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Housing growth, forests, and public lands in Northern Wisconsin from 1940 to 2000

Roger B. Hammer [a,*], Susan I. Stewart [b], Todd J. Hawbaker [c], Volker C. Radeloff [c]

[a] Department of Sociology, Oregon State University, 312 Fairbanks Hall, Corvallis, OR 97331, USA
[b] Northern Research Station, USDA Forest Service, 1033 University Place, Suite 360, Evanston, IL 60201, USA
[c] Department of Forest and Wildlife Ecology, University of Wisconsin – Madison, USA

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ABSTRACT

Rural, forested areas throughout the United States are experiencing strong housing growth with potentially detrimental impacts on the environment. In this paper, we quantify housing growth in Northern Wisconsin over the last sixty years to determine if growth rates were higher near public lands, which may represent an important recreational amenity. We used data from the U.S. Census to produce decadal housing density estimates, "backcasts," from 1940 to 2000 for northern Wisconsin to examine "rural sprawl" in northern Wisconsin and its relationship to forested areas and public lands. We integrated housing density estimates with the 1992/1993 National Land Cover Dataset to examine the relationship between rural sprawl and land cover, especially forests. Between 1940 and 2000, private land with <2 housing units/km^2 decreased from 47% to 21% of the total landscape. Most importantly, housing growth was concentrated along the boundaries of public lands. In 14 of the 19 counties that we studied, housing growth rates within 1 km of a public land boundary exceeded growth rates in the remainder of the county, and three of the five counties that did not exhibit this pattern, were the ones with the least amount of public land. Future growth can be expected in areas with abundant natural amenities, highlighting the critical need for additional research and effective natural resource management and regional planning to address these challenges.

1. Introduction

Rural America has witnessed strong housing growth since the late 1960s, when the social forces driving housing growth in rural areas underwent important changes in recent decades. In the second half of the 20th century, recreational amenities became a major determinant of housing and population growth (McGranahan, 1999; Galston and Baehler, 1995). Public opinion polls dating back to the 1940s demonstrate the desire of most urban and suburban Americans to live in more rural settings (Fuguitt and Zuiches, 1975; Fuguitt and Brown, 1990; Brown et al., 1997). These preferences resulted in directional shifts of migration and population growth patterns from suburban to rural areas in the late 1960s and early 1970s, and nonmetropolitan population growth outpaced metropolitan growth again in the 1990s. The result has been substantial increases in population size, housing density, and the extent of settlement in rural areas. Residential and commercial development is transforming the rural landscape in a process of exurbanization (Theobald, 2001), or rural sprawl (Hammer et al., 2004; Radeloff et al., 2005). Both social and biophysical impacts are evident in the wake of this transformation; housing growth has significant effects on land use (Kline et al., 2004; Kline, 2003; Wear and Bolstad, 1998; Turner et al., 1996; Douglas, 1994; Befort et al., 1988), agricultural productivity (Heimlich and Anderson, 2001), forest management (Parks et al., 2000; Nelson and Hellerstein, 1997; Wear et al., 1996, 1999; Marcin, 1993; Barlow et al., 1998; Marcin et al., 2002), wildlife habitat (Theobald et al., 1997), biodiversity (Pidgeon et al., 2007), and other ecosystem services.

Traditionally, large public land holdings such as National Forests were embedded in a rural landscape with low-density housing (Riebsame et al., 1996). Although public lands exclude housing development, one of the primary reasons they were established (Rome, 1998), public lands also offer highly valued amenities such as scenic beauty and recreational opportunities that attract housing development to their periphery. Empirical evidence suggests that housing growth is strong on areas surrounding public lands. Population projections for California indicate increasing human encroachment on wildland areas is likely (Struglia and Winter,

* Corresponding author. Tel.: +1 541 737 5406.
E-mail address: rhammer@oregonstate.edu (R.B. Hammer).

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2002). Adjacent open space has a clear effect on residential property values, indicating that open space is, itself, an amenity that home-owners value (Acharya and Bennett, 2001). However, this relationship has typically been studied in urban or suburban areas where the open spaces are small and generally modest in terms of their ecological significance. In response to rapid housing growth, some municipalities adopt open space policies, but research suggests that these may result in leapfrog development (Wu and Plantinga, 2003). Housing growth has occurred more rapidly in U.S. counties with federal lands than in others, but differences in growth rates could not be fully explained by the presence of federal lands, and non-Federal public lands were not considered (Frentz et al., 2004). Thus, the complex effects of public lands on growth patterns remain critical questions surrounding housing growth in rural areas, and our goal here was to examine the effects of public lands on housing growth more closely.

Although public lands include a great variety of land-cover types, the Midwestern U.S. public lands are predominantly forested. Therefore, the ecological isolation of public lands due to housing growth on nearby private lands is likely to result in the loss and fragmentation of forest ecosystems. Since their inception, public lands have been surrounded and interwoven with private lands, but land cover and land use were often similar across ownerships. As land cover in areas surrounding public lands changes due to rural sprawl, contiguity is lost and the ecological services of the public lands are affected (Hansen and Rotella, 2002). Public lands are at risk of becoming islands in a sea of human-dominated landscapes and are likely to suffer local extinctions and biodiversity loss (Blank et al., 2002). The relationship between larger tracts of forested lands and housing growth in rural settings has not been extensively investigated, and the rate at which rural sprawl is fragmenting intact, contiguous forests makes this a significant research gap (Radeloff et al., 2005).

