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Research Paper

Local policy and landowner attitudes: A case study of forest fragmentation

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ABSTRACT

Wisconsin is known for its extensive forest resources and its attraction to visitors and permanent and seasonal homeowners. Development, due to this attraction, within the state's private forestland has been a growing phenomenon for many years and communities are struggling to implement tools to reduce its negative impact. One group of tools is local land use policies, but many communities are not equipped to regulate more than the basics, such as minimum lot size, and it is not clear that moving beyond the basics would conserve future forest resources or whether or not private landowners would find more restrictive land use policies acceptable. In this paper, we conduct a case study of northern Wisconsin by analyzing two dimensions: the possible effect of local land use policy on forest fragmentation and landowner attitudes to policy. The purpose is to uncover whether conventional or density-based zoning conserves more forestland and which policies local landowners would support. We find that, one, density-based zoning can conserve more total and core forest than conventional zoning. Two, when landowners view a particular scenario as a severe threat, they are more inclined to support some forms of land use regulation over others. These findings indicate that local governments can open up a dialogue for more restrictive local land use policies for conserving forest and limiting forest fragmentation, if landowners understand the impact among various alternatives.

1. Forest fragmentation and the role of rural zoning

With over 16 million acres of forestland, Wisconsin's extensive and well-known forest resources supply timber, wood products, ecosystem services, and wildlife habitat. Northern Wisconsin exhibits a mixture of public and private land, a diverse land use history, and is a magnet for rural amenity development and seasonal home construction (Dahms & McComb, 1999; Gonzalez-Abraham et al., 2007; Haines, Kennedy, & McFarlane, 2011; Marcouiller, Clendenning, & Kedzior, 2002). Thirty-three to 82 percent of the housing stock in northern Wisconsin is seasonal homes in comparison to a range of 0–6 percent in counties with few recreational and aesthetic amenities (Haines & Roberts, 2015). Parcelization and subsequent housing growth in forested, rural areas are due to the combination of low land prices, relatively weak land use regulations, and attractive recreational and aesthetic amenities (Green, Marcouiller, Deller, Erkkila, & Sumathi, 1996; Michael, Boyle, & Bouchard, 1996). Nationwide, owners of almost 6 million acres of forested land indicated they had plans to subdivide and sell their property in the next 5 years (Butler, 2008). In Wisconsin, 18% of family forest owners with 10 or more acres are extremely likely or likely of selling or giving way their land (Butler et al., 2016).

Parcelization and development in heavily forested areas have been identified as an important determinant of landscape fragmentation (Gonzalez-Abraham et al., 2007; Haines et al., 2011; Holdt, Civco, & Hurd, 2004; Kilgore & Snyder, 2016). As development encroaches and perforates rural areas, land uses transition from logging and tree farming to recreation, retail and services. New development is criticized for scattering homes across the landscape in a low density pattern, placing buildings in fire prone areas, displacing wildlife from their habitats, and limiting the potential for efficient timber management (Bridges, 2008; Butler & Leatherberry, 2004; Cleaves & Bennett, 1995; Davis & Nelson, 1994; Glennon & Kretser, 2005; Gobster & Schmidt, 2000; Klase & Guries, 1999; Sabor, Radeloff, Hammer, & Stewart, 2003). Foresters observe the size of properties with which they work continue to decrease, making their work more challenging (L'Roe & Allred, 2013). In Wisconsin, the threshold size for logging is about 20 acres, and small-parcel logging firms are modifying their business strategies as parcel sizes decrease (Butler & Ma, 2011; Conrad, 2014; Rickenbach, Steele, & Schira, 2005).

In addition to the impacts on forested resources, local governments

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are struggling to implement tools to reduce the impact of parcelization and development. Zoning is a familiar, easy, and long-used tool (Hoch, Dalton, & So, 2000). York and Munroe (2010) investigated the impact of the existence of county zoning on land use conversion in Indiana. They found that zoning's presence is only marginally effective. A variation on general zoning is the use of forestry zoning, but it is ineffective in maintaining large contiguous tracts for timber management if minimum lots sizes are too small (Haines et al., 2011). Bayfield County, Wisconsin, for example, has two forestry districts. One district has a minimum lot size of 4.5 acres and allows residential development and the other district has a 35-acre minimum lot size and bars residential development (Bayfield County, 2017), but lands zoned in this district have been rezoned over time (Haines et al., 2011). Alternatively, clustering, open-space and conservation subdivisions, are regulations that specify the maximum density for residential dwellings per acre and the location (e.g., along an existing road), distribution (e.g., clustered), and size of lots (e.g., maximum size) while preserving the remaining land on the site for recreation, open space, farming, or forestry (Chadbourne & Chadbourne, 2000). It is assumed that these regulations will result in conserving working lands (Arendt, 2015). However, while it appears that open space lands are preserved in conservation subdivisions, these lands are maintained as prairie, mown grass, or non-timber producing woodlands (Göçmen, 2014) and clustering does not alter future land use patterns (Conway & Lathrop, 2005). Freeman and Bell (2011), who compared cluster and conservation subdivisions, found that conservation subdivisions produced a more permeable landscape for wildlife than the clustered ones. Density-based regulations for rural areas, unlike cluster or conservation subdivisions in a suburban setting, are designed to deal with subdividing land parcel by parcel. For examples, Minnehaha County, South Dakota (n.d.) allows one residential dwelling unit per 40 acres and Jefferson County, Wisconsin (2012) limits the number of lots splits from a parent parcel and uses a minimum lot size of 1-acre and a maximum of 2-acres. If two splits are allowed, the county recommends them to be adjacent (Jefferson County, Wisconsin, 2012). Minimum and maximum lot sizes are used to encourage the location of residential development on less productive lands or in areas where the agricultural land or forest has already been fragmented and to keep new small parcels adjacent to existing roads. It is unclear from past research if density-based regulations can maintain rural, working lands or if it only results in creating pockets of open space. The authors distinguish between density-based zoning and land or subdivision regulations. In general, Wisconsin zoning ordinances specify the uses, density and dimensions of parcels whereas land or subdivision regulations specify the process of subdividing land.

With increasing development and numbers of landowners, local governments need a stronger understanding if their policies will accomplish their desired intent and if landowners understand and agree with chosen development policies (Birch, 1996; Butler & Leatherberry, 2004). In the presence of regulatory uncertainty, especially the threat of stringent land use regulations, Mehmood and Zhang (2001) found that the likelihood of parcelization increases as forest landowners perceive that these restrictions negatively impact the long-term viability of their timber investment. In Wisconsin, this concern is likely a factor for private forest landowners as the development of the state's private forestlands has resulted in greater public awareness of land use conversion and loss of open space (Gobster & Rickenbach, 2004). Stone and Tyrrell (2012) also point out that while personal circumstances (such as the desire to transfer land to family or seeking property tax relief) are the primary drivers of parcelization decisions, the presence of proximate development creates market conditions and great offers to sell are often the reason landowners choose to subdivide their land in this context. The reasons why private forest landowners continue to own and value their forests are also influenced by a number of other attitudinal factors such as their views on timber harvest, use of forest resources for personal benefit, protection of the forest for conservation purposes, and recreational and hunting access (Ma, Butler, Kittredge, & Catanzaro, 2012; Metcalf, Gruver, Finley, & Luloff, 2016; Stone & Tyrrell, 2012). As a landowner there are also expenses stemming from management or taxes, potential profit associated with cutting or selling forestland, and the need for future planning, including determining how to handle ownership transitions (Mehmood & Zhang, 2001; Metcalf et al., 2016; Stone & Tyrrell, 2012).The overlapping and often competing interests influencing private forest landowners' parcelization decisions demonstrate the challenges facing forested towns in Northern Wisconsin that are responding to increasing development pressure and the associated need to build support for local land use regulations. These issues are complex and show why working with stakeholders must be a process of building understanding about the attitudes that shape the debate over local land use regulations. The potential for engagement in this process is strong, as a majority of private forest landowners are already actively engaged in decision making on their own properties addressing property management, silviculture, wildlife habitat, and recreational improvement (Joshi & Arano, 2009). There is a lot at stake in these decisions for landowners and for the community that is working to incorporate new development while preventing resource degradation and protecting the health and opportunities that have been provided by the forest.

