

REMOTE SENSING IN REGIONAL NATURAL RESOURCES MONITORING AND MAPPING: CHALLENGES AND SOLUTIONS IN CHICAGO WILDERNESS CONSERVATION

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ABSTRACT

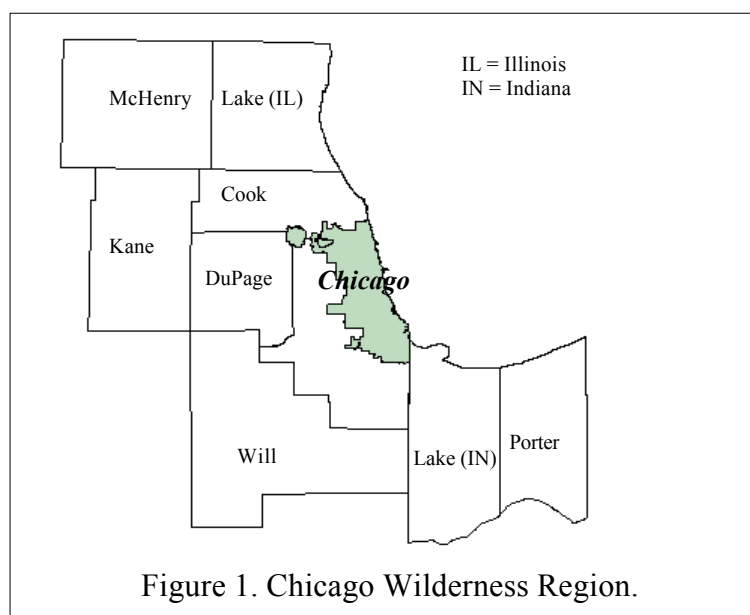
Chicago Wilderness is more than 81,000 ha. of protected areas in the urban and suburban matrix, as well as a coalition of more than ninety organizations committed to their survival. The long-term health of these imperiled communities depends on proper management of the more extensive, restorable lands that surround and connects the patches of high quality. Information critical to the success of conservation efforts in the region includes (1) a current vegetation map of Chicago Wilderness, in sufficient detail to make quantitative goal setting possible for the region's Biodiversity Recovery Plan; (2) quantified fragmentation status of the natural communities; and (3) patterns of land-cover change and their impact on the vitality of communities under threat. We used Landsat remotely sensed data and associated ground truthing to produce the current vegetation map. With multitemporal remote-sensing data we derived land-cover maps of the region in 1972, 1985, and 1997. Change detection analysis reveals the rapid acceleration of urban and suburban sprawl of the Chicago region in the past two decades. Satellite images provide striking visual comparisons of land use and health, as well as banks of geographically referenced data to make quantitative tracking of trends possible. The data provide biological foundation of quantitative goals for regional biodiversity restoration.

1. INTRODUCTION

Huge as it is, Chicago is a microcosm of some of the greatest challenges to the survival of Earth's biological diversity and to the quality of human life. Within the Chicago metropolitan region survive some of the world's best remaining examples of grasslands, woodlands, and wetlands of the eastern tallgrass prairie and grove region. Chicago's human inhabitants enjoy some of the richest cultural diversity and economic resources offered by any urban area on the globe. Yet pressures on the region's aquatic and terrestrial systems are rapidly eroding the vitality of its natural communities, implying present and future losses to human communities as well. Unplanned urban growth and suburban sprawl are among the main contributors to this accelerated degradation of natural communities, and to the deterioration of human living conditions. Organizations in Chicago's metropolitan region are linking efforts to reverse these trends.

In 1996, thirty-four Chicago organizations joined together to protect, restore, and manage the globally prominent natural communities of metropolitan Chicago through fostering their compatibility with the human communities whose lives they enrich. Under the umbrella of the

Chicago Region Biodiversity Council, this alliance of diverse and determined institutions – including local, state, and Federal government agencies, landowners, research institutions, and conservation organizations – now involves more than ninety members. The focus of the coalition is Chicago Wilderness, a regional nature reserve encompassing 81,000 ha. of protected lands and waters connected by greenways and wildlife corridors. It extends in a crescent around Lake Michigan, from southeastern Wisconsin, through Illinois, into northwestern Indiana. The six northeastern Illinois counties (Cook, DuPage, Kane, Lake, McHenry, and Will) and the two northwestern Indiana counties (Lake and Porter) encompass the city of Chicago and its suburbs (Fig.1).



