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Alternative future scenarios for open space protection in Kane County, Illinois

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ABSTRACT: Kane County is located on the western fringe of the greater Chicago metropolitan area. Development pressures there have caused rapid increases in land consumption and property values. The county's Forest Preserve District is actively purchasing land for conservation, but it is important to understand the long-term costs associated with current conservation goals. We developed 18 future scenarios to identify costs associated with acquisition, restoration, and long-term maintenance of conservation lands in Kane County. We evaluated these scenarios using a GIS-based framework for alternative futures modeling that accounted for urban growth as well as conservation suitability. Long-term costs were found to be less in areas of the county with less developed land compared to scenarios which included areas that have experienced higher levels or urban or suburban growth. By focusing on these less developed areas it was possible to build larger core reserves with a considerably smaller capital for land acquisition. Additionally, if restoration was not a focus, it is possible for larger quantities of more contiguous land to be acquired with less threat of impact from urban fragmentation. The results of our project will foster explicit consideration of the long-term costs associated with conservation strategies in Kane County, Illinois, as well as providing a means for evaluation of existing conservation goals. This low cost, tractable framework for scenario based modeling will benefit organizations with similar research objectives.

Keywords: Conservation planning, urbanization, geographic information systems, urban sprawl

INTRODUCTION

Sprawl is characterized as car-dependent, low-density, unplanned growth beyond the range of urban service and employment areas (Ewing 1997, Sierra Club 1999, USHUD 1999, Gillham 2002). This phenomenon contributes to habitat fragmentation and degradation, decreased biodiversity, and the introduction of exotic species (Theobald et al. 1997, Czech et al. 2000, Johnson 2001, McKinney 2002). Sprawl also impacts human health, as pollution, long commute times, road congestion, and insufficient open space have been linked to increased stress and physical ailments (Sierra Club 1999, Miller and Hobbs 2002, Kaplan and Austin 2004, Sturm and Cohen 2004, Miller 2006, Kaplan 2007, Tzoulas et al. 2007). To offset these effects, planners are utilizing an expanding set of growth management strategies that include scenario-based planning and alternative futures analyses.

Scenario-based planning focuses on contrasting possible outcomes of a particular decision (Coates 2000, Peterson et al. 2003). In conservation planning, this framework has been used to explore anthropogenic effects on natural areas and to identify sites suitable for acquisition as nature reserves (Peterson et al. 2003b, Lee and Thompson 2005). This method allows planners to examine relationships among key variables and utilize the resulting "possible" outcomes to inform the decision-making processes. Alternative futures analyses tend to address broader spatial and temporal scales, and incorporate scenario-based planning to assess various facets of different land uses (Steinitz et al. 1994; 1996, Baker et al. 2004).

Alternative futures studies typically use spatial modeling and Geographic Information Systems (GIS) to identify a set of possible outcomes for a given area (Steinitz et al. 1994; 1996; 2003). Many of these studies have examined the environmental effects of urban growth in a region (Steinitz et al. 1994; 1996; 2003, Brown 2000, Baker et al. 2004, Hulse et al. 2004). Because the focus is on comparing a suite of possibilities, alternative futures can be used as a powerful decision support tool. One drawback, however, is that these studies typically require substantial resources in terms of personnel, data, and funding, making them difficult for many small organizations to undertake.

The goal of this research was to explore tradeoffs among several possible alternative futures for open space acquisition in a rapidly urbanizing area in the Midwestern United States. Specifically, our first objective was to identify alternative future scenarios that address the quantity and location of open space at the county level. Second, we wished to calculate costs associated with acquisition, restoration, and maintenance under distinct conservation scenarios. Third, we sought to develop a tractable approach to modeling alternative futures using a widely available desktop geographic information system (GIS) that could serve as a framework for government or non-profit agencies with finite resources to develop and model scenarios specific to their particular needs. Finally, we provide a picture of how existing conservation goals, when implemented over the long-term, would have an effect on the extent of open space within the county and thus allow planners an opportunity to target a specific goal to implement.

METHODS

Study Area

Kane County, in northeastern Illinois, is located on the western edge of the greater Chicago metropolitan area and is currently experiencing the extreme growth rates characteristic of many rapidly urbanizing areas in the United States (Sierra Club 1998, Sierra Club 1999) (Figure 1, page 21). According to Kilburn (1959), the pre-settlement land cover of Kane County was approximately 56% prairie and 43% forest or woodland. Open-canopy savannas were also part of the regional land cover, however they were not delineated in historic data sets (Greenberg 2002). Between 1830 and 1860, prairies and woodlands in Illinois were cleared for agriculture at the rate of 3.3% per year (Iverson 1991). Today less than 1% of pre-settlement prairie and 31% of pre-settlement wooded areas exist in the state (Hansen 1986, Iverson

1991). Kane County is estimated to have only 17% forested land, although wooded habitat here increased by 17% between 1962 and 1985 (Hansen 1986).

FIGURE 1 The location of Kane County, Illinois, relative to the city of Chicago.

In the early 1900s there was a shift from agriculture to urban development as the leading factor causing land clearing in Kane County (Miller 2006). Since the 1930s the outward expansion of Chicago has caused rapid increases in population and development of remaining natural areas and agricultural land (Sierra Club 1998). Between 1870 and 1900, the population of Kane County grew from approximately 39,000 to 79,000 people. By 1930, the county's population had expanded to 125,000 and subsequently increased to nearly 210,000 in the following 30 years (Pfannkuche 2006). Between 2000 and 2030, the number of residents of Kane County is expected to grow from 400,000 to nearly 700,000 (NIPC 2003). Even more dramatically, the urban footprint is expected to expand from 16% of the county in 1998 to 52% in 2028, a 325% increase (Openlands 1999). As of January 2005, the majority of the developed land occurred in the eastern third of the county and once-distinct cities were beginning to coalesce (Figure 2). This pattern is expected to progress from east to west, and it is estimated that by 2030 the eastern and central two-thirds of the county will be urban, with only the western areas remaining primarily agricultural (Kane County Regional Planning Commission 2004).