In this paper, we use a case study approach in northern Wisconsin to examine the intersection of local land use policy and landowner attitudes. These two dimensions are critical to understand if more innovative planning policies are achieving forest conservation, reducing forest fragmentation, and if landowners find these policies acceptable. To study these two dimensions of local land use policy and landowner attitudes, we take a two-pronged approach. One approach is a spatial analysis focused on ten heavily forested towns in Wisconsin under different land use regimes. We use a build out model to analyze the extent to which conventional and density-based land use regulations impact forest fragmentation due to potential residential development. The other approach is a landowner survey in those same northern Wisconsin towns, purposefully designed to elicit responses to evaluate factors that influence support for a specific set of possible land use policies ranging from least restrictive (no regulation) to highly restrictive options.

2. Data and methods

We begin by discussing the study area and how we chose our cases. From there, we discuss the build-out scenarios and then the landowner survey.

2.1. Study area and case selection

Our study area was northern Wisconsin and initially included all counties with digital tax parcel and zoning data. The research design for this study required the identification of communities implementing density-based regulations against which a control group could be compared. Our study used five towns in Lincoln County as the experimental group because of its innovations in dealing with landscape change and development patterns through subdivision and density-based zoning regulations. At the time of the study, no other Wisconsin county in the Northwoods had moved towards a density-based direction. The control group used conventional zoning, and we chose five towns in five counties as comparisons. We considered all counties that comprise the USDA Forest Service's Northeastern and Northwestern units of the state to be viable candidates for our control group. The initial pool consisted of 21 counties and 389 towns. We reduced this pool by eliminating municipalities that did not maintain digital tax parcel and zoning spatial databases. The final set from which to select our sample consisted of 9 counties and 116 towns. No more than one town from each county was then matched with a Lincoln County town. We matched towns in the control pool with towns in Lincoln County

Table 1
Matched town characteristics.

		Match 1 Lincoln-King/ Oconto-Abrams		Match 2 Lincoln-Merrill/Oneida-Crescent		Match 3 Lincoln-Schley/ Bayfield-Kelly		Match 4 Lincoln-Scott/ Polk-St. Croix Falls		Match 5 Lincoln-Skanawan/Douglas-Maple	
Town characteristics	Percent Public & Industrial	24	24	6	3	6	5	0	0	22	19
	Square Miles	37	38	53	33	48	37	31	32	36	32
	Housing Density*	23.6	21.0	25.6	38.0	8.2	4.5	15.7	16.8	6	9.5
	Percent Forest	54	49	53	52	49	62	34	36	57	70
	Population	855	1856	2980	2033	909	377	1287	1119	354	649
	Housing Units	873	797	1355	1252	395	168	488	538	216	303
Survey	Sample size	Not surveyed				126	65	58	41	55	56
	Bad Addresses**					7	5	16	4	2	1
	Valid Responses					69	25	17	17	29	31
	Response Rate***					58.0%	41.7%	40.5%	45.9%	54.7%	56.4%

* Housing density is housing units per square mile.
** Bad addresses were returned by the postal service or through direct contact from current resident indicating the respondent no longer lived at that address.
*** Overall Response Rate of 51.4%.

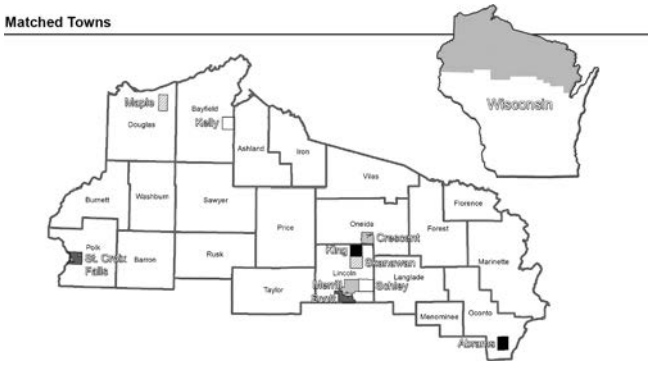


Fig. 1. Wisconsin map and matched towns.

using easily accessible and available data, specifically, percent forest cover, population, town area, housing density, and public land. These variables were assigned to each town using GIS overlay and joining techniques in ArcGIS (ESRI, 2010). Percent forest cover was derived from the 2011 USGS National Landcover Dataset (Homer et al., 2011), while the total population and housing density variables were generated from the 2010 census (US Census Bureau/American FactFinder, 2010). We determined the amount of public land by querying the tax parcel database on the owner's name field. For each Lincoln County town, we attempted to find the nearest matching town from the control group by systematically analyzing individual attributes. Though no two towns were exactly alike, we matched towns that exhibited the most similar characteristics for each variable. While each variable is not exactly the same, we tried to match as many variables as similarly as possible. Table 1 presents the matched towns and their respective variables and Fig. 1 displays a map of the area and the matched towns.

2.2. Build-out scenarios

We simulate full build-out using available GIS tools under two regimes to see if there are significant differences with forest fragmentation. Build-out models use current law or regulations to project development that could occur in a particular community. We used ArcGIS and Community Viz software for all build-out scenarios. The Community Viz program is an extension that works with ArcGIS and is used specifically for executing build-out scenarios to determine the potential locations where buildings may be constructed (see Janes & Kwartler, 2008; Walker & Daniels, 2017 for additional information about how Community Viz works). The scenarios reflect the likely pattern of development that would occur if all available land were developed to its maximum capacity. The build-out process takes into account spatial restrictions, like lot size, setback from roads, distance from shoreland, and distance between buildings. Community Viz allocates the units based on the constraints it is given. Thus, if in a maximum build out, 100 dwelling units were possible under the code, the program would place those units based on appropriate parcels that could be subdivided given the constraints. In these build out scenarios, these lots are large enough to handle the state minimum requirements for septic systems. Build-out models are only applicable where there is some form of planning that constrains the type and location of development. The most common form of spatial planning is through the local zoning ordinance. Zoning regulations are largely used to determine the intensity of development allowed on the available land. Relying primarily on zoning data to model future development has its limitations. Local governments commonly review and amend parts of zoning ordinances, so the odds that an existing zoning ordinance will remain static until complete build-out are doubtful. However, build-out scenarios emphasize what is possible under specific sets of regulations. Although residential development may not take place at the highest density, recognizing what is permitted helps to identify ways to modify regulations to improve resource protection.

Both parcel boundaries and zoning district boundaries are essential data layers for conducting a build-out analysis. Parcel boundaries are important because they represent the existing ownership structure and set the initial pattern for potential development. In most cases, zoning district information is stored independent from the parcel data, so before developing scenarios for each town, we merged both layers so that zoning information would be attached to each individual parcel. A few parcels had more than one zoning district and we chose the district that had the most area or had an obvious use. For example, if a house existed on the parcel, the zoning district became residential. Community Viz needs each parcel to have only one zoning district.

Environmental and physical landscape constraints played an important role in our build-out models. The assumption underlying our build-out scenarios was that future development would not occur on certain features like wetlands, water bodies, steep slopes, existing development, and within specified setbacks of roads, streams and lakes. Thus, numerous input layers were collected and added as development constraints in the model. Certain features were buffered by various widths to reflect the setback distances stated in each ordinance. We limited potential development to slopes of less than 15 percent after consulting planning and zoning professionals from the study region. We used a mask on slopes greater than or equal to 15 percent. Table 2 presents datasets and their sources that were used in the build-out analysis.

2.2.1. Conventional zoning scenarios

Conventional zoning is commonly found in most places where a minimum lot size, such as two acres, and setbacks (or distances) from

Table 2
Metadata for spatial data used in the build-out analysis.

Description	Source	Date	Data format
Land ownership	County	2015	Vector
Zoning districts	County	2015	Vector
Overlay zones	County	2015	Vector
Building locations	County	2015	Vector
Roads	County	2015	Vector
Soils	NRCS	2013	Vector
Slope	USGS National Elevation Dataset	2015	Raster 30m
Wetlands	Wisconsin Dept. Nat. Res.	2013	Vector
Hydrography	Wisconsin Dept. Nat. Res.	2013	Vector
Public lands	County	2015	Vector
Public service areas	County	2015	Vector
Floodplains	County	2015	Vector
Right of Ways	County	2015	Vector
Land Cover	USGS 2011 National Land Cover Database	2011	Raster 30m
Aerial Photography	USGS National Agriculture Imagery Program	2013	Raster 1m

lot lines are defined for each district type (e.g., residential) and creates an envelope within which a structure or house can be constructed. This scenario reflects the likely residential development pattern that would occur if all available land were to be developed under a minimum lot size. We used the specific local zoning ordinances to identify the minimum lot size and setbacks. The net developable land per parcel is calculated by first removing the environmental and physical constraints, such as lakes, streams, wetlands, flood plains, steep slopes, and public lands. We computed the number of potential dwelling units by dividing the net developable acreage by the minimum lot size for each parcel. The average of the front, side, and rear setbacks was used as a minimum separation distance between building points.

