Parcelization: Forest Change Agent in Northern Wisconsin

Anna L. Haines, Timothy T. Kennedy, and Daniel L. McFarlane

ABSTRACT

Parcelization-induced forest fragmentation is eating away at private, nonindustrial forests. Parcel sizes are declining and the number of landowners is increasing. These conditions make it challenging for resource managers to maintain economical timber harvesting on smaller privately held forested parcels. Shrinking parcel sizes also aggravate landscape and habitat fragmentation. In this article, we analyze parcelization and its link to private land-use change. Reconstruction of historic tax parcels and land use in three rural towns in Bayfield County, Wisconsin, allowed us to examine the effects of parcelization over a 53-year period. Our results indicate that parcelization is a significant factor in landscape change in northern Wisconsin. This research provides empirical evidence of the necessity to manage how private land is subdivided and used in amenity and natural resource rich areas.

Keywords: parcelization, forest fragmentation, landscape change, land use, landscape ecology, GIS

Landscape change in forested areas is currently a topic of concern to professional foresters and resource managers. Forest fragmentation, the division and isolation of existing larger forest patches, as a result of residential and urban development, has the potential to significantly alter natural landscapes (Zipperer and Dawson 1992). Rural sprawl, stemming from residential population growth in rural areas, is increasing with landscape fragmentation becoming a byproduct of this process (Gonzalez-Abraham et al. 2007). The amenity-rich forests of northern Wisconsin have experienced rural sprawl along with parts of northern Minnesota, Michigan, and Indiana (Radeloff et al. 2005). Intact interior forests in amenity-rich rural areas are in the greatest danger from rural sprawl and are a current topic of interest to foresters (DeCoster 1998, Gobster and Rickenbach 2004, Radeloff et al. 2005). We speculate that land division and parcelization is the precursor to landscape fragmentation and rural sprawl.

Little empirical evidence exists that directly ties parcelization to landscape fragmentation. Gonzalez-Abraham et al. (2007) found that the presence of buildings in northern Wisconsin led to habitat fragmentation. However, does parcelization lead directly to fragmentation? Our primary objective was to explore the relationship between parcelization and forest cover change. To answer our question, we used a case study methodology combined with an in-depth examination of parcelization and land use/cover in a single county in northern Wisconsin over a 53-year period. We find that parcelization leads to landscape fragmentation in expected and unexpected ways.

Bayfield County, on Lake Superior in northwestern Wisconsin, provided a favorable area for examination because of its location in the northern forested portion of Wisconsin (Figure 1). Bayfield County has made substantial progress in the digital mapping of tax parcels and comprehensive land-use planning. The Northwoods of Wisconsin are representative of a forested and lake states region that includes northern Wisconsin, Minnesota, and Michigan that has experienced amenity-led development pressure (Leatherberry 1999, Gobster and Rickenbach 2004). The sample towns of Delta, Bayfield, and Barnes provided a look into parcelization that represented contemporary snapshot parcel densities that were low (19 parcels/mi^2), medium (22 parcels/mi^2), and high (28 parcels/mi^2), respectively. Bayfield County is also a popular tourism and recreational area and a main connection point to the Apostle Islands National Lakeshore.

Bayfield County has 962 named lakes totaling 22,629 ac (Wisconsin Department of Natural Resources 2005). Areas in upstate Wisconsin, Michigan, and New York and

Received June 24, 2009; accepted May 4, 2010.

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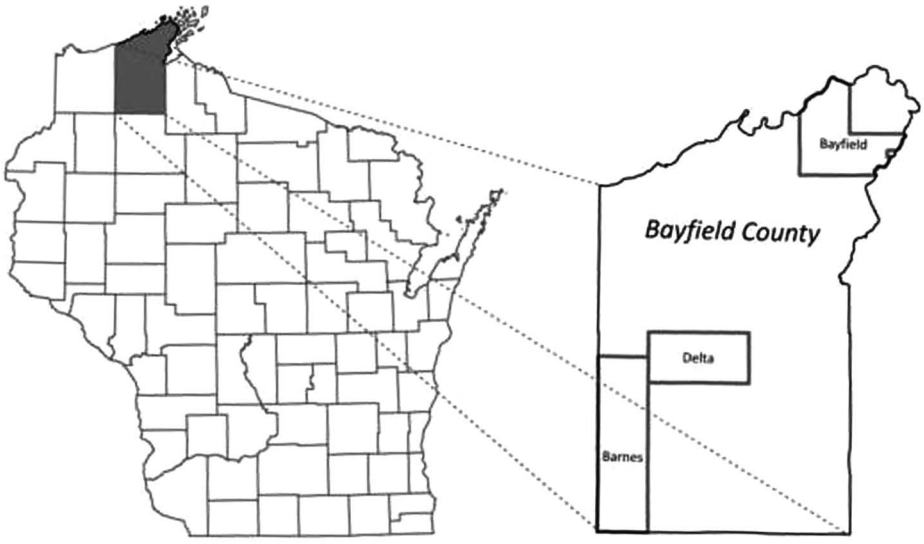

