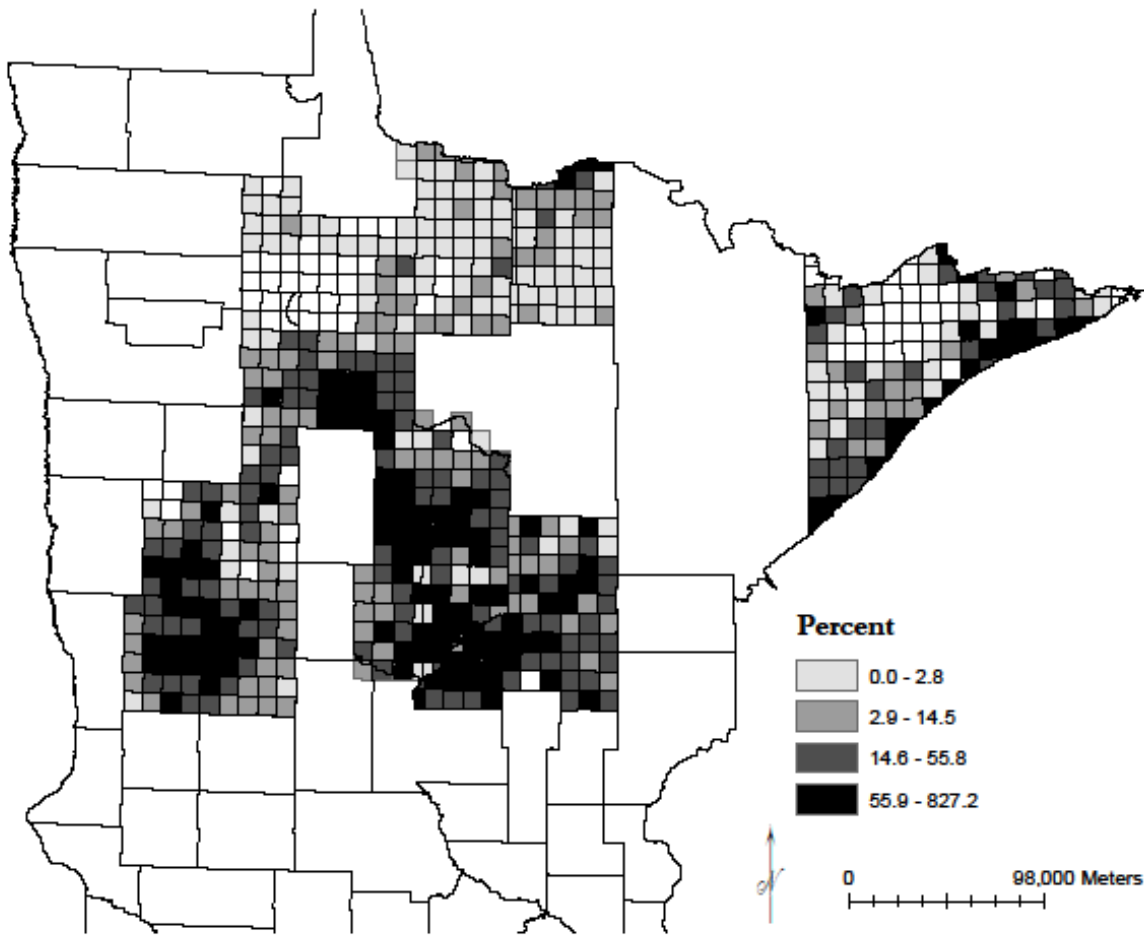


Figure 71. Extent of private forest land parcelization by township across the 10-county study area as estimated by the new parcelization metric (40-acre threshold). Darker shading indicates a more parcelized landscape.