2.2.2. Density-based scenarios

Density-based regulations as discussed previously are different from cluster or conservation subdivisions. Instead a density-based regulation for a residential district could limit the number of parcels that are divided from the parent parcel in addition to defining minimum and maximum lot sizes. This scenario imitates flexible lot sizes for potential residential development for the experimental towns in Lincoln County. We calculated the number of potential dwelling units by multiplying the net developable acreage by the required residential density articulated in the zoning ordinance. Lincoln County has established two residential density districts, RL-2, which allows for two dwelling units per 40 contiguous acres, and RL-4, which allows for four dwelling units per 40 contiguous acres (Lincoln County, Wisconsin, n.d.) with a minimum lot size of 40,000 square feet (which is large enough for a septic system). Both districts have a minimum lot width of 130 feet and minimum setbacks for the side yard are 10 feet, the rear yard is 25 feet, and the front yard depends upon the type of road and can vary from 30 to 50 feet. We used these setbacks for adjacency of parcels. We included a twenty percent efficiency factor to account for land that must be dedicated for roads, open space, and utilities (Community Viz, n.d.). There is no specific amount required in the ordinance.

2.2.3. Fragmentation metrics

A series of landscape fragmentation metrics were calculated to examine the cumulative impacts of potential development patterns generated by each build-out scenario for the forested lands in each town. Comparisons were made between the 2011 landcover and the projected build-out conditions to understand the difference between density-based and conventional zoning regulations. One-acre buffers were created around each building structure to represent a typical residential impact. Future forestland cover layers were derived for each town from the 2011 NLCD grid by using the buffers of the buildings to change pixel values to develop. Forest fragmentation of the current and predicted forest cover layers was measured using the forest fragmentation model developed by Parent, Civco, and Hurd (2007). The forest fragmentation model uses morphological image processing techniques to classify spatial patterns at the pixel level (UCONN CLEAR, 2009). The model creates four classes of forest pattern: patch, edge, perforated, and core. A patch is “defined as a relatively homogeneous nonlinear area that differs from its surroundings” (Leitão, Miller, Ahern, & McGarigal, 2006, p. 8). Pixels classified as patch represent small isolated fragments of forest that are completely surrounded by edge forest. Core area is “defined as the central portion of a patch that remains after removing a specified perimeter edge zone” (Leitão et al., 2006, p. 92). In our model, core forest was larger than 250 acres (UCONN CLEAR, 2017). Forest edge signifies both interior and exterior boundaries of core areas and patches. We used an edge width of 300 feet for determining forest fragmentation categories (UCONN CLEAR, 2017). Areas that are between core and edge classified pixels are defined as perforated forests. Perforation “is caused by the introduction of nonlinear patches (e.g., agricultural fields, houses) within the core area” (Leitão et al., 2006, p. 17). Perforated forests are typically degraded by edge effects (UCONN CLEAR, 2009). Fig. 4, in the results section, illustrates these four fragmentation metrics.

2.2.4. Build out limitations

Using Community Viz has limitations in terms of placing the new parcels on the map. It is possible that running numerous build out scenarios could result in alternative placement of new parcels. However, to deal with this limitation, we conducted a full build out analysis. For the density-based scenario, new parcels needed to be placed on existing roads per Lincoln County’s regulations. Without new roads, the number and placement of new parcels was limited by the number of 40-acre parcels within each of the towns. For the conventional scenario, alternative placement of new parcels is possible, which could affect the fragmentation metrics. Another limitation is the time and data requirements to include a large enough sample to test the statistical difference between conventional and density scenarios.

2.3. Landowner survey

To evaluate factors that influence private forest landowners’ support for land use policies, an 8-page survey questionnaire was mailed to owners of large parcels in six of the ten matched Wisconsin towns compared in the spatial analysis. A total of 402 landowners were selected from public parcel data for participation and recruitment was handled using a five-wave mailing adapted from Dillman’s (2007) tailored survey design method. The process began in March of 2012 with an introductory letter followed by two subsequent rounds of reminders that included a survey packet and a follow-up postcard mailed approximately a week to ten days apart. Budget limitations prevented surveying landowners in all 10 towns and also required the use of a 60-acre minimum parcel size for participation to accommodate a total sample size limit, which means that the results reflect attitudes of forest landowners in the selected towns with the largest acreage potentially affected by local land use regulations. The final sample, as described in Table 1, included landowners from the density-based scenario (Lincoln County) towns of Schley, Scott, and Skanawan and landowners from the conventional zoning scenario towns of Kelly (Bayfield County), St. Croix Falls (Polk County), and Maple (Douglas County). The decision to select these three conventional zoning scenario towns was due to their geographic proximity (see Fig. 1) within a region sharing similar forest and development conditions. Additionally, the address list was screened to ensure that these were valid individual owner contacts or family limited liability corporations.

The survey questionnaire was designed to enhance our understanding of the role of landowners’ attitudes in developing land use regulations to protect the health of the forest in northern Wisconsin towns. Survey questions were approved by IRB, reviewed by forestry

and social science researchers, and revised based on the results of pretesting with private forest landowners to address content validity concerns. The specific research questions addressed by this study are grouped together into the following geographic, demographic, and attitudinal analyses. The geographic analysis focuses on whether or not differences exist between landowners in the density-based zoning scenario towns (Lincoln County) and the matched conventional zoning towns. This analysis specifically compares these geographic groups to determine whether (a) private forest landowners in towns with density-based zoning (Lincoln County) perceive the threat of development on the health of woodland in their community as a more serious threat than those in the matched towns with conventional zoning; and to determine if (b) private forest landowners in towns with density-based zoning are more supportive of stricter land use policies than landowners in the matched towns with conventional zoning. The demographic analysis focuses on (c) whether variation in commonly studied demographic factors (age, total acres owned, political orientation) can explain the differences in perceived impact from development (severe threat, neutral, not a threat) on the health of woodlands in their community. And lastly, the attitudinal analysis explores whether the perception of threat from development on the health of woodland in their community results in differences in private forest landowners' (d) support for stricter land use policies or their (e) attitudes toward potential consequences of future development.

2.3.1. Survey procedure

Corresponding to the five research questions (a–e) laid out above each survey respondent was asked to answer geographic, demographic, and attitudinal questions. Connecting these questions directly to the spatial analysis, each survey was customized to include the build-out scenario specific to each town (examples are shown in Fig. 3). After reviewing their towns build-out scenario, survey respondents were then asked to select one of the following three options to complete this statement: Development is (1) "a severe threat to the health of woodlands," (2) "neutral to the health of woodlands," or (3) "not a threat to the health of woodlands" in this community. Additionally, the survey collected demographic information about respondents (as identified in research question "c" above), assessed support for land use policies and anticipated personal consequences of development.

- **Support for land use policies**: Respondents were asked to rate their likelihood of support for ten land use policy options ranging from least restrictive (no regulation) to highly restrictive options on a response scale from (+2) very likely to (-2) very unlikely. These ten options collectively represent the range of both conventional and density-based regulatory options that are possible in Northern Wisconsin in a simplified format to make their descriptions accessible to survey respondents. The text of each policy option was presented in the survey has been included along with graphic depictions in Fig. 2.
- **Anticipated personal consequences of development**: Respondents were asked to respond with their level of agreement from (+2) strongly agree to (-2) strongly disagree with the following statements regarding the possible impact of new housing construction and development in their community: (1) New development in my community increases property value. (2) New development in my community decreases my heirs desire to take ownership of my land. (3) New development in my community negatively impacts the beauty of my land. (4) New development increases the likelihood of negative interactions with members of my community. (5) New development decreases the quality of hunting in the area of my community. (6) New development in my community is disruptive to the timber production of the area. (7) New development in my community interferes with nature by decreasing the number and types of wildlife that are present now.

