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Parcelization and Land Use Change in the Rural Residential Landscape of the Catskill Region in New York State

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ABSTRACT: Parcelization is an increasing concern to land managers in rural regions of the United States. In order to protect vital ecosystem goods and services originating from rural lands, resource managers need to monitor decreasing parcel sizes and development. The Catskill region of New York State serves as the source of New York City's water supply. This is one of many ecosystem services from this region. This study documents the continued change in private, rural parcel sizes from 2004 to 2010 in the Catskill region. During the study period, which included an economic downturn, the average parcel size dropped from 5.6 (13.9 ac) to 5.3 (13.1 ac) hectares. We confirmed that the distribution of small private, rural parcels is diffuse across the study region, implying the transition from a land use focused on resource management to rural residential. A parcel density map of the region indicates where parcelization most threatens ecosystem services, thus providing a visual snapshot for resource managers and planners. Parcelization of rural lands continues despite outreach and extension programs available to landowners, including conservation easements, offered by locally-based conservation organizations and agencies to maintain the forested rural landscape. Land use zoning is another strategy that could secure the rural character of the region and ensure water quality and other ecosystem services into the future.

Keywords: parcelization, rural residential development, parcel density, ecosystem services, water quality, watershed

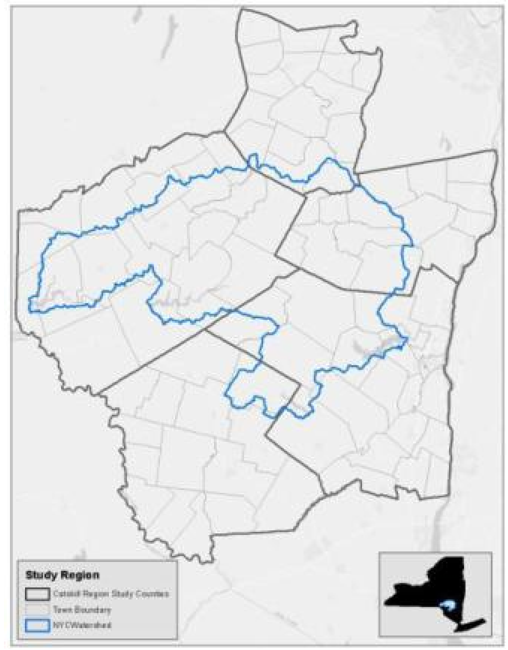
INTRODUCTION

Parcelization is the division of large tracts of land to smaller parcels, and subsequently a larger pool of landowners. The desire for large, residential lots has led to the increase in rural land parcelization (also known as exurban development) across the country and world. Research has shown that an increase in the demand for this rural-based, amenities-rich lifestyle has accelerated the loss of rural resources to rural residential development (Riebsame et al. 1996; Baron et al. 2000; Egan and Luloff 2000; Maestas et al. 2001; Mehmood and Zhang 2001; Dwyer and Childs 2004; Gobster and Rickenbach 2004; Merenlender et al. 2005; Mundell et al. 2009; Haines et al. 2011). Gobster and Rickenbach (2004) and Haines' (2011) work focused on rural development in Wisconsin. Mundell et al. (2009) documented the same phenomenon in nearby Minnesota while several researchers have examined the extent and effects of parcelization in the Rocky Mountain region (Riebsame et al. 1996; Baron et al. 2000; Maestas et al. 2001). Merenlender et al. (2005), among others, have conducted research on the impacts of exurban development in California. Exurban development is not unique to the United States (US). Rural residential development has been documented in Alberta, Canada, (Azimer and Stone 2003), Europe (van den Berg and Wintjes 2000), and Australia (Fisher 2003).

Rural residential is the fastest growing land-use type in the US. Sutton et al. (2006) reported that 37 percent of the US population lives in exurban areas, accounting for 14 percent of the land area. White et al. (2009) predicted a 51 percent increase in development of previously rural lands in the US between 2003 and 2030. Continued fragmentation of rural parcels has become a critical concern for conservation, making it difficult to manage the wide spectrum of ecosystem services, including: water quality, soil conservation, recreation, wildlife habitat, timber production, non-timber forest products (i.e., herbs, plants), and visual quality (Schulte et al. 2008).

These ecosystem values, particularly water quality, are important to the Catskill region of New York State (NYS), which includes the New York City (NYC) Water Supply System. Forested watersheds have long provided natural water filtration to numerous cities across the globe. New York City's water supply system, at 485,830 hectares (1.2 million ac), is the largest unfiltered surface storage and supply system in the US (Figure 1).

Figure 1. New York City's Catskill/Delaware System Watershed boundary.



Other notable unfiltered surface supply systems serve the US cities of Boston and Seattle.

Within the Watershed boundary, the Catskill Preserve and NYC Department of Environmental Protection (DEP) holdings make up 30 percent of the ownership, while the remaining 70 percent is privately held by primarily non-industrial owners (NYC DEP 2014). Since approximately three-quarters of the region is classified as forested, most of the private ownership is dominated by family forest owners (Anderson et al. 2012). The Catskill Preserve's scenic views and wilderness character draws urbanites from the major urban centers of New York City and Albany. Approximately 50 percent, more in some places, of homes and private properties in the region are second homes and weekend residences (Van Valkenburgh and Olney 2004; Hall et al. 2008).

