Combining landscape histories, spatial policy forecasts, and landscape ecology metrics to compare alternative futures in developing rural areas

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FACTORS INFLUENCING LAND PARCELIZATION IN AMENITY RICH RURAL AREAS AND THE POTENTIAL CONSEQUENCES OF PLANNING AND POLICY VARIABLES

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ABSTRACT

Rural communities in amenity rich areas continue to struggle in their efforts to manage growth and development in ways that protect key natural resources. Recent developments in GIS have made the development of alternative policy scenarios relatively easy to document and analyze. Parallel advances in landscape ecology have produced new metrics for estimating different dimensions of landscape fragmentation. Bringing these developments together, I compare the potential consequences of a set of proposed regulation schemes to evaluate likely impacts on landscape fragmentation. Researchers at the University of Wisconsin – Stevens Point created a spatial record of historic parcel and land use maps that allowed us to estimate baseline trends against which policy alternatives could be compared. I then projected future development based on a policy proposal presently being discussed as part of a comprehensive planning effort in the study area. The analysis shows a mixed ability of landscape metrics to more meaningfully express the outcomes of land use alternatives. I conclude by discussing the likelihood of policy adoption based on the potential consequences for actual landowners in the area.

INTRODUCTION

The landscape of rural America is continuing to experience a long-term transformation that reflects the changing needs and desires of a predominantly urban population. Requirements for food, fiber and mineral resources still provide the stalwart backdrop of rural economic activity that has existed for over 100 years, though the size of the population being provided for and its collective wealth have never been greater (Brown 2004). Additionally, mechanization has reduced the amount of labor necessary to meet this growing demand for rurally produced materials (Lobao and Meyer 2001). New and expanded needs for non-consumptive rural goods such as scenic beauty and ecological services (biodiversity, water purification, etc.) place further demand on a shrinking rural land resource that is gradually giving way to urban and exurban expansion. The growing claims on a dwindling rural resource have generated ongoing planning challenges (Daniels 1999). The efforts to manage population and housing growth in contemporary rural environments are the subject of this paper.

Analysts have long noted the need for improved planning in rural America (Daniels and Lapping 1996). Not all rural places are experiencing the out-migration and depopulation associated with increased mechanization of farming and forestry. Non-metropolitan regions rich in natural amenities have been facing waves of growth and change associated with recreational development and, more recently, retirement migration (McGranahan 1999). The changing demographics in such places present both opportunities and complications. On the one hand, newcomers bring enthusiasm and interest in proactive planning and community involvement (Jones et al. 2003). On the other hand, newcomers' views on natural resource use and the role of government do not always agree with longstanding traditions and mores in rural communities(Green et al. 1996). Planners working in such places are likely to find themselves in roles that involve conflict management and consensus building as much as if not more than the more traditional technical tasks of planning (Innes 1996; Shutkin 2001; Brickner and Millington 2004). These planners can benefit from tools and ideas that help bridge divides and forge new, shared understandings of how development impacts communities and natural resources and what might be done to mitigate negative consequences.

This paper explores the potential for rural planners to deploy a new set of tools drawn from landscape ecology, a field tangentially related to rural planning that applies conservation biology principles to large-scale research and management scenarios. I begin by reviewing some of the more salient challenges of rural land use planning with a particular focus on the difficulties involved in implementing plans and achieving plan goals. I then briefly review the development of landscape ecology metrics, focusing on two sets of metrics of particular salience to rural planners: *patch characteristics* (number of patches and mean patch size) and *nearest neighbor* measurements. I demonstrate the utility of these metrics through an example of plan-making scenarios in an exurban fringe town in central Wisconsin. Issues and shortcomings associated with the model are discussed in a concluding section.

The Need for Rural Planning

Citizens, planners and analysts commonly invoke the negative environmental and fiscal consequences of new and expanded development in the rural context. Introducing new homes, roads, and related development into a largely undeveloped landscape often has negative ecological consequences. These range from stormwater increases to the introduction of invasive exotic species and the loss and fragmentation of habitat (Hansen et al. 2005). In a related fashion, new rural development impinges on the productive landscapes that provide critical food, fiber, and increasingly energy resources required by human society (Daniels and Bowers 1997; Olson and Lyson 1999; Heimlich and Anderson 2001). Altogether, poorly planned rural development threatens to undermine the very life-sustaining systems humans depend on for continuing existence on the planet (Robertson and Swinton 2005).

New rural development also has fairly predictable fiscal impacts on local governments. Few studies are done to analyze the costs and benefits of *rural* development, but analysis of suburban sprawl typically highlights the relationship between high density and service efficiency (Carruthers and Ulfarsson 2003). Though boosters in outlaying areas may promote new development as a strategy for lowering local taxes and improving local economies, the record is decidedly mixed as to whether the new tax revenue exceeds the cost of providing additional public services (Logan, Whaley, and Crowder 1997; Deller, Marcouiller, and Green 1997).

In both the cases of ecological and fiscal impacts, previous research has demonstrated that the spatial nature of new development can either exacerbate or minimize negative outcomes. In general, the more dense form that the new development takes, the less its net impacts will be (Weitz 1999; Daniels 2001). Thus, “rural sprawl” is often cast in the same light as suburban sprawl: unnecessarily wasteful and destructive with respect to finite resources. Local governments have long used zoning, a rather blunt and simple legal tool, to translate desired density levels into enforceable development standards. Born of the urban environment and more geared towards segregating incompatible uses, zoning proves difficult to implement in rural, largely undeveloped areas.

Rural communities trying to implement zoning to manage the density of new development find themselves in a difficult situation. Simply zoning land in a particular way does not mean that the desired development will ensue; the American land use planning system relies primarily on private landowners to initiate projects (Cullingworth 1993). Secondly, most planners and elected officials in rural areas will realize that not the entire town or county could or should be developed at higher densities- this would obviate the goals of protecting habitat or reducing service costs. Instead, there must be limits placed on how much land can be developed without sacrificing the rural land resource. Demarcating new areas where higher density housing development (greater than one house per 40 acres) will and will not be allowed is tantamount to choosing winners and losers in the zoning game (Babcock 1966). This is something elected officials are not likely to relish doing, especially if the losers outnumber the winners (Downs 2005).

Rural planners have drawn from a number of fairly complex schemes to address the prospective inequities of limiting the amount of permissible high density development in rural areas. These range from easement acquisition and similar purchase of development rights (PDR) programs to promoting and/or requiring conservation subdivisions (concentrating density within a portion of a developing property) to the creation of "density markets" through a transfer of development rights (TDR) program (concentrating density within a portion of a developing town or county). Another option would be to limit development across the board, systematically down-zoning all lands to very low densities (i.e. less than one house per forty acres), but this is rarely considered, much less implemented with any long-term consistency (Arendt 1997).