The analysis of the survey data was conducted using IBM Statistical Program for the Social Sciences (SPSS, v. 24; IBM Corp., 2016) for each of the three (geographic, demographic, and attitudinal) analyses outlined above. The geographic analysis begins with research question (a) using an Independent Sample T-test to compare the mean difference in the perceived level of threat posed by development (severe, neutral, not a threat) for landowners in the density-based zoning scenario towns as compared to landowners in the matched towns with conventional zoning. For research question (b), the same analysis technique is repeated to evaluate difference in mean support for the ten land use policy options between these geographic groups. The demographic analysis focuses on research question (c) by using an ANOVA supported by multi-group comparisons derived from Tukey post-hoc significance tests to determine if demographic differences (age, total acres owned, and political orientation) exist between the three landowner threat perception groups (severe, neutral, not a threat). To complete the attitudinal analysis, ANOVA (Tukey post-hoc) tests are used to determine if differences in mean (d) support for the ten land use policy options exist; or if differences (e) in perceived personal consequences exist between the three landowner threat perception groups (severe, neutral, not a threat).

3. Results

We start this section with discussing the results from the build-out scenarios and then move to the landowner survey results.

3.1. Build-out scenarios

Based on the results of the build-out scenarios, 10,556 new dwelling units could be built in the ten towns in northern Wisconsin. About 48 percent of the new dwellings or 5026 could be built in the conventionally-zoned towns, compared to 52 percent or 5530 in the Lincoln County towns. If we assume a two-acre lot size, it would mean conventional towns could have an additional 10,052 acres of land consumed by residential development as opposed to 11,060 acres in the density-based towns. However, the analysis projected that at full build-out, towns under conventional zoning would exhibit a cumulative 12 percent decrease in total forestland due to residential development, despite the lower number of new dwelling units, while density-based towns are projected to have an 8 percent decrease.

Fig. 3 shows a build out analysis with the dots representing existing and potential new residential buildings for one of the town matches. The two maps illustrate how the density-based scenario limits the number of potential residential buildings and tends to place them near existing roads in contrast to the matched town where there are few limits on the numbers and placement of potential residential buildings. To dig further, Fig. 4 illustrates the current and projected pattern of forest fragmentation for one group of communities. It shows that much of the original core forest land in the Town of Kelly (conventional) is projected to be altered by potential new residential development. However, in the Town of Schley (density), it is difficult to discern differences between the two maps. The main difference between town scenarios reside in the spatial distribution of dwelling units. This is confirmed by comparing all groups of scenarios.

Because it can be difficult to distinguish visual differences from matched communities and their build-out landscapes, we used fragmentation metrics. We reasoned that because each town has a different configuration of forest and total amount of forest acres (even though similar % of forest), we normalized the fragmentation metrics on each town's original total forest. The results are displayed in Table 3 and show a larger percent decrease in total forest and core forest in the conventional towns versus the density towns. The one exception is the Town of Scott (a density-based town) that has a larger percent decrease in core forest, but a smaller percent decrease in total forest land in contrast to its match. Upon further examination, the fragmentation

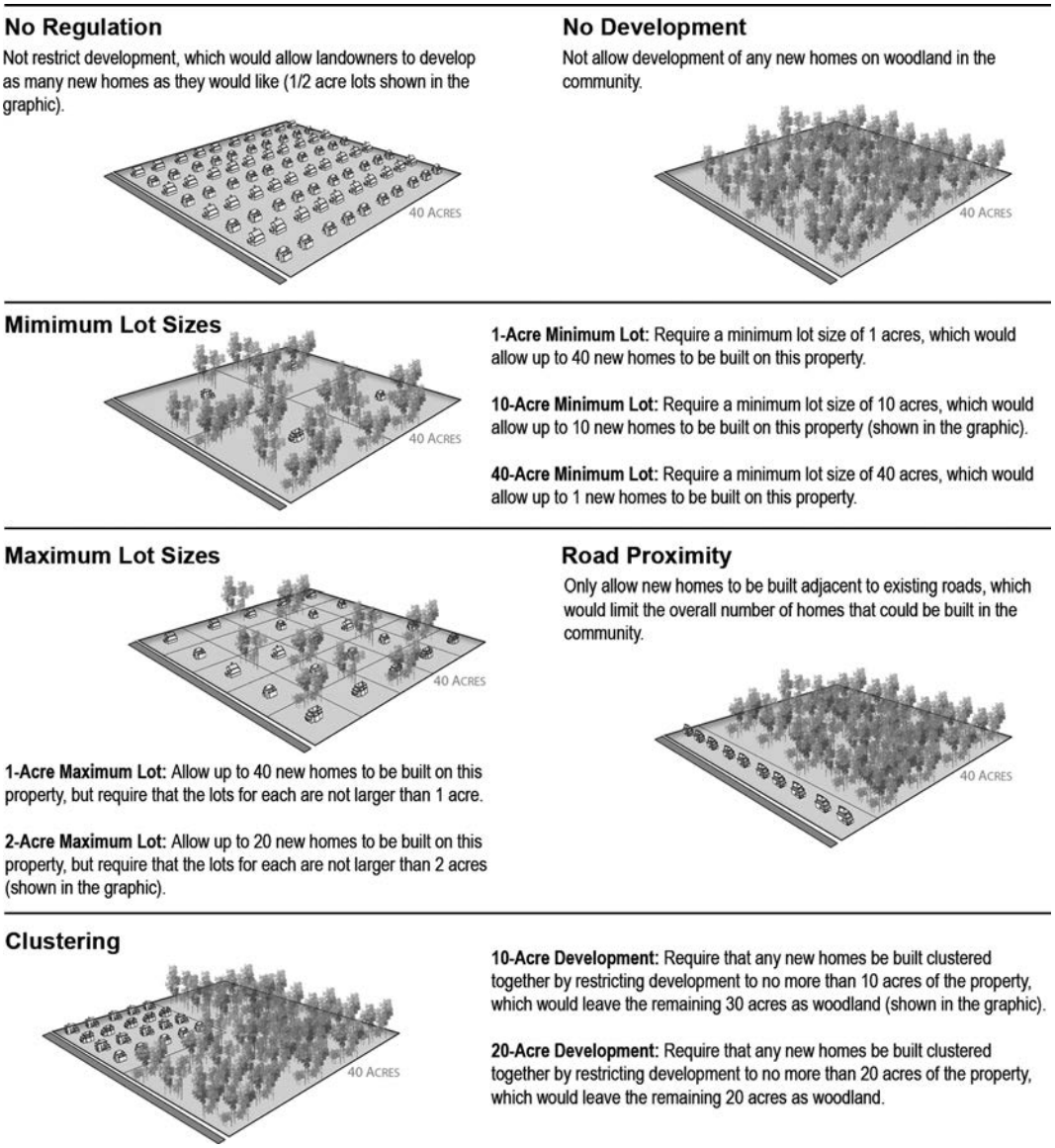


Fig. 2. Land use policy options.

maps show that the Town of Scott's forested areas are scattered throughout the town even prior to the build-out analysis, while its match, the Town of St. Croix Falls, shows larger areas of core forest before build-out, but core forest disappearing and becoming patches after build-out. For the other metrics, the patch metric shows a larger percent increase and the edge metric has a larger percent decrease for the conventional towns versus the density towns. The one metric that is virtually the same for conventional and density is the percent increase in perforated forest.

3.2. Landowner survey

The survey recruitment process resulted in an overall response rate of 50.9 percent (see Table 1 for a breakdown of individual town response rates). Data from the returned surveys were entered into SPSS and checked for errors following data entry. The following sections present the results of the statistical test for the geographic analysis (research questions a-b), demographic analysis (research question c), and attitudinal analysis (research questions d-e).

3.2.1. Geographic analysis

The geographic analysis of survey results began by exploring whether the more innovative density-based policy adopted in Lincoln County are related to higher levels of perceived threat or stronger support for more restrictive land use policy options among private forest landowners in these communities than in the matched, conventionally-zoned towns in other counties. Descriptive statistics revealed that after reviewing the build-out analysis for their towns 46.1 percent of respondents stated that development was a "severe threat" to the health of woodlands (Group 1), 33.1 percent of respondents stated that development was "neutral" to the health of woodlands (Group 2), and 20.8 percent of respondents stated that development was "not a threat" to the health of woodlands (Group 3). As shown in Table 4, the results indicate that for research question (a), the percentages of landowners in each of the threat perception groups are like that of the overall sample for both density-based zoning towns (Lincoln County) and conventional zoning towns (non-Lincoln County). The Independent Sample T-test confirms this result, showing that no statistically significant difference in mean values exist.