One challenge associated with understanding the process of change and isolation of forests and public lands is the lack of spatially detailed data on long-term rural development trends. Aerial photographs can reveal fine-grained changes in the patterns of buildings (Gonzalez-Abraham et al., 2007b), but interpreting time series of aerial photographs for large areas is cost prohibitive. Land-cover data derived from satellite imagery is available for the entire U.S. (Homer et al., 2007), but it does not support long-term change analysis because no imagery is available before the mid-1970s. Moreover, even 30-m resolution Landsat data (Vogelmann et al., 2001) fail to adequately capture the low-density settlement patterns under closed canopy forests.

As a cost-effective alternative to these methods, we developed methods to backcast housing densities for previous decades using either the 1990 (Radeloff et al., 2001) or the 2000 U.S. Census (Hammer et al., 2004). Our goal in this study was to estimate, or "backcast" sub-county and sub-municipal level housing unit counts and densities over a multiple-decade period by using the "year housing unit built" question from the 2000 census (U.S. Census Bureau, 2002) and county-level housing counts from prior decennial censuses thereby analyzed housing growth from 1940 to 2000 in northern Wisconsin at fine spatial resolution. We further refined our housing backcasting method by intersecting the census geography with public land and reallocating housing units from public to private land. With this fine-scale method of backcasting housing density, we examined rural sprawl in northern Wisconsin and its relationship to forested areas and public lands.

1.1. Northern Wisconsin

Northern Wisconsin exemplifies the cyclical population oscillations characteristic of rural natural resource dependent areas, with historic periods of decline and recent natural amenity-driven population growth and rural sprawl. These population and settlement changes affect both forest (Radeloff et al., 2001) and lake ecosystems (Schnaiberg et al., 2002), suggesting a need for a more comprehensive look at housing growth patterns in northern Wisconsin. Our study area is the 19 northernmost counties in Wisconsin (Fig. 1). A survey of Wisconsin residents suggests that socially, these 19 counties comprise a region with a distinct meaning and identity, and are typically referred to as "The North Woods" (Stedman, 1997). Ecologically, the region is part of the Laurentian Mixed Forest province (Keys et al., 1995). This region is more forested than the southern part of Wisconsin and is dominated by northern hardwood forests. A swath of coniferous forest, the Wisconsin Pine Barrens, extends northeast from Burnett County into Washburn, Douglas, and Bayfield Counties. The forested northern portion of Oneida County also contains coniferous forest. Vilas and Oneida counties tend to be mixed forest and forested wetlands. The southern counties in northern Wisconsin including Polk, Barron, Rusk, Lincoln, Langlade, and Oconto are more agricultural. Agricultural areas of limited extent are evident farther north near Lake Superior in Douglas, Bayfield, and Ashland Counties.

Understanding the current configuration of social and ecological conditions in northern Wisconsin requires an understanding of its post-European settlement history, which was largely dominated by its ecological resources. The timber industry's exploitation of the vast white and red pine and hemlock–hardwood forests stimulated rapid population expansion in northern Wisconsin in the post-Civil War era. The demand for Wisconsin lumber was fueled by the emergence of industrial cities in the Midwest. Between 1830 and 1930, about 320 billion board feet of softwood lumber was harvested in northern Michigan, Wisconsin, and Minnesota; nearly a quarter of it harvested in just five years between 1878 and 1883 (Williams, 1989). Wisconsin's contribution to timber production increased from 1.1 billion board feet in 1869 to 3.2 billion board feet in 1889, representing one-ninth of the total lumber production in the U.S. (Steer, 1948 as cited in Williams, 1989). Throughout the 1890s, Wisconsin was consistently among the leading timber-producing states in the U.S., holding the top position for a number of years (Bawden, 1997).

In the end, relentless timber harvesting was unsustainable. By 1900, the merchantable pine forests of Wisconsin had been exhausted and only inaccessible, low-yield, scattered tracts remained (Williams, 1989). This stagnation of the region's major industry triggered a region-wide decline. Decennial censuses measured a population decline between 1890 and 1910 in northern Wisconsin. Concerned with the economic and demographic decline in the region, the Wisconsin State College of Agriculture (University of Wisconsin), the state legislature, lumber companies, railroads, local newspapers, and land speculators encouraged people, particularly newly arrived immigrants, to settle in the cut-over area and to "farm among the stumps" (Clark, 1956a). During World War I, agriculture promoters surpassed the zeal and organization of their predecessors by planning farming communities, screening potential residents, and providing educational programs. As a result, 20,000 new farms encompassing two million acres were established in the cut-over region by 1920, half of them after the turn of the century (Clark, 1956b). However, northern Wisconsin is not well suited for agriculture, and with the post-war slackening in the market for agricultural commodities, agriculture declined rapidly in northern Wisconsin. By 1921, property tax delinquencies encompassed one million acres in 17 counties of northern Wisconsin; six years later, tax delinquencies had increased to 2.25 million acres (Clark, 1956b).

In an attempt to reverse forest depletion and eventually revive the timber industry, reforestation efforts began in the early 1900s.