Recent studies indicate that the parcelization of private land is occurring in the Catskill region. Between 1984 and 2000, the average parcel size dropped from 7.7 (19 ac) to 6.5 (16 ac.) hectares within the NYC Watershed. Most notable is the increase in the total number and aggregate area of parcels in the 2.02 to 4.05 hectare (5 - 10 ac) class (LaPierre and Germain 2005; Caron et al. 2012), a lot size that is especially appealing to rural residential homeowners interested in the aesthetic values and privacy provided by a rural residence (Merenlender et al. 2005; Caron et al. 2012).

Land use and land cover changes (LULCC) associated with parcelization and development can generate non-point source pollution, posing serious concerns for drinking water supplies. Many watershed land use studies have focused on agriculture and its effects on nutrient fluxes. For example, the literature indicates that the percent of watershed area dedicated to agriculture will influence the levels of phosphorous (Hill 1981), nitrogen (Johnson et al. 1997) and sediment concentration (Allan et al. 1997; Ahearn et al. 2005).

In the urbanizing environment, negative water quality effects are closely linked to runoff from impervious surface cover. The increase in impervious surfaces associated with a land use change to rural residences can alter the natural hydrological condition by increasing the volume and rate of surface runoff (with nutrients and sediments) and decreasing ground water recharge and base flow (Rogers and DeFee 2005; Xian et al. 2007). Despite concerns about the adverse impacts of parcelization in rural watersheds, no standardized convention exists to determine when or if a landscape has become too parcelized in the first place, or whether it has passed a threshold such that adverse impacts to water quality begin to occur (Hall et al. 2008; Lohse and Merenlender 2009; Anderson et al. 2012). Many studies have shown the links between percentage of land in urban development and water quality (Carpenter et al. 1998, Tong and Chen 2002, Groffman et al. 2004), but the generally accepted threshold of 10 percent impervious surface for water quality degradation (Schueler 1994) has been challenged by a number of studies that show increased negative water quality impacts with impervious surface as low as 2.4 percent (Conway 2007, Schiff and Benoit 2007, Dietz and Clausen 2008).

Low-density residential development in exurban and rural environments has been linked to significant negative water quality impacts, including non-point source contamination from lawn chemicals and fertilizers, septic systems, sump pumps, and fecal contamination, which can be intensified by impervious surface area (Mehaffey et al. 2005). Whereas urban development requires sewer infrastructure before higher-density development (less than one-half hectare per house) can be built, rural development (2-15 hectares per house) is almost invariably serviced by septic systems and, thus, not bound to existing or planned sewer service areas (Lohse and Merenlender 2009). Furthermore, research indicates that low density patterns of development can be associated with higher impervious surface area per housing unit (Stone 2004). Though the density of housing units is often positively correlated with impervious surface area and negatively correlated with forest cover (Lathrop et al. 2007; MacDonald and Rudel 2005), low density residential development can bring potential for water quality degradation, even if the landscape retains high forest cover. The National Land Cover Dataset (NLCD) indicates the Catskill region experienced an increase in forest cover from 70 percent in 1975 to 78 percent in 2002. The latest NLCD forest cover estimate from 2011 is 83 percent (MRLC 2016). Despite the high forest cover, Anderson et al. (2012) reported a strong link between parcelization, development, and impervious surface area in the Catskill region, indicating an increase of 416 square meters of impervious surface area when rural parcels are developed.

Although highly suspected, to date, there is no spatial empirical proof that demonstrates a transition of resource management to rural residential land use within the Catskill region. Documenting spatial parcelization patterns on a township scale could facilitate future management of important ecosystem values. Because rural residential development often progresses at a slow and seemingly non-threatening pace, resource managers and planners often do not perceive a threat to water quality, forest management, recreation or other ecosystem values – particularly with high forest cover. Spatial documentation of rural development will alert resource managers and planners in the region and allow them to develop strategies to react in an effective manner, if deemed necessary. In this paper, we document the spatial shift in parcel distribution from resource management to rural residential land use in the study region. We meet this goal by generating two measures of parcelization: 1) Mean parcel size metric and 2) Percent below threshold metric (Kittredge et al. 2008). Also, we examined the degree of parcelization within rural landscapes surrounding historic village boundaries, as well as the influence of adjacent public lands (i.e., Catskill Preserve, NYC DEP) on parcelization patterns. In addition, we developed a parcelization intensity map for the region.

METHODS

The study region consists of Delaware, Greene, Schoharie, Sullivan, and Ulster counties of New York State (Figure 2).

Figure 2. Study region comprised of five counties in the Catskill Region of New York State.