Because the natural remnants of highest integrity are small and isolated, their long-term viability depends on proper management of the surrounding matrix. The evolving Regional Biodiversity Recovery Plan, developed by the coalition, recommends goals and strategies that scale from these individual natural remnants to the metropolitan region as a whole. Satellite images and Geographic Information Systems (GIS) allow us to analyze threats and conservation success across these geographic scales – and across time. Our goals for this project were (1) to complete a current vegetation map of Chicago Wilderness in sufficient detail to be useful to the regional Biodiversity Recovery Plan; (2) to examine changes in land use and land cover over the past 25 years, and to highlight the most severe threats to the region's globally important natural remnants; and (3) to integrate the resulting vegetation map and data into the Biodiversity Recovery Plan and into the GIS database of Chicago Wilderness. Results of this project point toward future patterns, so that we can intervene before change outstrips adaptability.

2. METHODS

To produce the current vegetation map for the Illinois and Indiana portions of Chicago Wilderness, we used multispectral data from two Landsat Thematic Mapper (TM) scenes of northeastern Illinois [023/031] and northwestern Indiana [022/031], acquired on 10 and 19 October 1997, respectively. The two digital images were georeferenced to Universal Transverse Mercator (UTM) map coordinate. The classification system developed by the Chicago Wilderness was adopted and adapted for vegetation and land cover classification. The adapted classification system has 5 major community classes. These are divided into 15 natural and cultural (human-dominated) vegetation

communities, which are subdivided further into subcategories based largely on soil and moisture conditions (Table 1). Training signatures were identified from the 1997 Landsat TM data.

The training signatures characterized patterns of reflectance to individual types of natural community. In spring and summer of 1998, we undertook intensive ground truthing and botanical transects to assist in the training-sample selections. We identified locations of all ground-truthing

<i>Community Classes (5)</i>	<i>Communities (15)</i>	<i>Subcategories</i>
Forested communities	Upland forest	Dry mesic, Mesic, Wet mesic
	Floodplain forest	Wet mesic, Wet
	Flatwoods	Northern, Sand
	Woodland	Dry mesic, Mesic, Wet mesic
Savanna communities	Fine-textured-soil savanna	Dry mesic, Mesic, Wet mesic
	Sand savanna	Dry, Dry mesic
Prairies	Fine-textured-soil prairie	Dry, Mesic, Wet
	Sand prairie	Dry, Mesic, Wet
	Gravel prairie	Dry, Mesic
	Dolomite prairie	Dry, Mesic, Wet
Wetland communities	Marsh	Basin, Streamside
	Sedge meadow	
Cultural (human-dominated) vegetation communities	Cropland	
	Unassociated growth	Grass, Forb, Shrub, Tree
	Developed land	

Table 1. The classification system for vegetation and land-cover mapping in Chicago Wilderness.

data with a Global Positioning System (GPS). The GPS data were differentially corrected, projected to UTM coordinates, and converted into GIS format. After differential corrections, the spatial accuracy of the GPS data was within 1 meter. We referenced field notes and GPS data to locate and define training signatures of categories for natural and cultural (human-dominated) land cover. We then applied the training signatures to classify the Landsat images.