Figure 1. Study towns in Bayfield County, Wisconsin.

areas around the Rocky Mountains are experiencing exurban and rural growth because of the availability of land near popular natural resource amenities (Theobald 2001). Forest cover, kettle lakes, and other natural resource amenities that are popular with recreationalists and retirees dominate the northern region of Wisconsin. Vast quantities of timber reserves have provided this area with a rich logging history as the primary economic land production source of subsistence (Ostergren and Vale 1997, Gonzalez-Abraham et al. 2007).

Fragmentation and Parcelization

Parcelization is the division of larger landholdings into smaller ones. Land planners in suburban and exurban regions consider land division a precursor to development (Hoch et al. 2000). Does the same assumption fit a rural area? Past research does not directly address the parcelization question and focuses on fragmentation instead. The problem is that much research has used the term parcelization to mean fragmentation. In this article, we are interested in the specific process of legally splitting tax parcels and the effect of those splits on landscape change. The Public Land Survey System (PLSS) established square 40-ac tax parcels (Johnson 1976). Under current land division ordinances, land continues to divide from a 40-ac tax parcel to smaller sizes in simple shapes, such as squares and rectangles (Ohm 1999, Croissant 2004).

The importance of maintaining active forestry programs on private lands is one of the primary reasons why research focuses on parcelization. By active forestry, we mean managing land for its resource. In this sense, fragmentation is a potential problem. Ownership fragmentation originates from a larger parcel that has been subdivided and sold. New owners can bring with them conflicting goals and objectives for property management. Some owners may manage their land with a hands-off approach, letting nature take its course, which means little active forestry production management, while others may actively manage their property for its resources or recreational value. Nonindustrial private forestland (NIPF) owners control approximately 40% of all forested acres in the United States. Out of that group, about 30% manage for timber production (Butler and Leatherberry 2004). That equates to approximately 28 million ac of forestland managed for timber production out of 94 million NIPF total acres. Therefore, it is not surprising that we expect greater decline in the acreage of forestland that will be available for future production management of timber in parcelized areas.

In the United States in 1994, the average NIPF parcel size was 24 ac and is expected to shrink to 17 ac by 2010 if current trends continue (Sampson and DeCoster 2000). In the Catskills area of New York, researchers found that the average size of private parcels in a forested area decreased from 17.6 to 14.5 ac between 1984 and 2000 (LaPierre and Germain 2005). In Oneida County, New York, the average NIPF parcel size decreased from 36 to 24 ac between 1975 and 2000 (Germain et al. 2006).

As forested parcel sizes decrease, options for effective resource management diminish. These smaller, fragmented, and sometimes unconnected forest patches are more expensive and complicated for effective traditional timber resource management (Sampson and DeCoster 2000, Gobster and Rickenbach 2004). The cost of harvesting per acre of forestland increases as the size of the harvesting area decreases, especially when it dips below 50 ac (Butler and Leatherberry 2004). With shrinking forested parcel sizes come the resulting increase in numbers of forest owners and their differing land-management styles and goals. Between 1978 and 1994, approximately 2,526,000 additional NIPF ownership units were added in the United States (Birch 1996). Forestry professionals are concerned with how to maintain productivity and efficiency in the face of increasing harvesting costs, largely because of smaller parcels and increasing ownership disparity (DeCoster 1998, Gobster and Rickenbach 2004). Gobster and Rickenbach (2004) find that parcelization reduces larger resource-rich forested tracts to smaller recreational tracts, which may not be available for future harvesting purposes. In this research, we sought to link parcelization to forested parcel sizes and thus forest fragmentation. We did not seek to link parcelization to NIPF landowner objectives or decreasing harvest rates.

Methods

Contrary to other parcelization studies that sampled from a larger population, we recreated complete tax parcel histories for three rural towns over a 53-year period. Tax parcels were used because they are the smallest unit of analysis for parcels available. Tax parcels are also the level that local governments manage for tax and real estate purposes. Ownership parcels, found in plat books, display only parcels under a single ownership. These records can mask the true intent of the tax parcel owner, because multiple tax parcels can be hidden under a single ownership veil. Therefore, accurate accounting records were used that were available for this study. Although this methodology was time-consuming, it allowed for an in-depth analysis of historical parcel data.