Counties were broken down into a total of 84 townships and 31 villages. Spatial data were obtained through the NYS GIS Clearinghouse website (www.gis.ny.gov). For the year 2004, cadastral (tax) parcel centroids were partitioned by county, in which each county in the study area was obtained separately. For 2010, a single statewide database was available. Shapefiles of NYS counties, townships, and villages were obtained from the same source. All data were analyzed in ArcGIS V.10.1 using the NAD83 UTM 18N projection, and transformed to this, if necessary.

The 2004 data for all five counties were merged into one file. The 2010 data file was clipped to the five Catskill counties. Village data were first selected spatially using the Select by Location tool and the NYS village layer. Count, minimum size, maximum size, mean and sum for the "Acres" attribute (converted to hectares for this paper) were collected from the parcel layers for each village. After this analysis was completed, the parcels located in the village boundaries were removed from the dataset, given the emphasis on rural lands.

Prior to analysis, parcels identified as being under public ownership were removed from the dataset to restrict analysis to only private lands. The search included various municipal and state titles (i.e., City, New York, NYS). Parcels with an "Acres" attribute of zero were removed, as the focus of the research considers total area of townships into calculations.

When visualizing the 2004 data in ArcGIS, it was clear that some parcels were not in their correct spatial location. To avoid having to remove these parcels from the analysis, we used the municipal code attribute to create the population of parcels in each town's tax domain. This attribute is correlated to the state listing of municipal codes by township, available through the NYS GIS Clearinghouse website.

The "Acres" attribute was used to compare parcelization of private, rural parcels by township using three approaches. First, the number, minimum, maximum, standard deviation, mean, and cumulative area were computed for each township. Second, parcels were aggregated according to size classes: 0 to 0.4 hectares (0.01 - 0.99 ac); 0.4 to 2.02 hectares (1 - 4.99 ac); 2.02 to 4.05 hectares (5 - 9.99 ac); 4.05 to 20.2 hectares (10 - 49.9 ac); 20.2 to 40.48 hectares (50 - 99.99 ac); and 40.48 - plus hectares (> 100 ac) (Table 1).

Table 1. Size classes used for parcelization analysis (LaPierre & Germain, 2005).

Size Class	Justification for Class
0.0004 – 0.39 ha	
0.40 – 2.01 ha	0.40 ha (1 acre) minimum to classify forestland (Cubbage & O'Laughlin, 1993)
2.02 – 4.04 ha	2.02 ha (5 acres) minimum to classify NIPF owners studied in the Eight Mile River Watershed on Connecticut (Tyson & Worthley, 2001)
4.05 – 20.22 ha	4.05 ha (10 acres) minimum to enroll in American Tree Farm System®; minimum required to participate in NYC Watershed Forestry Program Forest Management Plan (NYC WAC, 2013)
20.23 – 40.46 ha	20.23 ha (50 acres) minimum needed to qualify for the §480-A of New York State Real Property Forest Tax Law
Greater than 40.46 ha	40.47 (100 acres) minimum for continually producing substantial amounts of timber (Birch et al., 1982)

(LaPierre and Germain 2005). Number of parcels and total area were recorded for each class and class distributions were compared among counties. Third, three minimum size thresholds were selected (4.04, 8.1 and 12.1 hectares) (10, 20, and 30 ac), and number and total area were recorded for parcels below and above each threshold by townships (Table 2).

Table 2. Justifications for threshold values used in adjusted mean analysis.

Threshold	Justification for Threshold
4.05 ha	Minimum (10 acres) to enroll in American Tree Farm System®; minimum to enroll in the NYC Watershed Forestry Program Forest Management Plan Program (LaPierre & Germain, 2005)
8.09 ha	Minimum (20 acres) for forest management (Kittredge et al., 2008)
12.14 ha	Minimum (30 acres) for sustained yield management of forests (Vickery et al., 2009)

For the 2010 parcel data, the *Near* tool was used to determine if village sprawl was present. The tool assessed which village was in closest proximity to each parcel centroid in the study area, and produced a distance value. Pearson's correlation coefficient was used to evaluate if a relationship existed between parcel size and proximity to a village.

The literature suggests that there is increasing parcelization in proximity to publicly held lands (Van Valkenburgh and Olney 2004). Lands held by the NYS Department of Environmental Conservation (DEC) was obtained through the NYS GIS Clearinghouse. The shapefile of NYC DEP lands was obtained from the NYC DEP. Using the Near tool, distances from parcel centroids to the closest public land boundary were generated. Parcel data were entered into Minitab Software to determine if a correlation existed between parcel size and distance to public land boundary.

Following Thomas et al. (2009), Parcel-based Density Analysis Protocol (P-DAP) was performed on the study region. With the use of parcel centroids, point density maps were generated for both 2004 and 2010 using a search radius (circle) of 12 hectares (30 ac). The grid size for the resulting density surface was set to 0.405 hectares (1 ac), no smaller than the smallest parcel. After a parcel density surface was generated, values were converted from average parcels per hectare to average hectares per parcel using the *Raster Calculator* tool.