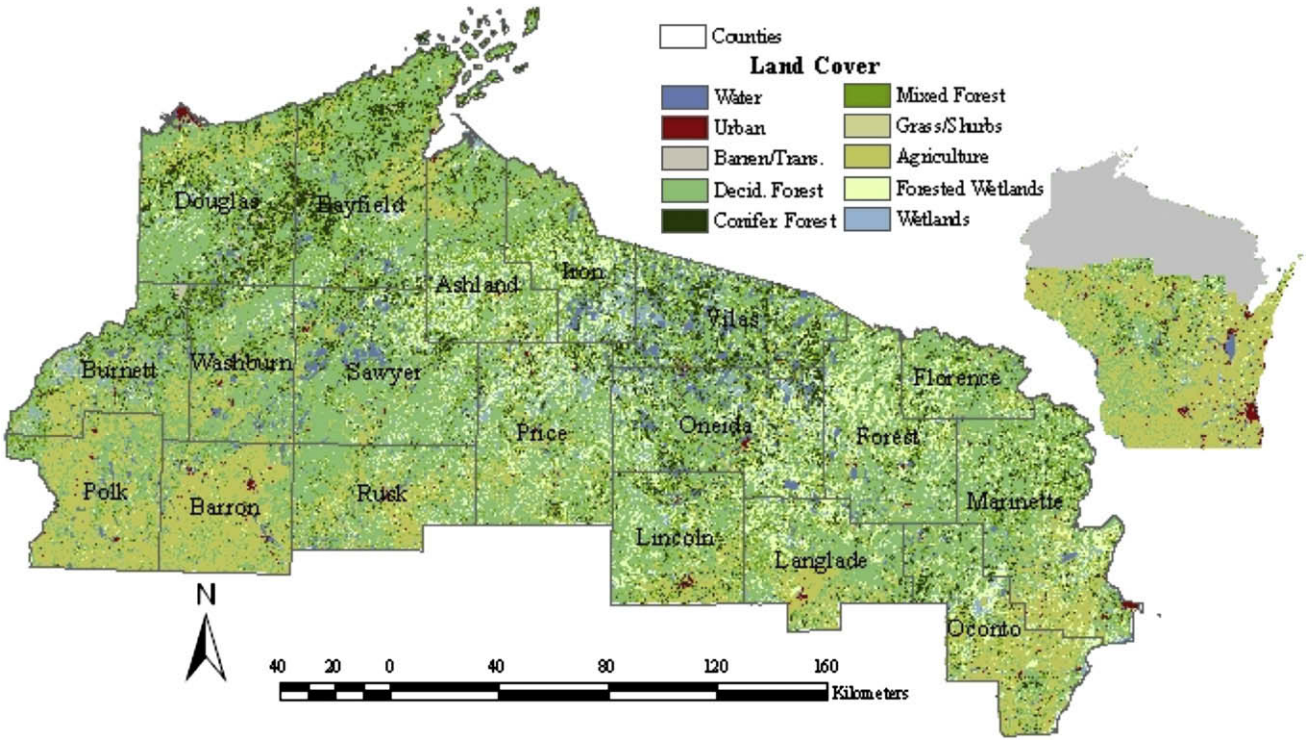

Fig. 1. Land cover (1992/1993) and county boundaries.

Although reforestation generated a significant backlash on the part of agricultural interests, by 1912 the state forest reserve had grown to 400,000 acres (Solberg, 1961). In the 1930s, the Federal Government purchased 1.5 million acres in northern Wisconsin and established the Chequamegon and Nicolet National Forests (Bawden, 1997). In 1933, Oneida County became the first rural county in the U.S. to adopt a comprehensive zoning ordinance. The ordinance established reforestation guidelines and allowed the county to abandon roads serving areas that were zoned for forestry, encouraging area residents to resettle in more densely populated areas (Bawden, 1997). Ironically, reforestation, like deforestation, precipitated yet another period of population decline in northern Wisconsin. By the 1960s, due to natural regeneration and reforestation efforts, over two-thirds of northern Wisconsin and 80% of Vilas and Oneida Counties was again forested (Kouba, 1973).

In the mid-1960s, population growth returned to northern Wisconsin (Durant and Marshall, 1968) in the form of retirees from metropolitan areas such as Chicago, Milwaukee, and Minneapolis/St. Paul. The service and retail industries that serve both retirees and tourists grew substantially. However, new economic and population growth was not uniform across northern Wisconsin, rather, it was focused in those subregions richest in environmental amenities, such as freshwater lakes and mature secondary forests (Voss and Fuguitt, 1979). Growth in these counties continued at a relatively rapid pace throughout the "turnaround" or "rural renaissance" decade of the 1970s, when nonmetropolitan counties grew faster than their metropolitan counterparts across the U.S. (Wardwell, 1977; Long and DeAre, 1985; Vining and Strauss, 1985; Fuguitt, 1985, 1995; Beale and Fuguitt, 1990). Although growth in northern Wisconsin subsided during the 1970s it again rebounded in the 1990s (Johnson and Beale, 1994, 1998), as it did in other nonmetropolitan counties of the U.S. In northern Wisconsin, amenity-rich counties continued to grow at annual rates exceeding the state average. Northern Wisconsin is thus a good study area to investigate rural housing growth patterns.

2. Methods

Census blocks are the smallest unit of geography for which basic census data are collected and tabulated. Census block groups, aggregations of census blocks still much smaller than counties, are generally the smallest unit of statistical geography for which sample, or "long form," data are tabulated. Since block groups are transected by a variety of political and statistical boundaries: incorporated places, minor civil divisions, and urbanized areas, we divided block groups into their constituent parts, i.e., partial block groups (PBGs). The use of "partial" block groups distributes a higher proportion of the variance in housing density among, rather than within, the geographic units (Hammer et al., 2004). The Summary File 3A (U.S. Census Bureau, 2002) includes tabulations for these partial block groups that we used to improve the geographical and statistical precision relative to using data for whole block groups.