Rural planners and communities have another option in the form of performance-based standards and development codes. Performance-based standards are meant to move the land use regulatory system away from Euclidean zoning- demarcating specific regions where particular uses are specified- and towards a system that reviews individual projects on their merits (Reps 1964). In the case of stormwater management, for example, regulations would focus on mitigating the impact of the development rather than a preemptive prohibition of any particular project (Arnold and Gibbons 1996). Thus, any density of housing may be permitted so long as it is shown that post-development runoff is equal to or less than pre-development runoff. Performance-based development codes typically make plain the connection between a regulation (stormwater standards) and the community's goal that the regulation furthers (clean water and flood control).

To date, many performance-based approaches have focused on the nuances of site landscaping (as in the example of stormwater management, or in the case of aesthetic screening or historic design standards) or other use-specific mitigations measures (as in the case of industrial uses that must meet air quality or noise performance standards). In the case of managing rural housing patterns, there has been little progress in identifying and operationalizing performance standards that could be used to appraise the impacts of new proposals (Baker, Sipe, and Gleeson 2006). Thus, density and lot-size standards remain commonplace and governments must either develop the complex schemes mentioned above to "console" the losers in the zoning game or simply declare everyone a winner and allow nearly any and all proposals to go forward. The evidence recorded to date suggests that with limited resources, many rural towns choose the latter (Hall and Clark 2007; Jackson-Smith and Bukovac 2000; Last 1997). This, in part, is why state and federal governments still maintain a role in local land use management, particularly where sensitive or critical public resources are placed at risk by haphazard rural development (Bollens 1992).

There remains the possibility that rural planners and local governments could develop capacity to adopt and implement performance-based alternatives to the "all or nothing" approach of Euclidean zoning. Doing so would require the understanding and application of metrics beyond simply density to plan for and regulate new development. Density standards are particularly problematic because, as mentioned above, people in rural areas may want to increase the density of particular development projects to minimize negative ecological and fiscal impacts but they also wish to maintain an overall rural density appropriate to the town or county. Calculated as the total area of a town or county divided by the number of homes found therein, the addition of any and all homes cannot help but increase the density. For example, a cookie-cutter subdivision of 50 homes on an 80 acre site has the same effect on a town's density as a conservation subdivision that locates those same homes on 20 acres and preserves 60 acres as permanently protected resource lands. Even a conservation subdivision could have significant negative impacts if the homes are located poorly within a parcel, town, or county. In short, the non-spatial nature of density standards commonly found in rural land use zoning codes limits their utility for a more impact-focused, performance approach to plan implementation.

Recent advances in geographic information systems (GIS) and related analytical software provide a plethora of new methods for measuring and assessing spatial development patterns. Many of these have yet to catch on with planners and local governments working in rural areas, in part because they are somewhat new, but perhaps also because they are largely framed as landscape ecology and conservation biology metrics useful only for considering habitat needs in conjunction with landscape planning. The terminology in landscape ecology alone may serve as a barrier for adoption in some contexts. The following section discusses in plain terms how spatial metrics developed by landscape ecologists could be appropriated by rural planners to more meaningfully assess new development proposals.

Tools of Landscape Ecology

Landscape ecology has emerged in the last twenty years as a rapidly developing trans-disciplinary subfield among conservation biologist, community ecologists, forest and wildlife managers, and others. Landscape ecologists study spatial variation in landscapes at a variety of scales with particular attention to the biophysical and societal causes and consequences of landscape heterogeneity (IALE Executive Committee 1998). Advances in spatial data availability (aerial and satellite imagery, maps, plant and animal movements) and computing power (both hardware and software) have fueled recent the growth in landscape ecology capabilities (Gardner, Turner, and O'Neill 2001).

Landscape ecologists apply a wide range of analytical tools and metrics to make sense of complex spatial patterns and transformations. Many tools focus on plant and animal habitat to better understand the abundance or absence of species and communities of species. A prominent set of tools examine habitat fragmentation to identify critical thresholds of habitat size, below which specific populations may cease to exist and therefore become extirpated or in some cases doomed to extinction. Landscape ecologists have revealed that it is not simply the size of habitats but also their quality, shape and arrangement on the land that can impact the number of species and size of communities supported by any given habitat patch (Bissonette and Storch 2003). Such findings are useful for carrying out species protection laws such as the Endangered Species Act as they can better target conservation, protection, and restoration efforts.

Beyond studying patches of habitat, landscape ecologists also explore the movement of species among patches. These movements are in large part dependent on the spatial arrangement of aggregate patches. To understand the nature of these relationships they have deployed GIS analysis to summarize, evaluate, and project the spatial dynamics of habitats species over time. The findings in this realm of study have been useful for designing wildlife movement corridors that can effectively bridge otherwise divided habitat patches (Hellmund and Smith 2006). This can be critical for the future of species in the many cases where expansion of existing patches or creation of new patches is relatively infeasible.

Several recent attempts have been made to better integrate landscape ecology tools and methods into land use planning scenarios (Aspinall 2004; Bell and Irwin 2002; Brabec and Smith 2002; Conway and Lathrop 2005; Gude et al. 2005; Jenerette and Wu 2001; Polimeni 2005). Table 1 notes some of the metrics that landscape planners have argued for consideration in land use planning scenarios (Leitão et al. 2006). A large share of these metrics require sophisticated understanding of landscape ecology concepts and specialized software for deriving actual measurements. For the most part, integrated landscape ecology and planning projects are developed and promoted by ecologists and conservationists with mixed levels of experience in on-the-ground, community-based planning and implementation (Hurley and Walker 2004). In many cases the recommendations include some form of development redirection or limitation that invokes the winner/loser scenarios discussed above (Tulloch et al. 2003).

[insert table 1 about here]

Urban and regional planners have also been drawing on the newly improved tools of GIS and the increase in maps and spatial data to improve their practices, but the explicit adoption of landscape ecology as an operating framework remains uncommon (Leitão et al. 2006). With a long history in using mathematical and computer scenarios, urban planners have developed several of their own approaches for projecting and analyzing future land use trends. “What-If”, for example, is a computer support system that integrates community input with GIS generated maps are related reports to forecast outcomes of different land use scenarios (Klosterman 1998). What-If and related planning support systems are relatively resource intensive in terms of time, money, and computing capabilities. They also tend to focus on completely built-up or soon to build-out urban and suburban environments, since this is the realm that most planners operate in. As a result it is still common to encounter rural communities using paper maps and acetate sheets to sketch out possible futures rather than GIS mapping systems.