We focused the trends analysis on fragmentation and loss of habitat over the past quarter century in the six northeastern Illinois counties only. For the analysis, we derived land-cover maps of the region at nearly equivalent intervals over the past 25 years (1972, 1985, 1997), starting with the earliest cloud-free data available for the Chicago region: a Landsat Multispectral Scanner (MSS) image of October 1972. The other two images used for comparisons were both Landsat TM. The most recent image is from October 1997 (our project started in November 1997); because of limited availability of cloud-free data, the midpoint image is from May 1985. We obtained historical land-cover information by referencing historical aerial photos, United States Geological Survey topographic maps, and county land-management records to select training signatures for classification of the 1972 MSS and the 1985 TM data. The MSS and TM data were geometrically rectified and transformed into UTM coordinates. The final geometric matching among these images fell within 1 subpixel. We then used supervised classification and maximum likelihood classification algorithms to process the images. Figure 2 illustrates the vegetation and land-cover map derived from the classification

3. RESULTS

Initially, we defined nearly 150 training signatures corresponding to the different subcategories and tried to detect as many subcategories as possible. After running the classification, regional land managers and ecologists verified the results and refined the training signatures as needed to improve the classification accuracy. We found that the Landsat TM data, with spatial resolution of approximately 30-m, could not reliably differentiate among similar community subcategories. To maintain a high level of accuracy at the regional scale, we collapsed the subdivisions and identified only the higher community classes.

To improve the classification performance, we relied on spatial information, such as GIS soil and wetland data, from other sources. We conducted post-classification GIS modeling to identify (1) critical cultural vegetation communities, (2) *wetland communities*, and (3) *floodplain forests*.

