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Status and Trends of Land Change in the Midwest–South Central United States—1973 to 2000

Professional Paper 1794–C

U.S. Department of the Interior
U.S. Geological Survey

Status and Trends of Land Change in the Midwest–South Central United States—1973 to 2000

Edited by Roger F. Auch and Krista A. Karstensen

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

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Cover:
Corn field and quonset barn on rolling land, with forested hills in background, south of Owensboro, Kentucky. Photograph by Thomas R. Loveland, 2003.

Inside cover:
Cattle grazing in less intensively used pasture northwest of El Dorado, Arkansas. Photograph by Mark A. Drummond, 2009.

Foreword

This Professional Paper is the first multitemporal assessment of late-20th-century land change in the conterminous United States across all regions and all land-use and land-cover sectors. The work is the culmination of nearly 10 years of research and development by the U.S. Geological Survey, with support from the U.S. Environmental Protection Agency and the National Aeronautics and Space Administration, as well as university collaborators. It represents the most complete and comprehensive analysis of the rates, types, distribution, and drivers of recent changes in land use and land cover. The study bridges the gap between coarse-scale continental and global assessments and fine-scale local and regional case studies.

Land-change studies attempt to explain the “what, where, when, how, and why” of changes to the vegetation and to the use of the land. Land-change research is aimed specifically at measuring where change is occurring (and where it is not occurring); which land-use and land-cover classes are changing (and what they are changing to); how much land is changing (and how fast); and what drivers are responsible for the measured changes. The goal is not only to understand the scope of change but also to provide the information base necessary to evaluate, predict, and manage the consequences of change.

Like many key issues in climate change and ecosystem functioning, land use and land cover are both drivers and indicators of environmental quality. The National Research Council has identified the understanding of land-use dynamics as one of the grand challenges for environmental research—no other global-change parameter is so tightly intertwined with issues of past, present, and future land-use practices, weather patterns, soil and carbon dynamics, ecosystem health and diversity, economic development and policy, technology issues, human population size and distribution, and overall human health. People and their use of the land are interrelated in complex ways, and the effects of land-use and land-cover change can have a huge impact on their quality of life, on the goods and services that they can expect from the land, and on the hazards that they may face. Despite these profound consequences, the Intergovernmental Panel on Climate Change’s Third Assessment Report has cited the lack of scientific understanding about the timing, magnitude, and direction of response of ecological, social, and economic systems to the combined effects of climate change and land-use and land-cover change as a key uncertainty in determining societal vulnerabilities and predicting both regional and global impacts of climate change.

Prior to this study, only sectorally specific or spatially limited assessments and inventories had been conducted to categorize land change in the United States. These efforts often included only certain land-use and land-cover classes or ownership categories, or they were conducted over short time intervals only, and integrating these various assessments into a comprehensive and consistent national synthesis of land change was not possible. The research presented in this Professional Paper has been specifically designed to provide the first comprehensive measurement of land-cover change in the conterminous United States.

Relying on Landsat satellite imagery—the longest continuous and consistent dataset of synoptic Earth observations—the authors characterize changes across 11 primary land-use and land-cover classes spanning four time periods between 1973 and 2000. For each of these time periods and classes, estimates of change are developed for each of 84 distinct ecological regions—or ecoregions—across the conterminous United States.

The results provide useful, if not essential, information for understanding climate change, biodiversity, resource management and planning, resource security, and disaster planning. A significant conclusion is that no single profile of land-use and land-cover change exists. Numerous different, and often complex, interactions between an ecoregion’s socioeconomic drivers and its biological and physical characteristics have produced widespread regional and temporal variability in the rates, types, and total extent of land change. Among the scientific findings presented are estimates of overall forest decline in response to increased rates of disturbance, urbanization, and agricultural intensification.

This research provides a critical ecoregional to national perspective of U.S. land change in the conterminous United States. With the completion of the 1973–2000 assessment, this study lays a foundation for understanding the Nation’s land-change dynamics and makes possible a new era for analyzing the consequences of land change, as well as for modeling future land changes.

Suzette M. Kimball
Acting Director, USGS

Preface

U.S. Geological Survey (USGS) Professional Paper 1794–C is the third in a four-volume series on the status and trends of the Nation's land use and land cover, providing an assessment of the rates and causes of land-use and land-cover change in the Midwest–South Central United States between 1973 and 2000. Volumes A, B, and D provide similar analyses for the Western United States, the Great Plains of the United States, and the Eastern United States, respectively. The assessments of land-use and land-cover trends are conducted on an ecoregion-by-ecoregion basis, and each ecoregion assessment is guided by a nationally consistent study design that includes mapping, statistical methods, field studies, and analysis. Individual assessments provide a picture of the characteristics of land change occurring in a given ecoregion; in combination, they provide a framework for understanding the complex national mosaic of change and also the causes and consequences of change. Thus, each volume in this series provides a regional assessment of how (and how fast) land use and land cover are changing, and why. The four volumes together form the first comprehensive picture of land change across the Nation.

Geographic understanding of land-use and land-cover change is directly relevant to a wide variety of stakeholders, including land and resource managers, policymakers, and scientists. The chapters that follow present brief summaries of the patterns and rates of land change observed in each ecoregion in the Midwest–South Central United States, together with field photographs, statistics, and comparisons with other assessments. In addition, a synthesis chapter summarizes the scope of land change observed across the entire Midwest–South Central United States. The studies provide a way of integrating information across the landscape, and they form a critical component in the efforts to understand how land use and land cover affect important issues such as the provision of ecological goods and services and also the determination of risks to, and vulnerabilities of, human communities. Results from this project also are published in peer-reviewed journals, and they are further used to produce maps of change and other tools for land management, as well as to provide inputs for carbon-cycle modeling and other climate change research.

This report is only one of the products produced by USGS on land-use and land-cover change in the United States. Other reports and land-cover statistics are available online at http://landcovertrends.usgs.gov.

Acknowledgments

The U.S. Environmental Protection Agency's Office of Research and Development and the National Aeronautics and Space Administration provided initial funding to support this project.

The U.S. Geological Survey's (USGS) Geographic Analysis and Monitoring Program and Climate and Land Use Change Research and Development Program provided long-term support for this research.

Adam Davis (USGS) provided extensive support in the production of figures and tables.

All photographs contained within this Professional Paper were taken by various members of the Land Cover Trends research project while conducting field investigations between 1999 and 2010.

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Conversion Factors

Inch/Pound to SI	Multiply by	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: °F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows: °C=(°F-32)/1.8

Regional Synthesis

Land-Cover Trends in the Midwest–South Central United States—1973 to 2000

By Roger F. Auch, Krista A. Karstensen, and Steven Kambly

Introduction

The Midwest–South Central United States is one of four major regions of the conterminous United States that were studied in the U.S. Geological Survey's "Status and Trends of Land Change" study. This research activity provides a holistic appraisal of contemporary land-use/land-cover change across the nation, filling a research niche that could not be supported by current resource inventories that are based on thematic land categories and ownership (Loveland and Acevedo, 2006). The U.S. Geological Survey, supported by the U.S. Environmental Protection Agency and the National Aeronautics and Space Administration, initiated the "Status and Trends of Land Change" study to better understand the spatial and temporal dimensions, as well as the consequences, of national land-use and land-cover change in the late 20th century (Loveland and others, 2002).

The "Status and Trends of Land Change" study used land-use/land-cover mapping derived from Landsat satellite imagery (and supported by higher resolution aerial photography), a statistical sampling strategy (Stehman and others, 2003), and geographic regionalization to provide information on the types, amounts, and rates of land change in the United States (Loveland and others, 2002). Level III ecoregions (U.S. Environmental Protection Agency, 1999) were selected as the geographic framework for the study because they have homogenous conditions of similar land forms, soils, vegetation, and land use.

The Midwest–South Central United States region contains 17 distinct ecoregions. Each ecoregion was gridded, then a random selection of "sample blocks" was drawn, the population size being determined by the expected amount of change (Loveland and others, 2002). The sample-block size for the 17 Midwest–South Central United States ecoregions was 10 × 10 km. Sampling allowed intense manual interpretation at the local scale (Sohl and others, 2004; Auch and others, 2012) that could be aggregated to broader scales, such as Level III ecoregions, to give statistically rigorous estimates of land-use and land-cover change. The interpretation of Landsat imagery across five study dates (1973, 1980, 1986, 1992, and 2000) provided the basis for creating land-use/land-cover maps for each sample block. Land use and land cover were classified using a modified Anderson Level I system (Anderson and others, 1976; Loveland and others, 2002) of 11 categories (see appendix 3 for definitions of land-use/land-cover classifications). The size of the minimum mapping unit was 60 × 60 m to allow for comparison between earlier Multispectral Scanner (MSS) sensor data and finer resolution imagery (30 × 30 m) of the Thematic Mapper (TM) and Enhance Thematic Mapper (ETM) sensors. Land-use/land-cover maps created from TM and ETM imagery were resampled to 60-m resolution.

The Midwest–South Central United States stretches from the northern forests of the Great Lakes area south to the bird's foot delta of the Mississippi River in Louisiana, and from the southern shore of Lake Erie in the northeast to the pine forests of east Texas in the southwest. Several distinguishing land-cover patterns emerge when looking at the Midwest–South Central United States. The ecoregions of the far-northern and southwestern parts of the region are dominated by forest, whereas the remaining ecoregions are either predominately agricultural or a combination of both agricultural and forest lands (fig. 1*A*). This region also includes what commonly is called the "industrial Midwest," an area whose growth historically has been based on transportation assets and manufacturing. The industrial Midwest is bracketed in the east by Cleveland and other cities in Ohio, in the northwest by the Minneapolis–Saint Paul region in Minnesota, in the north by Detroit and other cities in Michigan, and in the southwest by Saint Louis, Missouri (Auch and others, 2006). Large urban centers north or south of the industrial Midwest are few, if present at all (fig. 1*A*). The variability of recent land-use/land-cover change and stability in the Midwest–South Central United States has been based primarily on the major resources and settlement patterns of the region. These have included metropolitan growth, forest-management activities (wood harvest and forest regrowth), and agricultural stability, rearrangement, and intensification. This report discusses the aggregate changes in the Midwest–South Central United States during the entire study period (1973–2000), and it also presents greater detail in the 17 individual ecoregion summaries in the chapters that follow.