The proportion of land in parcels smaller than a management threshold value is a good indicator of how much land is still viable for management. The proportion of land that is considered unmanageable would correct for the presence of many small parcels, which can skew mean results. Proportions were calculated using the total hectares of unmanageable land divided by the total hectares of private parcels for each township using thresholds of 4.05, 8.1 and 12.1 hectares (10, 20, and 30 ac) (Table 2) (Kittredge et al. 2008).

RESULTS

The mean parcel size for the overall study area decreased from 5.63 hectares (13.90 ac) in 2004 to 5.31 hectares (13.11 ac) in 2010 (Table 3). When broken down into counties, Schoharie and Ulster counties experienced the largest change in mean parcel size, with Schoharie falling from 7.59 to 6.77 hectares (18.75 - 16.74 ac) (10.7% decrease), and Ulster declining from 3.49 to 3.10 hectares (8.62 - 7.65 ac) (11.3% decrease). Greene County dropped from 4.34 to 3.99 hectares (10.71 - 9.87 ac), and joined Ulster County as the two counties to have a mean below the 4.05-hectare (10 ac) threshold. Sullivan and Delaware experienced more subtle changes, with Sullivan declining from 5.35 to 5.28 hectares (13.23 - 13.04 ac), and Delaware decreasing from 9.78 to 9.52 hectares (24.16 - 23.53 ac) (Table 3).

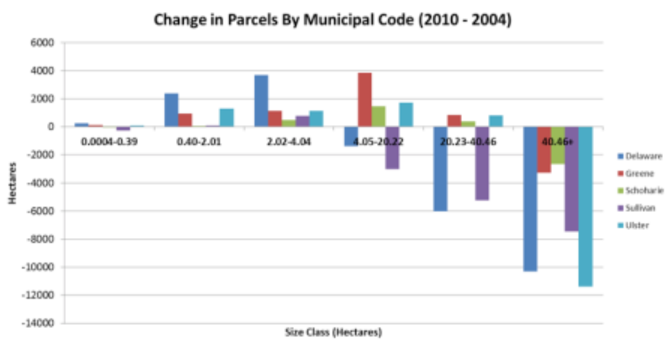
Table 3. Average parcel size in hectares of private rural parcels and percent change of these means by county between 2004 and 2010 by municipal coded search.

County	Delaware	Greene	Schoharie	Sullivan	Ulster	Study Area
2004	9.78	4.33	7.59	5.35	3.49	5.63
2010	9.52	3.99	6.77	5.28	3.10	5.31
Percent Change in Mean						
2004 - 2010	-2.6%	-7.8%	-10.7%	-1.4%	-11.3%	-5.7%

Assuming the observed rate of parcelization during the study period follows the same geometric trend into the future, the estimated mean parcel size of the region will decrease to 4.81 hectares (11.9 ac), 4.35 hectares (10.7 ac) and 3.94 hectares (9.7 ac) by the years 2020, 2030 and 2040, respectively.

With the addition of 4,258 parcels between 2004 and 2010, the total area of rural private parcels decreased by 36,185 hectares (89,378 ac). The study region experienced shifts of parcels from the large size classes (20.24 to 40.49 and > 40.49 hectares) (50 - 100 and > 100 ac) to smaller parcels (.4 to 2.02 hectares, 2.02 to 4.05 hectares, 4.05 to 20.2 hectares) (1 - 5, 5 - 10, and 10 - 50 ac) (Figure 3).

Figure 3. Change in hectare distribution from municipal code search by parcel size classes of rural private land by county in the Catskill Region of New York State between 2010 and 2004.



Thirty-seven percent of rural land was represented in the greater than 40.49 hectares (> 100 ac) size class, with 21 percent and 26 percent for the 20.24 to 40.49 hectare (50 - 100 ac) and 4.05 - 20.2 hectares (10 - 50 ac), respectively (Table 4).

Table 4. Change in distribution of private rural parcels in the study area of five counties (Delaware, Greene, Schoharie, Sullivan, Ulster) in New York State by parcel size from 2004 to 2010.

	2004			2010		
Parcel Size Class (ha)	Number of Parcels	Area (ha)	Percent of Area	Number of Parcels	Area (ha)	Percent of Area
0.0004 – 0.39	38,476	6,871.99	0.7%	40,609	6,998.52	0.7%
0.40 – 2.01	68,956	63,059.63	6.3%	71,045	66,026.43	6.8%
2.02 – 4.04	29,573	76,958.73	7.7%	30,378	80,343.08	8.3%
4.05 – 20.22	28,547	250,156.67	24.9%	28,494	252,318.06	26.1%
20.23 – 40.46	7,553	211,560.72	21.1%	7,205	202,678.46	20.9%
40.46 +	5,288	395,206.23	39.4%	4,920	359,279.25	37.1%
Total	178,393	1,003,813.95	100%	182,651	967,643.80	100%

Delaware and Greene counties experienced the biggest transfer of large parcels into the smaller classes. The greatest percent change in area occurred in the 0 to 0.4 and 0.4 to 2.02 hectare (0-1 and 1-5 ac) classes, adding 826.3 hectares (2,040.9 ac) in Delaware and 772.0 hectares (1,906.8 ac) in Greene. Ulster County experienced the greatest loss in area of the largest parcel class, totaling 11,386 hectares (28,124 ac) (a percent change of 18.9) (Table 5).