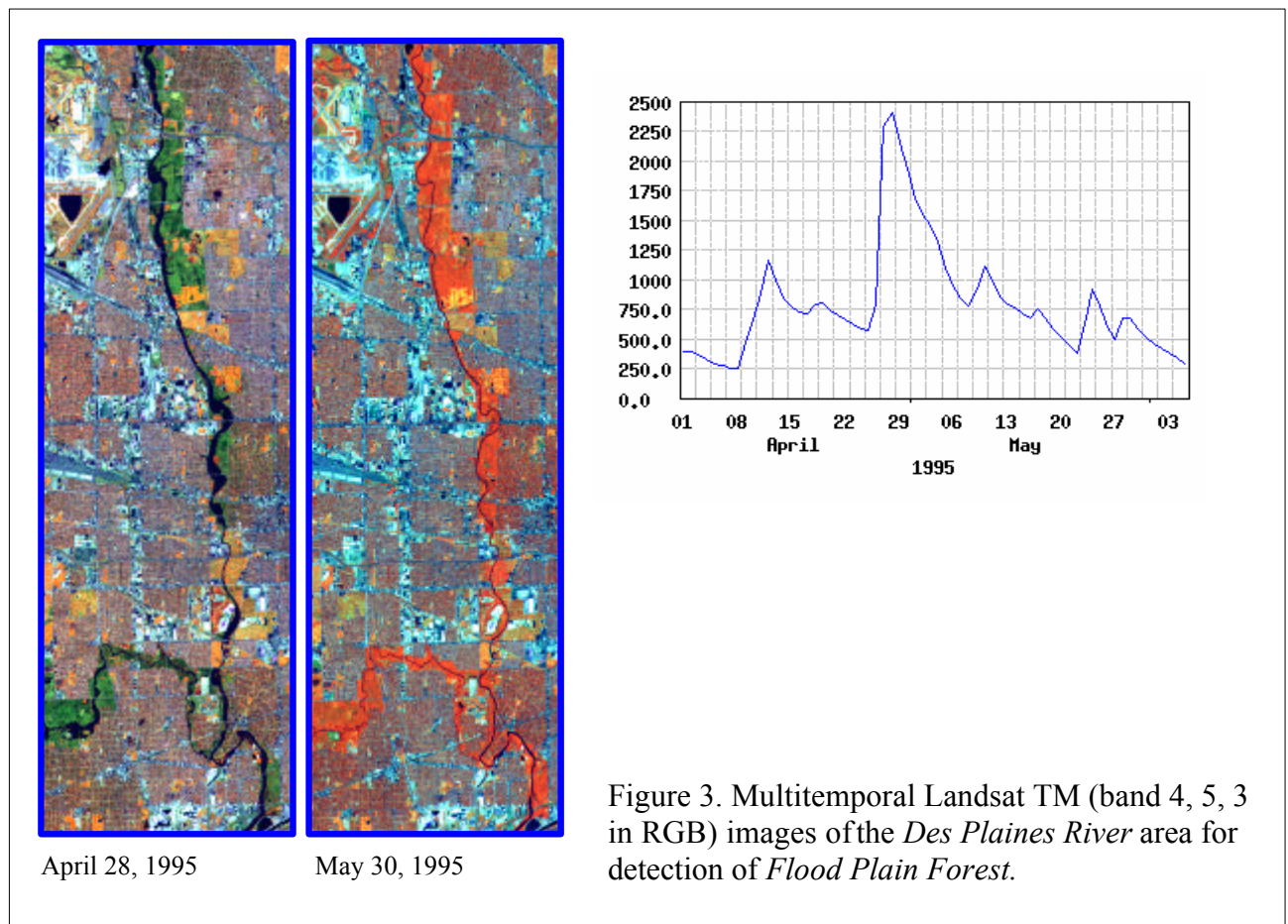
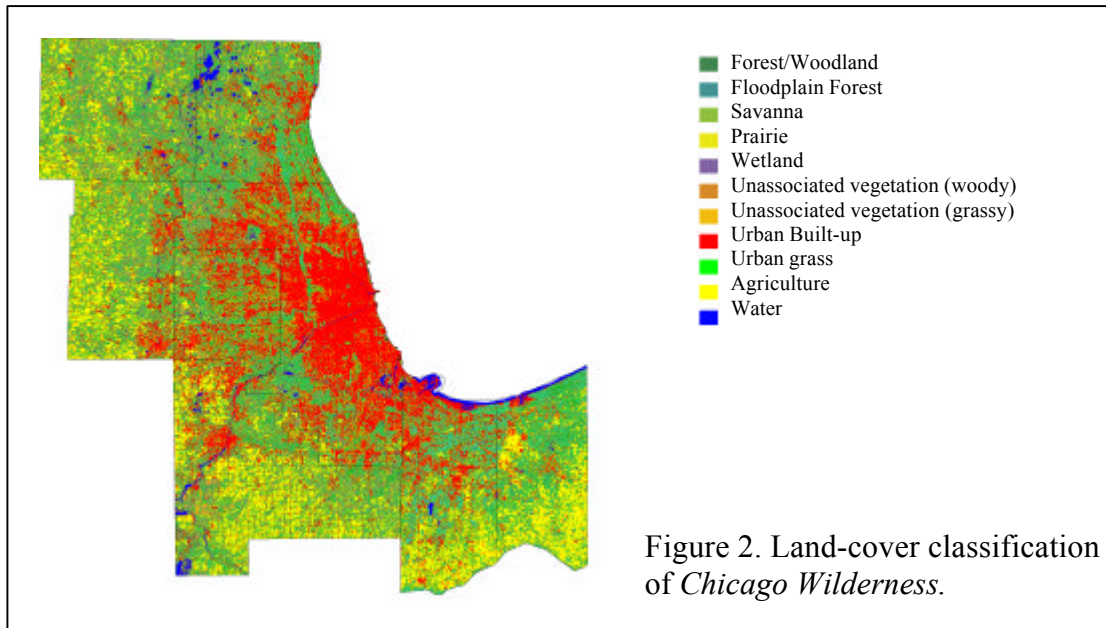
For cultural communities, we focused specifically on 2 degraded types that are in desperate need of restoration: *unassociated woody* and *unassociated grassy vegetation*. These low-grade communities have lost their defining characteristics because of recent land-use practices and interruption of life-maintaining ecological processes such as fire and hydrology. Unassociated woody vegetation is a mixture of shrubs and trees that do not occur together naturally, either historically or as associates in self-perpetuating communities. These woody patches develop as invasive plants take over fire-starved woodlands and savannas, cutover forests, unmanaged prairies and sedge meadows, and abandoned farm fields or Eurasian meadows. Unassociated grassy vegetation is mostly old fields that are now dominated by Eurasian cool-season grasses. The other 2 focal cultural communities are *developed land* and *cropland*. Developed land includes all lands dominated by human structures, including strip mines, buildings, cemeteries, roadways, and urban grasses. Cropland consists of row and forage crops.