For research question (b), examining support for the ten land use policy options, the results indicate that landowners in density-based zoning towns (Lincoln County) are not more willing to accept stricter land use policies to protect the health of woodlands than landowners in conventionally-zoned towns (non-Lincoln County). Survey respondents

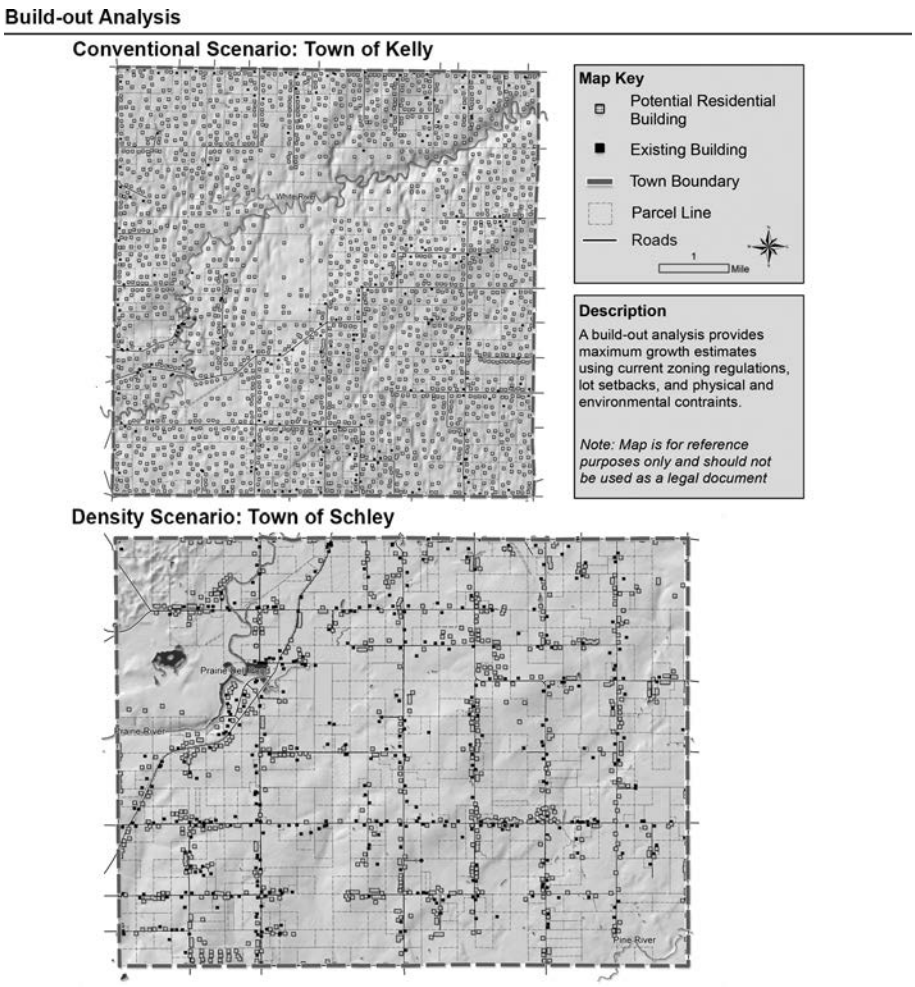


Fig. 3. Example build-out analysis.

were asked to rate their likelihood of support for the ten land use policies shown in Fig. 2, while considering the development of a 40-acre parcel in their community. As shown in Table 5, no significant mean differences were identified by the ANOVA test for the policy options presented in the survey. The results also clearly indicate that none of these land use policy options received strong, positive support from forest landowners regardless of the town's approach to zoning. While it is important to note that forest landowners rated a few options more positively, their collective responses only raised the likelihood of support to near neutral for larger minimum lot size requirements (10-acre and 40-acre) and the use of some form of driveway length ordinance to restrict development to areas near existing roads. Additionally, the results suggest that the most disliked options include no regulation, 1-acre minimum lot sizes, and both maximum lot size options (1-acre and 2-acre maximums).

3.2.2. Demographic analysis

The demographic analysis focused on research question (c) and the results of the ANOVA tests (shown at the bottom of Table 4) revealed that no statistically significant mean differences exist between threat perception groups for age, ownership (acres), or political orientation. As a result, the following trends are generally observed for all survey respondents who reported an average age of 60.0 years, average land ownership of 134.2 acres, and, as a group, are somewhat conservative in their political views.

3.2.3. Attitudinal analysis

The results for research question (d), shown in Table 6, demonstrate the complexity of identifying support for local land use policy options as significant differences exist between the three threat perception groups. In particular, the responses of Group 1 (severe threat) were significantly different in 17 out of 20 comparisons. Responses from Group 1 (severe threat) are more strongly negative than members of the other groups for seven of the presented options; with their most negative responses for no regulation, 1-acre minimum lot size, and maximum lot size policies. Group 2 (neutral) seem to fall about the midpoint between Groups 1 and 2. For Group 3 (not a threat) the results show little support for any policy other than 10-acre minimum lot sizes and landowners in this group are the most negative for any option that would allow "no development."

Acknowledging that these land use policy options are inherently connected to goals that individuals associate with land ownership, research question (e) explores attitudes toward consequences one may experience from development in their community. As shown in Table 7, the responses to the seven personal consequences of development statements were evaluated to determine if there is a significant difference in mean scores between the three threat perception groups. Again, significant differences emerged that emphasize a distinction between individuals in Group 1 (severe threat) and Group 3 (not a threat). The disconnect appears to be the primary goals for land ownership with Group 3, being distinguished by their strong agreement that new development will increase their property value, while Group 1 is distinguished by strong agreement that new development will negatively impact the beauty of the land, quality of hunting, and interferes with nature by decreasing the number and type of wildlife present.

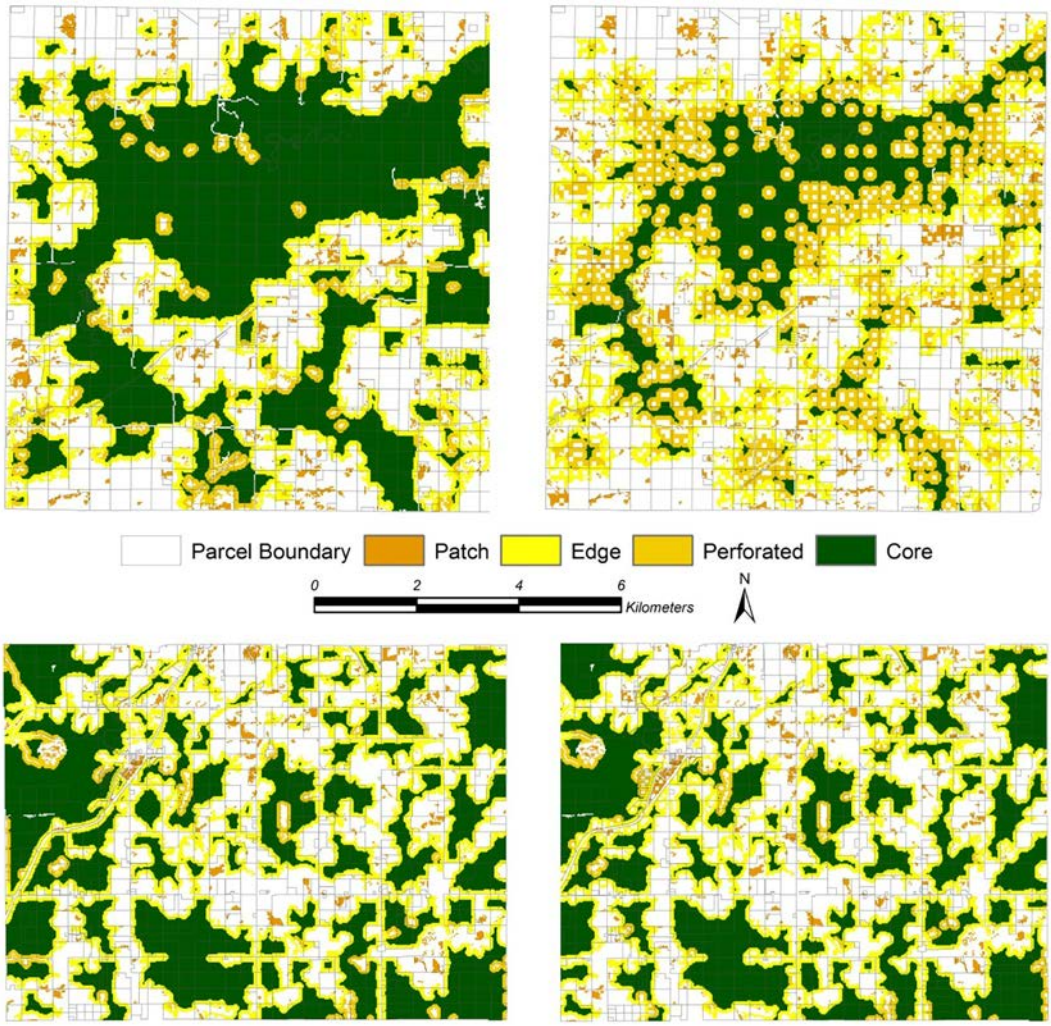


Fig. 4. Forest pattern results showing patch, edge, perforated, and core areas before and after build-out models for (a) Town of Kelly (Bayfield County) with conventional zoning and (b) Town of Schley (Lincoln County) with density-based zoning.