Regional Synthesis

The Midwest–South Central United States region, which includes 17 ecoregions, encompasses 1,267,606 km^2 (489,425 mi^2) in all or part of 19 states. For purposes of discussion, the 17 Midwest–South Central United States

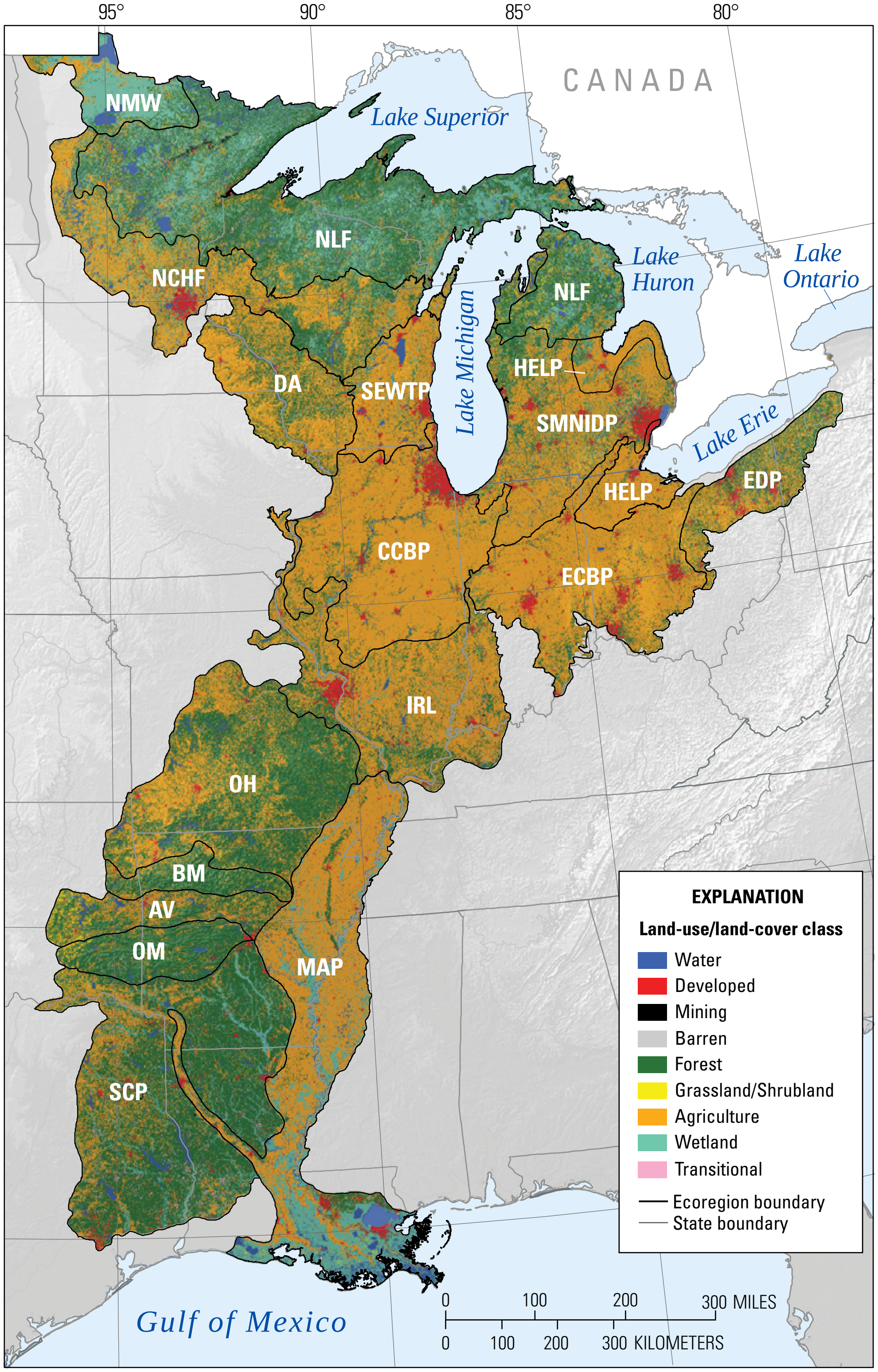


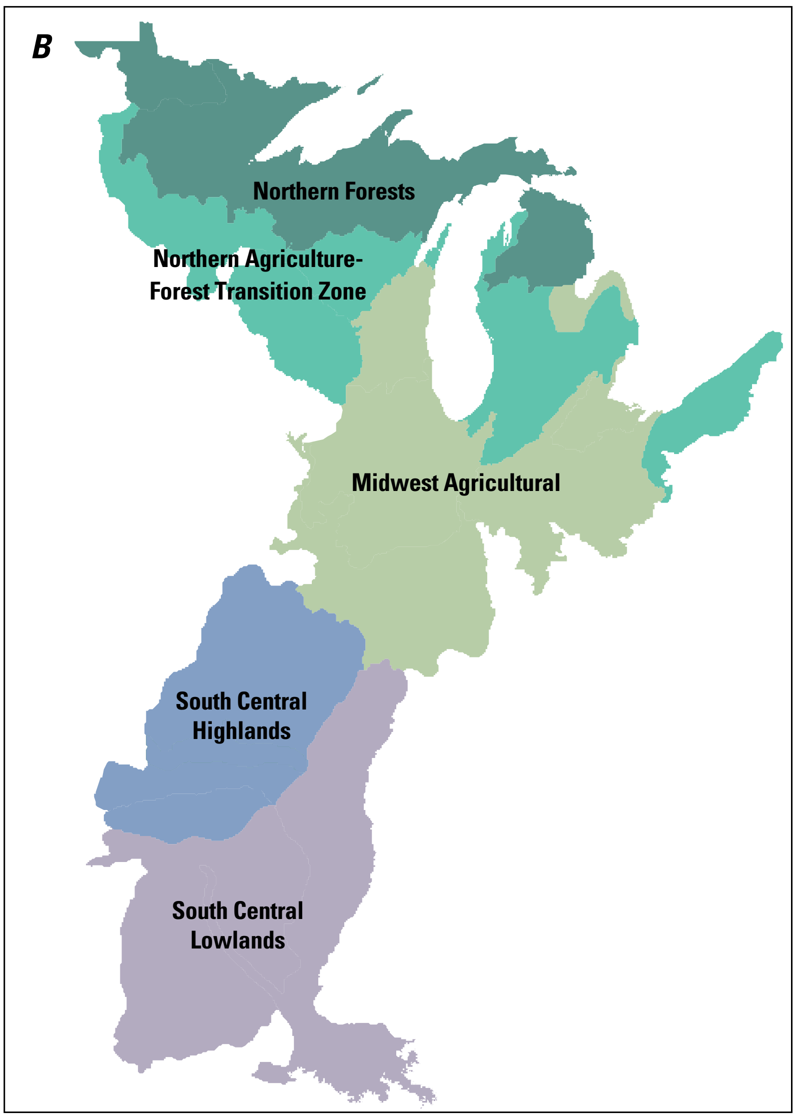
Figure 1. *A*, Map of all 17 ecoregions in Midwest–South Central United States, showing land-use/land-cover classes from 1992 National Land-Cover Database (Vogelmann and others, 2001); note that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. *B*, Map showing five main Midwest–South Central United States ecoregion groups, modified from U.S. Environmental Protection Agency's (2010) Level II Ecoregions for Midwest–South Central United States. Within each ecoregion group, individual ecoregions share many similar physical, biological, and land-use characteristics. *C*, List of five main Midwest–South Central United States ecoregion groups depicted in figure 1*B*; also listed are individual ecoregions included in each ecoregion group, as well as ecoregion abbreviations used in figure 1*A*.

ecoregions have been divided into five main groups, within which the ecoregions share many similar physical, biological, and land-use characteristics: the Northern Forests Ecoregions, the Northern Agriculture-Forest Transition Zone Ecoregions, the Midwest Agricultural Ecoregions, the South Central Highlands Ecoregions, and the South Central Lowlands Ecoregions (fig. 1*B*).

The leading land-cover classes in the Midwest–South Central United States during the study period (1973–2000) were agriculture and forest (table 1). Combined, they made up an estimated 80.5 percent of the region's land area in 1973. By 2000, agriculture decreased by 0.9 percent, and forest decreased by 1.9 percent. Loss of forest land cover was due primarily to timber cutting, which is reflected in the doubling of mechanically disturbed land, from 0.7 percent of the land area in 1973 to 1.7 percent in 2000. Forest also was converted to agricultural and developed land. Loss of farmland largely was the result of conversion to developed land, as well as, to a lesser degree, to grassland/shrubland. Wetland, the third most extensive land-cover class in the region, accounted for 8.9 percent of the area in 1973 but decreased to 8.5 percent by 1992; much of this decrease can be attributed to conversions to water and agricultural land.

The overall spatial change (the percentage of land area that changed at least one time from one land-cover class to another) in the Midwest–South Central United States was 9.9 percent (about 125,420 km^2). About 5.6 percent of the land area changed only once during the study period, whereas 3.3 percent and 0.9 percent changed two and three times, respectively. A small amount of land (0.09 percent) changed four times. Land that changed multiple times most likely reflected the cyclical nature of certain types of change such as forest management, in which timber cutting and regeneration may have occurred on the same land several times between 1973 and 2000.