Identification of the wetland communities from the 1997 October Landsat TM image was hampered by the extreme dryness of that autumn. Desiccated wetlands have reflectances and spatial patterns similar to bare-soil farmland and unassociated grassy vegetation. Wetland communities therefore were misclassified as cropland and unassociated vegetation. To address this problem, we referenced the TM image data to wetland maps developed by the Illinois Department of Natural (IDNS, 1996) and used GIS masking to identify the wetlands. The wetland communities that were identifiable by Landsat were primarily *basin* and *streamside marshes* and *sedge meadows*.

To identify floodplain forests, which are characterized by periodic flooding, we processed Landsat TM images acquired on 28 April and 30 May 1995. The 28 April image coincided with the time of peak discharge of the major rivers in the Chicago area, when most of the floodplain forests were inundated. The 30 May image, on the other hand, reflects normal water levels (Figure 3). The short time interval between the two images assures that most differences noted either reflect phenological changes or are related to flooding. After classification of both 1995 images, pixels that were labeled *water* (flooded) in the April image and *forest/woodland* in the May image were characterized as floodplain forest. We used Boolean logic GIS modeling to identify these floodplain forests.

To detect land cover change of the region and to assure accuracy, we recoded the classified Landsat data into 5 categories only: (1) *urban land*; (2) *natural area* (forest, woodland, savanna, shrubland, prairie, and wetland communities); (3) *unassociated vegetation*; (4) *agriculture*; and (5) *open water*. Assessments of the land-cover classification indicate high overall accuracy (about 93%) for the generalized 1985 and 1997 data. Because of the different spatial resolution of TM and MSS,

the classified 1972 MSS data were resampled to conform to the same spatial resolution as of the TM.



Dramatic increases in urban land dominate the land-cover changes detected between 1972, 1985, and 1997. Between 1972 and 1985, urban land increased by 14.5% (Table 2). This increase in urban and suburban sprawl accelerated to nearly 30% between 1985 and 1997. Between 1972 and 1997, the extent of developed land increased by an alarming 49%. Most of the suburban land expansion came at the expense of agricultural lands, with a total decrease of 37% over the 25 years. Yet more than one-fifth of natural area (21%, or 47,986 ha) (Table 2) was converted to urban use during that period. Rampant urban sprawl results not only in wholesale loss of natural (and degraded) lands, but also in extreme fragmentation and isolation of the remaining natural areas within the suburban matrix.

Another significant change in land cover is the increase in unassociated vegetation over time (Table 2). This increase reflects (1) degradation of natural lands in the absence of appropriate management and ecological restoration and (2) abandoned agricultural fields. But the increase in unassociated vegetation shown between 1972 and 1985 probably is inflated: coarser spatial resolution of the 1972 MSS data and lack of ground truthing made identification of this category difficult, and we likely underestimated its extent in 1972.

Category	1972	1985	1997	1972-1985	1985-1997	1972-1997
Urban land	227,487	260,498	338,612	+ 33,011 (15%)	+ 78,114 (30%)	+ 111,125 (49%)
Natural area	227,047	209,796	179,061	- 17,251 (08%)	- 30,735 (15%)	- 47,986 (21%)
Agriculture	599,462	468,804	375,537	- 130,658 (22%)	- 93,267 (20%)	- 223,925 (37%)
Unassociated vegetation	80,644	199,355	244,716	+118,711 (147%)	+ 45,361 (23%)	+ 164,072 (203%)

Table 2. Changes in land cover between 1972 and 1997 (in hectares).

4. DISCUSSION

The regional vegetation maps, as well as the baseline map of land cover from which they were derived, are serving as benchmarks against which we can measure progress toward the landscape-level goals of the Recovery Plan. In fact, this project was the catalyst for the development of the Chicago Wilderness system for community classification. Following this classification system, ecologists at a series of Chicago Wilderness workshops set priorities on community types according to global and regional status, importance, and distribution (Chicago Wilderness, 1999). In the process, they identified the ranked *conservation targets* toward which visions, goals, and strategies for regional recovery are directed.