Example of Applying Landscape Ecology Tools Through a Rural Planning Lens

Below we discuss a somewhat novel approach to analyzing land use options that appropriates landscape ecology tools to aid in a community-based planning scenario. We explore the potential for using basic fragmentation and spatial distribution metrics to both analyze past development trends and compare alternative scenarios of future rural development. Rather than using these metrics to analyze patches of habitat as a landscape ecologist would, we attempt to use them to measure and compare decidedly human aspects of the landscape. We focus on the creation of land parcels for two reasons.

First, government has long held the responsibility of administering the land parcel creation process (Johnson 1976). This responsibility is somewhat distinct from zoning in that it does not rely entirely upon the police power for its authority (Freilich and Shultz 1995). Second, land division regulations can be adopted even in the absence of zoning. In Wisconsin and other states, subordinate local governments (i.e., towns) are legally capable of adopting their own land division ordinances that can operate parallel to county and state regulations. So long as they are more stringent than county or state rules, a town does not need express approval from the county (Ohm 1999). This gives local governments greater power to enact more restrictive regulations that further local plan goals, even if the county does not fully agree with the town's perspective. Our research is meant to assist towns to understand how and why they may wish to modify and enhance their local subdivision regulations.

Case Background

The analysis in this paper centers on rural townships located in Columbia County, Wisconsin where we are working on a larger research effort seeking to better understand the drivers of rural land subdivision in amenity rich areas. Funded through a USDA Cooperative State Research, Education, and Extension Service (CSREES) grant, the University of Wisconsin Extension Center for Land Use Education (CLUE) is working with local extension educators, planners, and citizens to improve local planning performance in rural areas.

This research focuses on exurban communities facing significant growth from either urban fringe development or rural residential development. Wisconsin has two archetypical regions facing such development: the northern forested lakes region and the southeastern agricultural region. We selected two sets of communities, one from each region, based on a number of criteria: whether or not they had completed a modern-day 100% parcel map layer in their own GIS systems, whether they were proactively engaged in planning, and whether or not favorable community-University relations were in place.

Columbia County is located immediately north of Dane County, Wisconsin which is home to the State Capitol (Madison) and the University of Wisconsin's flagship campus. Dane County is consistently among the state's fastest growing places in terms of employment, housing, and population. While a number of planning efforts have taken place within Dane County, the surrounding counties have a more varied planning history, and this remains the only region in the state where there is no regional planning entity. Consequentially, spillover growth from Dane County has become an increasingly visible issue as lower land prices and property taxes lure home buyers further and further from downtown Madison.

Though changing, Columbia County remains a predominantly rural place with an overall population density under 70 persons per square mile, nearly 350,000 acres of farmland, and over $100 million in annual agricultural sales (National Agricultural Statistics Service 2002). The county's western edge is defined by the Wisconsin River and Lake Wisconsin, a 9,000 acre impoundment formed by a dam at the county's southwest corner.

The lake and the nearby Wisconsin Dells have long been a tourist attraction; tourists and travelers spent an estimated $160 million in the county in 2006 (Wisconsin Department of Tourism 2007).

In 1999 Wisconsin re-codified its planning laws to more clearly establish the role of comprehensive plans as prerequisites for legally defensible zoning and subdivision regulations. The changes in Wisconsin reflected the efforts of the American Planning Association and others to modernize state planning laws in the United States (Ohm 2000). Wisconsin's planning law provides a year 2010 deadline for local governments wishing to enforce zoning and subdivision regulations to create comprehensive plans that are consistent with those regulations and meet the new statutory definition of what a plan must include. The state also provides over $2 million annually in cost-share grants to local governments engaging in planning. The combination of the new planning law and the perception of rapid growth have motivated many communities to engage in comprehensive planning for the first time, including many in Columbia County.

METHODS

This work began with a spatial reconstruction of land division and development within the county over the time period 1940-2005. Because of the amount of data involved in our effort, we focused on three towns within Columbia County, each representing a different degree of contemporary land division (high, average, and low). We used the current geographic information system (GIS) digital parcel layer provided by the county and historic tax records to dissolve parcel lines according to the time period in which they were created. Working backwards, we created digital parcel layers for 1953, 1961, 1967, 1972,1983, 1991, 2000 and 2005. From these layers we were able to calculate the number of new tax parcels created over each period as well as their dimensional and landscape characteristics. We also reconstructed land use and land cover maps for the years 1940, 1968, and 2005. Space limitations prevent us from discussing all three towns; we focus here on the medium parcel fragmentation case: the Town of West Point.

We used past trends to develop probable future land division scenarios. We estimated the total number of potential new lots by size class by extrapolating past trends. Table 2 shows the annualized change in lot sizes by size class for the Town of West Point as well as the average annualized change across the entire period. This provided the basis for our estimate of future parcel change. We projected to a 37 year time interval to roughly equate the intervals for which we had data to construct land use patterns. We also developed a spatially-explicit amenity index to better identify regions within local towns where new parcels might be expected to be created. This index compiled several features thought to be associated with land development, including accessibility, and proximity to lakes. Similar to other recent research in Wisconsin, we found that lakeshore properties and near-lake areas were most likely to be subdivided over fifty-year period we reviewed.

[insert figure 2 about here]

We used relatively simple methods to develop reasonable projections of future land division and land development, operating on the assumption that most rural planners would not have access to the more sophisticated spatial econometric approaches highlighted in much of the landscape ecology and land economics research. Two alternative future scenarios were developed for the year 2043. One scenario was simply a spatial extrapolation of past trends. Areas zoned for residential development were projected to develop at densities similar to recent housing developments in the town. Figure 1 illustrates the zoning status and 2005 parcel pattern for the town and shows that most residentially zoned land in West Point is on or near Lake Wisconsin. To accommodate larger-lot residential development, it was assumed that some agricultural and forested areas would be rezoned to residential categories, but that these areas would develop at a lower density. This would replicate the pattern of low-density, off-lake housing that has occurred in the town since 1953. We did not extrapolate patterns of agricultural land loss to forestry.