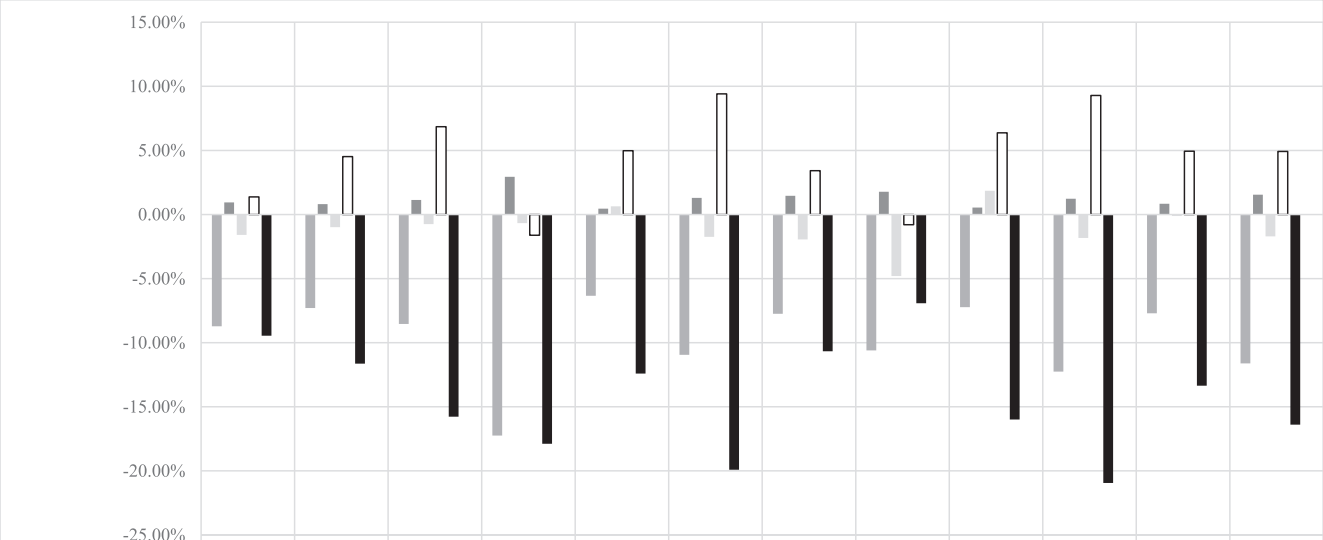
4. Discussion

Wisconsin's Northwoods will continue to face some level of residential development pressure due to increases in population and resulting demand for both primary and secondary homes. These high-amenity forested communities face significant change with anticipated negative impacts on forest health based on the analysis of current development regulations identified by the build-out scenarios. The trends from current forest pattern to build-out indicate increased fragmentation of forestlands in both sets of towns, but with a larger impact in the conventionally-zoned towns. With density-based zoning, the allocation of new housing units tends to either locate along current public roads and/or form small residential clusters by allowing for flexible lot sizes as opposed to distributing homes across the landscape. The Town of Scott could lose less forestland in comparison to its match but retain more core forest. This indicates that the state of a town's forestlands, in terms of the degree that fragmentation has already occurred, may alter both the local governments' and landowners' calculus of policy choices related to zoning.

That Lincoln County, Wisconsin moved in a density-based direction is unusual. The county had created a comprehensive plan and updated it in 2011. Part of the public participation process was a survey of 2000 households, resulting in a 42% response rate (Lincoln County Land Services Department, 2011). Eighty-seven percent strongly (50%) and somewhat agreed that forestry (logging) is an important part of Lincoln County's future and 53% agreed that Lincoln County should adopt regulations to limit growth in rural areas while protecting property rights. These responses influenced planning policies. One policy stated, the County would "[s]upport the long-term protection, conservation, and production of large blocks of forestland and farmland…" (p. 11). Former Lincoln County planning staff indicated that the then county board was convinced by their planning consultant that density-based zoning was an appropriate tool to implement the policy (Bowers, D., personal communication, April 9, 2018).

With increasing concerns over the cumulative impacts of rural residential development on forested areas, we detected smaller changes in forest fragmentation in areas with density-based zoning. Interestingly, even though a higher number of potential buildings were possible in the density-based towns, much greater and potentially significant changes in forest pattern was measured in the communities with conventional zoning ordinances. The relatively minor changes in forest fragmentation in the Lincoln County towns can be attributed to local land regulations that limit lot splits, allow smaller lots only along current public roads, and, when more than one lot split, clustering of development. These density-based zoning attributes limited the amount of forest fragmentation by causing overlap in the residential disturbance zone created by each new home. This smaller disturbance zone minimized the amount of core forestland that was affected and left much of the remaining landscape in protected open space which benefits the forest products industry (Marcouiller et al., 2002; Shindler, Brunson, &

Table 3
Change in total forest and normalized fragmentation metrics on original total forest.



	King - D	Abrams - C	Merrill - D	Crescent - C	Schley - D	Kelly - C	Scott - D	StCroixFalls - C	Skanawan - D	Maple - C	Density	Conventional
	Match 1		Match 2		Match 3		Match 4		Match 5			
Total	-8.72%	-7.30%	-8.54%	-17.25%	-6.34%	-10.95%	-7.75%	-10.60%	-7.23%	-12.26%	-7.70%	-11.62%
Patch	0.95%	0.81%	1.14%	2.94%	0.45%	1.29%	1.46%	1.77%	0.54%	1.23%	0.84%	1.55%
Edge	-1.59%	-0.98%	-0.75%	-0.67%	0.64%	-1.75%	-1.94%	-4.80%	1.85%	-1.83%	-0.12%	-1.71%
Perforated	1.37%	4.52%	6.85%	-1.62%	4.98%	9.41%	3.42%	-0.80%	6.37%	9.29%	4.94%	4.92%
Core	-9.45%	-11.63%	-15.77%	-17.89%	-12.41%	-19.91%	-10.68%	-6.92%	-15.99%	-20.95%	-13.36%	-16.39%
New Dwelling Units	1,205	794	1,861	1,392	747	940	1,117	843	600	1,057	5,530	5,026

Stankey, 2002; Stein et al., 2005) and species sensitive to human disturbances (Odell, Theobald, & Knight, 2003; Schulte, Pidgeon, & Mladenoff, 2005). Minimum lot size zoning, on the other hand, forced development to spread uniformly across the rural landscape, resulting in a more dispersed building pattern. The dispersion of buildings in this build-out analysis produced very little overlap between residential impact zones. Although the intent of setting large minimum lot sizes for residential development is to protect lands and retain the rural atmosphere by reducing the number of homes that can be built, it appears that a potential unintended consequence due to dispersion of housing is to decrease the total amount of forest and core forest, which could result in a decrease in timber production. Low density development, such as requiring five- to ten-acre lots like the towns in this study, usually means that development will spread out and fragment more of the landscape.

Although the exact demand for new development may vary based on several factors, the scenarios we analyzed indicates that density-based zoning regulations reduced the amount of forest fragmentation. In spite of the abundant forestland in each study area, a number of towns currently do not have a forestry-zoning district. The towns that have a forestry-zoning district allow for residential development, albeit oftentimes with a conditional use permit. Minimum lot size dimensions

Table 4
Threat perception: difference of means (independent sample T-test).