Not only have the scope of satellite imagery and the flexibility of GIS generated visual tools (the base maps) that can be manipulated manually for goal setting, management, and monitoring. They also have produced digitized layers of information--for example, the size and distribution of protected areas--that can be displayed and analyzed separately. This spectrum of images reveals how patches of single cover types are spread across the landscape. Clearly visible is the fragmentation of all remnant natural communities. The series also underscores the extent of unassociated vegetation--both a symptom of ecological decline and a signal of the potential for widespread restoration.

At the regional scale, we were not able to detect community types at hierarchical levels as fine as we had hoped for at the outset of the project. County by county, however, we may be able to push

resolution to more detail, enabling land managers to set landscape-level goals at the local scale. Even at the coarser regional scale of resolution, the magnitude of the most serious threats is apparent.

2. Examine changes in land use and land cover over the past 25 years, and highlight the most severe threats to the region's globally important natural remnants.

The 25-year horizon chosen for the project, as well as the three temporal "slices" within it, revealed dramatic trends in land use, commensurate with the coarser scale of regional resolution. Qualitative comparisons are forceful evidence that wholesale conversion is not the only landscape-level process threatening the natural communities of Chicago Wilderness. Fragmentation, isolation, and the quality of the matrix in which natural lands are embedded can be equally important. Through the accelerated transition of this cover type to urban structures, the integrity and viability of wild isolates have been compromised.

Quantitative comparison is particularly telling in the case of one of the most severe threats to regional biodiversity: urban and suburban sprawl and its consequences. Poorly planned development contributes more heavily to ecological degradation than does sheer population growth. Between 1970 and 1990, the surface area of metropolitan Chicago's developed land increased by 49% while its population grew by 4%. The Northeastern Illinois Planning Commission projects that the region's population will increase by 25% over the next 25 years (NIPC, 1998). At current rates, the accompanying conversion of open land would be catastrophic. Combined with the visual power of the land-cover maps, the quantitative results of the change-detection project argue strongly for reforming land-use policies.

Circumstance limited our ability to map and quantify some other pervasive regional threats. For example, aggressive plant species threaten almost every community type in Chicago Wilderness (Chicago Wilderness, 1999). Buckthorn (*Rhamnus*), an invasive shrub, holds its leaves into late fall, long after native species have lost theirs. Satellite images taken in November would have shown us the extent of this threat in the region, but in 25 years not one November image has been cloud-free. On the other hand, dry conditions in wetlands during 1997 prevented us from detecting the extent of the aggressive purple loosestrife (*Lythrum salicaria*). Acquisition and analysis of future images may provide us with missing information. Even now, the baseline data create a georeferenced framework for field reconnaissance of these threats and others.

3. Integrate the vegetation map and data into the Recovery Plan and into the GIS database for Chicago Wilderness.

Chicago Wilderness is founded on partnership. The regional change-detection project has provided a forum for collaboration of a broad suite of conservationists. Land managers with expert knowledge of ecosystems on the ground, scientists with skills in remote sensing and GIS, and urban planners with experience in the built environment cooperated across geography and across institutions. The availability of the database to Chicago Wilderness members and others is a vehicle for long-term persistence of this action-oriented partnership. A powerful result of this work is its potential as an organizing force for a regional conservation constituency. By presenting complex concepts from the Recovery Plan in accessible, striking visual form, the land-cover maps and quantitative measures of change can be a call to action for the public of Chicago Wilderness.

Erosion of the Chicago region's globally important biodiversity results not only from large-scale policy decisions, but also from the day-to-day activities of millions of households and businesses.

Strong, clear images of change in land use can motivate change in individual and group conservation behavior, from consumption habits to voting patterns. Such a transformation of regional culture is an ultimate goal of Chicago Wilderness.

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