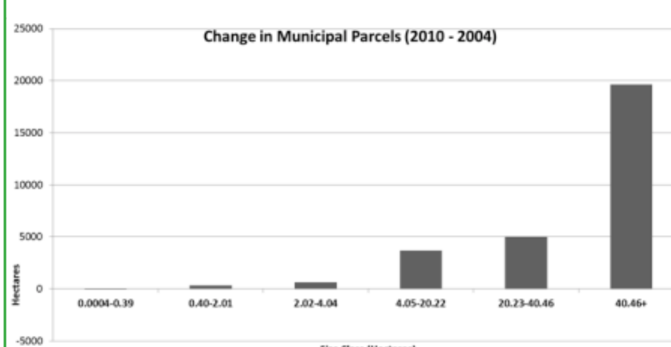
Table 5. Percent change in hectare distribution by parcel size class of private rural parcels in the study area of five counties (Delaware, Greene, Schoharie, Sullivan, Ulster) in New York State by parcel size from 2004 to 2010.

Parcel Size Class (ha)	Delaware	Greene	Schoharie	Sullivan	Ulster
0.0004 – 0.39	6.1%	6.8%	-0.8%	-7.1%	2.7%
0.40 – 2.01	9.2%	6.7%	1.0%	0.6%	5.3%
2.02 – 4.04	2.7%	3.5%	4.8%	4.3%	6.6%
4.05 – 20.22	2.6%	0.8%	4.0%	-5.5%	2.8%
20.23 – 40.46	-5.9%	-4.8%	1.2%	-10.5%	2.0%
40.46 +	-6.9%	-8.0%	-5.1%	-9.2%	-18.9%

Delaware County also lost a large number of hectares in the largest size class (11,153 hectares) (27,548 ac), but due to the large area that exists in that class, this accounted for only a 6.9 percent decrease.

Although the focus of the study is on private, rural lands in the study area, it is worth reporting the transfer of private lands to public ownership, primarily to the NYC DEP. Publicly held lands increased by 1,101 parcels, representing a corresponding addition of 29,280 hectares (72,321 ac) of land during those six years. When broken down into size classes, 80.6 percent of lands classified as public are represented in the greater than 40.48 hectare (100 ac) size class (Figure 4).

Figure 4. Change in hectare distribution of publicly held lands by parcel size classes in the study region counties (Delaware, Greene, Schoharie, Sullivan, Ulster) between 2010 and 2004.



The proportion of unmanageable lands to the total available private, rural area was generated for each town as dictated by the three study threshold levels (4.05, 8.1 and 12.1 hectares) (10, 20 and 30 ac) (Table 6).

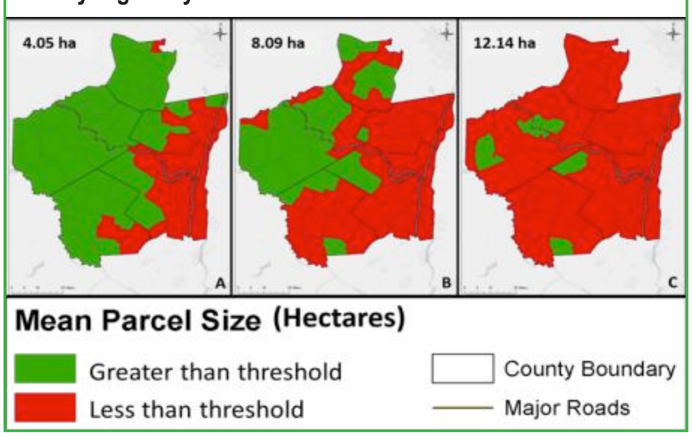
Table 6. Percent unmanageable change from 2004 to 2010 in the study region of five counties (Delaware, Greene, Schoharie, Sullivan, Ulster) in New York.

	2004			2010		
County	4.05 ha	8.09 ha	12.14 ha	4.05 ha	8.09 ha	12.14 ha
Delaware	9.39%	16.26%	21.78%	9.71%	16.98%	22.64%
Greene	18.93%	28.30%	34.88%	20.48%	30.15%	36.98%
Schoharie	11.39%	20.04%	26.68%	11.86%	21.02%	28.02%
Sullivan	15.26%	23.06%	29.29%	16.68%	24.86%	31.16%
Ulster	21.88%	32.43%	40.21%	24.80%	35.81%	43.70%
Total	14.66%	23.04%	29.45%	15.82%	24.61%	31.19%

Percent Change from 2004 - 2010		
4.05 ha	8.09 ha	12.14 ha
3.4%	4.4%	3.9%
8.2%	6.6%	6.0%
4.2%	4.9%	5.1%
9.3%	7.8%	6.4%
13.4%	10.4%	8.7%
7.9%	6.9%	5.9%