FIGURE 2 The spatial pattern of developed land in Kane County, Illinois, in 2005 compared to the pattern generated by an urban growth model for the year 2030.

Like Kane County, rapid urbanization is impacting much of the greater Chicago region. To offset these impacts, a group of organizations collectively known as the Chicago Wilderness (http://www.chicagowilderness.org) focus on the preservation of open space in the 13-county region. The Kane County Forest Preserve District (FPD) is a member of the Chicago Wilderness consortium and is one group responsible for the acquisition and maintenance of open space in Kane County. The FPD has recently taken a proactive approach to preserving non-urban land (Sierra Club 1998, Openlands 1999, Kane County 2005). Prior to 1999, approximately 2833 ha were set aside by the Kane County FPD as open space. In 1999, a county-wide bond initiative provided $106 million that allowed the FPD to purchase an additional 2226 ha of open space over a five-year period, representing a 78% increase in total holdings. In 2005, a similar initiative provided $70 million for the acquisition of additional open space in the county (Kane County 2005).

Scenarios

As development extends westward, the price of agricultural land will escalate and limit the ability of public and private organizations to acquire open space (McMillen 1996, Atack and Margo 1998, McDonald and McMillen 1998, Acharya and Bennett 2001). To investigate approaches aimed at achieving an enhanced network of open space in Kane County, we created scenarios based on existing policies there that allowed us to compare trade-offs regarding land quantity, location, and total cost over a 30-year period. It is the stated policy of the Kane County FPD that available properties surrounding existing forest preserve lands or adjacent to water bodies be given priority over other potential acquisitions (Kane County 2005). Due to the uncertainty of land availability in Kane County, acquisitions are typically evaluated on a case by case basis.

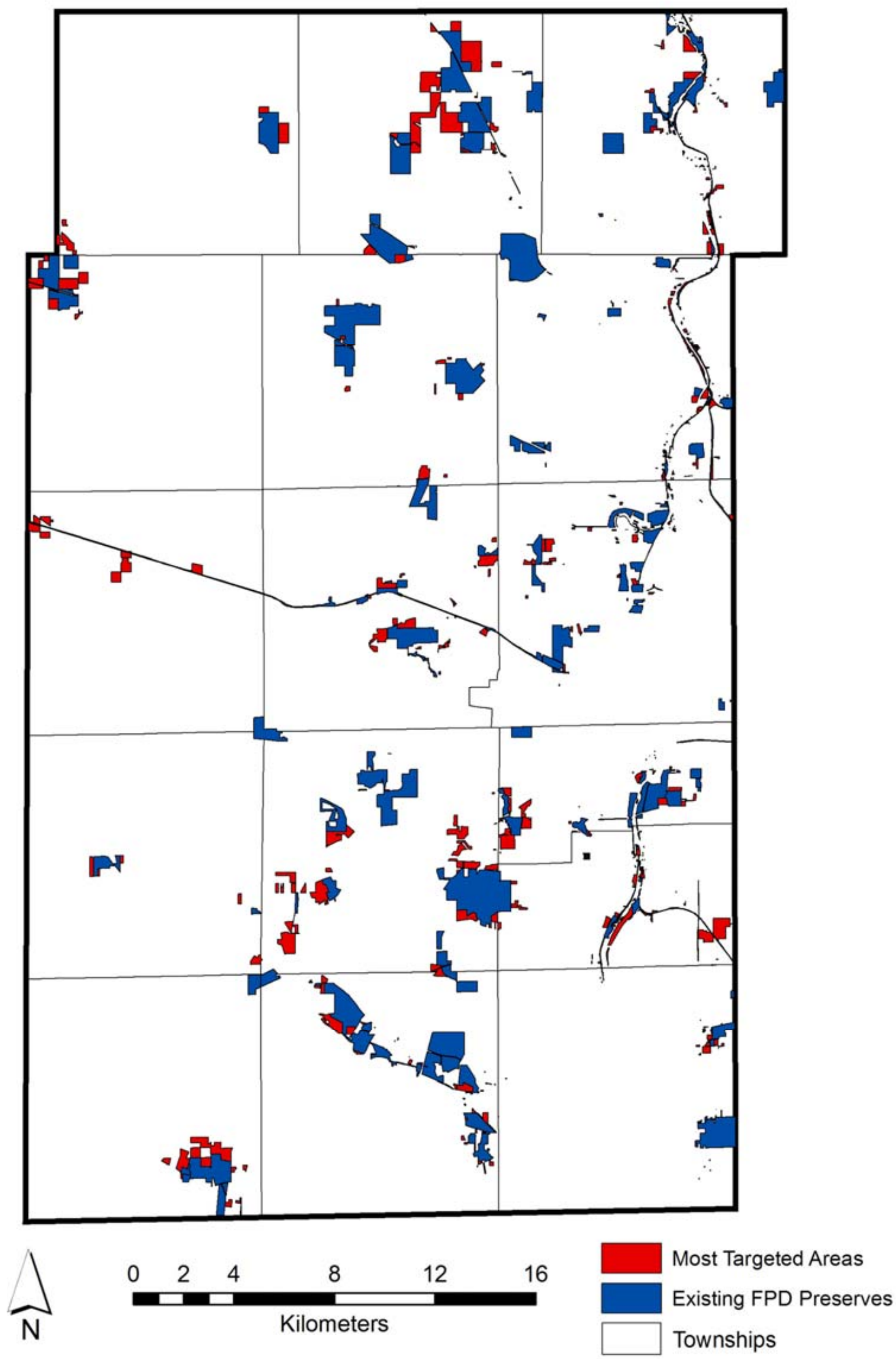
We developed a series of alternative scenarios to reflect the goals of the Kane County FPD and to explore the effects of variation in funding levels, the spatial and temporal distribution of open space over time, and the impact of differential weighting of conservation priorities. These scenarios were created under the assumption that the FPD must first act on behalf of Kane County's open space needs therefore we focused on addressing their stated conservation goals. Scenarios that modify existing policy in Kane County, including specific ecological issues such biodiversity conservation, habitat creation, or minimum reserve size were not developed as it was not our intent to suggest specific policy changes. Additionally, as they are not expressly identified by the goals of the FPD, agricultural lands have not been considered for preservation.