Development is (a) _____ to the health of woodlands in this community.	Severe Threat (Value = 1)	Neutral (Value = 2)	Not a Threat (Value = 3)
Percentage of Respondents			
All Survey Responses (n = 179)	46.1%	33.1%	20.8%
Lincoln County (n = 111)	46.8%	28.8%	24.3%
Non-Lincoln County (n = 68)	44.1%	39.7%	16.2%
Research Question (a): Mean Scores			
Lincoln County (mean)	1.7		
Non-Lincoln County (mean)	1.8		
Independent Sample T-test			
Levene's Test Significance	0.107		
Significance (2-tailed), Equal Variances Assumed	0.655		
Development is (a) _____ to the health of woodlands in this community.	Severe Threat (Value = 1)	Neutral (Value = 2)	Not a Threat (Value = 3)
Research Question (c): Mean Scores			
Age	60.1	59.5	60.5
Total Acres Owned	146.0	116.4	134.8
Political Orientation *(1 = strongly conservative through 5 = strongly liberal)*	2.5	2.3	2.4
ANOVA (between groups)			
Age	d.f. = 2/F= 0.11/Sig. = 0.90		
Total Acres Owned	d.f. = 2/F= 1.38/Sig. = 0.25		
Political Orientation	d.f. = 2/F= 0.46/Sig. = 0.63		

***p value ≤ .01, **p value ≤ .05, *p value ≤ .10.

Table 5
Support for policy options: difference of means (independent sample T-test).

	Land Use Policy Options									
	No regulation	1-acre min. lot	10-acre min. lot	40-acre min. lot	Max. 1-acre lot	Max. 2-acre lot	Cluster 20-acres	Cluster 10-acres	Road proximity	No dev.
Mean Scores										
Density-Based (Lincoln County Townships)	−1.52	−1.45	−0.13	0.12	−1.54	−1.45	−0.86	−0.60	−0.02	−0.68
Conventional Zoning (Non−Lincoln Matched Townships)	−1.30	−1.39	−.28	0.16	−1.51	−1.52	−1.00	−0.87	−0.01	−0.84
Significance (2−tailed)										
Density-Based → Conventional	0.172	0.722	0.500	0.853	0.886	0.652	0.468	0.309	0.708	0.426

***p value ≤ .01, **p value ≤ .05, *p value ≤ .10.

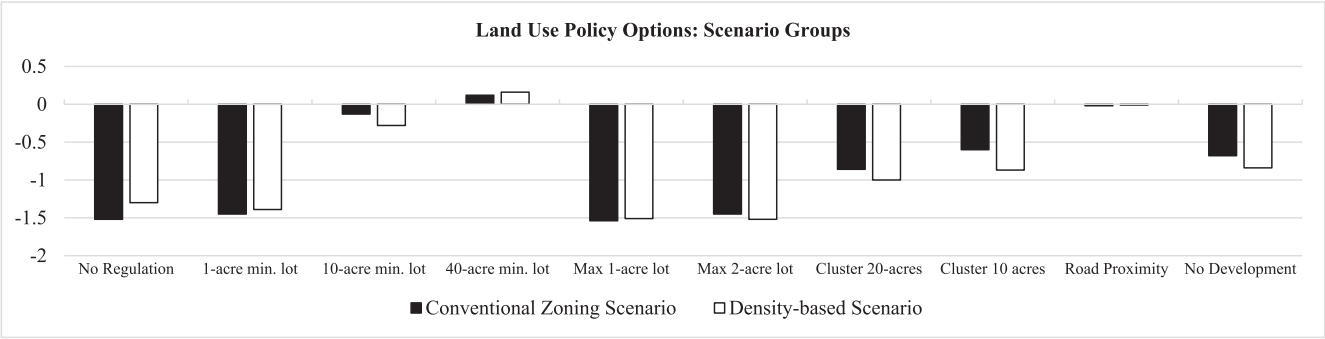


Table 6
Support for policy options: difference of means (ANOVA).

		Land Use Policy Options									
		No regulation Mean diff.	1-acre min. lot Mean diff.	10-acre min. lot Mean diff.	40-acre min. lot Mean diff.	Max. 1-acre lot Mean diff.	Max. 2-acre lot Mean diff.	Cluster 20-acres Mean diff.	Cluster 10-acres Mean diff.	Road proximity Mean diff.	No develop. Mean diff.
Group 1: Development is a "severe threat" to the health of woodlands in this community											
1→2	Neutral	−0.45**	−0.51***	−0.74***	.99***	–	−0.39**	−0.51**	–	0.75***	0.63***
1→3	Not a Threat	−0.65***	−0.76***	−0.74**	1.7***	−0.51**	−0.60***	−0.65**	–	1.3***	1.1***
Group 2: Development is "neutral" to the health of woodlands in this community											
2→1	Severe Threat	.45**	0.51***	0.74***	−0.99***	–	0.39**	0.51**	–	−0.75***	−0.63***
2→3	Not a Threat	–	–	–	0.71**	–	–	–	–	–	–
Group 3: Development is "not a threat" to the health of woodlands in this community											
3→1	Severe Threat	0.65***	0.76***	0.74**	−1.7***	0.51**	0.60***	0.65**	–	−1.3***	−1.1***
3→2	Neutral	–	–	–	−0.71**	–	–	–	–	–	–

» Significance level based on Tukey HSD post-hoc analysis.
***p value ≤ .01, **p value ≤ .05, *p value ≤ .10.

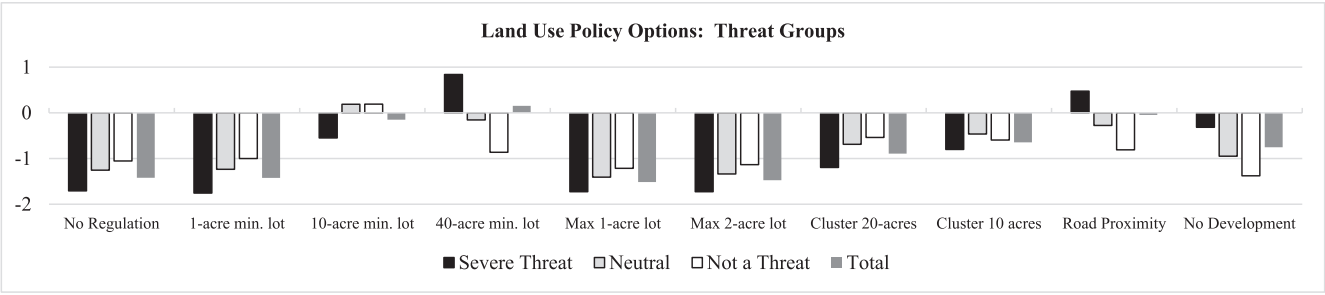
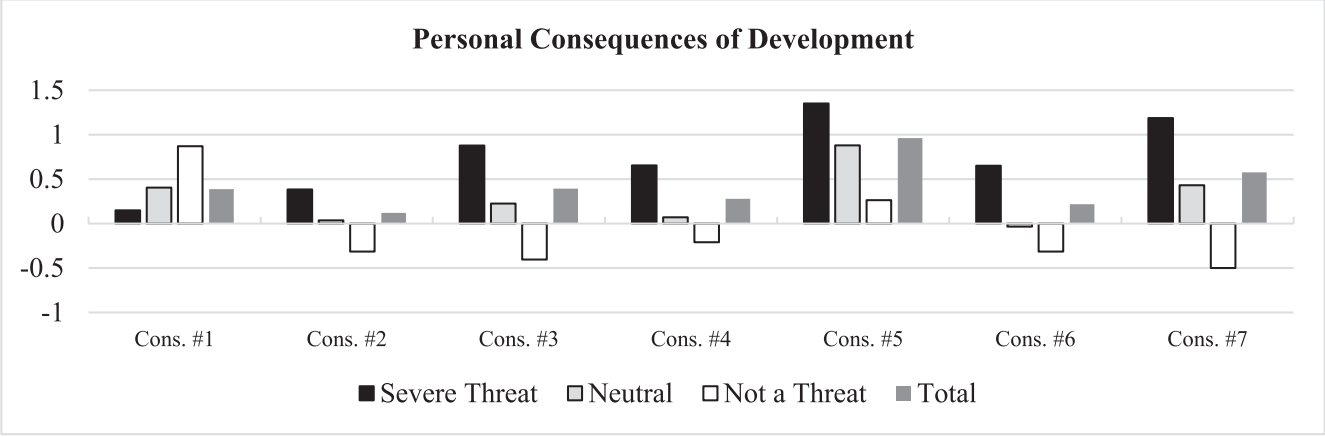


Table 7
Personal consequences: difference of means (ANOVA).