Other studies used existing plat book maps (which provide ownership records) for their source data, whereas we used tax parcel data from the tax assessment records (ownership plus tax parcels). Medley et al. (2003) created a temporally comprehensive sample

of ownership parcels for a single town in Ohio between 1912 and 1989. Heasley (2000) used ownership parcels for 3 towns (out of 23) in the Kickapoo Valley in Wisconsin to analyze parcelization and landscape change between 1930 and 1995. Drzyzga and Brown (1998) recreated ownership parcels between 1970 and 1990 to analyze the affects of parcelization on forest fragmentation in three lower Michigan counties. Mehmood and Zhang (2001) used ownership parcel size to analyze private forest parcelization trends between 1978 and 1994 in the United States. Tax parcel maps provided parcelization histories in some studies. LaPierre and Germain (2005) randomly sampled private forested tax parcels from 1984 and 2000 from a larger population. Holdt et al. (2004) examined the effects of parcelization on forest fragmentation by examining tax parcel histories using parcel maps between 1960 and 2000. To describe historic parcelization in Bayfield County, we needed to reconstruct historic tax parcels from available existing data.

Improvements in technology have provided innovative methods to analyze the spatial location of new parcels on the landscape. Reverse parcelization methodology provided the most efficient technique to reconstruct historic tax parcels in seven 5- to 10-year increments dating back to 1954. Ownership parcels are popular for historic reconstruction because of their ease of acquisition and conversion into a suitable digital format capable of analysis. Unfortunately, ownership parcels are only available in certain years (in plat books) and display parcel ownership, not the individual tax parcel. A visual investigation of historic plat books can mask the true intent of the parcel owner. Underneath ownership parcels can lay subdivided tax parcels awaiting sale and subsequent development (Figure 2). To reconstruct historic tax parcels accurately, we obtained a current digital tax parcel layer from the Bayfield County Land Information Officer. Expecting there to be fewer and larger parcels back in time, we merged lots into their parcel of origin to create parcel layers at various historic periods. Tax assessment rolls were visually inspected between two corresponding snapshot years, with parcels in the more recent snapshot year merged where applicable to create the parent parcel in the previous snapshot year (Figure 3). Reconstructed tax parcel histories were generated in this manner for a total of eight snapshot years: 1954, 1960, 1967, 1972, 1981, 1991, 2001, and 2007.

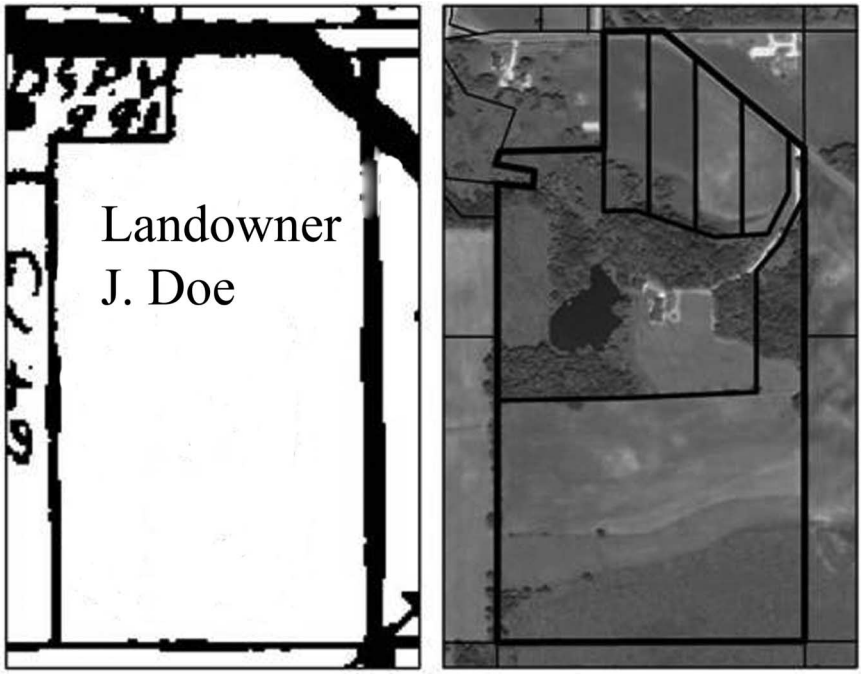

Figure 2. The figure on the left displays an ownership parcel as represented on a plat book. The figure on the right displays the tax parcels for the same time period. The ownership parcel view hides the multiple tax parcels this owner has created.

The next step was to reconstruct historic land-use patterns. Aerial photography was located for the three study towns in Bayfield County for 1938, 1972, and 2005. Because of the limited availability of aerial photography, digital parcel layers obtained from the county, and the limited availability of plat books, we were not able to completely synchronize reconstructed land-use patterns and tax parcel histories. Land-use patterns were reconstructed by digitizing category boundaries on the computer screen based on the aerial photographs for each snapshot year. Land-use categories included forest, open space (OS), developed, and other. OS land-use included rangeland, pasture, agriculture, and barren land. Our analysis compared the amount of developed land-use change inside parcelized windows to the amount of developed land-use change outside parcelized windows to determine if the change is significant in one area or another. All parcels that split during the study period were compiled to create "parcelized windows," and parcels that did not split during the study period were compiled to create the "nonparcelized windows." The "parcelized windows" contain all parcels that split, dissolved into a single polygon that encompasses all historic parcelization during the study period for the three study towns. Croissant (2004) found that land use follows parcel lines, and that the change of parcel lines can also instigate a change in land use. We expect that there will be more land-use change in the parcelized windows than the nonparcelized windows. The amount of private land-use change in both parcelized and nonparcelized windows was summarized by acreage.