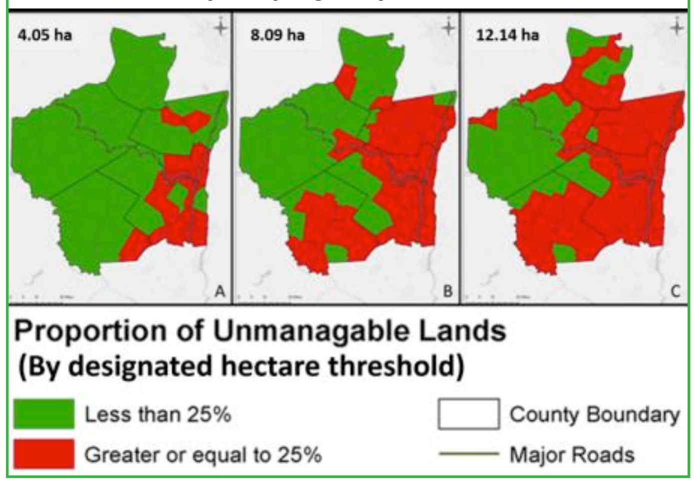
The highest percent of unmanageable land for 2010 occurred in Ulster County, with 24.8 percent (4.05 hectares) (10 ac), 35.8 percent (8.1 hectares) (20 ac), and 43.7 percent (12.1 hectares) (30 ac). The region's percent unmanageable for 2010 fell to 15.8 percent, 24.6 percent, and 31.2 percent at the 4.05, 8.1 and 12.1 hectare (10, 20, and 30 ac) thresholds, respectively. The progression of mean parcel sizes by town that fall under the designated thresholds of 4.05, 8.1 and 12.1 hectares (10, 20 and 30 ac) indicate a dichotomy between the eastern and western portions of the region (Figure 5).

Figure 5. Progression of mean private, rural parcel sizes in relation to defined threshold by town for the five-county study region by thresholds.



At the 4.05 hectare (10-ac) threshold, most towns in the study region have less than 25 percent unmanageable rural lands; however, at the 12.1 hectare (30-ac) threshold, less than one-third of the towns have less than 25 percent unmanageable rural lands – the majority located in the western (Delaware) portion of the study region. As the threshold increases to 12.1 hectares (30 ac), only five towns are left with means larger (Bovina, Delhi, Hardenburgh, Forestburgh, and Tompkins). The progression of proportion of unmanageable private, rural lands in relation to the three defined thresholds indicates more severe parcelization issues in the eastern portion of the study region (Figure 6).

Figure 6. Progression of proportion of unmanageable private, rural lands − sizes in relation to defined threshold by town for the five-county study region by thresholds.



A Pearson correlation indicated no correlation (0.017) between parcel size and proximity to village boundaries. Since all private, rural parcels in the study region were used in this analysis, the mean characteristics of parcel size are the same as recorded for the study area. The average distance of a parcel from a village boundary was 8.69 kilometers (5.4 miles). Minimum distance from villages was found at >0.02 kilometers (.01 miles), with the median falling at 7.89 kilometers (4.9 miles), and a maximum at 28.7 kilometers (17.8 miles). Proximity to publicly held lands also did not yield significant results. We examined the correlation between parcel size and distance to public land boundary at 4.827, 0.804, and 0.402 kilometers (3, 0.5, and 0.25 miles). The Pearson correlation was -0.008.

A parcel density map of the study region was generated to display parcel class distribution across the study region There is a trend between the east and west portions of the study region. In the east, there are more pronounced clusters of smaller parcels, compared to the western portion of the study region which shows a more scattered distribution of small parcels (Figure 7).

DISCUSSION

The study region had an average parcel size of 5.63 hectares (13.9 ac) in 2004, dropping to 5.31 hectares (13.1 ac) in 2010. This falls below the 2010 nationwide projection by Sampson and DeCoster (2000) of 6.88 hectares (17 ac) for nonindustrial private forestlands. We project it will be less than 4 hectares (10 ac) by 2040.