Although the overall spatial change for the Midwest–South Central United States was 9.9 percent, a few ecoregions had much greater amounts of spatial change. The Ouachita



C

EXPLANATION

Northern Forests Ecoregions
NMW – Northern Minnesota Wetlands Ecoregion
NLF – Northern Lakes and Forests Ecoregion

Northern Agriculture-Forest Transition Zone Ecoregions
NCHF – North Central Hardwood Forests Ecoregion
DA – Driftless Area Ecoregion
SMNIDP – Southern Michigan/Northern Indiana Drift Plains Ecoregion
EDP – Erie Drift Plains Ecoregion

Midwest Agricultural Ecoregions
SEWTP – Southeastern Wisconsin Till Plains Ecoregion
HELP – Huron/Erie Lake Plains Ecoregion
ECBP – Eastern Corn Belt Plains Ecoregion
CCBP – Central Corn Belt Plains Ecoregion
IRL – Interior River Lowland Ecoregion

South Central Highlands Ecoregions
OH – Ozark Highlands Ecoregion
BM – Boston Mountains Ecoregion
AV – Arkansas Valley Ecoregion
OM – Ouachita Mountains Ecoregion

South Central Lowlands Ecoregions
MAP – Mississippi Alluvial Plain Ecoregion
SCP – South Central Plains Ecoregion

Figure 1.—Continued.

Table 1. Areal percentages of land-use/land-cover classes in all 17 Midwest–South Central United States ecoregions for each of five study years (1973, 1980, 1986, 1992, 2000) and corresponding margin-of-error values for 85-percent confidence interval (in brackets).

[Percentages are of total area in all Midwest–South Central United States ecoregions. See appendix 3 for definitions of land-use/land-cover classifications]

Land-use/land-cover class	1973 [margin of error] (% of area)	1980 [margin of error] (% of area)	1986 [margin of error] (% of area)	1992 [margin of error] (% of area)	2000 [margin of error] (% of area)
Water	5.2 [1.2]	5.3 [1.2]	5.5 [1.2]	5.5 [1.2]	5.6 [1.2]
Developed	3.6 [0.5]	3.9 [0.6]	4.2 [0.6]	4.5 [0.6]	5.1 [0.7]
Mechanically disturbed	0.7 [0.1]	1.0 [0.2]	1.4 [0.2]	1.2 [0.2]	1.7 [0.2]
Mining	0.1 [0.1]	0.1 [<0.1]	0.1 [<0.1]	0.2 [<0.1]	0.2 [<0.1]
Barren	<0.1 [<0.1]	<0.1 [<0.1]	<0.1 [<0.1]	<0.1 [<0.1]	<0.1 [<0.1]
Forest	37.5 [1.2]	36.8 [1.1]	36.2 [1.1]	36.1 [1.1]	35.7 [1.1]
Grassland/Shrubland	1.1 [0.2]	1.2 [0.2]	1.4 [0.2]	1.5 [0.2]	1.3 [0.2]
Agriculture	42.9 [1.4]	42.9 [1.4]	42.8 [1.4]	42.5 [1.4]	42.0 [1.4]
Wetland	8.9 [0.9]	8.7 [0.8]	8.6 [0.8]	8.6 [0.8]	8.5 [0.8]
Nonmechanically disturbed	0.0 [<0.1]	<0.1 [<0.1]	0.0 [0.0]	0.0 [<0.1]	<0.1 [<0.1]

Mountains, South Central Plains, and Northern Lakes and Forests Ecoregions each exceeded the region's percentage of overall spatial change (fig. 2; table 2). Most of the change in these ecoregions, which include forested land in Arkansas, Oklahoma, Louisiana, Texas, Minnesota, Wisconsin, and Michigan, was related to timber cutting and regrowth. Ecoregions whose overall spatial change was substantially less than that of the region generally were agricultural ones such as the Southern Michigan/Northern Indiana Drift Plains, Central Corn Belt Plains, and Huron/Erie Lake Plains Ecoregions. The leading land-cover conversion in these ecoregions was agriculture to developed. The ecoregion that experienced the lowest amount of change, the Driftless Area Ecoregion, was predominantly agricultural, having only limited increases in developed land.

Overall spatial change also is evident in the ecoregion groups (fig. 1*B*), which have been subdivided on the basis of their similar land-cover compositions (fig. 1*A*) and topography. Ecoregion groups that, in general, have level to undulating topography and limited amount of forested land (for example, the Midwest Agricultural Ecoregions and the Northern Agriculture-Forest Transition Zone Ecoregions) tend to be dominated by agriculture, and they experienced moderate amounts of change (table 2). Ecoregion groups in which forest was the principal land-cover class, such as the Northern Forests Ecoregions, the South Central Lowlands Ecoregions, and the South Central Highlands Ecoregions, experienced greater amounts of change, nearly double that of the highly agricultural ecoregion groups. In terms of large amounts of land-cover change, the Ouachita Mountains Ecoregion (33.9 percent change), in the South Central Highlands Ecoregions group, and the South Central Plains Ecoregion (27.1 percent change), in the South Central Lowlands Ecoregions group, could have been placed together to form a new ecoregion group, the "Industrial Southern Pine Forestry Ecoregions" group. Although ecoregion groups present an interesting scale concept to envision, the rest of this report concentrates on the greater Midwest–South Central United States region and the 17 ecoregions within it.

No single story of land-use/land-cover change in the Midwest–South Central United States during the 27-year (1973–2000) study period has emerged. Forest harvest (and subsequent regrowth) was the major driver of change in some ecoregions, whereas in others it was continued urbanization of farmland; in still others, economic stimuli and governmental farm policy were the main drivers of change, resulting in the expansion, contraction, or adjustment of agricultural land. For example, in the Mississippi Alluvial Plain Ecoregion, several unique stories of change were observed, including the loss of coastal-marsh wetlands to water and also, to a lesser extent, the clearing of bottomland hardwood forests (forested wetlands) to agricultural land. Although both of these losses were to the wetland land-cover class, they resulted in gains by two different land-cover classes, and they were for different reasons.

Land-use/land-cover change in the Midwest–South Central United States during the 27-year study period can be assessed in several different ways, such as net and gross changes in individual land-cover classes. Net change is the total amount of losses in a land-cover class subtracted from the total amount of gains, a measure of the difference in land cover between two points in time (Loveland and Acevedo, 2006). Gross change is the total area gained and lost in a particular land-cover class (Loveland and Acevedo, 2006). If all land-cover change occurred only one time in the same

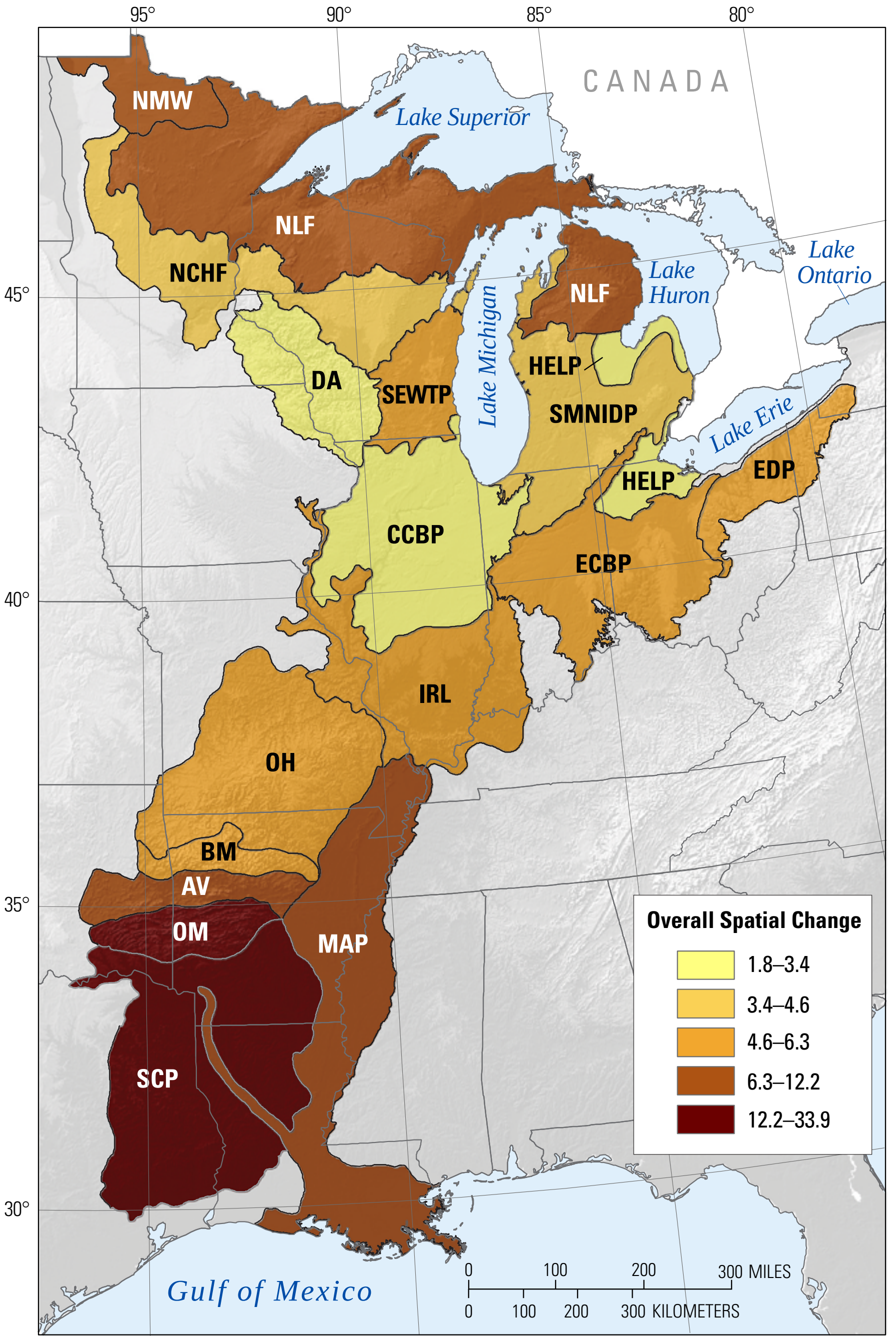


Figure 2. Map showing overall spatial change, as percent of ecoregion area, for each of 17 Midwest–South Central United States ecoregions over entire study period (1973–2000).