Landscape ecology metrics provided the tools to analyze spatially the amount of forest fragmentation in Bayfield County during our study period. For the purpose of this study, any tax parcel that contained 50% or more forest cover was included in the analysis as a forested parcel. Using FRAGSTATS 3.3 [1], we calculated four metrics to evaluate the change in forest and developed fragmentation from 1938 to 2005 (McGarigal and Marks 1995):

- Number of Patches (NP)—NP of each different land-use type.
- Total Core Area (TCA)—Sum of the patch area that is 10 m from the patch edge for each different land-use type.
- Largest Patch Index (LPI)—Percent of the landscape comprised by the largest patch for each land-use type
- Fractional Dimension Index Mean (FRAC_MN)—Measures shape complexity for individual patches across all patches of each land-use type.

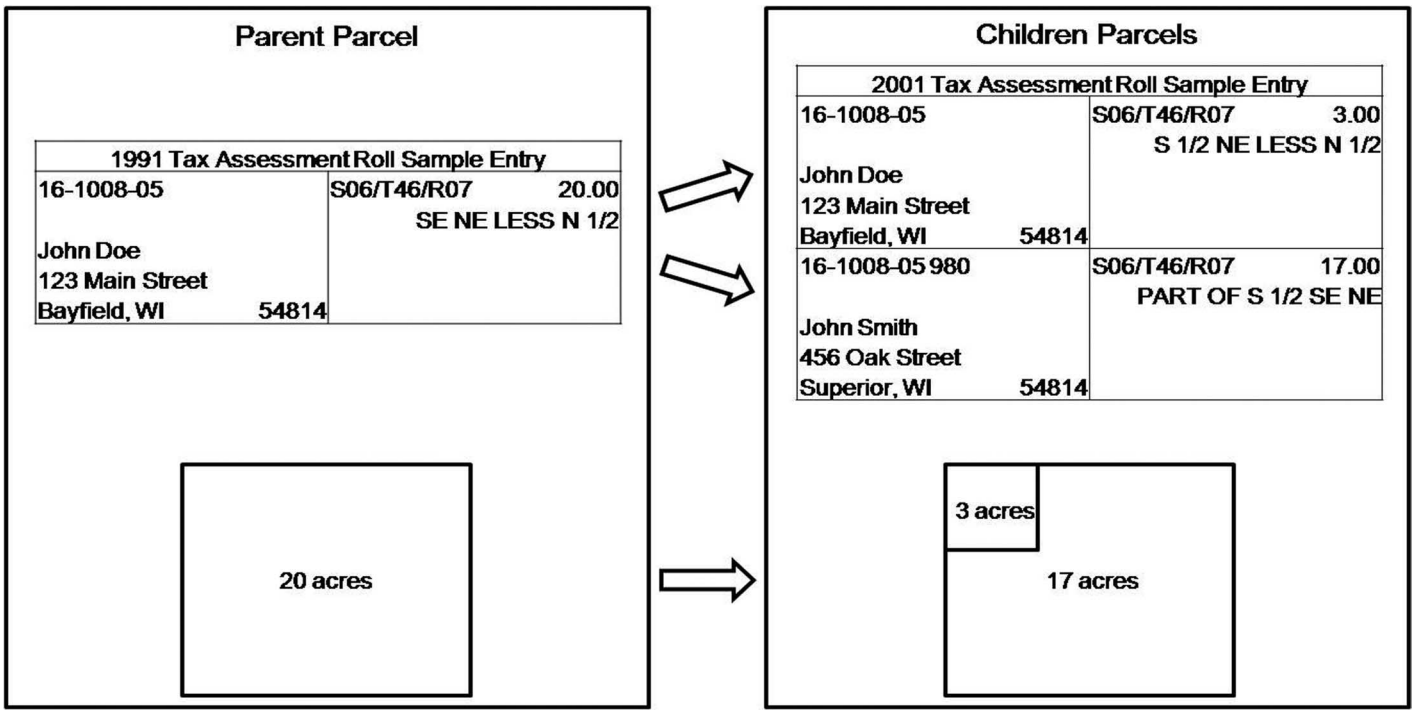

Figure 3. Reverse parcelization methods used to reconstruct historic tax parcels for three sample towns in Bayfield County, Wisconsin.