Unfortunately, counties are the finest scale geography with by-and-large stable boundaries, and they are too coarse to address many ecological research issues. To overcome this problem, we developed a technique to approximate the geographic pattern of residential density over a 60-year period. We used the question "About when was this building first built?" from the census "long-form" questionnaire. For the 19 counties of northern Wisconsin, the aggregate "long-form" sample was 36% of households. The actual county tabulations of housing units from the respective census years demonstrate that the initial historical estimates of the number of housing units by partial block group based on the 2000 census "year housing unit built" question suffer from serious underestimation problems. We allocated the number of housing units missing from the estimate of housing units for each county to partial block groups within the county, in order to compensate for the known county-level error. To do so, we adjusted the estimated number of housing units in each partial block group according to the growth that occurred in that partial block group during the next decade relative to the growth that occurred in the county. For

counties in which the ratio of the number of missing housing units exceeded the change in housing units, housing units remain missing after the first adjustment. This necessitates a second adjustment that allocates the remaining missing units based on the number of housing units, rather than on the increase in housing units (For a more complete description and discussion of the method, see Hammer et al., 2004 *Appendix A*).

The use of land-ownership information further improves housing density estimates. Since block groups can contain both private and public lands, we intersected the block group boundaries with public land boundaries (Wisconsin Department of Natural Resources, 2002). In block groups that contained both public and private land, we reallocated housing units from all public land holdings to private lands. We used the same land-ownership data for all decades (1940–2000) because historic land-ownership data were not available. Fortunately, most of the transitions from private to public land in northern Wisconsin had already occurred by 1940.

To examine housing growth near public lands, we selected public land parcels larger than 100 km^2, due to their greater potential ecological significance than smaller public land parcels, and created a 1-km buffer around those large public land parcels. Our buffer analysis does not constitute a spatial statistical approach. We are interested in the spatial association of private land that has experienced housing growth with public land and forested lands. We must compare that spatial association with the spatial association of private land that has not experienced housing growth with public land and forested lands. There does not seem to be a spatial statistic that can accomplish this complex comparison of associations and so we utilize a simple buffer analysis instead. Data were summarized and mapped in six housing density classes based on the number of housing units per square kilometer: less than two; at least two but less than four; at least four but less than eight; at least eight but less than 16; at least 16 but less than 32; and 32 or more. These class breaks were selected to illustrate change in the lower range of housing density, the part of the density spectrum most significant in rural areas. The housing densities included seasonal housing units as well as those occupied year-round. In several subregions of northern Wisconsin, seasonal housing units exceed 50% of the housing stock.

We used the National Land Cover Data (NLCD) of the U.S. Geological Survey (Vogelmann et al., 2001) to identify forested areas. The NLCD is a land-cover classification based on 1992/1993 Landsat Thematic Mapper imagery with 30-m pixel resolution. For our analysis, we defined forests as all areas classified as deciduous, coniferous, or mixed forest in the NLCD. No comparable forest-cover data exist for prior decades, precluding an analysis of forest-cover change and housing growth.

3. Results

Approximately 69% of the land in northern Wisconsin is privately owned (33,935 km^2) and in 1940, privately owned land containing <2 units/km^2 represented nearly half the land area in the region (Fig. 2). Privately owned land with ≥2 but <4 units/km^2 constituted an additional 17% of the land area, making it a distant second among the housing density categories. Combined with the publicly owned land, 78% of the land area in the region contained <2 units/km^2 and 95% of the land area (47,062 km^2) contained <4 units/km^2. In 1940, land with ≥8 units/km^2 constituted less than 2% of the region.

The most dramatic decadal change in housing density occurred between 1970 and 1980 (Fig. 2). Housing density increases in northern Wisconsin reflected the national trend of the nonmetropolitan turnaround decade of the 1970s. Privately owned land with <2 units/km^2 declined steadily during the period and, by 2000, occupied just 21% of the total land area in northern Wisconsin, less than one half of the area it represented in 1940. The rate of decline in area of the lowest density category was greatest during the 1970s with a loss of 28%. However, in the 1980s and 1990s, the rate of decline reverted to a lower level of just over 6% per decade, similar to its historical rate of approximately a 10% decadal decline from 1940 to 1970. Land with ≥2 but <4 units/km^2 increased 20.4% during the 1940s; however, its growth rate slowed in the ensuing decades and began a steady decline in the 1970s.

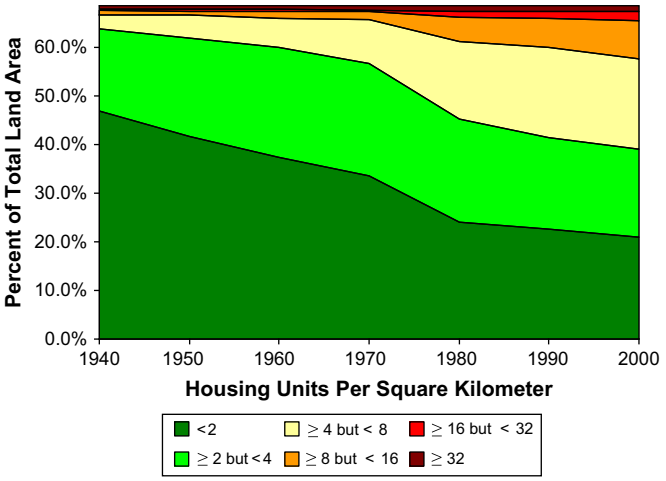

Fig. 2. Proportional area of housing density categories, 1940–2000.