Table 2. Overall spatial change in each Midwest–South Central United States ecoregion (in square kilometers and as percent of ecoregion) for entire study period (1973 to 2000) and corresponding margin-of-error values for 85-percent confidence interval (in brackets).

Ecoregion		Ecoregion area (km^2)	Overall spatial change [margin of error]	
			(km^2)	(% of ecoregion)
Northern Forests Ecoregions				
Northern Minnesota Wetlands Ecoregion		24,427	2,003 [562]	8.2 [2.3]
Northern Lakes and Forests Ecoregion		189,889	23,166 [3,988]	12.2 [2.1]
	Totals	214,316	25,169 [4,072]	11.7 [1.9]
Northern Agriculture-Forest Transition Zone Ecoregions				
North Central Hardwood Forests Ecoregion		91,205	4,195 [1,277]	4.6 [1.4]
Driftless Area Ecoregion		47,590	857 [238]	1.8 [0.5]
Southern Michigan/Northern Indiana Drift Plains Ecoregion		73,987	3,107 [666]	4.2 [0.9]
Erie Drift Plains Ecoregion		30,622	1,868 [429]	6.1 [1.4]
	Totals	243,403	10,027 [1,460]	4.1 [0.6]
Midwest Agricultural Ecoregions				
Southeastern Wisconsin Till Plains Ecoregion		30,999	1,767 [403]	5.7 [1.3]
Huron/Erie Lake Plains Ecoregion		27,362	739 [219]	2.7 [0.8]
Eastern Corn Belt Plains Ecoregion		83,533	5,263 [2,255]	6.3 [2.7]
Central Corn Belt Plains Ecoregion		98,794	3,359 [1,186]	3.4 [1.2]
Interior River Lowland Ecoregion		93,272	5,130 [1,399]	5.5 [1.5]
	Totals	333,960	16,257 [3,006]	4.9 [0.9]
South Central Highlands Ecoregions				
Ozark Highlands Ecoregion		108,332	6,392 [758]	5.9 [0.7]
Boston Mountains Ecoregion		17,068	939 [154]	5.5 [0.9]
Arkansas Valley Ecoregion		26,606	2,208 [372]	8.3 [1.4]
Ouachita Mountains Ecoregion		26,506	8,985 [1,378]	33.9 [5.2]
	Totals	178,512	18,524 [1,607]	10.4 [0.9]
South Central Lowlands Ecoregions				
Mississippi Alluvial Plain Ecoregion		141,895	13,338 [3,831]	9.4 [2.7]
South Central Plains Ecoregion		155,520	42,146 [5,288]	27.1 [3.4]
	Totals	297,415	55,484 [6,543]	18.7 [2.2]
All Midwest–South Central United States ecoregions		1,267,606	125,462 [8,873]	9.9 [0.7]

area, then net change and gross change would be the same. But a number of land-cover classes tended to change multiple times in the same area over time. For example, a stand of forest might be cut for timber harvest, then it would be restocked either actively or passively with young trees, and finally it could return to forest conditions, all during two or three time periods. Another example might be an agricultural field that changed land-use classes more than one time and then slowly returned to forest. The difference between gross and net change in a land-cover class in which most change is unidirectional (for example, to developed) tends to be small. The difference between gross and net change is large in land-cover classes in which cyclic or multiple changes affect the status of that land cover (for example, forest). A clearer picture of overall change emerges by examining both gross and net changes (table 3).

The five land-cover classes that had the highest gross spatial change over the entire study period (1973–2000) are as follows:

- Forest, 92,868 km^2 (margin of error, 7,366 km^2)
- Mechanically disturbed, 68,613 km^2 (margin of error, 7,022 km^2)
- Agriculture, 37,241 km^2 (margin of error, 3,193 km^2)
- Grassland/shrubland, 26,560 km^2 (margin of error, 2,882 km^2)
- Developed, 18,793 km^2 (margin of error, 3,046 km^2)

The five land-cover classes that had the largest net areal change (either gains or losses) over the entire study period (1973–2000) are as follows:

- Forest, −23,094 km^2 (margin of error, 3,215 km^2)
- Developed, 18,513 km^2 (margin of error, 3,052 km^2)

Table 3. Gross spatial changes and net areal changes in land-use/land-cover classes in all 17 Midwest–South Central United States ecoregions for entire study period (1973 to 2000) and corresponding margin-of-error values for 85-percent confidence (in brackets).

[Percentages are of total area in all Midwest–South Central United States ecoregions. See appendix 3 for definitions of land-use/land-cover classifications]

Land-use/land-cover class	Gross spatial change (1973–2000) [margin of error]		Net areal change (1973–2000) [margin of error]	
	(km^2)	(% of area)	(km^2)	(% change)
Water	9,699 [982]	0.8 [0.1]	4,651 [2,881]	7.1
Developed	18,793 [3,046]	1.5 [0.2]	18,513 [3,052]	40.6
Mechanically disturbed	68,613 [7,022]	5.4 [0.6]	12,187 [2,517]	134.3
Mining	2,304 [613]	0.2 [<0.1]	750 [463]	48.8
Barren	593 [231]	<0.1 [<0.1]	−117 [105]	−22.0
Forest	92,868 [7,366]	7.3 [0.6]	−23,094 [3,215]	−4.9
Grassland/Shrubland	26,560 [2,882]	2.1 [0.2]	2,930 [1,222]	21.7
Agriculture	37,241 [3,193]	2.9 [0.3]	−11,706 [3,124]	−2.2
Wetland	12,496 [1,367]	1.0 [0.1]	−4,208 [2,817]	−3.8
Nonmechanically disturbed	684 [907]	0.1 [0.1]	94 [122]	0.0

- Mechanically disturbed, 12,187 km^2 (margin of error, 2,517 km^2)
- Agriculture, −11,706 km^2 (margin of error, 3,124 km^2)
- Water, 4,651 km^2 (margin of error, 2,881 km^2)

A summary of net areal change in each land-cover class for each time period can be found in table 4. Discussions of individual land-cover classes follow.

Forest Land-Cover Class

Forest experienced the largest amount of change of any land-cover class in the Midwest–South Central United States during the 27-year study period. Forest decreased by 23,094 km^2 between 1973 and 2000, a 4.9 percent decrease (table 3). The gross change in forest was much higher, at 92,868 km^2 (table 3). Only two ecoregions, the Driftless Area Ecoregion and the Southeastern Wisconsin Till Plains Ecoregion, had almost the same amounts of forest land cover in 2000 as in 1973. The other 15 Midwest–South Central United States ecoregions all had less forest land cover (as an areal percentage) in 2000 than in 1973.

The story of the loss of forested land in the Midwest–South Central United States ecoregions is more complex than it may appear to be. The two ecoregions that had the greatest percentage of forest decline, the Ouachita Mountains Ecoregion (−5.7 percent) and the South Central Plains Ecoregion (−4.9 percent), also were the forest-harvest areas that practiced the most cyclic silviculture methods. Most of the land that was mapped as having been logged (mechanically disturbed land-cover class) in 2000 most likely will revert to forest land cover in a short time span, perhaps five or six years in the future. Decreases in forest land cover in the primary wood-harvesting ecoregions that were mapped in 2000 indicate that timber cutting had intensified, and the amount of area affected had grown, when compared to earlier dates in the study period.

Forest was also lost to other major land-cover classes during the study period. Forest had a net loss to agriculture across all four time periods, but the loss was most pronounced between 1973 and 1986 when contemporary agricultural land use still was generally expanding in several ecoregions, such as the Ozark Highlands Ecoregion. The net gain in agriculture from forest in the Midwest–South Central United States (an estimated 5,498 km^2) may represent a more permanent loss of forested land, but, if land uses change again, passive or active afforestation may occur on this agricultural land, and it again may return to forest. Conversion of forest to developed (an estimated 4,531 km^2) was a permanent loss because of the unidirectional nature of this type of change.

Wood harvesting (forest to mechanically disturbed; figs. 3*A*,*B*) was the leading type of land-cover change in the Midwest–South Central United States during the study period, at an estimated 62,212 km^2. Most of this type of change occurred only one time on the same land, but in the two ecoregions that were heavily engaged as part of industrial southern-pine region (the South Central Plains and Ouachita Mountains Ecoregions), some areas were harvested twice during the study period; thus, the actual footprint of land impacted was less than the overall area that was cut. Other leading ecoregions for forest harvest include the Northern Lakes and Forests, Mississippi Alluvial Plain, and

Table 4. Net areal changes in land-use/land-cover classes in all 17 Midwest–South Central United States ecoregions during each of four time periods and corresponding margin-of-error values for 85-percent confidence (in brackets).

[See appendix 3 for definitions of land-use/land-cover classifications]

Land-use/land-cover class	Net change [margin of error] (km²) 1973–1980	1980–1986	1986–1992	1992–2000
Water	1,915 [1,823]	1,362 [775]	989 [420]	385 [642]
Developed	3,677 [861]	3,454 [573]	3,821 [662]	7,562 [1,554]
Mechanically disturbed	3,188 [2,041]	4,841 [2,157]	−1,506 [1,900]	5,664 [1,931]
Mining	48 [101]	98 [107]	292 [226]	312 [395]
Barren	−44 [47]	−58 [70]	−81 [89]	66 [81]
Forest	−9,070 [2,231]	−8,512 [2,230]	−982 [2,006]	−4,530 [2,355]
Grassland/Shrubland	1,801 [767]	1,982 [1,124]	1,535 [1,236]	−2,388 [1,088]
Agriculture	103 [1,058]	−1,079 [736]	−4,000 [857]	−6,730 [1,494]
Wetland	−2,233 [1,784]	−1,476 [836]	−109 [431]	−389 [697]
Nonmechanically disturbed	616 [881]	−612 [881]	42 [66]	48 [139]

Northern Minnesota Wetlands Ecoregions. Because of its much larger size, the Northern Lakes and Forests Ecoregion actually had more forest land harvested than did the Ouachita Mountains Ecoregion, but the cutting intensity was less than one-half of that of the Ouachita Mountains Ecoregion. Mechanically disturbed land-cover class was one to three percent of the Northern Lakes and Forests Ecoregion during the study period, whereas it was 4 to nearly 10 percent of the Ouachita Mountains Ecoregion during that same time period. The primary tree species targeted for "even-age management" harvesting (that is, clearcutting) in the southern Midwest–South Central United States ecoregions include loblolly and shortleaf pine (*Pinus taeda* and *Pinus echinata*, respectively) (see, for example, Bentley and others, 2002) and, in the northern Midwest–South Central United States ecoregions, aspen (*Populus tremuloides*, *Populus grandidentata*), birch (*Betula* spp.), and various conifer species (*Pinus* spp., *Picea* spp., *Abies balsamea*, *Tsuga canadensis*, *Larix laricina*) (see, for example, Reading and Krantz, 2002).