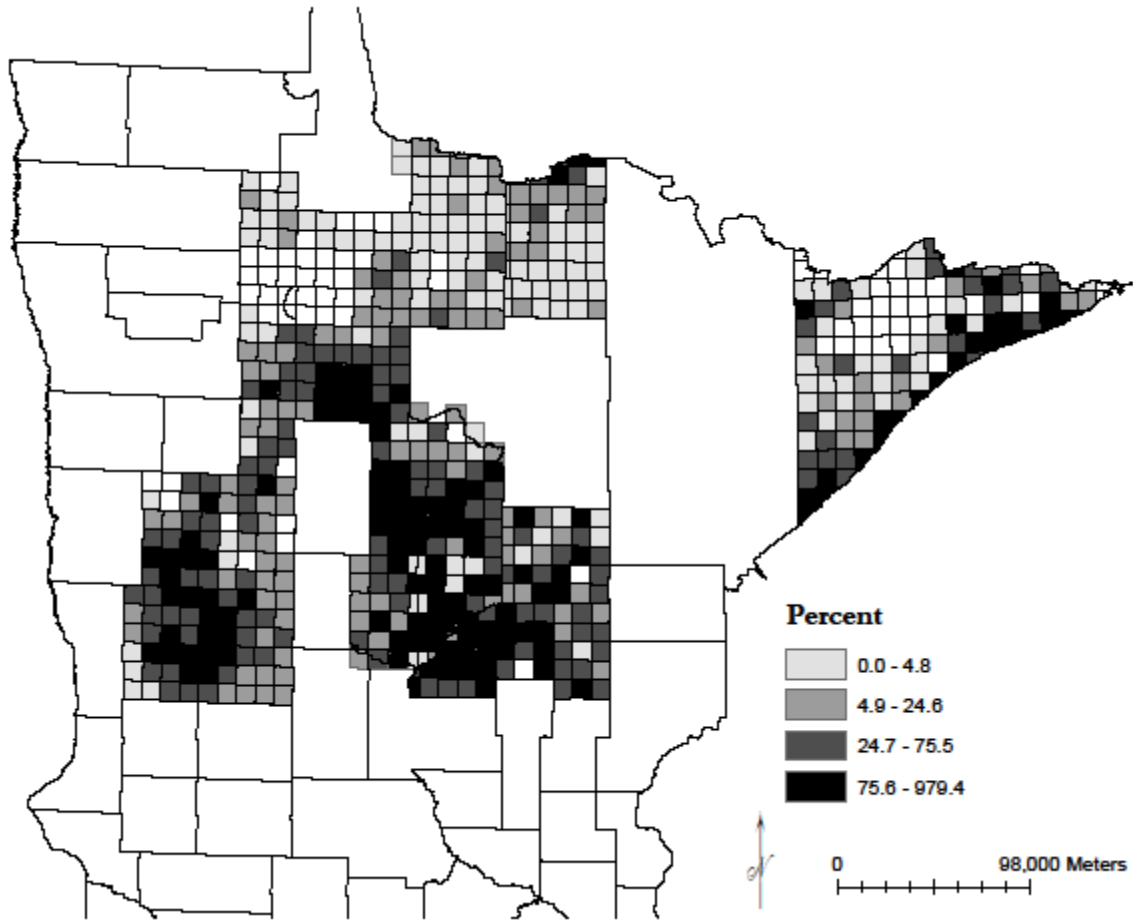


Figure 72. Extent of private forest land parcelization by township across the 10-county study area as estimated by the new parcelization metric (60-acre threshold). Darker shading indicates a more parcelized landscape.