[insert figure 1 about here]

An alternative scenario is based on a set of policy changes being considered by the town as part of its comprehensive planning process. This policy proposal would prevent large-scale small-lot subdivisions through a requirement that all subdivisions over four lots in number be designed as conservation subdivisions with a new minimum parcel size of two acres. The town would only permit such developments in the areas already zoned for residential uses. All other land in the town would be subject to a limit on the number of lots allowed based on total land ownership and a requirement that all new lots be sized between two and five acres. No new lots would be permitted from any parent ownership parcel smaller than 35 acres, and a sliding scale allotment would be established on the following ownership classes:

- 35-79 acres: one new lot permitted
- 80-159 acres: two new lots permitted
- 160-239 acres: three new lots permitted
- >240 acres: four new lots permitted (maximum)

The new policy alternative is meant to slow down the rate of land use change in the town and protect farmland from haphazard development. Even with a present policy prohibiting large-lot subdivisions on rural land, the town is finding that home buyers are willing to purchase entire forty-acre lots to acquire a building site. This artificially accelerates the rate of farmland loss. The new rules would limit construction to new lots developed in accordance with the town's subdivision regulations. The conservation subdivision concept could potentially preserve the rural character of the town and limit the potential for runoff associated with higher density development near the lakeshore regions. The proposed approach might also serve to more evenly distribute the "windfall" associated with residential lot sales in the town.

We manually located the new parcel allocations on a GIS layer using point features to represent the centroids of the "hypothetical lots" to show the potential 2043 parcel patterns. Existing patterns and recent developments guided the number and size of lots allocated to residentially zoned regions. In the case of the proposed policy scenario, we entered only the number of two-acre parcels that could be accommodated by a parent parcel while still maintaining half the total tax parcel as undeveloped open space. The number of projected small parcels exceeded the number of two acre parcels that could be located in this manner. We proceeded to allocate additional two acre lots as splits from larger parcels currently zoned for agricultural uses. Every large ownership parcel was projected to use its full allocation of new permitted lot splits. Besides these new small lots and the remainder lot created from the parent parcel, no other lot splits were permitted under the proposed policy scenario. Figure 2 summarizes the actual number of parcels and projected number of parcels for the years 1953-2043. The estimated impact of the restriction on lots smaller than one acre is apparent in the new policy column in this figure, so too is the effect of redirecting smaller lots away from the shore and across the town, as the number of 30-40 acre lots increases faster than the trends would suggest.

[insert figure 2 about here]

We focused on using two sets of landscape ecology metrics to describe spatial trends associated with the two alternative patterns of land development. One set is a measure of dispersion, the mean nearest neighbor (MNN) value. Landscape ecologists use the MNN to calculate the ratio between an actual spatial distribution and a random distribution of the same number of features in a similar sized space. The resulting measure indicates how non-random or clustered the actual distribution is, and monitoring the ratio over time can be useful for describing rates of dispersion (Thompson 1956). Here, we propose using the actual MNN as a logical measure of the degree of dispersion occurring within the town. Our hypothesis is that due to the addition of new lots, both scenarios will reduce the MNN value in West Point, but the new policies proposed in the West Point land use plan will lead to a more dispersed parcel pattern compared to the status quo.

In addition to mean nearest neighbor we used patch measurements of the different major land use classes in the town to analyze trends and estimate future patterns. We used our historic land use maps to delineate agricultural, forested, and residential patches for 1940, 1968, and 2005. We used historic records and recent town land use assessments to differentiate between active farmsteads and non-farming development. We calculated the proportion of parcels by size class that were found in non-farm residential use and applied this proportion to the new parcels associated with the 2043 projections. These residential parcels were buffered to an area of 1.5 acres, an approximation of the "development impact" for homes in an agricultural landscape.

Land use layers were analyzed with the freeware program FRAGSTATS to summarize patch characteristics. We focused on three fragmentation metrics: the total core area, the number of patched by land use class, and the patch index for land use classes. We buffered the different land use patches by 33 feet (10 meters) to obtain core area measurements. Again, because it distributes new residential development away from the lake and into the heart of the town, we expect the proposed policy revisions to lead to greater fragmentation of the town's landscape than the extrapolation of past trends.

RESULTS

Figures 3(a) – (e) illustrate the past and projected pattern of land parcels in the Town of West Point. Each dot represents the center of a parcel. One can see the trend in near-lakeshore lot development and figure 3(d) shows the projected trends that would largely continue the past pattern. Figure 3(e) reflects the potential new policies being discussed by the town.

[insert figure 3 about here]

We compared MNN values across these time periods to assess the impact of the policy changes. The MNN values and the ratio of MNN to expected MNN given a fully random distribution of points are shown in table 3. Actual to expected ratio values greater than one indicate a dispersed pattern and values less than one indicate a clustered pattern. The ratio values for West Point were all greater than one, which is consistent with a rural township, but the ratio values in table 3 also indicate that the pattern is becoming more clustered over time. The projected MNN value was lower for the extrapolated pattern than for the proposed policy change pattern, but the difference between the two patterns was surprisingly small. Also, the ratio for the proposed policy change pattern was smaller than the ratio for the extrapolation, indicating that the proposed policy changes would lead to a more clustered arrangement of parcels.

[insert table 3 about here]

We also compared the alternative land use scenarios to the landscape fragmentation trends underway in the town. Results for the three landscape metrics are shown in table 4. The trends from 1940-2005 indicate increasing fragmentation of the agricultural/open component of the town landscape. For example, the portion of the town covered by the largest patch of agricultural land use has declined 10% in each time period leading up to 2005.

[insert table 4 about here]

Both in the number of patches and the core patch area, the growth in residential land uses is apparent in the fragmentation analysis, as are differences between the two 2043 scenarios. Our trend-based allocation of housing units is spatially consistent with the trend of new housing emerging in “clusters.” In this way, the number of residential patches is lower than the total number of residential lots. The proposed policy scenario redistributes the residential patches across the landscape, resulting in a much greater number of such patches.

The number of agricultural patches was somewhat surprising, with the proposed policy alternative leading to a decrease in the number of patches. This, combined with a stable core area total, implies that the average patch size in the proposed policy scenario increased dramatically.

Each of the 2043 projections shows an end to the declining agricultural/open patch index. In part, this reflects our conservative buffering of new residential land use; we were most interested in direct interference of residential uses on agricultural uses. We realize that indirect complications could arise due to the introduction of more non-agricultural households in the farming landscape. The largest patch index for residential uses fell below 1% in the proposed policy scenario, again reflecting the more dispersed pattern on the landscape.

DISCUSSION AND CONCLUSIONS

We set out in this research to explore the potential for landscape ecology metrics to aid planners to understand the spatial consequences of alternative land use scenarios. We focused on a subset of metrics that seemed to have intuitive explanatory power for planners and citizens looking for something more spatially sophisticated than density measures. Our results are somewhat mixed.