Factors considered in developing these scenarios included the extent of developed land in the county, the network of open space under the jurisdiction of the FPD (Figure 3, page 23), recent acquisition history, and the FPD's emphasis on acquiring land adjacent to existing conservation areas or bordering water bodies (Kane County 2005). We then created models to evaluate all possible combinations of these factors to understand potential interactions among them and to examine the resulting suite of future outcomes.

To explore interactions among factors, we used a three-level approach that combined a single conservation funding scenario (primary), a secondary scenario weighting proximity to water or existing open space, and a tertiary scenario exploring differences in land availability. The primary scenarios (*high*, *trend*, and *low*) reflected the level of financial support for open space acquisition by identifying the total amount of land to be purchased per five-year period. We assumed that funding would not fall to pre-1999 levels and defined these scenarios as follows: for each five-year period, *high* mandated the acquisition of up to 2023 ha of open space, *trend* reflected recent patterns and set a goal of 1214 ha, and *low* limited purchases to 405 ha.

We developed the secondary scenarios to reflect the conservation priorities of the FPD by identifying the effects of trade-offs involved in differential weighting of parcels adjacent to open space and to water bodies. The first scenario (hereafter, *open space*) weighted parcels near existing open space 2:1 over those adjacent to water bodies. These scenarios are intended to buffer existing conservation areas and increase their total area. In addition to larger preserve sizes, this option may provide habitat for species requiring larger contiguous areas. The second scenario (hereafter, *water*) weighted properties adjacent to water bodies 2:1 over those bordering open space. These scenarios may buffer at-risk water bodies, act as recreation areas, or provide wetland habitat. The third scenario, *equal weight* emphasized these two groups of parcels in equal proportions.

FIGURE 3 Open space in the 15 townships of Kane County, Illinois, under the jurisdiction of the Forest Preserve District in 2005 (in blue) and the areas most consistently targeted by scenarios (in red).



The tertiary scenarios explored issues of land availability within the county as a function of differing spatial patterns of urban expansion. The county is divided into three distinct vertical "tiers" of townships, ranging from mostly urban in the eastern areas to mostly agricultural in the west (Figure 3, page 23), and the tertiary scenarios were based on these differences. The first of these (hereafter, *western tier*) prioritized conservation in the western third of the county by concentrating all acquisitions in that area. This scenario was meant to address the consequences of acquisitions focused where there is less development and land is less expensive and encourage growth of larger, less fragmented conservation areas. The second scenario (hereafter, *county-wide*) weighted all geographic locations within the county equally. This will help to provide equal access to the citizens of Kane County.

Data

We used a series of vector layers provided by the Kane County FPD as our primary GIS data sources (KCGIS 2005). Urban and non-urban land uses were derived from a digital parcel layer containing zoning classifications. Residential, industrial, or commercial parcels were categorized as "urban"; all others were classified as "non-urban". Collectively, "urban" areas served as a baseline by delimiting the extent of development in 2005. The remaining parcels were considered "available" for either acquisition or development in the future. We combined lakes, rivers, streams and wetlands into an all-inclusive "water" layer and the baseline extent of open space was derived from a layer containing locations of FPD lands (KCGIS 2005).

In a comprehensive study of the greater Chicago region, the Openlands Project (1999) predicted that developed land in Kane County would increase from 16% in 1998 to 52% in 2028. This estimate was used to calibrate our urban growth model. We assumed that developed land would increase at a constant rate of four percent, compounded annually, and this figure was used to determine the increase in the county's urban land during each five-year time step.

Modeling Framework

Alternative futures models were constructed for both urban growth and open space acquisition. The bulk of model development was done using ModelBuilder, the internal graphical modeling interface for ArcGIS (ESRI 2005), as it allowed several program tools to be streamlined into a single process. These models were designed to work in tandem and run in five-year time steps with urban growth occurring prior to open space acquisition in each period.

We assumed that new development was more likely to occur adjacent to existing urban areas (Kim et al. 2003). The likelihood that a parcel would be developed was weighted based on its Euclidean distance from existing urban development. In dense urban areas the Euclidian distance weights are higher than less dense areas. In addition, undeveloped parcels inside municipal boundaries were weighted proportionately higher (25%) to reflect an increased likelihood of development in those areas. The growth model selected those undeveloped parcels with the highest combined weight of distance to existing urban and inclusion in municipal boundaries and reclassified those as "urban" relative to the percent urban grown for each five year period.

Euclidean distance was also used to weight proximity to existing open space and water bodies. For the *western tier* scenarios, an additional weight (25%) was added to those westernmost townships to promote open space acquisition there. The addition of urban or conserved areas does directly influence the availability of parcels for subsequent time steps, however due to the differences in open space quantity and conservation focus there are substantial differences between scenarios. Parcels selected for development or acquisition in a given time step were removed from the pool of available parcels for subsequent iterations.

Costs

The total cost of implementing each scenario was calculated after the 2030 time step as a combination of land price and management and maintenance costs, expressed in US dollars. Land prices currently tend to be the highest in the eastern, more urbanized part of Kane County (Ed Leuer, Value Masters, Real Estate Appraisal, personal communication), reflecting a general trend for properties to be more expensive when they are in highly developed areas (McMillen 1996, Atack and Margo 1998, McDonald and McMillen 1998, Acharya and Bennett 2001). Real estate values here can be represented by a gradient from $121,000/ha in the east to $17,000/ha at the western edge of the county (Ed Leuer, Value Masters, Real Estate Appraisal, personal communication).