Land with ≥4 but <8 units/km^2 grew from less than 3% of the land area in northern Wisconsin in 1940 to nearly 20% in 2000, a more than six-fold increase. This category experienced its most dramatic growth during the 1970s with a nearly 80% increase in size. Likewise, the next density category with ≥8 but <16 units/km^2 grew dramatically during the 1970s (increasing by 214%) and occupied five percent of the region (2469 km^2) by 1980. Although it did not grow as much during the next two decades, areas with ≥8 but <16 units/km^2 encompassed nearly eight percent of the land in northern Wisconsin by 2000. Thus, these two intermediate categories with density ranging from ≥4 to <16 units/km^2 expanded from a mere 1869 km^2 in 1940 (3.8% of the total land area) to 13,164 km^2 (over one quarter of the land area) in 2000.

The final two categories, representing the highest densities with ≥16 but <32 units/km^2 and with ≥32 units/km^2, grew by 600% and by 200% respectively during the six-decade period. However, the total land area developed at these higher densities remained fairly small, representing a combined area of approximately 3% of northern Wisconsin.

3.1. Spatial variation of housing growth

In 1940, there were very few areas in northern Wisconsin in the density categories ≥16 but <32 units/km^2, and ≥32 units/km^2 (Fig. 3). Areas with ≥16 units/km^2 tended to be small, scattered widely, and isolated, i.e., most were surrounded by areas with few or no housing units. These ≥8 but <16 units/km^2 peripheries generally did not connect or agglomerate multiple high-density areas. This was the case throughout the region, even in the southwest near Minneapolis – St. Paul, in the southeast near Green Bay, and in the northwest near Duluth-Superior, indicating an absence of suburban sprawl in the region. Even the areas with a mere ≥4 but <8 units/km^2 were quite scattered.

By 1960, the development of the Northern Highlands Lake District in Vilas and Oneida Counties had begun, with an expansion

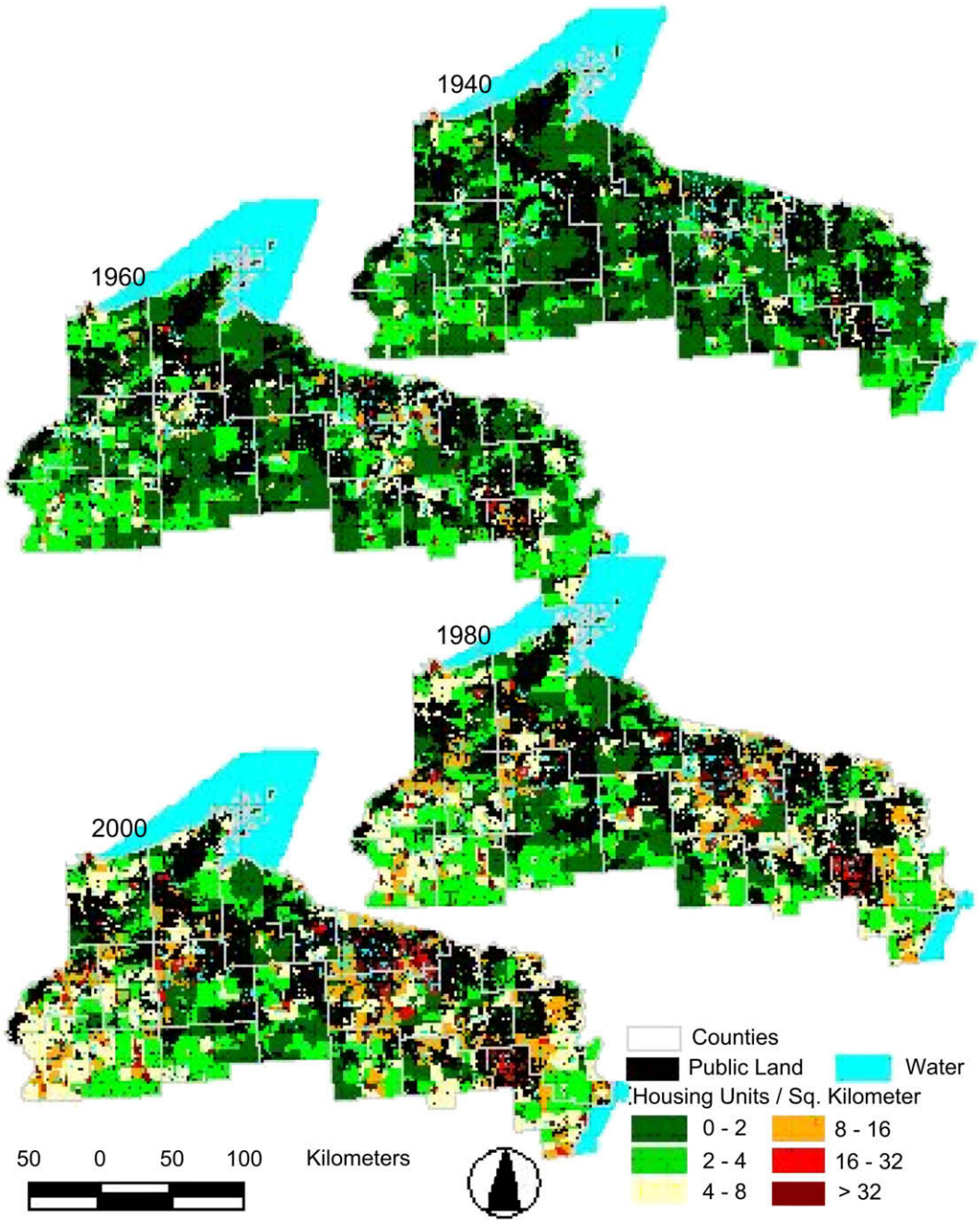

Fig. 3. Housing density: 1940, 1960, 1980, and 2000.

of areas with ≥8 units/km^2 along the border of the two counties and a large area with ≥4 but <8 units/km^2 extending south through Oneida County and into Lincoln and Langlade Counties (Fig. 1). Housing densities increased in numerous previously settled areas, especially in Vilas County, although areas of very low housing density, with <8 units per km^2, in the eastern portion of Vilas County adjacent to public land, also began to experience housing growth. The private land interspersed with public land in the northern arm of Oconto County increased from largely ≥4 but <8 units/km^2 to ≥8 units/km^2, while the area with ≥4 but <8 units/km^2 spread south in Oconto County and east into Marinette County. The northern portion of Sawyer County that is interspersed with lakes and public land also grew, with ≥4 but <8 units/km^2 housing density areas predominating by 1960. In 1960, there was little evidence of exurban expansion emanating from Minneapolis – St. Paul, Green Bay, and Duluth-Superior.