We were surprised to find that the mean nearest neighbor values were nearly equivalent for the two future scenarios compared, even though they seemed to represent rather diverse futures for land use policy in the town. The metric we used is technically referred to as the "Euclidean" nearest neighbor as it measures the shortest straight line distance between points. We also compared "Manhattan" nearest neighbor values, which calculates distances between points along two connecting lines at right angles, similar to the distance one would travel between points in an urban neighborhood. These values were also nearly identical for the two 2043 scenarios.

These results cast doubt on the prospect of using MNN as a meaningful measure of dispersion in a performance-based rural land use code. Our initial attempt at utilizing this metric relied upon the MNN analysis function available in the statistical analysis package for ArcGIS 9. Again, our purpose was to find readily accessible metrics with intuitive potential for rural planning application. The MNN module in ArcGIS only generates summary statistics, it does not provide a full table of nearest neighbor values. To explore what goes on in the "black box" generating MNN statistics, we generated a table of neighbor measurements for all neighbors within a specified distance of each parcel point feature. We then ranked these distance values for each point feature to allow us to explore their distribution more closely.

We immediately noticed that the nearest neighbor values were highly skewed. Figure 5 illustrates this by showing a histogram of nearest neighbor values for parcels in the Town of Westpoint in 2005. This distribution suggests that median values may be a better metric for comparing nearest neighbor values. We also wanted to explore ways to address potential bias inherent in analysis of first nearest-neighbors. This bias results when pairs of landscape features are clustered closely together, while the entire set of pairs may be spatially dispersed. Analyzing only the first nearest neighbor would result in a low median and mean value, suggesting spatial clustering when the pattern is instead diffuse.

[insert figure 5 about here]

To address this, we compared mean and median nearest neighbor values for the 1^{st} through 13^{th} nearest neighbor; the results of this analysis are illustrated in figure 6. We selected the 3^{rd} and 5^{th} nearest neighbor for further analysis and documented trends in these metrics over time. We also calculated additional median nearest neighbor values for the two future alternative scenarios. Figure 7 illustrates the results of this comparison. Compared to measures of 1^{st} nearest neighbor, the 3^{rd} and 5^{th} neighbors show a more striking discrepancy in median values between the town's proposed policy and what might be expected under the status quo. The median nearest neighbor values actually increase slightly when one analyzes the 3^{rd} and 5^{th} nearest neighbor under the town's proposed policy. In contrast, the status quo scenario that focuses parcels near Lake Wisconsin results in a continuing decline of 3^{rd} and 5^{th} nearest neighbor. This illustrates more clearly the dispersion likely to occur should the town adopt the new policy.

[insert figure 6 about here]

Our fragmentation analyses were also somewhat confounding. In hindsight, it may be argued that our spatial definition of "patches" deserves more scrutiny. For example, we conflated agriculture and open space, a practice common among planners. From a landscape ecology perspective, we perhaps needed to more clearly identify the species we are interested in. If we are focusing on farmers and viable agricultural operations rather than treeless, house-free landscape patches, we would need to specify a minimum spatial threshold for an agricultural patch. For example, we may find that actual agricultural use (hay cropping, tilling, or pasturing) only occurs on patches of land larger than 20 acres.

This would reduce the number of patches in the town in all time periods but could potentially amplify the differences one could expect from our two future scenarios.

Recommendations for Future Research

The research we report here is exploratory in nature and we plan to use a number of lessons to refine our approach. We used a fairly rudimentary approach for estimating future land parcel patterns and land use. We reasoned that we would like to know how easy (or difficult) it may be for a rural planner to replicate our approach. The allocation of new parcels was a fairly simple GIS task that was somewhat time-consuming, but would not take as long in a town experiencing slower change. We will in the future conduct similar exercises on our slow-growth case example, and this approach will also be replicated in a set of northern Wisconsin towns. With the increasing number of towns and counties throughout the nation that have digital parcel maps and GIS, we believe that this approach could be used in more communities to illustrate likely impacts of land use regulation change.

The data set we have amassed will allow us to conduct more sophisticated spatial-econometric analyses of trends and drivers. We anticipate conducting these analyses once we have completed parcel histories for all six towns under study. It will be interesting to compare the projections generated by the more complex models with our simplistic “back of the envelope” approach. Such a comparison could either obviate or substantiate the time and effort that goes in to detailed and accurate econometric modeling.

We found the mean 1^{st} nearest neighbor to be a problematic statistic and were more satisfied with the response of the median value of the 3^{rd} or 5^{th} nearest neighbor when comparing alternative land use and development scenarios. By moving away from mean nearest neighbor, we risk sacrificing the intuitiveness of the nearest neighbor landscape metric. It is easier to conceive of a rural town planning meeting discussing the distance between one house and its closest neighbor than it is to imagine a discussion of the 5^{th} or n^{th} nearest neighbor, though admittedly we have yet to introduce these metrics to the rural planning situation being considered here. It will be interesting to learn to what extent any of these measures are found useful and meaningful by citizens and decision makers in rural planning situations.

Finally, we are working to encourage more communities to regularly archive digital copies of their parcel layers and related GIS records to allow for future research analyzing parcel fragmentation and land use change in a wider set of communities. It has been our experience that county land information officers use a wide range of protocols for recording and storing this data; a more uniform approach would facilitate greater access and use of these records. Of particular interest is the potential for these data sets to help assess and illustrate the degree to which a town or county has achieved or is at least moving towards the goals expressed in their comprehensive plans. Another purpose would be to assess the degree to which implementation tools such as zoning and subdivision regulations are being enforced with consistency (Brody, Highfield, and Thornton 2006).

Table 1. Commonly used landscape ecology metrics adapted from (Leitão et al. 2006)

Landscape Ecology Metric	Description
Patch Richness	Measures the number of different habitat classes present in a landscape
Class Area Proportion	Measures the proportion of each class in the landscape
Number of Patches	Measures the total number of patches of a specified land use or land cover class
Mean Patch Size	Measures the average patch size of a class of patches
Largest Patch Index	The percentage of the landscape comprised by the largest patch
Perimeter to Area Ratio	Relates the shape of a patch to its size to express the amount of associated edge
Mean Nearest Neighbor Distance	Measures the distance between patches that are members of a class
Contagion	Measures the relative aggregation of patches of different type at the landscape scale

Table 2. Average annual change in number of parcels by size class in the Town of West Point, Wisconsin.