Our method of assessing land costs was based on a parcels distance to the urban fringe. To aid in simplifying the location of parcels relative to the urban fringe, the county was dissected into 10 equally spaced east-to-west columns. To determine the location of the urban fringe, we calculated the percent of each column covered by urban area. We subsequently identified a sharp increase in urban land in the eastern half of the county. Based on this observation, we defined the urban fringe as the easternmost county with 27% or more urban land cover and assigned it the highest land values. Land prices for the western 5 columns decreased relative to their distance from the core. This same method was re-applied to model outputs from the future extents of urban land to account for increased costs over time. The end result was a westward 'movement' of the urban fringe and higher land costs over time.

There was little unaltered land remaining Kane County in 2005, due to the conversion first to row-crop agriculture and the ensuing trend of urbanization (Miller 2006). The county's FPD encourages the preservation and restoration of "historic resources and habitats." Because native grassland has experienced much greater declines in the region compared to woodlands (Hansen 1986), we focused on the acquisition of land that could potentially be restored to prairie to illustrate this method and make it more tractable.

Prairie restoration costs were calculated using information provided by two private firms that specialize in restoring native grasslands and have projects in the Chicago metropolitan area (Applied Ecological Services, Brodhead, WI; Driftless Area Stewardship, Glenhaven, WI). We averaged estimates of the wholesale costs provided for various components of the restoration process, including seed, tilling, planting, mowing and burning, The total cost of prairie restoration was $4133/ha for parcels in row-crops and $4752/ha for hayfields or pastures, reflecting the additional work required to restore the latter land covers compared to areas that had been plowed.

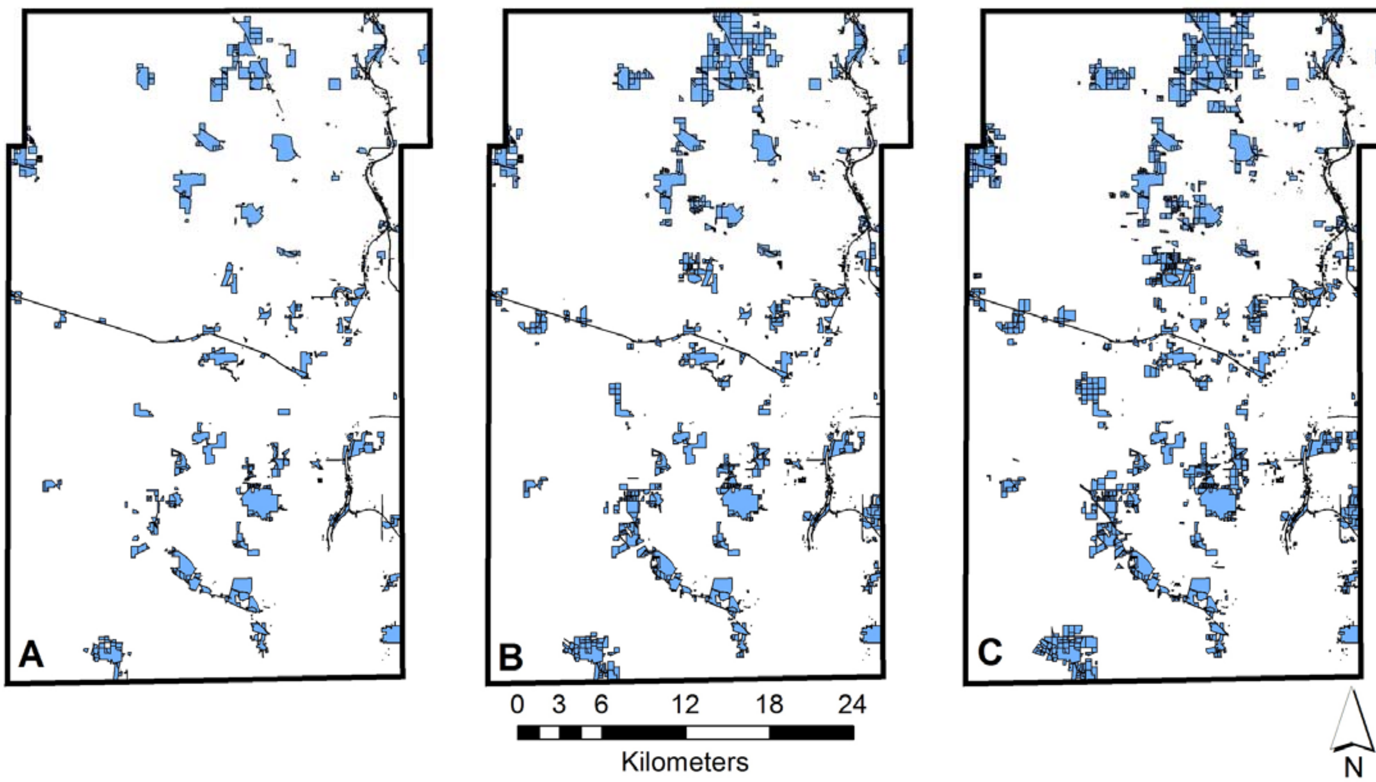
In the absence of active management, restored prairies will become degraded over time by the encroachment of woody vegetation (Ryan 1986, Gibson and Hulbert 1987). For this reason, we included an additional cost of $215/ha for mowing and burning once during each five-year period. By including restoration and maintenance costs, we were able to assess the benefits of restoring land as it was acquired as opposed to allocating all funds to land acquisition and postponing restoration until a later date.

RESULTS

Scenarios

The overall amount of urbanized land in each of the county's three geographic regions was similar across all 18 scenarios. On average, 81% of the eastern tier was developed by 2030, compared to 59% and 29% in the central and western tiers, respectively. The location of urban land in the *high* scenarios did vary more than other scenarios, likely due to displacement caused by heightened competition from conservation land uses. In these scenarios, urbanized land in the western tier ranged from 24% to 33% compared to a somewhat narrower range (± 5%) in the central and eastern tiers.