Forest regrowth directly from harvest (mechanically disturbed to forest) was the second leading type of land-cover change during the study period, at an estimated 35,426 km². Most of this rapid forest regeneration occurred in the southern ecoregions, where suitable tree-growing sites were planted with pine; it took place in many aspen-growing areas of the northern ecoregions as well. Aspen, which regenerates from its root stocks, quickly regrows after cutting. Aspen had not been considered as a major commercial tree species until the World War II era when it was determined that it could be pulped for paper production; more recently, aspen has been used as a component of oriented strand board construction panels (Lamb, 1967; Structural Board Association, 1999).

Figure 3. Recently harvested forested areas in Midwest–South Central United States (forest to mechanically disturbed land-use/land-cover change). *A*, Close-up view of clearcut area in Ouachita Mountains Ecoregion. *B*, Clearcut hillside in distance in Northern Lakes and Forests Ecoregion.

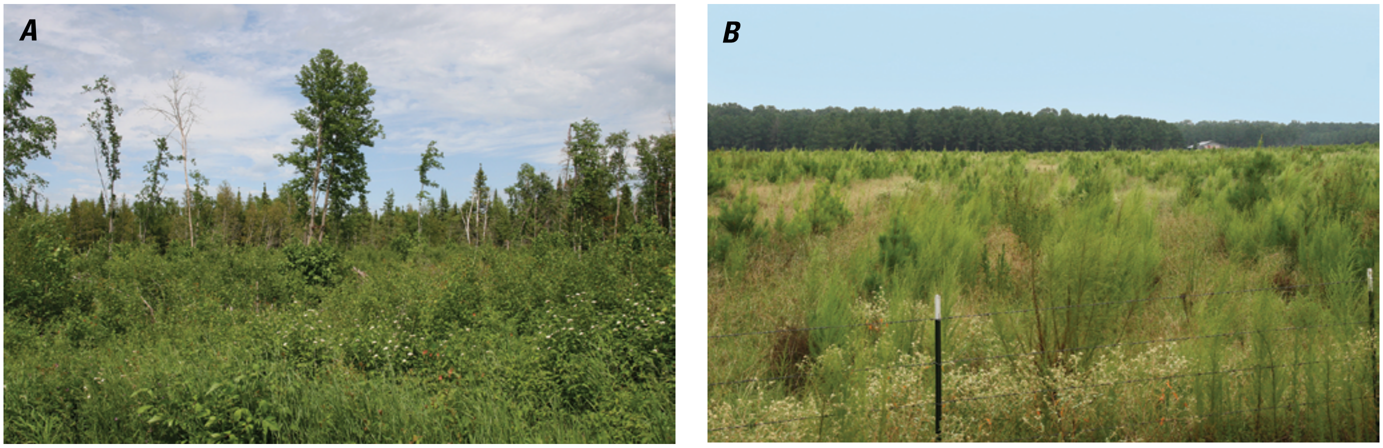


Figure 4. Forest regrowth after harvesting, leaving intermediate landscape of young trees, in Midwest–South Central United States. *A*, Regenerating stand of aspen in Northern Minnesota Wetlands Ecoregion. *B*, Young pines in grassy field in South Central Plains Ecoregion.

Another estimated 14,577 km^2 of harvested forest reverted to grassland/shrubland (mechanically disturbed to grassland/shrubland; figs. 4*A*,*B*). The Northern Lakes and Forests Ecoregion, probably influenced by a shorter growing season, was the leader in this type of land-cover change (an estimated 6,140 km^2), but the South Central Plains and Ouachita Mountains Ecoregions also experienced substantial amounts of this type of conversion. Less optimal site conditions, such as soils that were less suitable for tree growth, may be reason for slower forest regeneration in certain areas.

Former agricultural land also became forested land in the Midwest–South Central United States during the study period. A rapid conversion from agriculture to forest affected an estimated 4,359 km^2, the leading ecoregion being the South Central Plains Ecoregion (an estimated 1,895 km^2), followed distantly by the Mississippi Alluvial Plain and North Central Hardwood Forests Ecoregions. A mixture of both active and passive afforestation on suitable tree-growing sites (the result of land uses changing away from farming and ranching) most likely was the reason behind this type of change. Agricultural land also could change to forested land through several steps that include an intermediate grassland/shrubland stage. It is difficult to determine how much agricultural land went through an intermediate step before becoming forested land because the amount of grassland/shrubland-to-forest change also includes land that had changed from mechanically disturbed to grassland/shrubland at an earlier date. An estimated 16,233 km^2 of land that converted from grassland/shrubland to forest during the study period came from harvested forest land that regenerated more slowly and also former agricultural land. The leading ecoregions for this type of land-cover change included the South Central Plains Ecoregion (an estimated 5,201 km^2) and the Northern Lakes and Forests Ecoregion (5,030 km^2).

Grassland/shrubland was the only land-cover class that had a net loss to forest. Almost all other land-cover classes had net gains from forest (fig. 5), as indicated by the overall net decrease in the forest land-cover class during the study period.

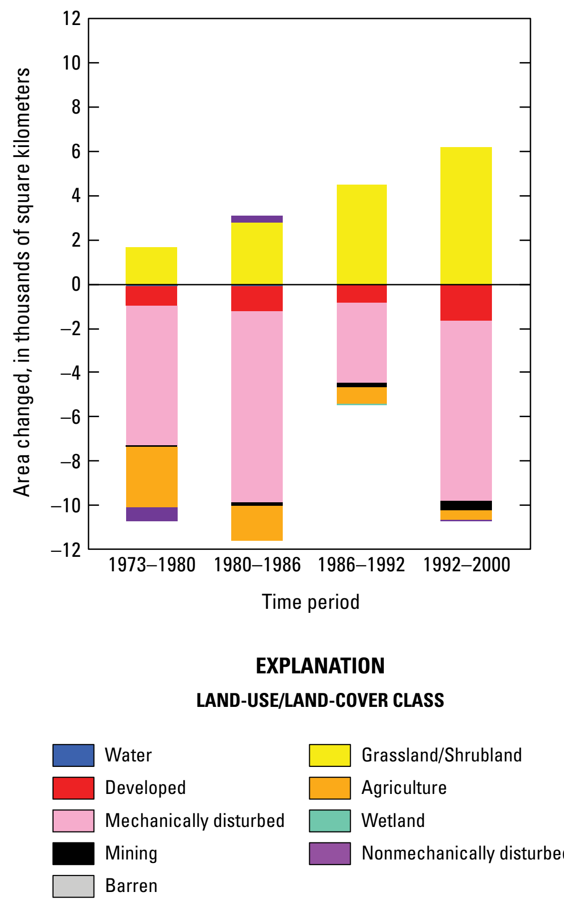


Figure 5. Gross change (area gained from, and lost to, other land-cover classes) in forest land-cover class in all 17 Midwest–South Central United States ecoregions over entire study period (1973–2000). Colored bars above zero axis indicate land-cover classes that lost area to forest and amounts of area lost, whereas colored bars below zero axis indicate land-cover classes that gained area from forest and amounts of area gained.

Agriculture Land-Cover Class

Agriculture land cover played a leading role in shaping the landscape in the Midwest–South Central United States between 1973 and 2000 (figs. 6*A*,*B*,*C*). Although agricultural land primarily was being lost to developed land, a small percent of the region's agricultural land was being converted to grassland/shrubland. The primary gain in the agriculture land-cover class in the region was caused by forested land being cleared for agricultural expansion.

Although the trend of agricultural land losing to developed land (figs. 7*A*,*B*) was seen in every time period, the greatest amount of this type of change occurred between 1992 and 2000, possibly owing to the overall population increase of major metropolitan areas. The ecoregions whose leading land-cover change was agriculture to developed included the Eastern Corn Belt Plains, Central Corn Belt Plains, and North Central Hardwood Forests Ecoregions. The driving force behind the increase in developed land in the Eastern Corn Belt Plains and Central Corn Belt Plains Ecoregions likely was related to the expansion of metropolitan areas such as Indianapolis, Indiana, and Chicago, Illinois. In the Northern Central Hardwood Forests Ecoregion, upscale exurban housing became more abundant on land that previously was agricultural because of growth in and around the Minneapolis–Saint Paul, Minnesota, area. The conversion of agricultural land to developed land, seen more commonly in the northern ecoregions of the Midwest–South Central United States than in the southern ecoregions, was primarily due to the size of the metropolitan areas. Large-scale metropolitan areas were fewer south of the Saint Louis, Missouri, area, and much of the gain in developed land in the southern ecoregions of the Midwest–South Central United States was accompanied by a loss in forested land.

Gains in agricultural land primarily resulted from the clearing of forests (fig. 8). The forest-to-agriculture conversion was one of the top ten most common conversions in the Midwest–South Central United States in each time period. The largest gains in agriculture occurred in the South Central Highlands Ecoregions group, an area commonly referred to as "the Ozarks." The ecoregions that gained the most agricultural land during the study period include the Ozark Highlands, Ouachita Mountains, and Boston Mountains Ecoregions, where cattle, poultry, and hog farms were the principal source of agricultural productivity (figs. 9*A*,*B*).