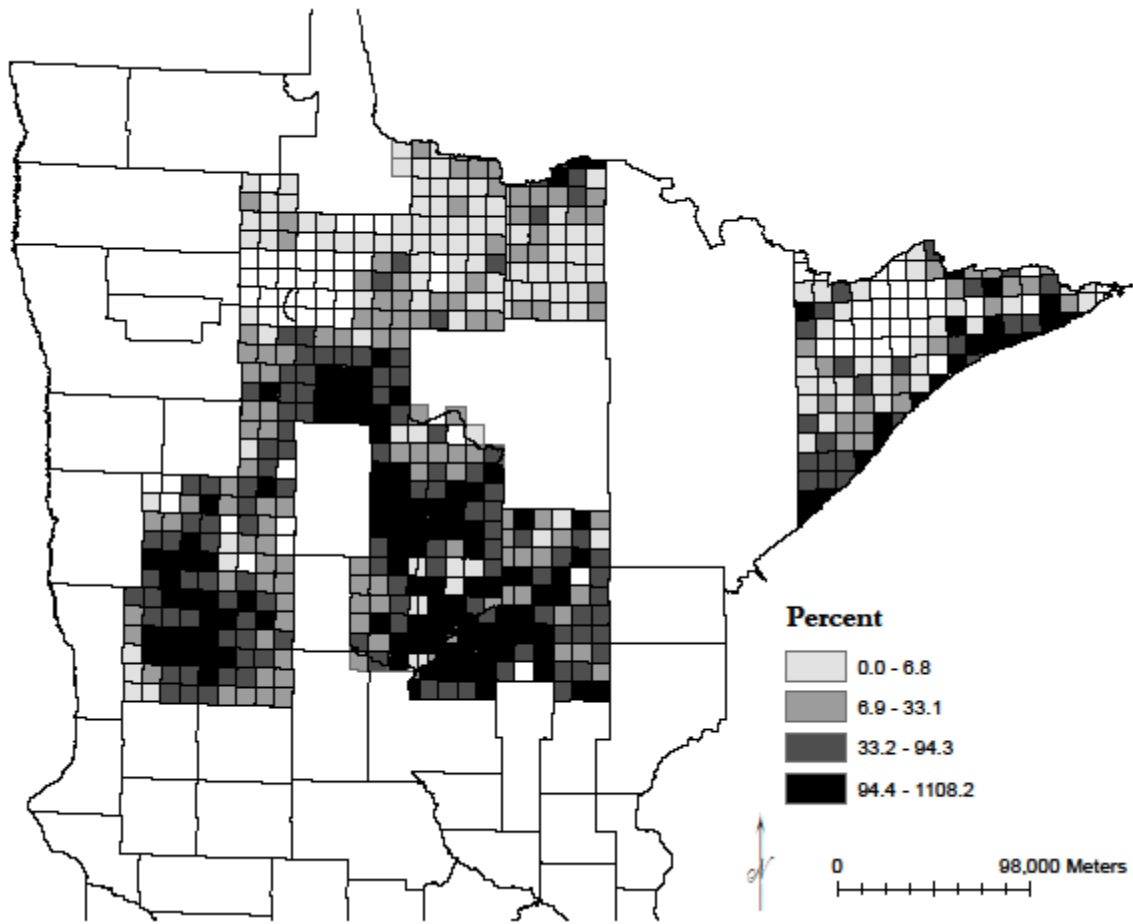


Figure 73. Extent of private forest land parcelization by township across the 10-county study area as estimated by the new parcelization metric (80-acre threshold). Darker shading indicates a more parcelized landscape.

OLS Models Developed – All Forest Land in Parcels 20 Acres or More in Size

The results shown in Table 3 are from OLS regressions using data from private forested parcels 20 acres in size. Each regression corresponds to one of the previous regressions that used data from all private, forested parcels. The four previous models were replicated with the dataset truncated at all private, forested parcels more than 20 acres in size.

Table 3. Regression results using forested parcels at least 20 acres.

Model	I			II			III			IV		
Variable	Average Parcel Size			80 acres			60 acres			40 acres		
	Coeff.	SE	p-Val	Coeff.	SE	p-Val	Coeff.	SE	p-Val	Coeff.	SE	p-Val
% Change in population 96-06	-1.830	0.382	0.000	0.362	0.064	0.000	0.262	0.047	0.000	0.162	0.030	0.000
Average of totalner	754.503	2875.593	0.793	-46.289	481.569	0.923	-109.634	356.246	0.758	32.352	224.787	0.886
totemv08	0.000	0.000	0.245	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
% of adj_lakeacre more than 20 acres	0.616	0.239	0.011	-0.054	0.040	0.178	-0.027	0.030	0.366	-0.026	0.019	0.166
% of adj_pblclnacre more than 20 acres	-0.071	0.180	0.693	0.029	0.030	0.336	0.034	0.022	0.135	0.029	0.014	0.045
% of adj_roadacre more than 20 acres	-0.064	0.319	0.840	0.148	0.054	0.006	0.087	0.040	0.030	0.046	0.025	0.067
% of 1600macre more than 20 acres	-0.312	0.349	0.373	0.069	0.059	0.237	0.055	0.043	0.206	0.035	0.027	0.194
R ²	107.509	33.899	0.002	9.315	5.710	0.104	6.388	4.224	0.131	2.717	2.658	0.307
Adjusted R ²	0.072			0.154			0.167			0.171		
F-Statistic	0.053			0.137			0.150			0.154		
Model p-Val-value	3.932			9.226			10.147			10.327		
n	0.000			0.000			0.000			0.000		
n	364.000			362.000			362.000			358.000		