	1953-1961	1962-1967	1968-1972	1972-1983	1984-1991	1992-2000	2001-2005	Annual Mean
0-2	16.6	6.2	9.6	2.8	3.8	17.0	29.8	12.3
2-5	1.3	0.5	-0.4	3.5	1.9	4.2	2.2	1.9
5-10	1.1	0.7	0.4	3.0	1.0	1.4	2.6	1.5
10-20	.05	1.0	-0.4	2.0	1.3	0.4	-1.2	0.5
20-30	0.4	0.0	0.6	0.7	0.1	0.1	0.4	0.3
30-40	-1.3	-0.2	-0.2	-1.0	-0.1	-0.1	1.4	-0.2
40+	0.1	-0.5	-0.4	-1.2	-1.1	-1.0	-3.2	-1.0

Table 3. Mean nearest neighbor (MNN) measurements for tax parcels in the Town of West Point, Wisconsin and projections to 2043.

	MNN (feet)	Change in MNN from previous time (feet)	Actual: Expected Ratio
1953	699		1.25
1961	601	-98	1.17
1967	577	-24	1.15
1972	529	-48	1.09
1983	516	-13	1.13
1991	496	-20	1.11
2000	443	-53	1.06
2005	405	-38	1.02
2043 trend	334	-71	0.98
2043 proposed policy	337	-68	0.96

Table 4. Select fragmentation metrics for the Town of West Point, Wisconsin for 1940, 1968, 2005, and two 2043 scenarios.

	Patch Class	1940	1968	2005	2043 trend	2043 proposed policy
Core Area (acres)	Ag	15310	1359	11815	11549	11437
	Developed	37	328	984	1473	1758
	Woodlot	3178	4445	5557	5353	5317
Number of Patches	Ag	4	11	119	128	150
	Developed	23	77	211	302	506
	Woodlot	70	90	79	145	117
Largest Patch Index	Ag	82%	72%	62%	60%	59%
	Developed	0%	0%	1%	1%	0%
	Woodlot	3%	4%	5%	5%	5%