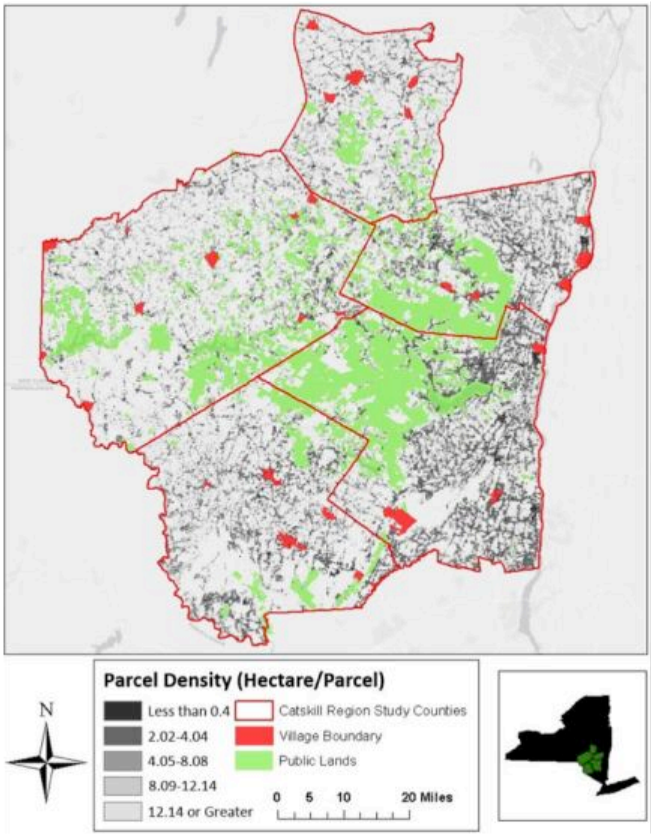
LaPierre and Germain (2005) reported an average parcel size of 5.87 hectares (14.5 ac) in the eastern portion of the NYC Watershed in 2000, down from 7.13 hectares (17.6 ac) in 1984. Caron et al. (2012) reported the average parcel size of Delaware County falling from 10.89 hectares (26.9 ac) in 1984 to 9.51 hectares (23.5 ac) in 2000. While the results of this study are less dramatic, the decrease is still significant given the shorter time frame and economic circumstances during the study period. Zhou and Sornette (2008) concluded that the real estate bubble burst in mid-2006 continued its decline through the official end of the "great recession" in 2009 (U.S. Bureau of Labor Statistics 2012). Studies by LaPierre and Germain (2005), Caron et al. (2012) and Anderson et al. (2012) fell within the real estate boom of the late 1990s, correlating to the more dramatic decrease in average parcel size in the NYC Watershed. It is logical to assume that the depressed real estate sector would curtail the effects of parcelization across the landscape. It may have relented, but average parcel size continued to decline. Our results demonstrate that even during difficult economic times, average parcel size of rural lands continues to decline. Germain et al. (2006) reported a similar trend of declining parcel size during a period of population decline and depressed economic activity in Oneida County, just northwest of the study region.

It should be noted that concurrent with the decline of larger private rural parcels from parcelization, some private land holdings were transferred to the public sector through land acquisitions by the NYC DEP (Figure 4). Following the 1997 Memorandum of Agreement, NYC was required to acquire land and conservation easements to maintain water quality in the NYC Watershed. Whether in public or private hands, NYC DEP has a vested interest in maintaining undeveloped forest cover. The larger the parcel, the better for both forest management and water quality. Vickery et al. (2009) suggested that parcel size should be 12.1 hectares (30 ac) to conduct sustained yield management. At this threshold, 31 percent of the region's rural lands are unmanageable, with the remaining 69 percent of forested private, rural lands large enough to implement sustainable forest management. If the threshold is further increased to 20.24 hectares (50 ac), which is the minimum required to enroll in the NY State Forest Tax Law, only 55 percent of the private forestlands would qualify for the program. At these threshold values, we suggest the region can continue to produce a wide spectrum of ecosystem services, but if current trends continue, they will pose a challenge for managers and planners.

The literature suggests shared public land boundaries have a positive impact on property resale values, thereby encouraging parcel splits. This trend has been documented in relation to state forest lands in the Midwest and federal lands in the Rocky Mountain region (Dwyer and Childs 2004; Lorah and Southwick 2003; Mundell et al. 2009). Despite the presence of the pristine and scenic Catskill Preserve, we found no statistically significant relationship between parcelization and the proximity to public land. While land in close proximity to public lands is not shown to be a hot spot for parcelization, the impact public lands can have on development can be seen in the town of Shandaken, which has 70 percent of its area as part of the Catskill Preserve (Shandaken 2014). With the reduction of available private area, there is increased pressure of development on the remaining available private lands. Consequently, along the well-traveled corridor of State Highway 28, we found a high concentration of parcels falling in the 2.02 to 4.05 hectare (5 - 10 ac) category, most prized for rural residential home ownership. Overall, Shandaken has 20 percent of its available rural land falling in parcels less than 4.04 hectares (10 ac), and has experienced a dramatic drop in parcels shifting from large size classes 20.23 to 40.46 and > 40.47 hectares (50 - 100 and > 100 ac). Currently, 35 percent of private forest lands are not large enough to support sustained yield management (minimum of 12.1 hectares / 30 ac).

Proximity to villages and cities and ease of access to locations of interest are typically associated with parcelization and parcel splits (Egan and Luloff 2000; Mehmood and Zhang 2001; Gobster and Rickenbach 2004; Mundell et al. 2009). This study affirmed those previous findings related to cities and access systems, but not villages and hamlets. The bulk of parcels in the lower size classes are concentrated in the southeast portion of the study region in the general vicinity of Interstate 87 and the major urban centers of Kingston, Albany, and New York City (Figure 7).

Figure 7. Parcel density of hectares per parcel for five-county study region for 2010 parcel data.