FRAGSTATS has dozens of available metrics from which to use. Leitao and Ahern (2002) suggested 10 metrics for use when applying landscape ecology concepts in planning. Many of the metrics seem repetitious and we chose those metrics that would measure change in a few different ways.

Results

Bayfield County experienced notable change to its forested landscape during our study period, with forested parcel sizes decreasing. In 1954, the average size of privately held forested parcels (parcels with 50% or greater forest cover) was 28.7 ac and by 2007 the average size decreased by 43% to 16.2 ac. Likewise, the average parcel size for all private parcels in 1954 was 26.6 ac and by 2007 that average size decreased by 50% to 13.3 ac. Although forested parcel size decline did not match OS and developed parcel size decline, the average size is much smaller than necessary (about 35 ac smaller) for active forest management purposes (Butler and Leatherberry 2004). This smaller size parcel does not preclude an individual landowner from forest management.

The effects of this change in forested parcel size are evident by examining the results of the forest fragmentation analysis. The number of private forested parcels increased in all three sample towns by over 73%, while the number of forested patches increased by nearly 81% (Table 1). The TCA of forested patches decreased by 9%, and the LPI decreased by 42%. Forested patch fractal dimension shows an increase in forested patch complexity. On its face, increased complexity would be considered a positive impact especially for biodiversity. However, when combined with other metrics such as the TCA metric, the implications for biodiversity and traditional extraction methods of forest resource management are not positive. Developed land use experienced a 336% increase in the NP, along with an increase in TCA and LPI. Developed patches are growing in size and perforating the landscape. The number of OS patches, OS TCA, and OS LPI all decreased, indicating that OS is declining on the landscape. These results indicate that developed land use is the primary outcome of the fragmentation of forest patches in our three study towns. Fragmentation of forest cover shows the negative effects of increased parcelization.

The next facet of parcelization we analyzed was the change in private land use in parcelized and nonparcelized windows. De-

Table 1. FRAGSTATS metric results for open space, developed, and forest patches for 1938 and 2005 with percent change.

Parcels	Patch class	NP	TCA	LPI	FRAC_MN
1938 Fragmentation results					
n = 2,355	Open space	323	525	0.091	1.115
	Developed	265	77	0.024	1.066
	Forest	155	24,854	44.39	1.082
2005 Fragmentation results					
n = 4,087	Open space	229	298	0.069	1.115
	Developed	1,156	396	0.032	1.073
	Forest	280	22,553	25.753	1.094
1938–2005 Class metric percent change					
73.50%	Open space	−29.10%	−43.20%	−24.10%	0.10%
	Developed	336.20%	411.50%	31.70%	0.60%
	Forest	80.60%	−9.30%	−42.00%	1.10%

NP, number of patches (quantity of patches); TCA, total core area (acres); LPI, largest patch index (range of 0–100; 0 = increasingly small patch, 100 = a single patch of the corresponding patch type covering the entire landscape); FRAC_MN, fractal dimension index mean (range of 1 to 2; a result near 1 indicates a simple perimeter shape such as a square, and a result near 2 indicates a highly complex, convoluted shape).

Table 2. Land-use change of private lands in parcelized and nonparcelized windows from 1938 to 2005 in three sample towns in Bayfield County, Wisconsin.

	Percent of private land in land cover type in 1938	Percent of private land in land cover type in 2005	Parcelized window: Change from 1938 to 2005 (ac)	Nonparcelized window: Change from 1938 to 2005 (ac)	Parcelized window: Percent change from 1938 to 2005	Nonparcelized window: Percent change from 1938 to 2005
Developed	1	5	2,993	521	871	133
Forest	84	80	−1,887	−1,346	−9	−3
Other	15	15	−1,107	824	−28	10

Table 3. Private forest land-use change in parcelized and nonparcelized windows from 1938 to 2005 in three sample towns in Bayfield County, Wisconsin.

	Parcelized window: Land cover change from 1938 to 2005 (ac)	Nonparcelized window: Land cover change from 1938 to 2005 (ac)	Parcelized window: Land cover percent change from 1938 to 2005	Non-parcelized window: Land cover percent change from 1938 to 2005
Forest to developed	2,480	545	71	15
Forest to other	996	2,989	29	85

veloped land-use acreage increased inside these previously parcelized windows by 871% (2,993 ac), while developed land-use acreage increased in nonparcelized windows by 133% (521 ac; Table 2). Although one would expect land-use change within the parcelized windows, the nonparcelized windows still experienced land-use change despite the fact that no parcels had been subdivided. Forested land cover decreased inside parcelized windows by 9% (1,887 ac) and decreased outside of parcelized windows by 3% (1,346 ac; Table 2).