FIGURE 4 The spatial distribution of open space under the low (A), trend (B), and high (C) scenarios the 2030 time step. The secondary scenario here is equal and the tertiary scenario county-wide. See Methods for details on scenario development.



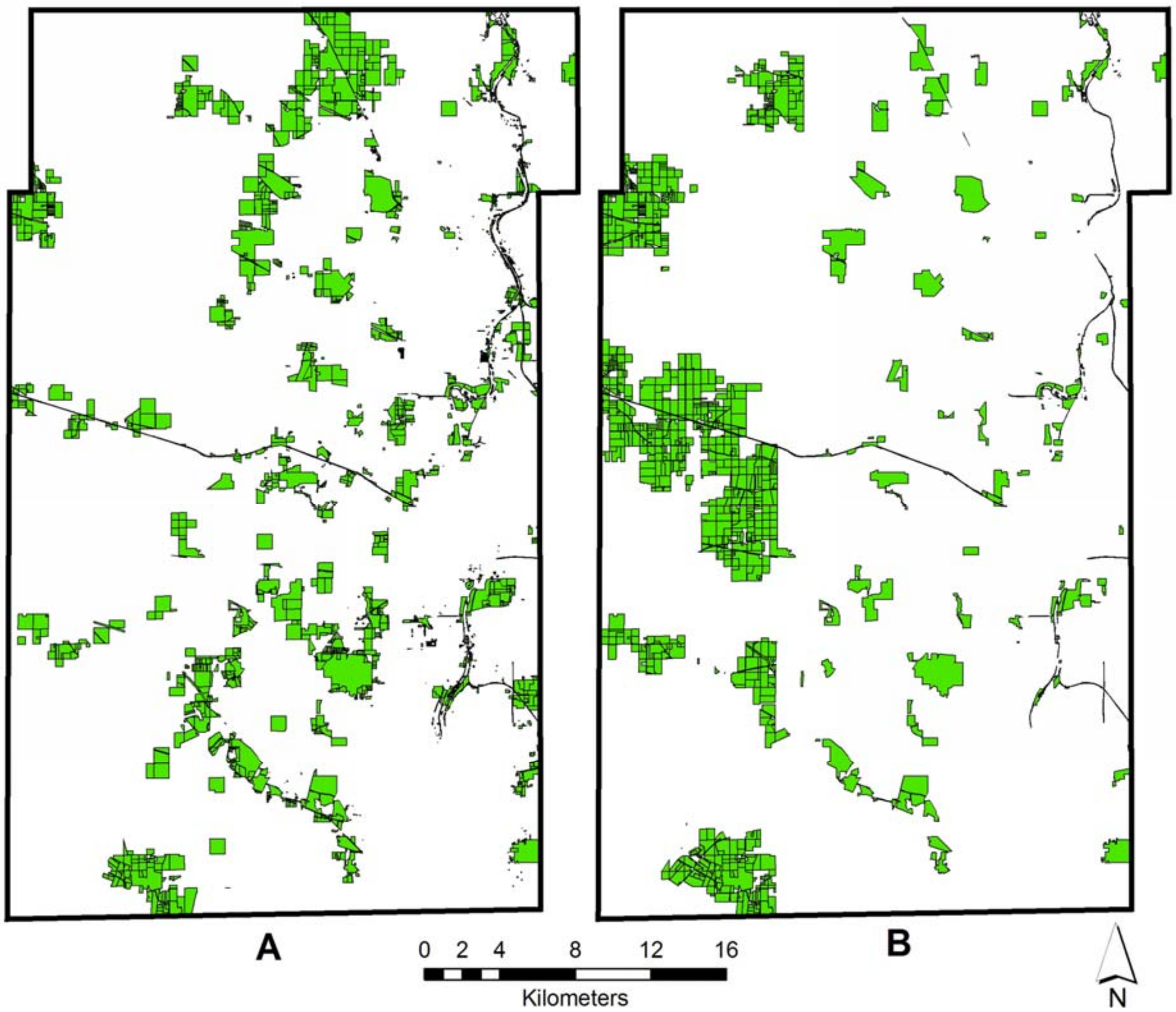
Although the quantity of open space was influenced entirely by the primary scenarios (*high*, *trend*, and *low*) (Figure 4), the spatial distribution of open space was influenced most by the tertiary scenarios as the most consistently targeted areas were focused near existing preserves (Figure 3, page 23). *Western tier* scenarios ranged from 35% to 69% of open space acquired in this portion of the county (Table 1, page 27), depending on whether expenditures were *high*, *trend*, or *low*. In contrast, the *county-wide* scenarios resulted in relatively little land being acquired in the western tier (13% to 22%), and instead emphasized acquisition in the central tier, where up to 57% of newly added open space was located (Table 1, page 27, and Figure 5, page 28).

The secondary scenarios played a lesser a role in determining the spatial distribution of open space in Kane County, likely because there were only slight differences in the location of land acquired under the open space and water scenarios (Table 1, page 27).

TABLE 1 The predicted area of open space acquired between 2005 and 2030, the total area of open space including land held prior to 2005, and percentages of open space per tier in Kane County, Illinois, for each alternative future scenario in 2030. Each tier reflects a vertical region accounting for roughly a third of the county's total geographic area. See *Methods* for details on scenario development.