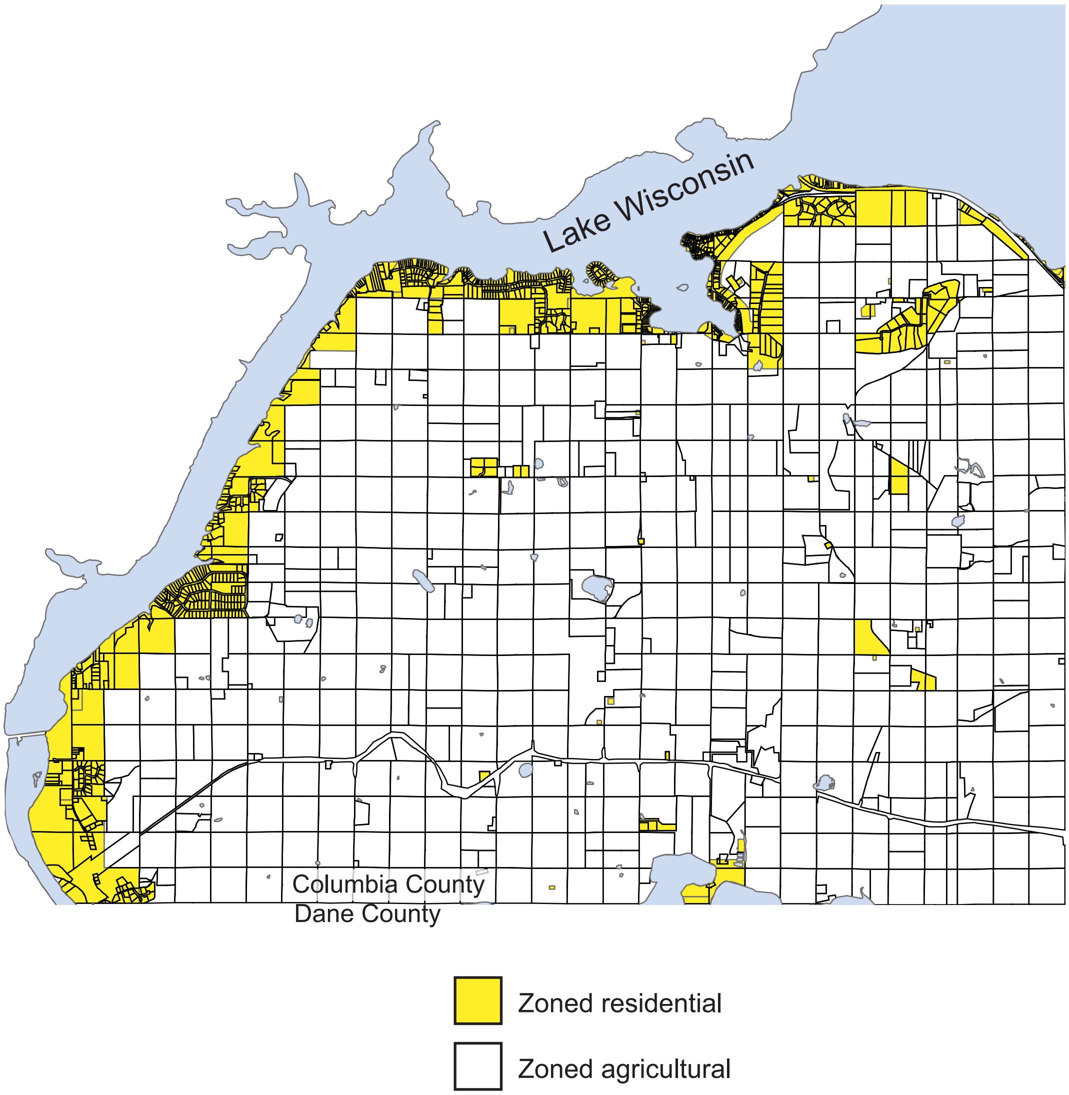

Figure 1. Zoning and 2005 parcel configuration for Town of West Point, Wisconsin

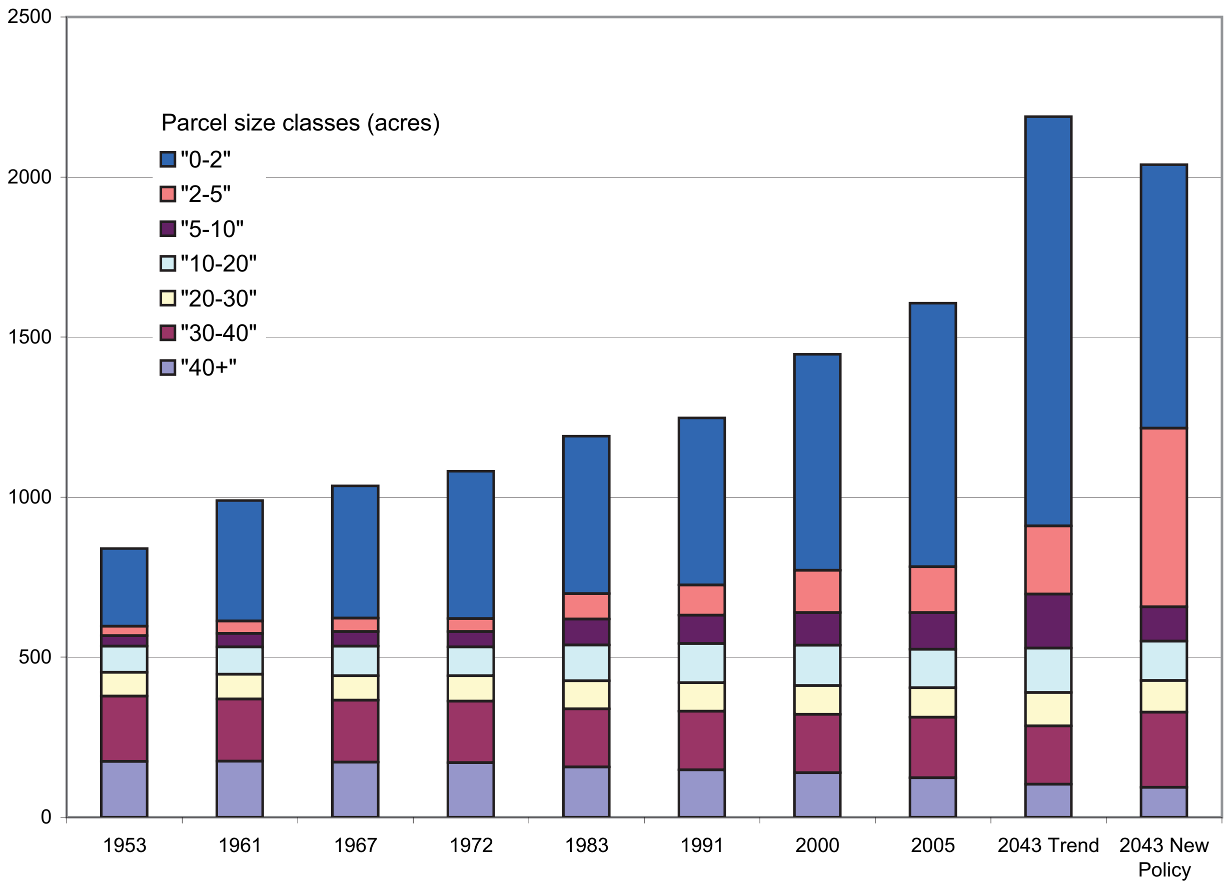

Figure 2 Actual number of parcels and projected number of parcels for the years 1953-2043, arranged by size class

(a)

(b)

(c)

(d)

(e)

Figure 3. Centroids of tax parcels in the Town of West Point, Wisconsin (a) 1953 (b) 1972 (c) 2005 (d) 2043 estimated extrapolation of past trends (e) estimated impact of proposed policy changes

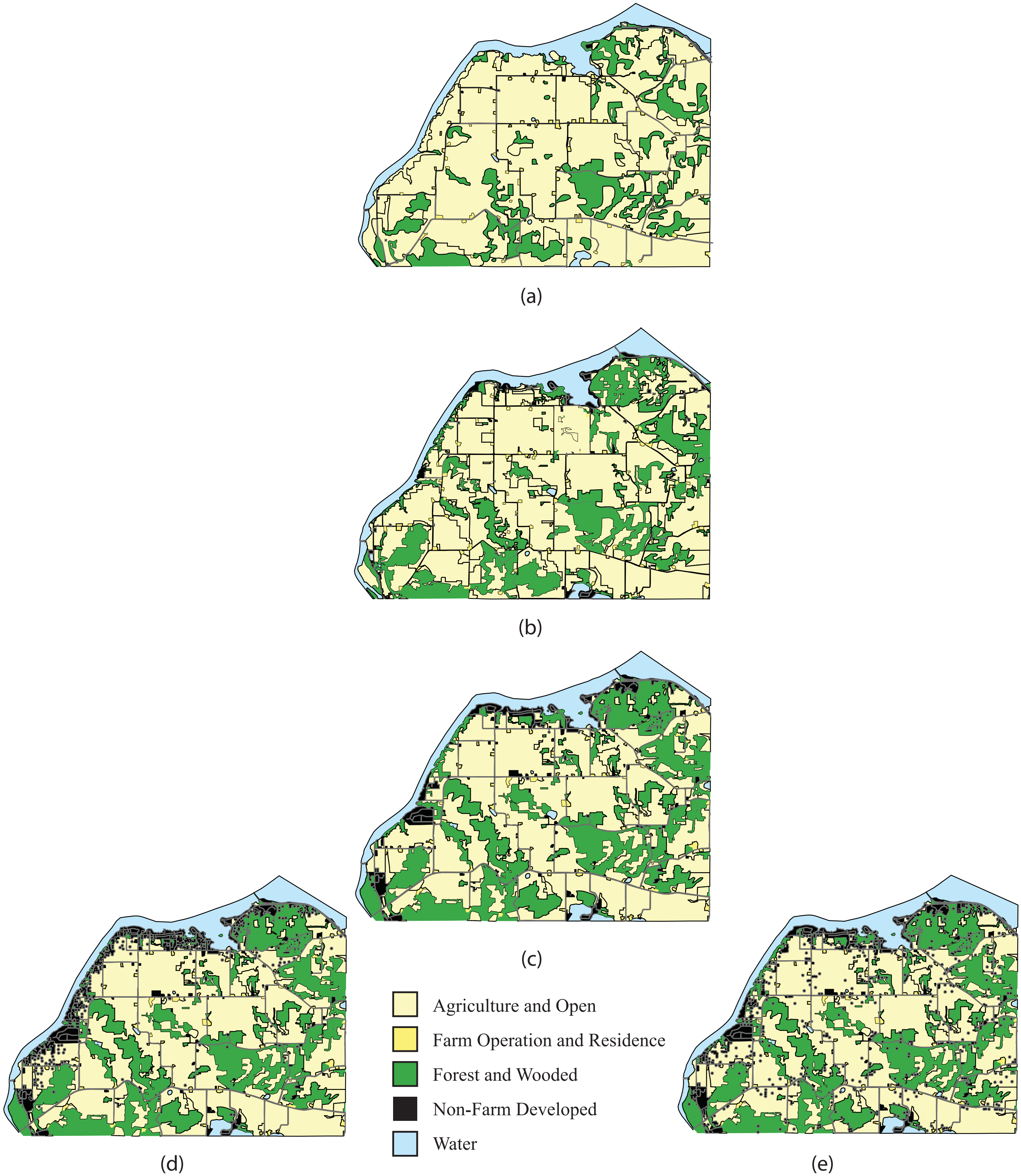

Figure 4. Land use in the Town of West Point, Wisconsin (a) 1940 (b) 1968 (c) 2005 (d) 2043 estimated extrapolation of past trends (e) estimated impact of proposed policy changes