Basic parcel descriptive statistics do not tell the entire story. Our next step was to determine the quantity of land removed from the forest base and converted to developed and other land uses in parcelized and nonparcelized windows. Table 3 illustrates that land converted from forest to developed use was significantly greater inside parcelized windows versus forest converted to developed land use in nonparcelized windows.

The location of new developed land use during the study period proved interesting. Nearly 95% of all private developed parcels (226/239) in nonparcelized windows were located within 100 m of parcelized windows during the study period. Of those 226 parcels, only 26 were quarter section (approximately 40 ac) in size, meaning they had not split since their initial creation by the PLSS. Forty-eight percent (108/226) of the developed parcels were in platted subdivisions that split before 1954. The average size of all new developed parcels in nonparcelized windows was 7.2 ac. After removing all platted subdivision parcels from the selection, the average size of the remaining 118 parcels increases to 13.2 ac.

Our results illustrate and reinforce that parcelization is a forbearer to landscape change in a rural, forested region in northern Wisconsin. When we look beyond the metrics and numbers to the aerial photos and the tax parcel maps, the presence of natural resource amenities, especially inland lakes, is an important factor in parcelization and fragmentation of the forested landscape. Before 1972, new tax parcels in the town of Barnes were primarily concentrated adjacent to inland lakes. After 1972 parcelization continued around inland lakes, but also expanded into the forested areas away from inland lakes as available land supplies adjacent to water diminished (Figure 4). Successive parcelization also occurred before 1972 parcel splits around inland lakes.

Fragmentation of forest TCA is evident by examining land use and land cover change between 1972 and 2005 in the town of Barnes (Figure 5). The appearance of developed patches on the landscape in successive tiers from inland lakes is creating noncontiguous forest parcels with a resulting smaller TCA.

Discussion

Results from the landscape ecology metric analysis indicate that forest fragmentation is increasing. Increases in the NP, combined with decreases in the forest TCA and LPI illustrates that private forested patches in Bayfield County are increasing in number while decreasing in size. Results from a study of tax parcel boundaries and landscape change in rural Indiana found that forest cover change was more likely to occur around parcel boundaries further linking parcelization to forestland change (Croissant 2004). Our results can serve as a warning call for planners and public agencies to increase their review of lightly regulated parcel splits, while including more options for the preservation of large tracts of production forestland. Additionally, our results indicate that parcelization is a prime factor in future fragmentation. Limiting parcelization could have an impact on future fragmentation of the forest. Our results provide empirical support for other research that illustrates the negative effect of diminishing parcel sizes on productive timber harvesting (DeCoster 1998). Rural areas with lower economic yields, such as forestry and farming, find themselves being pushed away because of the factors of urbanization as it encroaches on rural working land areas (Sampson and DeCoster 2000). Supporting the notion that smaller forested tracts are detrimental to economic resource management, a study in western Oregon found that timber harvesting was more likely to occur on larger ownership tracts (Cleaves and Bennett 1995). However, the authors note that even the smallest ownership units they examined (1–9 ac) still maintained a 12% harvesting rate of participation. Because of the increasing quantity and total acreage of smaller units, a sizeable portion of harvestable timber can remain for harvesting purposes (Cleaves and Bennett 1995).

Our results also indicate that parcelization is a precursor to forest fragmentation.