Scenario			Acquired	Total	% of total open space by tier		
Level 1	**Level 2**	**Level 3**	**(ha)**	**(ha)**	**West**	**Center**	**East**
High	Open space	Western focus	10,062	15,540	69%	20%	11%
		County-wide	10,040	15,518	22%	54%	24%
	Water	Western focus	10,108	15,586	69%	20%	11%
		County-wide	10,017	15,495	20%	54%	25%
	Equal Weight	Western focus	10,076	15,554	69%	20%	11%
		County-wide	10,082	15,561	20%	54%	26%
Trend	Open space	Western focus	6,019	11,497	58%	27%	15%
		County-wide	6,023	11,501	19%	53%	28%
	Water	Western focus	6,046	11,525	58%	27%	15%
		County-wide	6,055	11,533	16%	57%	27%
	Equal Weight	Western focus	6,009	11,487	58%	27%	15%
		County-wide	6,024	11,502	17%	55%	28%
Low	Open space	Western focus	1,975	7,453	35%	41%	24%
		County-wide	1,958	7,437	14%	54%	31%
	Water	Western focus	2,008	7,486	35%	41%	24%
		County-wide	2,010	7,488	13%	56%	31%
	Equal Weight	Western focus	2,008	7,486	35%	41%	24%
		County-wide	2,004	7,482	14%	54%	31%

FIGURE 5 The distribution of open space after the 2030 time step under the county-wide (A) and western focus (B) scenarios. The primary scenario here is high and the secondary scenario open space. See *Methods* for details on scenario development.



Costs

Total cost of land acquisition for each alternative future was influenced most by the tertiary scenarios, which either weighted parcels in the western tier of the county or weighted all parcels equally. The combination of a high investment in land acquisitions and equal weighting of parcels produced similar results under each of the three secondary scenarios, averaging a total of $1.03 billion in cost over 25 years (Table 2, page 30). Conversely, scenarios with maximum funding that focused on acquiring land in the western tier of the county averaged $602 million for the same period. Scenarios with moderate funding levels and an equal focus on all parcels averaged $626 million and resulted in the acquisition of approximately 40% less land (Table 2, page 30). The *western tier* scenarios consistently showed higher quantities of acquired land for less money, regardless of initial funding levels, restoration, or maintenance (Figure 6).

FIGURE 6 The relationship between cost (millions USD) and total acquired land (ha) for each of the 18 scenarios. Code descriptions: L=Low, T=Trend, H-High; O=Open Space, E=Equal, W=Water; and C=County-Wide, W=Western Tier.

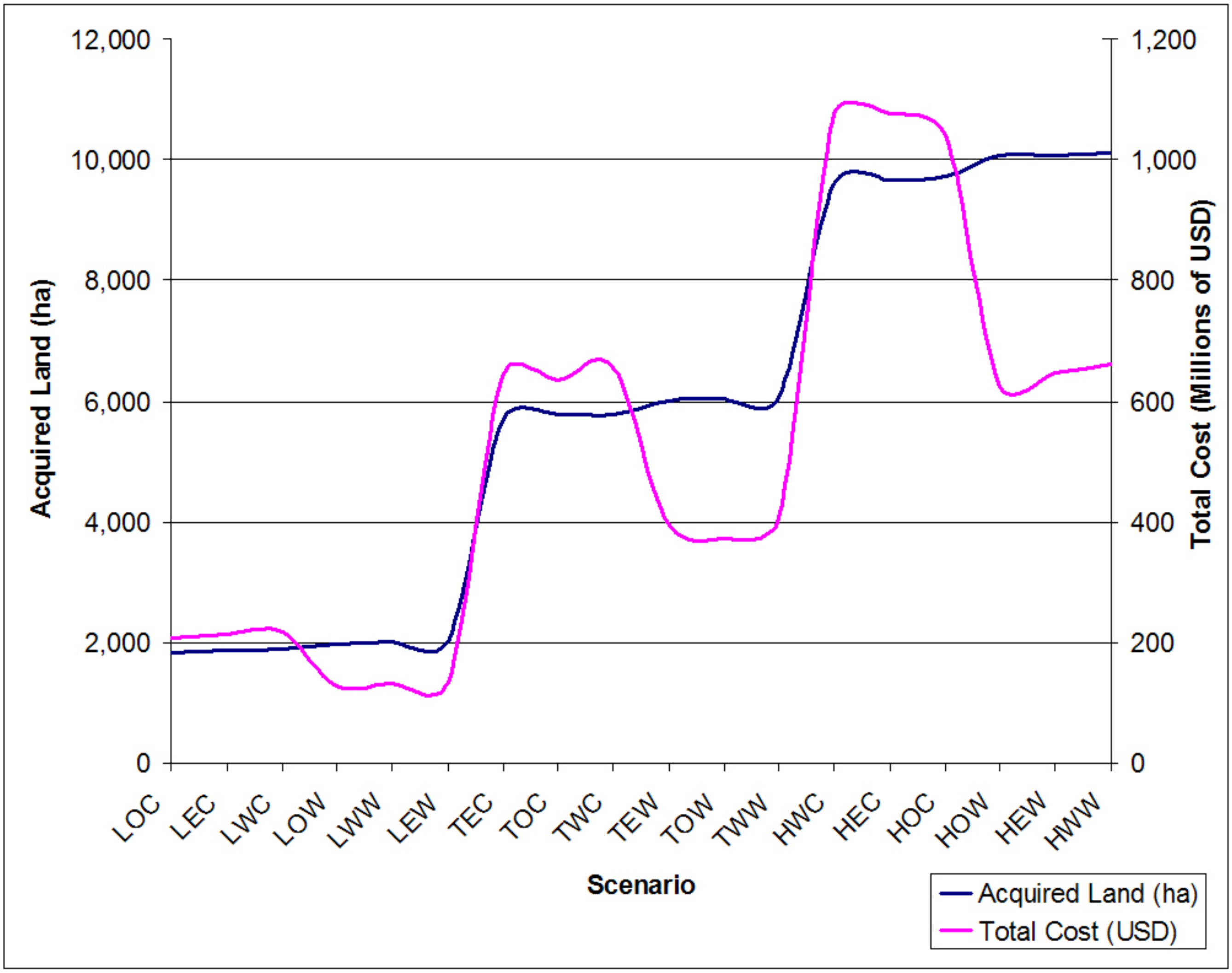


TABLE 2 Results of alternative futures model runs for each combination of primary, secondary, and tertiary scenarios. Outputs include the total area of land acquired, not including those prior to 2005, and the monetary costs associated with land acquisition, restoration, and maintenance. See *Methods* for details on scenario development.