Housing density patterns in 1960 and 1980 exhibited dramatic differences, as would be expected from the decline of the lowest two density categories and growth of the two intermediate density categories during the 1970s (Fig. 2). The spatial pattern of this pronounced change was similar to that of the previous two decades, when Vilas, Oneida, and the northern portions of Sawyer and Oconto Counties changed considerably. Low-density privately owned land virtually disappeared in Vilas County between 1960 and 1980. The area with ≥4 units/km^2 in southern Forest County expanded significantly forming a nearly unbroken corridor across the border area of Forest, Oconto, Langlade, Lincoln, and Oneida Counties. Areas with ≥4 but <16 units/km^2 also expanded in

Burnett and Polk Counties near Minneapolis – St. Paul, the first clear instance of metropolitan expansion in the region. Marinette County, near Green Bay, exhibited perhaps the most striking change with much of the privately owned land transitioning into ≥4 units/km^2, with the exception of the southeast corner and the privately owned areas interspersed with public land in the northwest.

Although the pace of change slowed in the 1980s and 1990s, the 2000 pattern demonstrates that housing development continued to expand, especially in Polk County near Minneapolis – St. Paul. "Spillover" growth also seemed to occur to a much greater extent in Iron County along the border with Vilas County. Densities in Oconto County immediately adjacent to Green Bay also increased.

3.1.1. Housing growth and land cover

According to the 1992/93 NLCD (Table 1), 62.8% of northern Wisconsin was forested, and this proportion was even higher for public lands (73.6%). Of the private land with <2 units/km^2, a disproportionate amount was forested, 67.3%, as would be expected, but private lands with intermediate housing densities, ≥8 but <16 units/km^2, were also mostly forested, 62.3% (Table 2). Areas with ≥2 but <8 units/km^2 were less forested, approximately 52%, and considerably more agricultural, approximately 35%. Wetlands were more prominent in areas with lower housing density (15.4% of areas with <2 units/km^2) and on public lands (23.5% of total area) and less prominent in areas with higher housing densities (9.4% of areas with ≥16 units/km^2) or in private ownership (13.1% of area).

Because historic land-cover information was not available, we compared the 1992/93 land cover of areas that remained low density, <4 units/km^2, between 1940 and 2000 with those areas with low density in 1940 in which housing density increased substantially by 2000 (Table 3). Of the 231,315 km^2 that grew from <4 units/km^2 in 1940 to ≥16 units/km^2 in 2000, 72.4% was forested in 1992/93 compared to 60% of the land area that continued to contain <4 units/km^2 in 2000. In other words, forested areas with initially low housing density were more likely to experience growth or areas that experienced housing growth were more likely to become forested. Overall, areas with ≥16 units/km^2 in 2000 were only 54.8% forested. Areas that transitioned from <4 units/km^2 in 1940 to ≥4 but <16 units/km^2 in 2000 tended to be less forested (54.9%), and more agricultural (32.1%). Finally, areas transitioning into higher density categories were less likely to contain wetlands than those areas that remained low density throughout the six-decade period.

3.1.2. Housing growth and public land

Overall, private land near (<1 km) large tracts (>100 km^2) of public land had considerably lower housing density than areas at greater distances from public lands in 1940 (2.6 and 3.7 units/km^2 respectively, Table 4). For the region as a whole, housing density in the 1-km buffer of public lands was just 70% as high as housing density outside the buffer. However, this varied by county. In six counties, Burnett, Florence, Forest, Oneida, Price, and Sawyer, housing density within the public lands buffer was nearly as high as housing density in the remainder of the county. In Bayfield, Oconto and Vilas Counties, 1940 housing density within the public lands buffer was already higher than outside the buffer (109%, 136%, and 113% respectively).

Housing grew at a faster rate within the public lands buffer compared to the remainder of the county during the period from 1940 to 2000 in all but five of the 19 counties. Four of those five counties (Polk, Barron, Rusk, and Sawyer) are in the southwest tier of the region, and close to Minneapolis – St. Paul. The greatest rate of housing growth occurred near public lands in Vilas County with an addition of nearly four units/km^2 between 1940 and 2000. Although housing grew faster in areas within 1 km of large tracts of public land, housing density in 2000 remained slightly lower within the 1-km buffer than beyond it across the region. However, in Bayfield, Florence, Oneida, Price, Oconto, and Vilas Counties, housing density within the 1-km buffer exceeded housing densities beyond the buffer. This was particularly evident in Oconto, where densities within the buffer were twice as high as outside the buffer, and in Bayfield where densities within the buffer were approximately 25% higher.