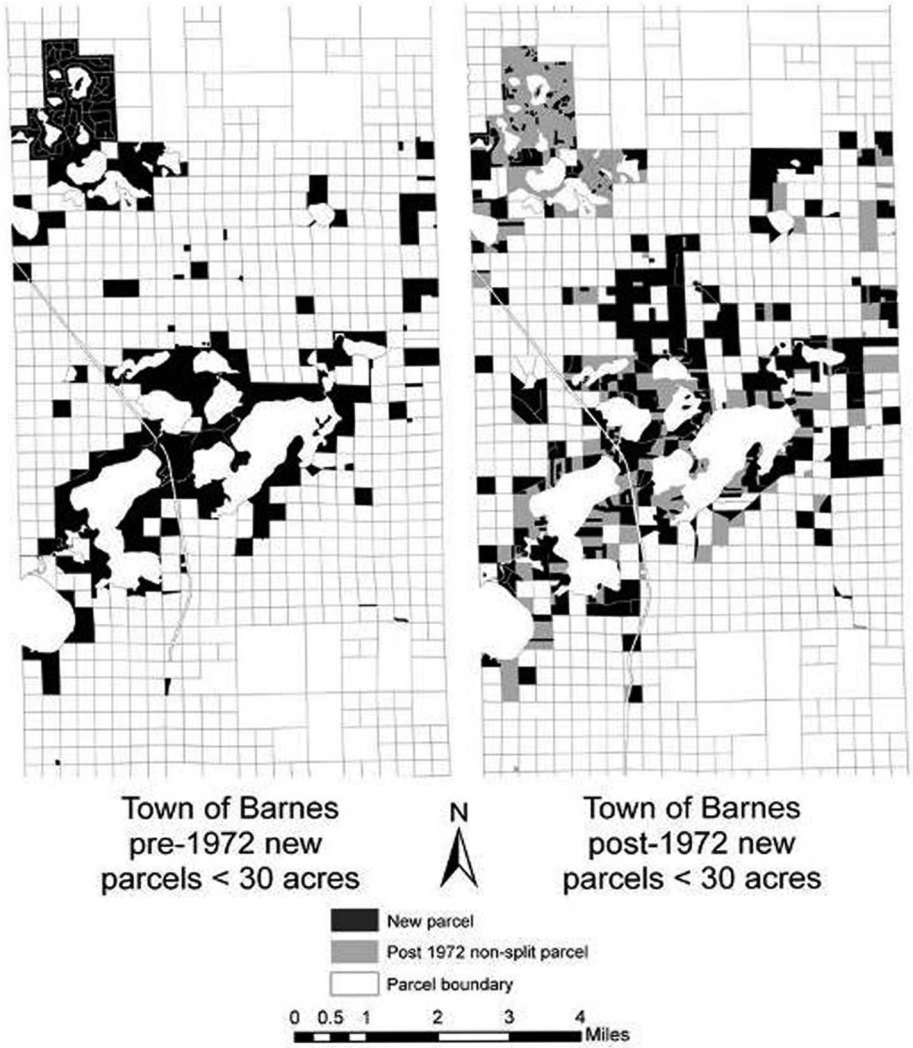

Figure 4. The left diagram displays all new parcels less than 30 ac in size before 1972 and the right diagram displays all new parcels less than 30 ac in size from 1973 to 2007. Note that the before 1972 parcels divided again into smaller parcels after 1972.

We were not surprised that developed land use significantly increased inside parcelized windows. However, we were surprised by the magnitude of the change. The eightfold increase of developed land use inside parcelized windows does not indicate a good future picture for forest patches at risk of parcelization. The percent change analysis shows that the change of developed land use inside parcelized windows is significantly greater than the change of land use outside parcelized windows. Our results not only show the expected increase of developed land use inside parcelized windows, but they also show the subsequent loss of forestland inside areas that are under the influence of parcelization (Table 2). Barlow et al. (1998) found in a study of the effects of urban sprawl on timber that proximity to higher population densities, and urban-type land uses resulted in decreased timber harvesting rates. Our results indicate that as parcelization increases, developed land use also increases, potentially leading to an increase in population. However, we do not attempt to analyze or infer any implications of NIPF landowner objectives on parcel size or harvesting rates.

Although these results have illustrated the trend of increasing parcelization and subsequent landscape change, do residents and stakeholders in rural working land areas share similar views of this phenomenon? A survey of northern residents, most of whom were oriented toward forest resource management and protection, revealed that respondents believe that parcelization without development would still allow for productive forestland management (Gobster and Rickenbach 2004). Unfortunately, our results indicate that as more land succumbs to parcelization, the likelihood increases that it will transform to a developed land use in the future. Respondents also noted that as parcel sizes shrink, the forest composition transitions from higher value aspen, pine, and oak species to lower-value species such as red maple, a detrimental result for local mills (Gobster and Rickenbach 2004). These same respondents did maintain a perceived connection between parcelization and development. Our results indicate that actual events mirror the perceptions of survey participants.

The spatial location of developed parcels supports the positive feedback loop of unchecked parcelization. As the results indicate, within the nonparcelized window 95% of the parcels that developed (e.g., forest to residential) occurred within 100 m of parcelized windows. This phenomenon illustrates the attraction of development to areas already experiencing parcelization and development. Development within the nonparcelized window also illustrates the long lag time that can occur after a parcel splits and before the land-use change. In this case the supply of developable parcels was available without parcelization occurring. The notion that there is an available supply of parcels still undeveloped does not bode well for forest fragmentation. Indeed, it is possible and highly likely that we do not know the amount or location of the current parcel supply.

The methodology used to recreate historic land-use patterns is a limiting factor in this study. Aerial photography interpretation provided the primary source for land-use patterns. Contemporary color aerial photography provided improved resolution and details of the landscape in contemporary periods. Therefore, we expect that the 2005 land-use patterns are more accurate than the previous two snapshot years. Additionally, contemporary and historic aerial photography coverage was leaf-on. It is likely that the forest cover of Bayfield County masked some private residences and that data were not included in our analysis. Land-use patterns were manually identified and digitized; therefore, human error could have introduced additional errors into the calculation of land-use change statistics.