Scenario	Acquired Land (ha)	Total Acquisition Cost (USD)	Restoration Costs (USD)	Maintenance Costs (USD)	Total Costs (USD)
High, Open Space, Western focus	10,067	583,758,627	38,368,362	3,803,751	625,930,740
High, Open Space, County-wide	9,728	1,003,881,680	32,331,637	3,167,272	1,039,380,590
High, Water, Western focus	10,110	618,404,217	37,919,685	3,854,704	660,178,606
High, Water, County-wide	9,617	1,040,700,775	31,127,953	3,150,233	1,074,978,961
High, Equal, Western focus	10,079	604,305,447	37,998,330	3,841,488	646,145,265
High, Equal, County-wide	9,669	1,042,338,142	31,289,740	3,161,593	1,076,789,475
Trend, Open Space, Western focus	6,025	348,136,740	22,507,599	2,298,747	372,943,086
Trend, Open Space, County-wide	5,761	613,651,498	18,186,172	1,894,763	633,732,433
Trend, Water, Western focus	6,048	378,507,777	22,258,810	2,303,046	403,069,633
Trend, Water, County-wide	5,776	636,936,926	18,106,782	1,898,461	656,942,169
Trend, Equal, Western focus	6,012	369,596,428	22,333,635	2,307,026	394,237,090
Trend, Equal, County-wide	5,698	626,112,897	17,471,730	1,875,743	645,460,369
Low, Open Space, Western focus	1,977	119,035,350	6,983,491	755,368	126,774,209
Low, Open Space, County-wide	1,831	200,454,660	5,192,629	615,121	206,262,410
Low, Water, Western focus	2,010	124,237,260	7,153,778	797,404	132,188,442
Low, Water, County-wide	1,887	212,119,109	5,316,860	635,330	218,071,300
Low, Equal, Western focus	2,010	123,222,960	7,065,119	764,126	131,052,205
Low, Equal, County-wide	1,868	207,815,578	5,250,618	639,557	213,705,753

The tertiary scenarios were also the primary influence on restoration costs (Table 2, page 30). In contrast to the initial purchase costs, restoration costs were higher in the *western tier* scenarios because there was a higher percentage agricultural land there. The average cost of restoration in the *high* scenarios was $38.3 million for western tier compared to $30.3 million *county-wide* scenarios.

Unlike the monetary expense required for restoration or acquisition, the costs of maintenance did not have as significant of a financial impact. Rather, the cost of maintenance mirrored those of restoration in areas where restorable land was acquired. The average costs to maintain restored lands in the *western tier* scenarios with maximum funding levels were just over $3.80 million (Table 2, page 30). In comparison, maintenance costs with maximum funding and a county-wide focus was $3.20 million. Although there were differences in the quantity and distribution of row-crops and grasslands between the western and central tiers, this did not substantially impact the total costs.

The total cost for implementation of each alternative future reflected the combined expenses of acquisition, restoration, and long-term maintenance. The pattern in total costs was similar to those for land acquisition. Although the overall cost of restoring land in the *western tier* was more than in the central areas, the lower purchase prices in this area were more than sufficient to absorb this extra cost. The average cost for a county-wide *high* scenario averaged $1.06 billion, compared to expenditures of $644 million if acquisitions were focused in the western tier of the county. In comparison, scenarios with moderate funding levels and an acquisition focus on the entire county averaged $645 million in total costs (Table 2, page 30).

DISCUSSION AND CONCLUSIONS

We used an alternative futures framework to compare the influence of several factors on the future extent of open space in a rapidly urbanizing landscape in Kane County, Illinois. To maximize relevance, we developed 18 scenarios based on FPD policies that currently guide the acquisition of open space. These scenarios incorporated uncertainty of land availability by considering future patterns of urban growth. We quantified the total area of open space acquired under different scenarios in a spatially explicit fashion and estimated the associated monetary costs of acquisition, ecological restoration, and future maintenance. Our research provides a framework that can be implemented and expanded by agencies with limited resources to meet their own needs.

These 18 scenarios are intended as a guide to planners. Since the conservation goals of Kane County are not specific beyond their targeting of certain types of land, this approach may better suited to identifying conservation targets within the county. As it is not our decision to make, we cannot identify a “best” scenario for Kane County but rather provide all 18 as possible outcomes of their current decision processes and allow the FPD to decide what most fits their desired outcome.

A unique aspect of our research is the focus on ways that existing policy can be applied more effectively to open space conservation, in contrast to other studies that have taken a more comprehensive approach to assessing the effects of urbanization on natural resources. Our method provides a starting point for others who wish to implement similar studies. Work done in the Willamette Basin of Oregon, for instance, identified three contrasting land use regulation scenarios by focusing on patterns of urban growth and conservation strategies, and their impacts on ecological processes in the region (Baker et al. 2004, Berger and Bolte 2004, Hulse et al. 2004). In another example, Steinitz et al. (1996) examined possible futures for Camp Pendleton, California with the goal of determining ways to minimize the impacts of rapid urbanization on biologically diverse natural areas. These studies generally addressed a broader suite of the potential effects of urban growth on the environment in their respective locations. However, smaller organizations with limited resources may be forced to limit their focus to a few key issues.

We developed our modeling framework on the basis of two key aspects of policy guiding open space acquisition in Kane County. We evaluated trade-offs associated with emphasizing particular areas in open space acquisition at two different scales in our secondary and tertiary scenarios. The secondary scenarios were more fine-grained and focused on either land proximate to existing open space or adjacent to water bodies, but did not yield substantially different outputs. Because of current open space acquisition policies, existing FPD lands tend to already occur near water bodies, thus effectively negating any influence of one of these scenarios over the other.