Although the underlying drivers and consequences of agricultural land-cover change vary geographically, socioeconomic influences can be considered the principal underpinning for regional change. In the early 1970s, socioeconomic influences helped to create a "boom" atmosphere in agriculture. This agriculture boom resulted in the continually increasing values of commodities in ecoregions such as the Arkansas Valley Ecoregion (Robert Coats, University of Arkansas, oral commun., 2011; see also, Demissie, 1986). Additionally, net farm incomes in areas such as in the South Central Highlands Ecoregions group increased significantly owing to increased domestic prices and also to growth in export markets (Robert

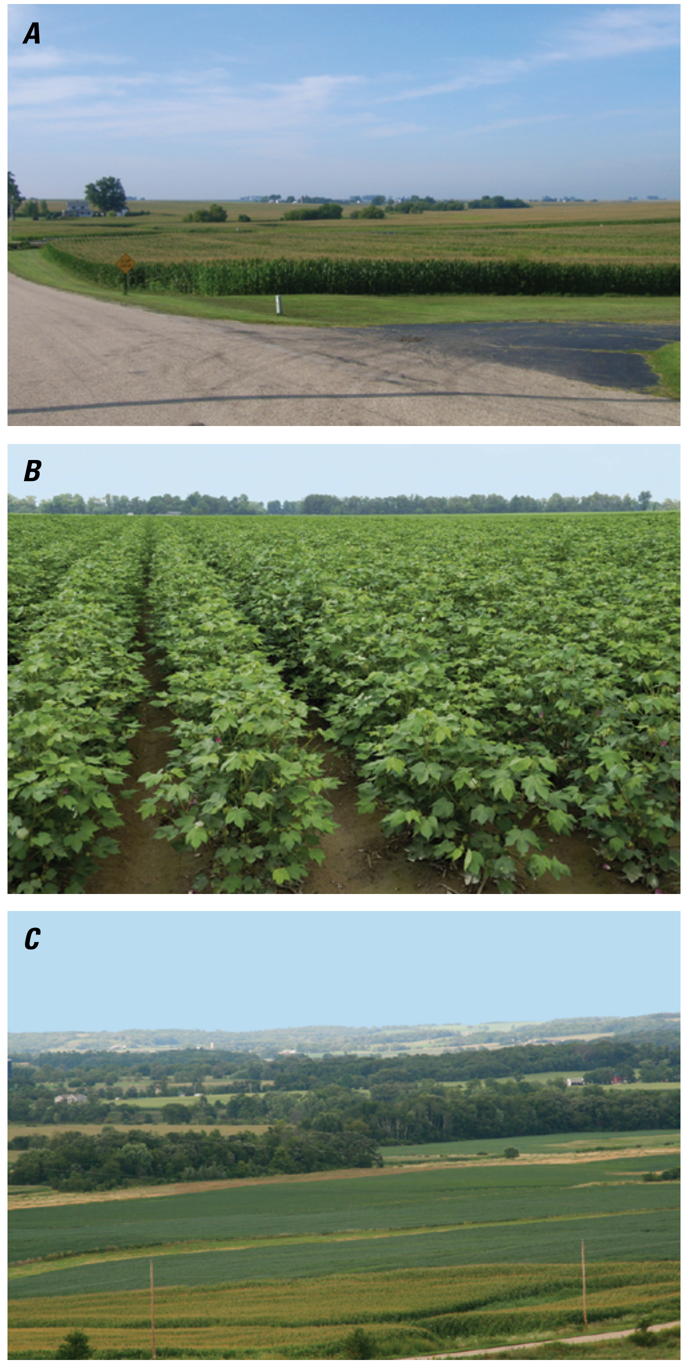


Figure 6. Agricultural areas in Midwest–South Central United States. Nearly level land and deep soils produce copious amounts of row crops such as corn, in Central Corn Belt Plains Ecoregion (*A*), and cotton, in Mississippi Alluvial Plain Ecoregion (*B*). Slightly rolling topography in Southeastern Wisconsin Till Plains Ecoregion (*C*) is more varied but still highly agricultural.

Coats, University of Arkansas, oral commun., 2011; see also, Demissie, 1986). Overall, agricultural expansion early in the study period in the Midwest–South Central United States was helped primarily by the availability of abundant credit from various sources, as well as high inflation rates and low interest rates on loans, the latter of which increased greatly by the end of the 1970s. Indeed, the greatest amount of area converted between 1973 and 1980 was from forest to agriculture.

The agriculture boom was short-lived, and, by 1979, the Federal Reserve was adopting changes in monetary policy that would have a particularly severe impact on agriculture. In the early 1980s, economic conditions began to reverse, and, within a few years, farm prices fell, inflation slowed, and the demand for agricultural land declined, all while export markets declined and problems with farm lenders increased. This combination of factors sent asset values plummeting. Nationally, the value of farm assets declined about $300 billion (30 percent) between 1981 and 1987 (Barnett, 2000); however, in some areas such as the Midwest–South Central United States, the situation was much worse. Land values in the Eastern Corn Belt Plains and Central Corn Belt Plains Ecoregions fell by about 50 percent in nominal terms (Barnett, 2000). The percentage of land that converted to agriculture decreased significantly after the period between 1973 and 1980. It was at about this time that the Conservation Reserve Program (CRP) took effect. Although the agriculture-to-grassland/shrubland conversion was not a significant story in the larger Midwest–South Central United States region, effects of both the CRP and overall farmland

Figure 7. Interface between developed and agricultural areas in Midwest–South Central United States (agriculture to developed land-use/land-cover change). *A*, Edge of new residential subdivision abutting field still in agricultural production, in Central Corn Belt Plains Ecoregion. *B*, Aerial photograph of same area as in *A*, showing juxtaposition of different land-use/land-cover classes (both images taken in 2009).

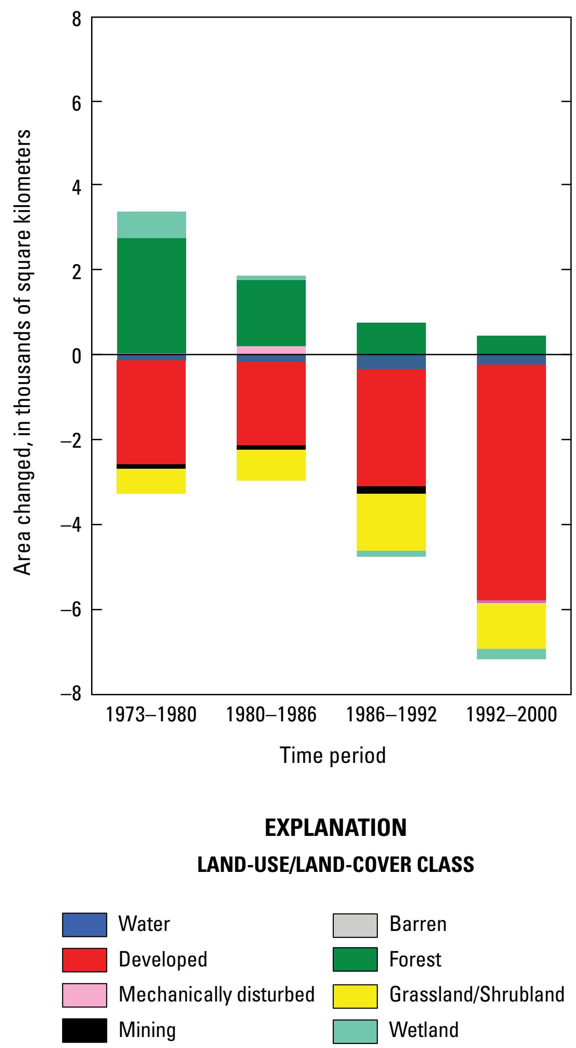


Figure 8. Gross change (area gained from, and lost to, other land-cover classes) in agriculture land-cover class in all 17 Midwest–South Central United States ecoregions over entire study period (1973–2000). Colored bars above zero axis indicate land-cover classes that lost area to agriculture and amounts of area lost, whereas colored bars below zero axis indicate land-cover classes that gained area from agriculture and amounts of area gained.

abandonment are evident in certain ecoregions such as the Eastern Corn Belt Plains and Ozark Highlands Ecoregions.

As the rates of conversion from forest to agriculture slowed, the rates of agriculture-to-developed conversion began to increase. The socioeconomic implications of the conversion from agricultural land to developed land vary from ecoregion to ecoregion, but, overall, land values for developed land uses typically exceed those for rural land uses (Alig and others, 2004). For many landowners, the trend toward increased development potentially can increase their net worth, allowing them to either borrow more to expand their operations or sell their land for capital gains (Alig and others, 2004). Development nearby also can provide off-farm job opportunities that, for the average farm household, mean earning more away from the farm than on it (Ahearn and others, 1993; Alig and others, 2004). As with any socioeconomic driver, however, the loss of agricultural land to developed land can alter ecosystems' characteristics such as water quality and wildlife habitat, as well as affect farm sustainability (see, for example, Brown and others, 2009; U.S. Environmental Protection Agency, 2011).

Figure 9. Agricultural areas in South Central Highlands Ecoregions group. *A*, Poultry barns (confined-animal-feeding operations) on edge of forest in Boston Mountains Ecoregion. *B*, Cattle grazing on pastureland next to wooded area in Ouachita Mountains Ecoregion.

Developed Land-Cover Class

The developed land-cover class consists of built-up land and also its supporting infrastructure, which includes roads, transmission lines, power-generating facilities, and water-treatment plants (figs. 10*A*,*B*,*C*,*D*). Highly maintained recreational lands such as athletic fields, parks, golf courses, and ski resorts also are included in the developed land-cover class. At the beginning of the study period (1973), developed lands covered about 3.6 percent of the Midwest–South Central United States region. By 2000, an estimated 5.1 percent of the region was developed, an increase of 42 percent. The largest per-period increase (13 percent) occurred between 1992 and 2000, which was a time of substantial residential expansion (von Hoffmann, 1999). In each period, most newly developed land converted from farmland; the remaining developed land converted from forested land (fig. 11). Once development has taken place, nearly all land remains in a built-up or developed state.