The variable percent change in population is significant in all four models and total estimated market value is a significant predictor in Models II-IV. However, the population change variable has a negative influence in the Model I, and a positive influence in the other 3 models. This suggests that when using average parcel size as the left hand side variable increases in population decrease the probability of a parcel being parcelized. That is counterintuitive to most beliefs regarding population increases and parcelization. Percent of acres adjacent to public land is significant in Model IV but not the other three models. Percent of acres adjacent to public roads is significant and positive for Models II and III, but not the other two models.

Figures 74-76 illustrate various characterizations of parcelized forest landscapes across the ten county study area using the proposed new metric of a parcelized landscape when only 20+ acre forested parcels are included.

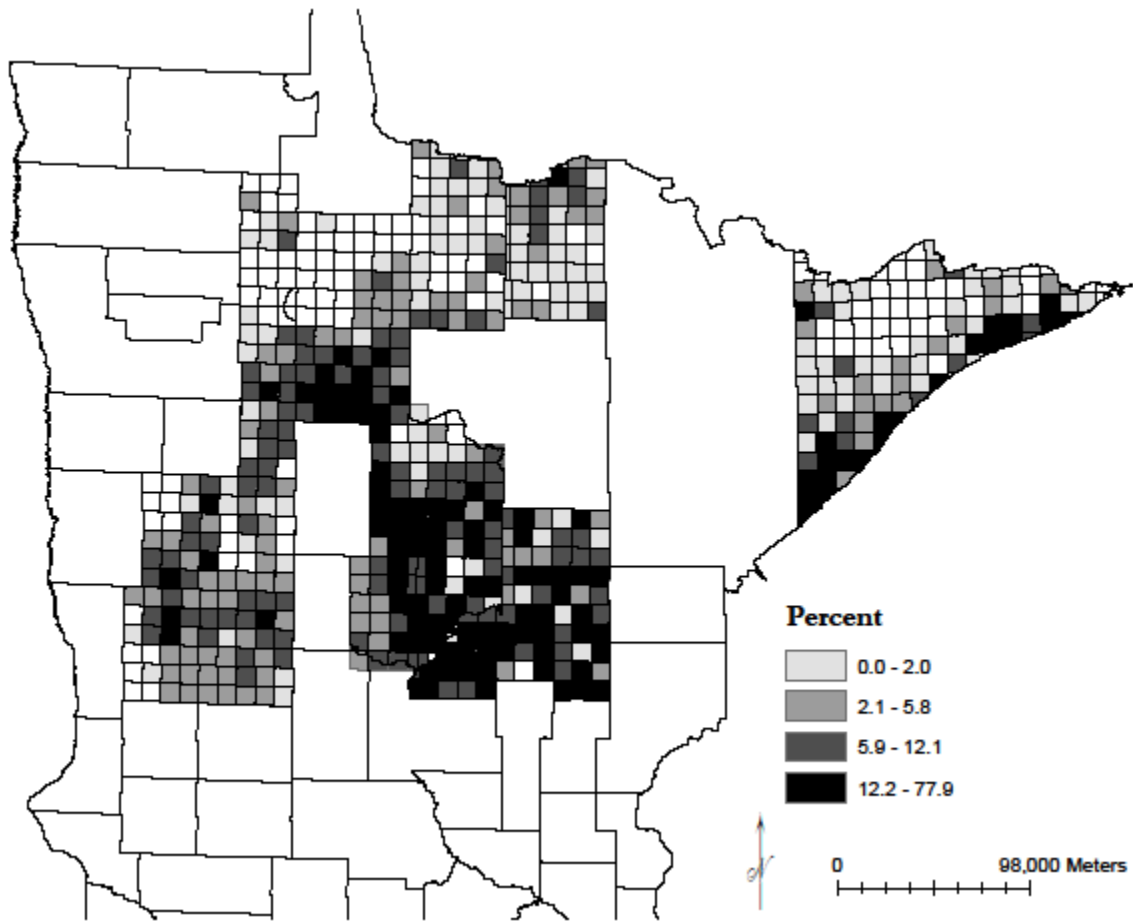


Figure 74. Extent of private forest land parcelization by township across the 10-county study area as estimated by the new parcelization metric. Only 20+ acre parcels are included in the analysis (40-acre threshold). Darker shading indicates a more parcelized landscape.