In contrast, the differences in the more coarse-grained tertiary scenarios between the *western tier* and *county-wide* emphases were considerable. In the former, all open space was acquired in the western tier of the county because land in that area was less fragmented in 2005, the starting point of our models. This allowed for much larger, contiguous areas to be acquired. In comparison, the *county-wide* scenarios distributed the open space more evenly across the county. The implementation of a western tier scenario would result in larger quantities of land being acquired in comparison to their county-wide counterparts. Even though the western tier tends to include a much higher percentage of agricultural land that can be restored, the cost of restoration is still low in comparison to that of acquisition. If the goal is to increase the quantity of grasslands, scenarios providing more land would be preferable. In contrast, if maximizing area or increasing public access were the desired effects, then restoration may not be as important (Haight 2005).

The larger contiguous areas resulting from the *western tier* scenarios may have greater value for biodiversity by minimizing fragmentation and edge effects (Saunders et al. 1991, Theobald et al. 1997, Helzer and Jelinski 1999, Johnson 2001, McKinney 2002, Mason et al. 2007, Pescador and Peris 2007). For example, Herkert and others (2003) concluded that areas smaller than 100 ha may serve as habitat sinks for grassland birds in the midcontinental United States. Alternatively, humans may benefit from access to open space as it provides both physical and mental benefits for those who utilize them (Miller and Hobbs 2002, Kaplan and Austin 2004, Miller 2005, Kaplan 2007). Scenarios focused on acquiring land throughout the county would increase access of open space to more residents, but would not allow for the larger areas allowed by the *western tier* scenarios. An additional benefit to these western tier scenarios is the large savings had by focusing on less expensive areas. These scenarios consistently returned equal or larger quantities of land for sizable reductions in cost.

The final trade-off that we examined was whether to immediately restore purchased properties, or delay restoration until some later date and instead dedicate those funds to acquiring more open space. This is an important consideration in Kane County and other areas under extreme development pressures, as available land is in limited supply and prices will likely increase over time. The option to purchase land now and restore it at a later time would add up to 650 ha, or 6.5% more open space under some *high* scenarios. Conversely, it may be more important to restore grasslands for native species concurrently with land acquisition; deferring restoration until a later date runs the risk that these species may no longer be present in sufficient numbers to colonize the newly restored habitat.

Our approach was not without its limitations, however. Although ArcGIS is widely available and considered to be the standard in GIS software, it does have drawbacks when used in an alternative futures framework. When this research was initially conducted, one such drawback stemmed from the fact that ArcGIS 9.0 was not designed to work in an iterative fashion, making it difficult to automate transitions between time steps and between the open space and urban growth models. This issue has subsequently been addressed with the addition of an iterative function to ArcGIS 9.3. An additional challenge had to do with the automation of the model. We were able to streamline many of the tools using ModelBuilder (ESRI 2005); however, some specific tools were unable to be used sequentially. Some processes required hands-on intervention, thus increasing the time required to run the models. To deal with this issue, we developed our models in several distinct sections. The inability of the software to automate the modeling framework more fully could potentially be rectified in new versions of the software, and it may be possible to address some of these concerns by editing scripts outside of ArcGIS.

Another potential limitation of our work is related to the generalized nature of our urban growth model. Whereas this method is well-suited to Kane County, which has a well-defined urban core in the east and decreasing level of development from east-to-west (KCRPC 2004), it may not be as useful in areas with more complex patterns of urbanization. There is a body of work focused on modeling different patterns of human settlement (e.g., Li and Gar-On Yeh 2000, Kim et al. 2003, Liu and Phinn 2003), and one of these approaches may be more appropriate for quantifying patterns of urban growth over time in other regions. Some workers have argued that predictions of future development may not be sufficient relative to actual development trends (Alberti 1999, Pickett and Cadenesso 2006, Conway and Hackworth 2007). Similarly, Costanza (2000) asserts that scenarios may influence policy development that may determine where urban growth will occur in a region, thus indirectly impacting patterns of urbanization.

Our research represents an exploration in scenario development and a method that can be further developed to address additional research objectives. To extend our research, others may adapt this method using different criteria and other data sources to develop scenarios that address their particular circumstances and goals. For example, data on the status and distribution of rare species or ecological community types could be combined with our model to identify key areas for particular conservation targets. Moreover, land held in trust by non-profit organizations (e.g., The Nature Conservancy, The Trust for Public Land) or other government agencies in a given region could also be considered as components of open-space networks. Effectiveness of these scenarios could be evaluated for their ability model land preservation, protect open space, conserve biodiversity or protect key natural areas (Kiester et al. 1996, White et al. 1997, Taylor et al. 2007). Scenarios could also be constructed to represent distribution, access and usage of protected natural areas by the community (Foltete and Piombini 2007, Oh and Jeong 2007).

The ideal ecological application of this framework would include a collaborative effort including cross-county, and cross-organization data to maximize understanding of biological, hydrologic, etc. processes in the region (Cort 1996, Barko et al. 2003). In the case of our research, data from surrounding counties and other regional conservation groups was severely limited thus requiring us to focus on the actions of the political boundary of Kane County, and the actions of their FPD.

Studies wishing to further incorporate biodiversity or habitat conservation may include reserve design algorithms (Pressey et al. 1997, Leslie et al. 2003, Snyder et al. 2007, Game and Grantham 2008). These algorithms are able to target specific habitat or species and make conservation decisions based on these goals. Because Kane County did not have “rules” to influence site selection beyond what was previously discussed, these methods did not add value to our research, though they could be used in similar situations.

Input from scientists and the public may help aiding in scenario construction that is ultimately a better representation of both the ecological and aesthetic needs of a region (Vogt and Marans 2004, Balram and Dragicevic 2005, Metro 2007). Involvement by the public may help to garner additional support for conservation, increasing interest and leading to monetary or time donations. When visualized, results of these models may make communication with those not familiar with the planning process easier, and may lead to increased funding for open space acquisition, restoration, further scenario development, or larger more comprehensive studies (Tress and Tress 2003).

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