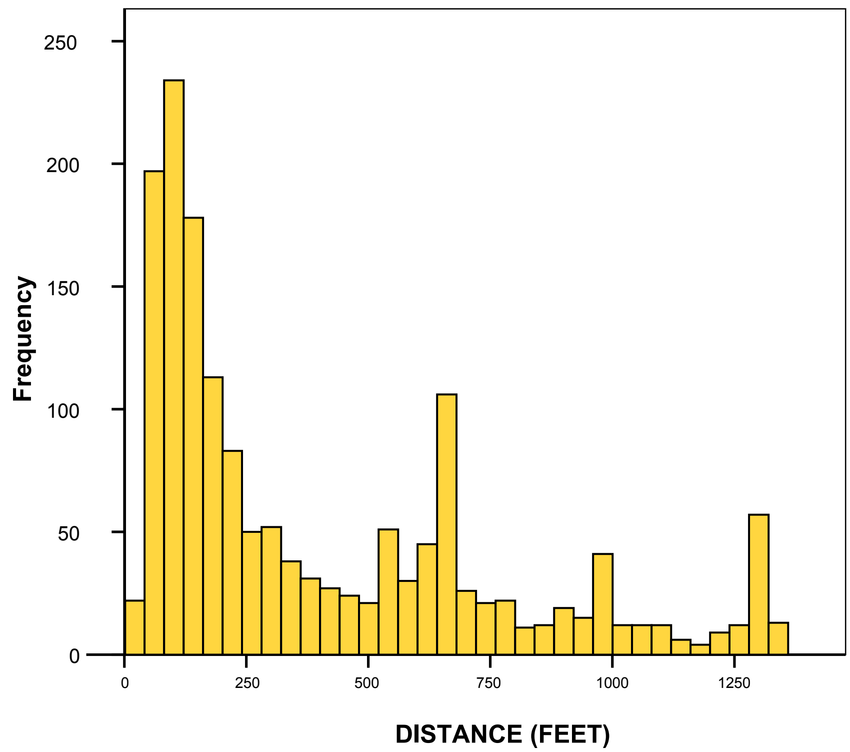

Figure 5. Histogram illustrating median 1st nearest neighbor values for parcels in the Town of West Point, 2005

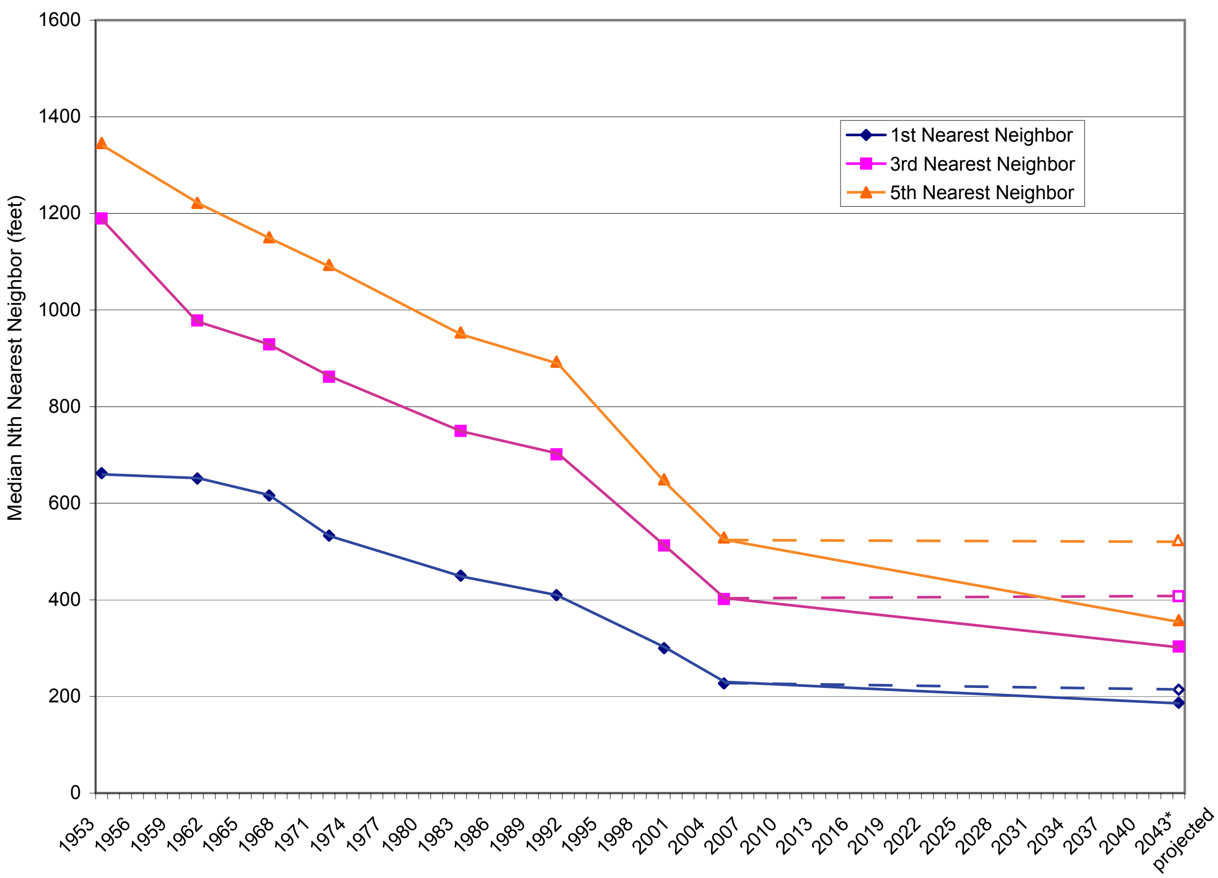

Figure 6. Changes in median distance for 1st, 3rd, and 5th nearest neighbor for parcels in the Town of West Point, 1953 - 2043. Solid line indicates actual past trend and estimated 2043 value based on a scenario that continues historic spatial pattern; dashed line represents the alternative land use strategy considered by the town.

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