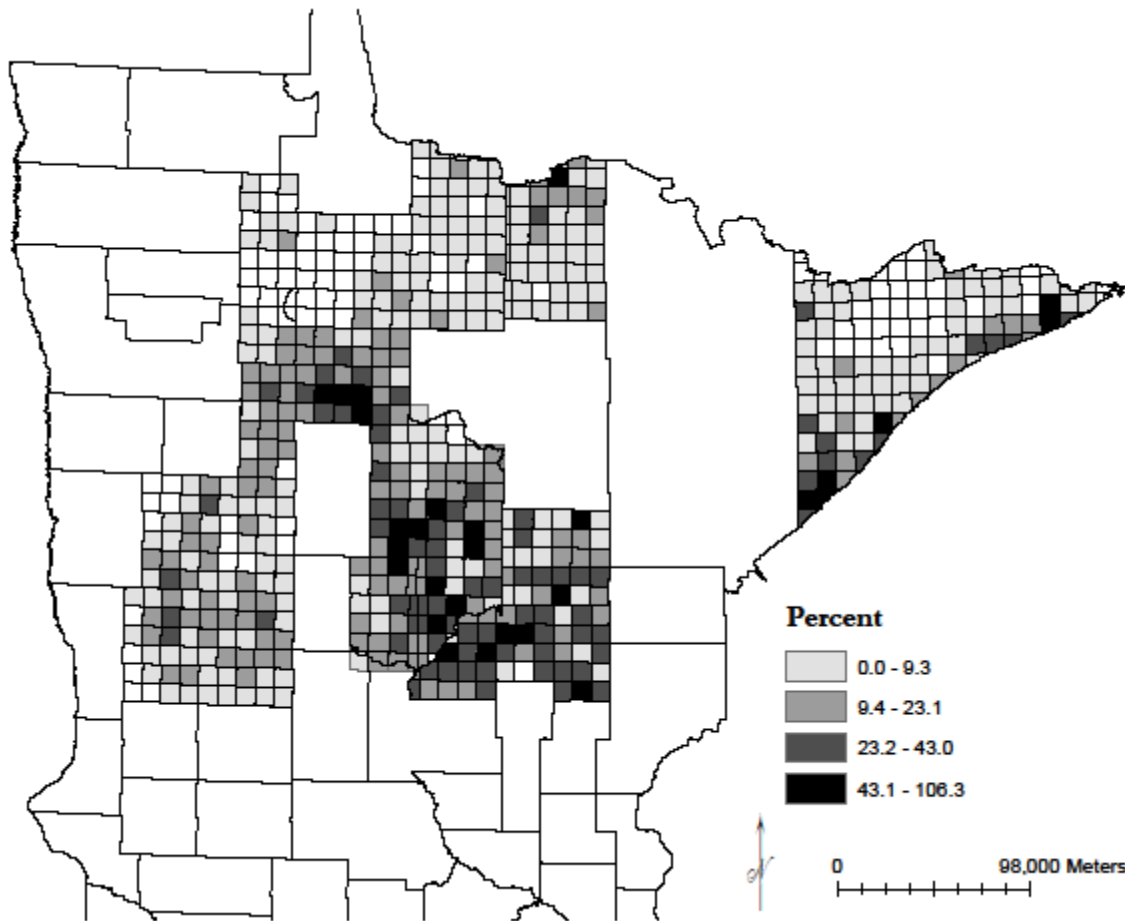


Figure 75. Extent of private forest land parcelization by township across the 10-county study area as estimated by the new parcelization metric. Only 20+ acre parcels are included in the analysis (60-acre threshold). Darker shading indicates a more parcelized landscape.