Towns in this proximity experienced proportions of unmanageable land well over 25 percent, even at the 4.05-hectare (10 ac) threshold (Figure 6). Proximity to village and hamlet boundaries did not correlate with increased parcelization. This result contributes to the theory of rural residential sprawl, characterized by an increase in the small parcel size classes of 2.02 to 4.05 hectares (5 - 10 ac) – "single home ownership with big backyards" (Daniels 2001; LaPierre and Germain 2005). The variability among parcel sizes at increasing distances from a village center indicates that there are both small and large parcels diffused in more remote areas of the study region. Ownership objectives are generally urban or suburban-based, and not in synch with resource management and a working landscape, ultimately having a negative impact on some ecosystem services (Daniels 2001; Kline et al. 2004; Caron et al. 2012). The slow transition from resource management to rural residential can lead to complacency among policy makers, as the data and physical imprint on the landscape is not visually shocking. The high degree of forest cover in the region further veils the negative effects of parcelization on the rural landscape, adding to that complacency.

The majority of the private rural land area is still in parcels of 20-plus hectares (50-plus ac). Larger, undeveloped parcels with forest cover are most compatible with water quality. As these larger parcels are slowly converted to rural residential uses, water quality will be compromised along with other ecosystem services such as timber production, wildlife habitat, recreation opportunities and visual quality. Currently, numerous organizations are attempting to maintain the region as a forested working landscape that is compatible with water quality. The Watershed Agriculture Council (WAC), which was created as part of the MOA between the Environmental Protection Agency and NYC, serves as the central umbrella organization collaborating with NYC DEP, NYS DEC, USDA Forest Service, Cooperative Extension, and a long list of non-government organizations. Its mission is "to promote the economic viability of agriculture and forestry, the protection of water quality, and the conservation of working landscapes through strong local leadership and sustainable public-private partnerships." WAC applies strategic watershed management approaches that benefit the general public through incentivized, on-site practices performed on private lands. This "payment for ecosystem services" approach empowers private landowners to be surface-water stewards of NYC's drinking water. The whole farm and forest management planning assistance programs incorporate all the latest best management practices for water quality. To keep rural lands intact and in forest production, WAC subsidizes participation of rural properties in New York's Forest Tax Law by cost-sharing forest management plan expenses. The program provides significant property tax relief for forest landowners who make a long-term commitment to forest stewardship, ultimately curbing the rate of parcelization (WAC 2016). In addition, WAC administers a conservation easement program that complements NYC DEP's "land acquisition program," which includes both fee and easement purchases – all of which protect rural land from parcelization and development in perpetuity. Through June 2015, approximately 136,000 acres were conserved by either fee purchase or easement (NYC DEP 2015).

During the last two decades, NYC and its partners have spent over $2 billion in the NYC Watershed to maintain ecosystem services (NYC DEP 2014). To a large extent, water pollution threats from agricultural and forest operations are neutralized. However, rural residential development continues to threaten the future viability of water quality. Land use zoning remains as a policy tool that could decrease the rate of parcelization as well as manage it spatially across the region. For example, the Adirondack Park located in northern New York provides a zoning model that has been in place since 1973 through the Adirondack Park Agency Land Use and Development Plan. The Adirondack Park encompasses approximately 6 million acres, 48 percent of which is "forever wild," with the remaining 52 percent in private ownership. These private lands are under the following land use classifications, listed by name, minimum lot size and percent of private land within the Adirondack Park: Hamlet – none (1.8%), Industrial Use – none (0.4%), Moderate Use – 0.52 ha (1.3 ac) (3.4%), Low Intensity Use – 1.29 ha (3.2 ac) (9.1%), Rural Use – 3.43 ha (8.5ac) (34.2%) and Resource Management – 17.25ha (42.7ac) (51.0%) (APA 2016). If managers and planners determine it is important to maintain a certain percentage of rural land in larger parcels to provide ecosystem services, a "resource management" zoning classification would be effective. It would not, however, be popular with Catskill region property owners. The development of such a strategy would require a well-designed collaborative process, similar to the one used to establish the 1997 MOA between the region and NYC (NYC DEP 2014).

CONCLUSIONS

This study serves as a baseline to monitor future rural residential sprawl in the Catskill region. Although there is a concentration of smaller parcel sizes closest to the Interstate 87 corridor, our findings do not point to any real parcelization "hot spots" in the study region. Therein lies the problem. The parcelization activity is not clustered around the region's villages, or the public land holdings; it is diffused across the rural landscape in the form of rural residences – many of them second homes. Resource managers, planners, and policy makers will need to closely monitor this trend in the coming decades, and consider strategies to both curtail and address the cumulative impacts of rural resident sprawl. At what point do we reach the tipping point in which ecosystem services are seriously threatened? Clearly, it will depend on the "service" in question. The most prominent ecosystem service in this case is potable water for NYC. New York City is a high-profile example of a city that must preserve the rural character of its water source to maintain high water quality. As the tipping point approaches, reducing the negative effects of low-density, rural residential development in a forested landscape is likely to require a creative mix of policies to maintain long-term water quality.

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