4. Discussion

Housing densities on privately owned land in northern Wisconsin changed dramatically from 1940 to 2000. In 1940, 78% of the combined public and private land area contained <2 housing units/km^2 but in 2000 barely 50% of the land area exhibited <2 units/km^2. Moreover, in 1940 most of the land area with <2 units/km^2 was privately owned, while in 2000, most (60%) was publicly owned. Three areas experienced particularly sharp increases in housing density and the virtual disappearance of the very low housing densities most closely associated with the "North Woods." Two of those areas are now suburban, or more appropriately exurban, emanating from the Green Bay and Minneapolis – St. Paul Metropolitan Areas. The lake district of Oneida and Vilas Counties is the third of these areas. It is rural in nature and far distant from any metropolitan agglomeration, principally stretching along the common boundary of the two counties. Although the density levels in other areas of northern Wisconsin do not match those in the two areas and the lake district, the compact pattern of development which was prevalent in 1940 and remained evident as late as 1970 no longer persists.

Growth in northern Wisconsin from 1940 to 2000 was not characteristic of urban sprawl, except in the two metropolitan fringe subregions mentioned above. Spatially the housing growth was unrelated to the locations of towns, transportation corridors, or other features of urban form. Instead, lakes, forests and public lands were the features around which development was organized, a trend consistent with housing development across the

Table 1
Land-ownership and land cover, 1992/1993.

	Urban/barren	Forest	Agriculture	Wetland	Total
Private	1%	58%	28%	13%	33,734
Public	1%	74%	2%	23%	15,379
Total	1%	63%	20%	16%	49,113

Table 2
Land cover, 1992/1993 and housing density, 2000.

Units/km^2	Urban/barren	Forest	Agriculture	Wetland	Total
<2	1%	67%	16%	15%	10,371
≥2 but <4	0%	51%	35%	13%	8839
≥4 but <8	0%	52%	36%	12%	9195
≥8 but <16	1%	62%	24%	12%	3871
≥16	11%	55%	25%	9%	1457

Table 3
Land cover, 1992/1993 and housing density change, 1940–2000.

From <4 to	Urban/barren	Forest	Agriculture	Wetland	Total
<4	1%	60%	25%	14%	19,211
≥4 but <16	1%	55%	32%	12%	9677
≥16	2%	72%	17%	9%	257

Table 4
Public land buffers (1 km) and housing density by county, 1940–2000.

County	1940 Housing density			2000 Housing density			1940–2000 Growth rate			% Public
	<1 km	≥1 km	Ratio	<1 km	≥1 km	Ratio	<1 km	≥1 km	Ratio	
Ashland	2.35	3.58	0.66	3.71	5.14	0.72	0.58	0.44	1.32	33.4%
Barron	1.31	4.73	0.28	2.47	9.80	0.25	0.88	1.07	0.82	3.8%
Bayfield	2.71	2.49	1.09	6.57	5.35	1.23	1.43	1.15	1.24	47.0%
Burnett	2.64	2.91	0.91	8.16	8.44	0.97	2.09	1.90	1.10	29.5%
Douglas	1.92	7.97	0.24	3.30	11.29	0.29	0.72	0.42	1.72	36.8%
Florence	1.99	2.24	0.89	5.88	5.64	1.04	1.95	1.51	1.29	41.5%
Forest	2.49	2.90	0.86	5.83	7.57	0.77	1.34	1.61	0.83	54.3%
Iron	2.39	3.52	0.68	5.20	5.83	0.89	1.17	0.66	1.79	47.8%
Langlade	2.55	4.40	0.58	5.32	7.49	0.71	1.09	0.70	1.55	30.4%
Lincoln	1.23	3.70	0.33	3.74	8.32	0.45	2.05	1.25	1.64	18.8%
Marinette	2.30	4.14	0.56	7.24	10.32	0.70	2.14	1.49	1.43	26.7%
Oconto	5.54	4.07	1.36	18.58	9.36	1.99	2.36	1.30	1.81	29.2%
Oneida	3.16	3.52	0.90	13.03	11.89	1.10	3.13	2.38	1.32	24.0%
Polk	1.74	3.51	0.50	4.32	9.57	0.45	1.49	1.73	0.86	5.9%
Price	2.25	2.50	0.90	4.72	4.24	1.11	1.10	0.70	1.58	31.4%
Rusk	1.05	2.69	0.39	1.52	4.17	0.36	0.45	0.55	0.81	17.5%
Sawyer	2.33	2.41	0.96	6.41	7.06	0.91	1.75	1.93	0.91	39.1%
Vilas	4.01	3.55	1.13	19.18	16.14	1.19	3.78	3.54	1.07	42.4%
Washburn	1.44	2.84	0.50	4.30	7.40	0.58	2.00	1.60	1.25	27.5%
Total	2.59	3.68	0.70	7.52	8.28	0.91	1.90	1.25	1.52	31.3%

nonmetropolitan portions of the Lake States during this time period (Hammer et al., 2004; Radeloff et al., 2001, 2005). Thus this housing growth is best characterized as rural sprawl, where low and moderate density housing extends across much or all of the private land eligible for development, and any spatial clustering or agglomeration occurs because of the location of amenities. In this regard, northern Wisconsin continues to be a place where natural and social histories are intertwined.

Between 1940 and 2000, areas that experienced housing growth starting with <4 units/km^2 and increasing to ≥ 16 units/km^2 were disproportionately forested in the early 1990s, according to the NLCD. This must be viewed not only as a selection effect, where home-owners select forested parcels upon which to build homes, but also as a treatment effect. Between 1970 and 1990 forest cover in the Upper Midwest increased most rapidly in low-density residential areas and in counties in which a large percentage of homes were vacant and intended for seasonal use (Brown, 2003). This suggests that forested parcels, as well as surrounding parcels, that are "treated" with houses are also more likely to become forested. Residential development can occur on abandoned agricultural land, which then becomes forested, but forest land can also be developed for residential purposes following timber harvest and then become reforested. The growth of forest cover in areas with low-density housing occurs not only on the residential parcels but also in the proximate area as management practices adjust to accommodate the attitudes and behaviors of residential neighbors (Brown, 2003).