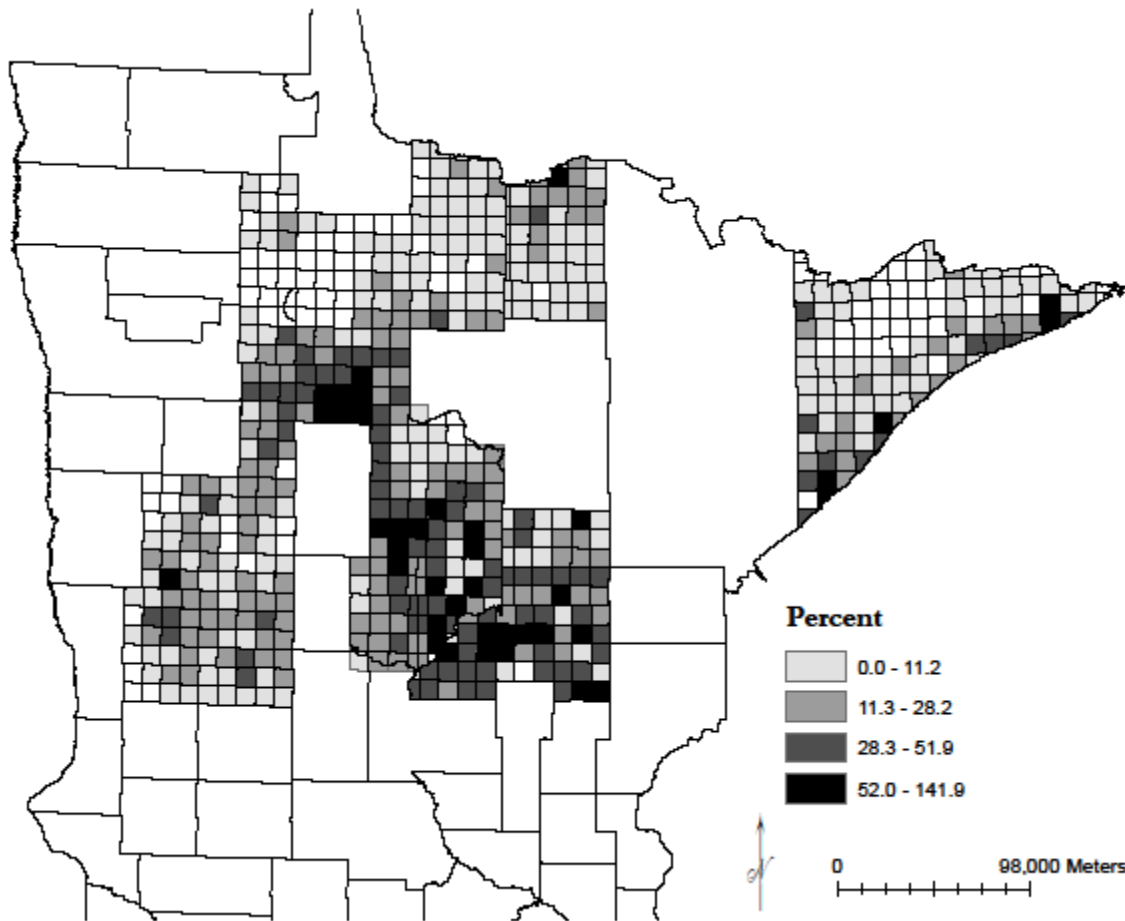


Figure 76. Extent of private forest land parcelization by township across the 10-county study area as estimated by the new parcelization metric. Only 20+ acre parcels are included in the analysis (80-acre threshold). Darker shading indicates a more parcelized landscape.

Discussion

When comparing the results from the eight regression models, some patterns emerge. In Models II to IV of Table 2, percent change in population, total estimated market value, and percent of forested acres adjacent to public water are all significant and positive predictors. In Models II to IV of Table 3, percent change in population and total estimated market value are both significant. Change in population is always significantly associated to parcelization and adjacency to public roads is significant in models analyzing parcels 80 acres or less in size and 60 acres or less in size, but not significant once the parcels reach a size under 40 acres. Regardless of the parcel's size, percent change in population always has a significant effect. However, its influence was negative in both models using average parcel size as the independent variable. When analyzing all private, forested parcels, adjacency to public water is significant.

The fit of Model I using all forest land and only parcels at least 20 acres was poor in both instances. The models with the new parcelization metric consistently produced a better fit of the

data to the new metric describing a parcelized landscape. The models also identified a number of patterns of association between the predictor variables and the independent variables. For example, change in population was statistically significant at each level (less than 80 acres, less than 60 acres, less than 40 acres) using the new variable. The new metric of parcelization appears to be an improvement over conventional predictor of parcelization, (average parcel size) because it takes into account parcel distribution and amount of forest land per township. By using this new metric we were able to equalize the characteristics of each township, regardless of total land size in each township. This results in more statistically meaningful results regarding the associations of parcelization.