Development in the Midwest–South Central United States region occurred primarily by the expansion of existing metropolitan areas, and increased suburban and exurban growth resulted in a larger urban footprint for the region during the study period. Exurban areas are areas near the fringe of a large urban area that have low density and high population growth; at least 20 percent of their residents commute to an urbanized area, and at least 20 percent of their residents live outside of municipal boundaries (Berube and others, 2006). The Midwest–South Central United States region also was characterized, however, by the growth of urban centers or micropolitan areas (that is, areas that have populations of at least 10,000 but less than 50,000), which function independently of metropolitan areas.

The largest (by a considerable amount) increase in developed land occurred in Midwest–South Central United States ecoregions that are predominately agricultural but also include large commercial and industrial cities. As would be expected, among the most common conversions in these ecoregions was from farmland to developed land, and this was the fifth most common conversion in the Midwest–South Central United States during the 27-year study period (1973–2000). These conversions took place mostly on agricultural land near the fringes of existing metropolitan areas, in the form of medium- or low-density residential and commercial development. Notable examples include metropolitan Chicago, Illinois; Minneapolis and Saint Paul, Minnesota; Detroit, Michigan; Indianapolis, Indiana; Columbus, Ohio; and Saint Louis, Missouri. In each of these metropolitan areas, many suburban and exurban counties grew at rates that range from about 30 to over 200 percent during the 27-year study period. In the Central Corn Belt Plains Ecoregion, which had among the largest amounts of land that converted from agriculture to developed, three of Chicago's suburban counties had population increases of greater than 100 percent between 1970 and 2000 (U.S. Census Bureau, 1970–2000 [various years]). The two central counties of the Minneapolis–Saint

Paul metropolitan region, located within the North Central Hardwood Forests Ecoregion, were ringed by eight counties that had population increases of 93 to 251 percent. The Saint Louis area, in the Interior River Lowland Ecoregion, had one suburban county and two exurban counties that grew by 116 to 205 percent between 1970 and 2000 (U.S. Census Bureau, 1970–2000 [various years]). In each of these expanding metropolitan areas, lower density settlement patterns have resulted in a greater amount of developed land per capita in outlying areas as compared to central cities.

Some of the more recent development in the Midwest–South Central United States has occurred in exurban counties. For example, Livingston County, Michigan, which is within commuting distance of Detroit, Lansing, and Ann Arbor, Michigan, increased in population by 35.7 percent between 1990 and 2000, and it increased by 166.2 percent between 1970 and 2000 (U.S. Census Bureau, 1970–2000 [various years]). Saint Tammany Parish, Louisiana, located on the north shore of Lake Pontchartrain across from New Orleans, Louisiana, grew by 32.3 percent between 1990 and 2000 and by 200.8 percent during the entire 27-year study period. Residents of exurban areas are attracted to the amenities of rural living, and their communities are characterized by low-density housing that often is intermingled with farmland, forest, water, and wetlands. More land per capita is converted to developed land cover in exurban areas because their density of development is substantially lower than that of suburban areas.

At the same time that suburban and exurban areas were growing in population and construction of transportation infrastructure, housing, schools, hospitals, and commercial establishments were increasing to accommodate that growth, many central cities were losing population. For example, Saint Louis lost 44 percent of its population during the 27-year study period, and Cleveland, Detroit, and Chicago lost 36 percent, 32 percent, and 14 percent, respectively. In some instances, the large-scale loss of population signaled the decline or disappearance of churches, schools, retail establishments, and viable neighborhoods, as well as substantial losses to the tax base.

Development in the Midwest–South Central United States did not always occur only in or near large metropolitan areas but, rather, also took place in micropolitan areas and adjacent counties, which are socially and economically integrated with large urban cores (U.S. Office of Management and Budget, 2003). By 2003, about 10.3 percent of the United

Figure 10. Developed areas in Midwest–South Central United States. *A*, New, large-scale residential area and golf course on north side of Cincinnati, Ohio, metropolitan area, in Eastern Corn Belt Plains Ecoregion. *B*, Manufacturing plant on outskirts of Lafayette, Louisiana, in Mississippi Alluvial Plain Ecoregion. *C*, World headquarters of major automobile-manufacturing corporation, in Southern Michigan/Northern Indiana Drift Plains Ecoregion. *D*, Boat launch and parking area, in Northern Minnesota Wetlands Ecoregion.

States population lived in micropolitan areas, whereas about 83.0 percent resided in metropolitan areas (Mackun, 2005). The largest micropolitan areas were generally the fastest growing, as indicated by the percentage of population change between 1990 and 2000 (Mackun, 2005). Among the most rapidly growing micropolitan areas in the Midwest–South Central United States was the Traverse City, Michigan, area, which is located in the Northern Lakes and Forests Ecoregion. Traverse City had a 23.3 percent increase in population between 1990 and 2000, and it also experienced large increases throughout the entire 27-year study period, owing to the demand for resort and second-home development. Other high-growth micropolitan areas include Brainerd, Minnesota, also within the Northern Lakes and Forests Ecoregion, and Branson, Missouri, in the Ozark Highlands Ecoregion.

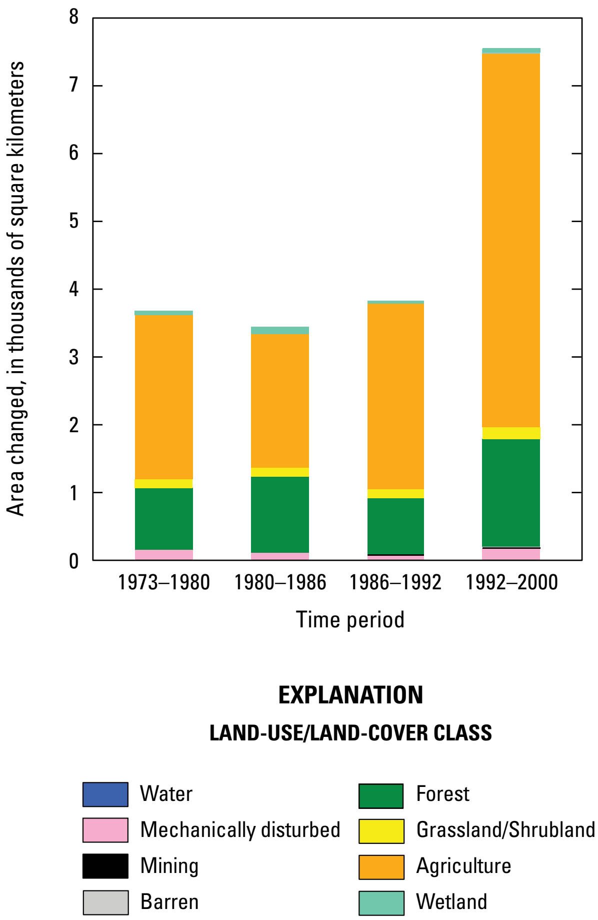


Figure 11. Estimated area gained in developed land-cover class from other land-cover classes in all 17 Midwest–South Central United States ecoregions over entire study period (1973–2000). Colored bars indicate land-cover classes that lost area to developed and amounts of area lost.

Transitional Land-Cover Classes

The transitional land-cover classes—mechanically disturbed, nonmechanically disturbed, and, to some degree, grassland/shrubland—represent transitional stages of land-cover/land-use change in the Midwest–South Central United States. During the 27-year study period, the mechanically disturbed and nonmechanically disturbed land-cover classes almost never persisted longer than one time period; however, agriculture or forest that converted to grassland/shrubland before converting to (usually) forest may have persisted in several time periods. Transitional land-cover classes, although the least extensive in areal percentage at any one time, cumulatively had a substantial effect on land change, especially land-cover change, in the Midwest–South Central United States.

Although the mechanically disturbed land-cover class never accounted for more than two percent of the Midwest–South Central United States region at any one time (table 1), the conversion of forest to mechanically disturbed was the leading type of change, affecting 62,212 km^2; however, some areas were cut twice during the 27-year study period, and, thus, the actual amount of land that was harvested was smaller. The amount of mechanically disturbed land as a percentage of land-cover composition grew over time, the last three study dates (1986, 1992, 2000) having more than the first two (1973, 1980). The areal percentage of mechanically disturbed land in 2000 was more than twice as much as that in 1973 (table 1).

Land that has been mechanically disturbed by wood harvesting could either regenerate directly back to forest by the next time period, or it could experience a slower regeneration, converting to grassland/shrubland before being classified as forest again. The latter is illustrated by the conversion from mechanically disturbed to grassland/shrubland, the fourth leading type of change in the Midwest–South Central United States, at an estimated 14,577 km^2. Agricultural deintensification, farmland abandonment, or land idled for more than one season was another source of the transitory or semitransitory grassland/shrubland land-cover class (land enrolled in the Conservation Reserve Program could be considered semitransitory). The conversion from agriculture to grassland/shrubland affected an estimated 5,187 km^2, primarily in the Ozark Highlands, South Central Plains, North Central Hardwood Forests, and Eastern Corn Belt Plains Ecoregions.

The least common transitional land-cover class in the Midwest–South Central United States was nonmechanically disturbed. This land-cover class records forest mortality caused by wildfire, storm damage, or insect devastation. During the 27-year study period, fire likely was the most common cause of this rather infrequent conversion. This type of change was detected primarily in the Northern Lakes and Forests Ecoregion, where certain forest-management practices on public lands took place (for example, allowing wildfires to occur in designated wilderness areas; Drobyshev and others, 2008). Although low-intensity burning is a common forest-management practice in the southern parts of the Midwest–South Central United States, it typically does not cause stand-replacing land-cover change and, thus, is not easily detected using this study's methodology.

Transitional land-cover classes, although small in regional extent at any one time, usually affect substantial amounts of area in particular ecoregions, especially those intensively involved with forestry land use. The physical environmental conditions—for example, surface albedo and surface roughness (Barnes and Roy, 2010), erosion and sedimentation, and biomass—of these transitional land-cover classes also are potentially altered. Environmental impacts that stem from these changing conditions potentially could include adverse effects on water quality and quantity, carbon sources and sinks, wildlife habitat, and biodiversity (Loveland and Acevedo, 2006).