Conclusions

Parcelization is the originating step in the process of landscape change. Subsequent

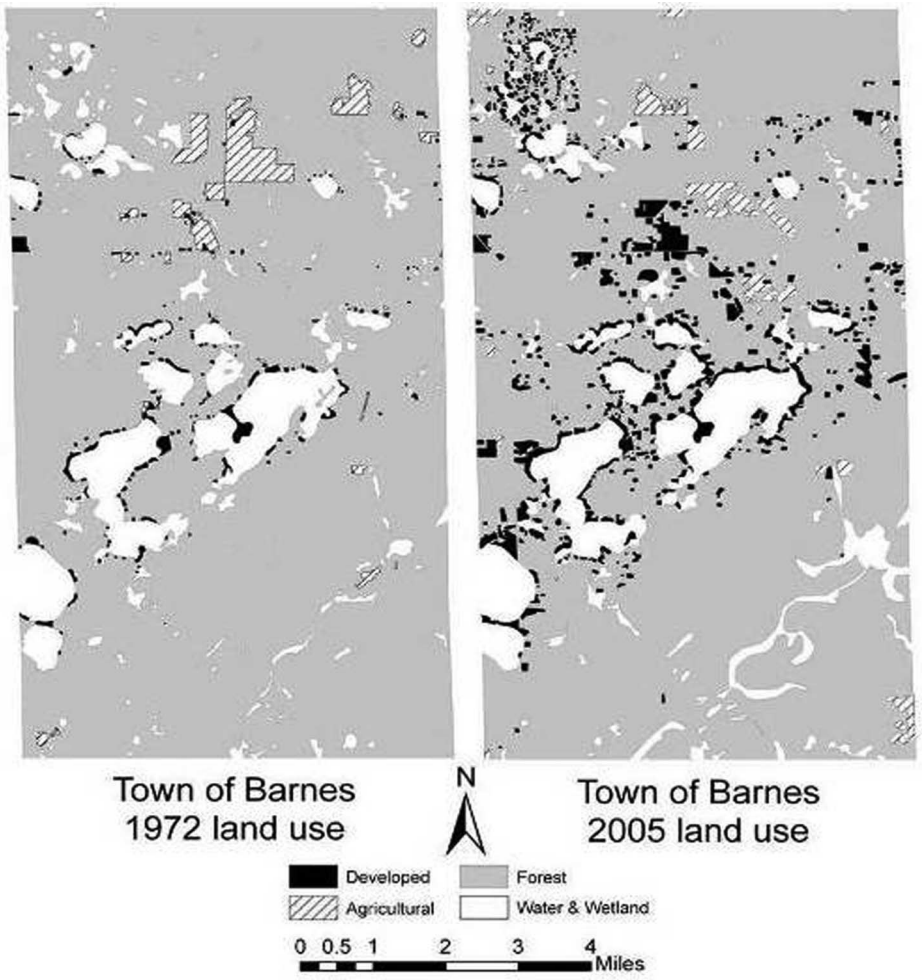

Figure 5. Land-use patterns in the town of Barnes in 1972 (left) and 2005 (right).

to a parcel split, the options dwindle for planners and resource managers to protect vital land production resources and critical habitats. In addition, the lag time after a split occurs to the development of that parcel can take decades in these rural forested regions. As pointed out by other studies, parcelization is a key topic regarding the loss of land production resources. These results are applicable to other northern forested regions experiencing amenity-led development pressure, especially the region that extends across northern Minnesota, Wisconsin, and Michigan (Leatherberry 1999, Gobster and Rickenbach 2004). Parcelization is not an issue unique just to the United States. Leppanen (2008) noted that parcelization is one of the most important issues to the future profitability of forestry in Finland. Finland has experienced increased parcelization for reasons similar to the rural northern hardwood areas of the Midwest. Finnish residents share the dream of owning their own parcel of land with a summer cottage in forested lake areas. Critical to protecting natural resource-rich land from fragmentation resulting from parcelization in the United States is the ability to target preservation and conservation tools before the loss of land to parcelization and subsequent development.

Northern forested areas under pressure of fragmentation will benefit from policies that encourage cluster developments and other regulatory and nonregulatory techniques that allow for larger forested TCAs and patch contiguity. Protection of these critical natural resources begins at the level of political and administrative control, namely, the tax parcel.

Finally, spatial reconstruction efforts in this study were intense because of the amount of time and resources needed to recreate historical tax parcel layers. We are working to encourage more communities to regularly archive digital copies of their parcel layers and related geographic information system records to allow for future research analyzing parcel fragmentation and land-use change in a wider set of communities. It has been our experience that county land information offices use a wide range of protocols for recording and storing these data. Greater uniformity in recording and storage of these data would facilitate greater access and use of these records.

Endnote

[1] FRAGSTATS is a computer software program used to analyze the spatial pattern of a landscape using landscape ecology metrics in a raster-based layer format. Landscape ecology examines the patterns and interactions of different landscape patches and how these interactions change over time within a landscape mosaic (McGarigal and Marks 1995).

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