The results from the OLS regressions indicate that the new parcelization metric improves the fit of the models as compared to average parcel size on the set of regressions that use all forested parcels as a data set. A higher adjusted R^2 value is achieved when using the new metric than when average parcel size is used as the dependent variable, suggesting the study's new parcelization metric has greater power in explaining associations with parcelization.

When further analyzing the set of regressions developed from using the data set that included all forested parcels, several patterns regarding associations of parcelization emerge. The influence of the change in population variable became greater at higher successive acreage screening levels. This correlation seems intuitive; as more people move to an area, the landscape will become parcelized to provide housing for the additional population and service industries (e.g., grocery stores, shopping malls) are needed. Adjacency to public roads is significant at the 80- and 60-acre screen, but not at 40 acres. The pattern of significance seems to suggest that access to larger parcels of land is more important than to smaller parcels. This follows with the idea that additional hunting, fishing, and/or recreational opportunities exist on larger parcels of land. The parcel's EMV and adjacency to public water are significantly correlated with a parcelized landscape at all three acreage levels. This means the higher the taxable value of land, the more likely the land will be divided up and sold.

The fact that adjacency to public water had a significant effect on the extent to which a landscape is parcelized across all acreage levels was expected. It has long been known that waterfront property commands a higher sellable value than non-waterfront property (Doss and Taff 1996). It stands to reason that owners of waterfront property will try to capture the greatest economic potential of the land by subdividing the property. The fact that waterfront property is so parcelized is one reason we chose to conduct the analysis based on two data sets; one using all forested parcels and the other only considering forest parcels 20 or more acres in size.

The results from the OLS regressions based on the data set containing forested parcels 20 or more acres in size shows that the new parcelization metric improves the fit of the models as compared to using average parcel size as a measure of parcelization. As with the previous data set that contained all forested parcels, a higher adjusted R^2 value is achieved when using the new parcelization metric than when average parcel size is used as the independent variable. This again

suggests the dependent variables have more explanatory power in explaining associations with parcelization when the new metric is used.

Conclusions

Using the results from the analyses, one can conclude that forest landscapes experiencing a large, positive change in population will tend to be more parcelized. This appeared to be true across the ten county study area, regardless of the average parcel size, location of the parcel and amount of forest land in the landscape. This relationship between total estimated market value and parcelization was also positive; the higher total EMV is for the township, the more parcelized the landscape. When parcels less than 20 acres in size were removed from the analysis, adjacency to public waters is no longer significant. This can most likely be attributed to the large amount of development along lakeshore within the study area. Adjacency to public land and public roads is significant in parcels 20 or more acres in size. These factors tell a story of accessibility; recreational and hunting access is very important on Minnesota lands. The more forested parcels that are either adjacent to public land or public roads in a township, the more likely that township is to become parcelized. This is an interesting finding, as research has suggested that more owners surrounding public land makes it more difficult to gain access to that land (Snyder et al. 2009).

There are several additional questions this study not addressed in this study. For example, the study did not identify which adverse impacts associated with a parcelized landscape (habitat fragmentation, biotic community health, forest productivity, recreational access, conversion to developed land uses) are of greatest concern. Depending on the focus of the consequences of parcelization, the strategies for mitigating these effects can be quite different. Because of this subjective nature of characterizing what constitutes a parcelized landscape, each situation and associated solution may be unique. Further analysis is needed to understand how a parcelized landscape impacts goods and services associated with working forests.

Correctly characterizing parcelization across a large area begins with the recognition of important patterns associated with and drivers of parcelization within the landscape. A substantial barrier to making these assessments is the availability of data. In this study, because the area examined was extensive (ten counties), many problems were encountered while attempting to obtain the data needed to make this characterization. For example, each of the ten counties records parcel transactions differently. The frequency by which such parcel records are updated and made available in a GIS format also varies, as does the temporal extent of parcel level data. One county may have spatial GIS data recording parcel owners spanning many years while another county is still working on creating their first GIS database. Characterizing the rate by which a landscape becomes parcelized can only be done if time-series data of parcelization activity is available. Such data would enable researchers to describe the degree to which a landscape is parcelized at separate points in time, which would help identify the characteristics of parcels most susceptible to parcelization. It would be useful to discuss with land management agencies the need to maintain and improve parcel-level data in a GIS format to facilitate such future analyses.