		Personal Consequences of Development Items						
		Inc. prop. value	Dec. heirs desire to own	Neg. beauty land	Inc. neg. interactions	Dec. quality hunting	Disrupt timber product.	Dec. # & type of wildlife
		Mean diff.	Mean diff.	Mean diff.	Mean diff.	Mean diff.	Mean diff.	Mean diff.
Group 1 Comparison (Severe Threat)								
1 → 2	Neutral	–	–	0.65***	0.59***	0.47**	0.68***	0.75***
1 → 3	Not a Threat	−0.72***	0.70***	1.3***	0.86***	1.1***	0.97***	1.7***
Group 2 Comparison (Neutral)								
2 → 1	Severe Threat	–	–	–0.65***	−0.59***	−0.47**	−0.68***	−0.75***
2 → 3	Not a Threat	−0.46*	–	0.63**	–	0.62**	–	0.93***
Group 3 Comparison (Not a Threat)								
3 → 1	Severe Threat	0.72***	−0.70***	−1.3***	−0.86***	−1.1***	−0.97***	−1.7***
3 → 2	Not a Threat	0.46*	–	−0.63**	–	−0.62**	–	−0.93***

» Significance level based on Tukey HSD post-hoc analysis.
***p value ≤ .01, **p value ≤ .05, *p value ≤ .10.



range from 4.5 acres in the Town of Kelly (Bayfield County) to 10 acres in both the towns of Abrams and Maple (Oconto and Douglas Counties respectively). Through our scenario analysis, this minimum lot size would continue to fragment the forest, particularly the core forest area of each town.

4.1. Landowner attitudes

The results of the survey analysis provide important information about how private forest landowners respond to the threat of development on forest health in their community. The geographic analysis, which revealed no statistically significant difference between landowners in conventional zoning and density-based towns, suggests that the adoption of a density-based approach to protect core forest areas is not the result of some underlying geographic difference in awareness or support for stricter policies between private forest landowners. The implementation of density-based policies appears to be the result of other local resources, such as local leadership, land use outreach, or personal relationships.

Rather than looking for geographic differences in landowners, the demographic and attitudinal analyses focus on how to utilize the results of the build-out scenarios by focusing on comparing groups created by landowners' response to questions assessing the threat posed by potential development in their community. The demographic analysis revealed that the average respondent was 60 years old and male, which is consistent with Butler's (Butler et al., 2007) finding that family forest owners tend to be a relatively homogeneous group of older males. Additionally, the demographic analysis show that the level of perceived threat (severe, neutral, not a threat) is not associated with differences in age, acres owned, or political orientation.

The attitudinal analysis demonstrates that perceived threat and personal consequences of development may play a more significant role in influencing support for stricter land use policies. It is clear that none of the land use regulations tested in the survey (notably including the option for "no regulation") receive strong positive support, which demonstrates the complexity of finding consensus on how to respond to the impact of development on forestland. Outreach efforts seeking to utilize build-out scenarios similar to those presented here can benefit from the attitudinal analysis that reveals support for land use policies and anticipated personal consequences of development that distinguishes Group 1 (severe threat) from Group 2 (neutral) and Group 3 (not a threat). For this study area, Group 1 represents nearly half of all survey respondents, and based on the results of the ANOVA analysis between these groups for the land use policy options, this group holds unique attitudes toward development regulation. Group 1's endorsement or acceptance of land use policies does not follow neatly from least to most restrictive. Rather they are selective in their support and, generally, are most supportive of policies that maintain larger parcel sizes, such as 40-acre minimum lot sizes, or restrict development to the edge of the forest with road proximity restrictions. This selective support of land use regulations, even among those who see development as a severe threat, was also observed by Quartuch and Beckley (2014) in New Brunswick and Maine. They describe private forest landowners as comfortable with some level of government regulation, but interviews also revealed views of regulations as either unrestrictive (very limited effect on how they use their land) or as well-intentioned and ineffective

due to a lack of enforcement. This is very different from Group 3 (not a threat) who expressed a consistently negative view of nine of the ten land use policy options.

The differences in the response to land use policy options may be explained by these groups' anticipated personal consequences of development as the data suggest that Group 3 (not a threat) is motivated by the potential for rising property values as a positive impact from development, while Group 1 (severe threat) are motivated by other factors. These results suggest that members of Group 1 (severe threat) are motivated by protecting scenic beauty of the land, preventing development that negatively affects hunting quality, and threats to the number and type of wildlife observed in their community. A possible interpretation is that individuals who perceive development as a severe threat to the health of forests are prioritizing the non-monetary benefits of forestland ownership with an emphasis on the recreational benefit of hunting and wildlife viewing. This has been described by Gobster and Rickenbach (2004) as "the outdoor lifestyle … a strongly revered trait among many Wisconsin residents." Their work goes further to describe the inconsistent environmental decisions of those seeking the amenities associated with the outdoor lifestyle as their actions are frequently a driver of residential development in forested landscapes. Interpreting these as primary goals for their community may help explain their support for large minimum lot sizes that can protect acreage needed for quality hunting experiences and keeping development in close proximity to roads, which also may be seen as a pathway for protecting core forest and hunting lands. Potentially more challenging for local land use policy implementation is the emphasis of Group 3 (not a threat) on the real estate and development value of their property, which L'Roe and Rissman (2017) have documented as a common motivator among smaller investment landowners who are taking control of forestland previously held by large forest product companies in Wisconsin. In an environment where even those that see development as the greatest threat only indicated neutral support for a few policy options, it is easy to see the challenge that lies ahead if a community is dominated by those who share Group 3's perception of the lack of threat from development and their emphasis on development and real estate goals. Rather than seeing land use policies as a way to protect the shared goal of healthy forests in their community (consistent with those seeking the outdoor lifestyle), their priorities seem to place a greater emphasis on less regulation of land use and greater opportunity for residential development.

5. Conclusions

Ultimately, communities looking for how to proceed with efforts to protect the forested landscape can draw key lessons from this study. One, zoning regulations can impact the future density and pattern of development. Two, we learned from this analysis that "large" lot sizes within forest districts do not preserve/conserve forest for timber production. If timber production is a goal, there are a few zoning ordinance rules to consider. One possibility is to include a density-based district that limits the number of parcel splits, locates new parcel splits along existing public roads, and more than one lot split should result in clustering of residential development. A second possibility is to create large minimum lot sizes, such as 40 acres. This size would allow loggers to get onto a site if the landowner wants timber production as part of his/her land management, but only if the landowner does not locate a house in the center of the parcel. Also, large minimum lot sizes may create a barrier to more affordable housing and could spur additional lot splits for seasonal homes in the region. A third possibility is to create exclusive forestry districts akin to exclusive agriculture districts that exist in southern Wisconsin. Exclusive agriculture districts usually have large minimum lot sizes (35-acre minimum) and prohibit most uses except for agriculture and the farmer's house. An exclusive forestry district could do the same and would allow protection of core forest areas.

Finally, examining both landowner attitudes and land use policy scenarios can inform the local policy dialogue that should happen among landowners, elected officials, and local government staff. Without an understanding of the landowner attitudes, policy makers may propose local land use policies that cannot be implemented due to strong opposition. On the other hand, local land use scenarios that can inform landowners and others about implications among various policy proposals, including build-out scenarios, can provide one way to focus the local discussion and can assist communities by focusing the scope of planning activities. Our analysis between the build-out scenarios and the landowner survey shows that there is a segment of the population in northern Wisconsin that highly values forest health and conservation and are willing to discuss policies to achieve those ends. Creating long-term scenarios that illustrates how particular policies may or may not achieve forest health and conservation can open up a conversation with some landowners. Our results showed that while none of the land use regulations were strongly supported by landowners, there were several that were less disliked by landowners. Lincoln County also illustrates that with useful public participation and meaningful objectives and policies articulated in a county plan, communities can create regulations that are meant to achieve those stated policies. Using a build-out analysis in conjunction with a community dialogue about potential policies and regulations can assist in connecting forest preservation objectives with reasonable policy tools.

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