Although forest expansion is associated with low-density housing development or rural sprawl, forest with an 'understory' of houses does not provide the same ecosystem services as uninhabited forest. Each housing unit creates a disturbance zone, which is the area around where habitat quality is degraded (Theobald et al., 1997; Gonzalez-Abraham et al., 2007a). Housing development influences ecological processes at a variety of scales (Brown, 2003). Human activities linked to housing development cause avoidance behavior in certain species, increased nest abandonment by neotropical birds, predation of neotropical birds and other small vertebrates by domestic pets, changes in predator–prey relationships and species competition, and increased populations of species that thrive in human-dominated environments including exotic invaders (Gonzalez-Abraham et al., 2007b). Timber harvests are reduced in areas experiencing population and housing growth (Sabor et al., 2003; Wear et al., 1999) and increased fire suppression, including quicker initial response, reduces the size of wildfires (Cardille et al., 2001; Syphard et al., 2007). Moreover, housing development is accompanied by road construction, followed by increases in traffic counts and speed, resulting in greater landscape fragmentation (Hawbaker et al., 2005), by removing habitat and subdividing otherwise contiguous areas with sharply defined linear gaps (Miller et al., 1996; Hawbaker et al., 2006). Roads constrain the movement of certain species (Mader, 1984), facilitate the movement of others, act as dispersal corridors for invasive species (Parendes and Jones, 2000), and interrupt and redirect hydrologic flows (Wemple et al., 1996).

Like forests, public lands are important in shaping housing growth patterns and are in turn impacted by those patterns. Between 1940 and 2000, the rate of housing growth was 1.5 times higher in areas within 1 km of large tracts of public land than in more distant areas. Although housing densities near large tracts of public land remained lower in 2000, a continuation of the differential rates of growth will result in housing densities proximate to public land surpassing that in more distant areas by the end of the current decade. While public ownership precludes housing development on the parcel itself, public ownership appears to attract residential development in the vicinity, perhaps because public land management enhances current or expected future locational benefits people seek in residential location, such as scenic views, privacy, and recreational opportunities.

Federal, state, and county governments in northern Wisconsin established most public lands as part of a broader effort to establish social and economic stability in the region. When public lands were established (largely before 1940), the conditions and activities on adjacent lands, which served as unofficial buffer areas, were very similar to or indistinguishable from those on the newly purchased public parcels. But since their establishment, the unique role of public lands as biological reserves has grown in importance while at the same time residential development and accompanying commercial and infrastructure development have encroached. The unofficial buffer zones have been lost, and few public lands are now embedded in a larger, unfragmented landscape. Conditions and activities on the mosaic of proximate private lands influence the composition, function, and structure of ecosystems on public lands, even wilderness areas (Cole and Landres, 1996). The myriad ecological disturbances associated with housing development described above spill over into public lands. As their connections to

larger ecosystems are disrupted by housing growth, public lands are increasingly prone to biological isolation and other transboundary management problems (Kelson and Lilieholm, 1999).

Strategies for the management of national, state, and county forests are partially dependent upon the demographic characteristics of the surrounding landscape. For example, human ignitions account for the majority of all wildland fire ignitions (Cardille et al., 2001; Syphard et al., 2007). The expansion of homes into areas with wildland vegetation, known as the wildland urban interface (WUI), raises concerns for fire managers. The Oconto County portion of the Chequamegon-Nicolet National Forest (CNNF) experiences high frequency wildland fires. It has an extensive and fire-prone wildland urban interface. Approximately one-third of the district is comprised of fire-prone ecosystems currently supporting jack pine and red pine vegetation. The area contains a relatively high proportion of private inholdings that, as evidenced by our analysis, have experienced rapid development in recent decades. Likewise in Bayfield County, the CNNF contains fire-prone pine barrens ecosystems and two towns encompassing the district are currently developing Community Wildland Fire Protection Plans.

5. Conclusions

Between 1940 and 2000, private land with no housing units or very low housing density was lost, forested areas were developed and/or areas that developed became forested, and private land near large tracts of public land transitioned from having much lower housing density than other areas to having approximately the same housing density as other areas. Housing growth was not concentrated around cities and villages, existing roads, or other urban features, but around recreational and scenic amenities, including public lands. Our results have important implications both for ecological and social research in rural areas as well as for natural resource management and regional planning. Public land managers need specific boundary management practices to ameliorate the effects of proximate housing growth. Areas with high and growing housing density are less amenable to the establishment of large expanses of consolidated forest, and those same areas exert pressure on forest-based recreational resources. Understanding these trends can inform the choice of critical areas for preservation for such purposes as wildlife corridors; re-establishment of depleted ecosystems, such as pine savannahs; and sustainable resource management.

The patterns of growth in northern Wisconsin highlight the importance of recreational amenities for housing growth in recent decades. This is particularly true in those counties with significant natural amenities that attract visitors and migrants; housing in such counties will be unevenly distributed and its location is significant for purposes of planning and management. Future growth can be expected in areas that provide home-owners with scenic views and access to recreation, again highlighting the critical need for additional research and effective natural resource management and regional planning to address these changes. The changing patterns of housing growth and the changing determinants of those changes should be pursued in future research using multivariate spatial models that can both help us understand the past and anticipate the future.

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