Another issue associated with conducting parcelization studies across a large spatial extent is formatting and interpreting the data that is obtained. It took considerable effort to manipulate the study's 100,000 parcel-level data records within ArcView, Excel, and SPSS. A particularly problematic issue that was encountered with the parcel data was multiple, adjacent parcels with a common owner. For tax or survey purposes, often a 40-acre parcel of land is treated as two separate 20-acre parcels. Even though the same individual owns both parcels, it still appeared in the database as two separate parcels. Without developing computer routines to identify these parcels, dissolved the boundaries between these adjacent parcels, and then merged them into a single parcel record, the analysis would have greatly exaggerated the extent to which Minnesota's northern forest landscape has been parcelized. We suspect that other studies that have attempted to quantify and characterize parcelization may not have fully accounted for this issue.

Some counties also have multiple ownership records for one parcel; this occurs when more than one person owns and pays taxes on that parcel. A manual inspection based on parcel locations and acreages was carried out to correct this problem as it also would have exaggerated the effects of parcelization. Because of the study's focus on forest parcelization, parcels that were not "forested," defined as having 50% or greater forest cover were not considered, nor were public lands and parcels located within city boundaries. To account for the development along lakeshores, data analysis was performed at two levels; one being all private, forested parcels and the second being all private, forested parcels 20 or more acres in size. Without these careful screens and manipulations of the data, a characterization of the extent to which the 10-county study area has been parcelized would have been misleading and/or inaccurate.

This study portrays the difficulties encountered when attempting to model and assess parcelization activity across a spatially large landscape. It is one of the first to examine parcelization from this point of view—one that describes the current state of the landscape. The associations with a parcelized landscape identified by this study may be useful in developing strategies to mitigate its effects. The study's methodology and findings provide a framework for the continued study of parcelization and how it relates to many other issues. For example, future parcelization research could examine the relationship between forest parcelization and fragmentation or parcelization and its specific effects on biodiversity, water quality, or recreational access. An important limitation to these follow-up studies is the availability of parcel-level data. At the time the study was undertaken, the data we obtained from the MN DNR to conduct this study is not available for many regions in Minnesota and not likely available in several areas of the United States. Perhaps further research could modify the methodology applied in this study such that similar analyses can be carried out across a range of parcel-level data formats. Overall, the results in this study shed light on the process and subjectivity of defining a parcelized landscape and provide a good base for further research.

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Appendix A

Table 4. Descriptive statistics for all forested parcels (at least one acre).

	N	Minimum	Maximum	Mean	Std. Deviation
Average of acreage2	373	3.17731	972.366787	71.59281	1.06E+02
Average of totalner	373	0.00313	0.022107	0.007268	0.002148417
totemv08	365	0	1475193700	1.42E+08	1.65E+08
% of adj_lakeacre	373	0	99.910752	30.18216	2.55E+01
% of adj_pblclnacre	373	0	100	48.01474	3.44E+01
% of adj_roadacre	373	0	100	64.19495	1.91E+01
% of 1600macre	373	0	100	9.45	19.108
% Change in population 96-06	373	-43.2836	100	6.933975	1.64E+01

Table 5. Descriptive statistics for forested parcels 20 acres or more in size.

	N	Minimum	Maximum	Mean	Std. Deviation
Average of acreage2 over 20 acres	373	20.7327	1052.27125	113.2917	1.17E+02
Average of totalner	373	0.00313	0.022107	0.007291	2.16E-03
totemv08	365	0	1475193700	1.41E+08	164100000
% of adj_lakeacre over 20 acres	373	0	100	30.19454	2.69E+01
% of adj_pblclnacre over 20 acres	373	0	100	51.76108	3.53E+01
% of adj_roadacre over 20 acres	373	0	100	66.0646	1.97E+01
% of 1600macre over 20 acres	373	0	100	9.68	19.025
% Change in population 96-06	373	-43.2836	100	7.099556	1.63E+01