Wetland Land-Cover Class

The wetland land-cover class was the third largest (following agriculture and forest) in the Midwest–South Central United States throughout the study period. The variation in characteristics of wetlands in the region are considerable, ranging from the coastal wetlands and bottomland hardwood forests of the Mississippi Alluvial Plain Ecoregion (and other southern ecoregions) to the inland wetlands such as peatlands in the northern ecoregions of Minnesota, Wisconsin, and Michigan (primarily in the Northern Lakes and Forests Ecoregion). And, although the overall change in the wetland land-cover class was small (an estimated 0.4 percent change, from 8.9 percent in 1973 to 8.5 percent in 2000), change in wetlands is arguably one of the most environmentally and socioeconomically concerning issues in regards to groundwater supply, water quality, floodwater storage, shoreline erosion, and climate change. Two major federal policies designed to protect wetlands—the Wetland Conservation Provisions (also known as "Swampbuster"), which was authorized in the 1985 Farm Bill, and the Wetlands Reserve Program, which was authorized in 1990 (U.S. Department of Agriculture, Natural Resources Conservation Service, 2015)—were initiated during the study period. Although these policies may not have played a large role in wetland gains in the entire Midwest–South Central United States, they likely played a significant role in individual ecoregions.

Wetland loss in the Midwest–South Central United States was related principally to conversions to water and, secondarily, to conversions to agriculture. Both coastal and inland wetland areas were affected by human and natural processes. Human-induced changes in coastal wetlands included building of levees on the Mississippi River, canal dredging, draining of wetlands for agriculture, and modifying drainage patterns, as well as sediment erosion and land subsidence, whereas inland wetlands were affected primarily by ditching and tile draining (U.S. Department of the Interior, 1994; Williams and Cichon, 1994; Prince, 1997; Caffey and Schexnayder, 2003; Morton and others, 2003). Natural variations in wetland extent in the Midwest–South Central United States were the result of sea-level rise, storms, and, to a lesser extent, wetter climatic conditions (Williams and Cichon, 1994).

Most of the wetland-to-water conversion occurred in the Mississippi Alluvial Plain Ecoregion where an estimated 4,367 km^2 of wetland loss (much of it coastal marsh) translated to a 2.6 percent increase in the water land-cover class (figs. 12*A*,*B*). Most of the wetland loss took place in the first time period (1973–1980; table 5), reinforcing the findings of Couvillion and others (2011) that, between 1973 and 2000, coastal-wetland loss in Louisiana was greatest between 1973 and 1985. In the northern wetlands, one of the historically most important land-cover changes was the conversion of

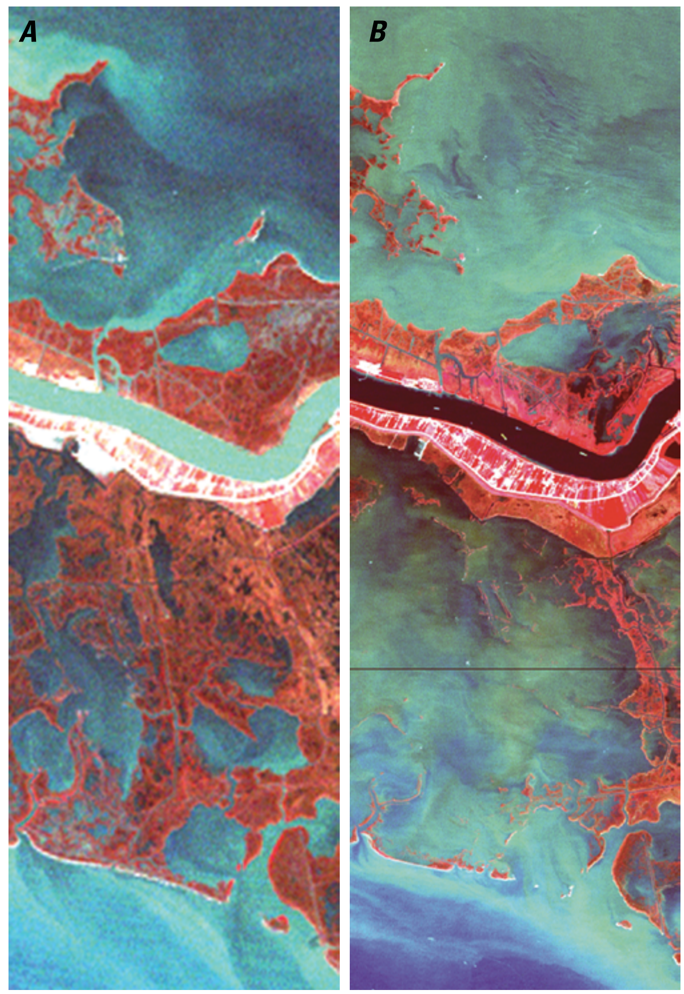


Figure 12. False-color Landsat satellite images of part of lower Mississippi River delta, in Mississippi Alluvial Plain Ecoregion, illustrating loss of wetlands between 1973 (*A*) and 2001 (*B*). Mosaic of coastal marsh (dark red areas) and open water can be seen in lower half of 1973 image (*A*). By 2001 (*B*), most wetland areas have been replaced by open water. Sources of imagery: 1973, Landsat Multispectral Scanner; 2001, Landsat Enhanced Thematic Mapper.

wetlands to agricultural land (Prince, 1997), accomplished by ditching and tile draining. These practices were most active in the northern ecoregions of the Midwest–South Central United States between 1870 and 1920 and also between 1950 and 1980 (Prince, 1997); however, draining for agricultural expansion also was common in the southern wetland areas, primarily in the Mississippi Alluvial Plain Ecoregion. In the Midwest–South Central United States overall, these practices were generally curtailed in the 1980s owing to both the national farm crisis and the introduction of certain agroenvironmental policies, as indicated by a decline in the amount of land that converted from wetland to agriculture in the time periods after 1986 (1986–1992, 1992–2000).

Although gains in the wetland land-cover class were not prevalent in the Midwest–South Central United States, these types of land-cover conversions did occur, and they may have been a result of drivers such as changes in both climate and domestic policies. For example, whereas the water-to-wetland land-cover change may have been related to interannual weather fluctuations, gains in wetlands from agricultural land may have been related to the Wetland Conservation Provisions and the Wetlands Reserve Program. The Wetland Conservation Provisions prohibit program participants from converting remaining wetland areas on their agricultural land to cropland or pastureland unless the amount of wetland area is compensated through wetland mitigation (U.S. Department of Agriculture, Natural Resources Conservation Service, 2015). The Wetlands Reserve Program is a voluntary program that offered landowners the opportunity to protect, restore, and enhance wetland areas on their property. (Note that the current [2015] federal farm bill has replaced the Wetland Reserve Program with Wetland Reserve Easements, although the overall policy has not changed; U.S. Department of Agriculture, Natural Resources Conservation Service, 2015.) Wetland had the greatest net gain from agriculture (an estimated 236 km^2) between 1992 and 2000 when both of these programs had been fully implemented, although probably not all of the agriculture-to-wetland conversion was the result of these polices.

Water Land-Cover Class

The water land-cover class, which accounted for an estimated 5.6 percent of the Midwest–South Central United States in 2000, was relatively stable during the study period, experiencing only a slight increase (0.4 percent). The Midwest–South Central United States region contains some of the largest river systems in the nation, including the Mississippi, the lower Missouri, and the Illinois Rivers. The most significant changes that affected the water land-cover class were associated with the wetland and, to a much lesser extent, agriculture land-cover classes.

The loss of water to wetland, the most common conversion for the water land-cover class, occurred primarily in the Mississippi Alluvial Plain Ecoregion. This type of conversion also took place in the Northern Lakes and Forests Ecoregion where 661 km^2 of water changed to wetland, likely the result of the natural succession of emergent wetland communities, as well as interannual weather fluctuations.

Although the Mississippi Alluvial Plain Ecoregion lost some of its open water to wetlands, it also gained open water from wetlands; however, the area that converted from wetland to water was much more substantial than that of water to wetland. Gains in water may be chiefly related to natural fluctuations of, and changes in, climate and precipitation. Small gains in water that came from agriculture may be traced to the creation of catfish (predominately the channel catfish, *Ictalurus punctatus*) farm ponds, mainly in the Mississippi Alluvial Plain Ecoregion (note that catfish ponds were mapped as the water land-cover class, whereas seasonally inundated rice fields were not).

Grassland/Shrubland Land-Cover Class

The grassland/shrubland land-cover class accounted for about 1.3 percent of the Midwest–South Central United States in 2000. Regionally, no significant gain or loss of grassland/shrubland occurred during the study period; most of the changes in grassland/shrubland are associated with forest-management methods practiced in the region. The amount increased slightly between 1980 (1.2 percent) and 1992 (1.5 percent), which may be a reflection of agricultural-land abandonment owing to both the agroeconomic crisis of the 1980s and implementation of the Conservation Reserve Program.

Other than changes in grassland/shrubland caused by the timber industry, the loss of grassland/shrubland may best be associated with small gains in agriculture; however, this type of conversion was not a leading land-cover change during the study period. The small percentage of grassland/shrubland that converted to agriculture was chiefly in the Ozark Highlands Ecoregion, and it may be the result of increases in cattle and poultry production, which also includes increased haying, more intense use of pasturelands, and (or) the building of structures for confined-animal-feeding operations.

Gains in grassland/shrubland, which did not have a large impact on the Midwest–South Central United States, were chiefly related to losses in agriculture; the largest such gains were seen in the Ozark Highlands, South Central Plains, and Mississippi Alluvial Plain Ecoregions. And, although the gains were smaller, this type of conversion also was common in the North Central Hardwood Forests Ecoregion and in the Southeastern Wisconsin Till Plains Ecoregion. Although the CRP played less of a role in the Midwest–South Central United States than it did in the Great Plains, it can explain some of the conversions from agricultural land to grassland/shrubland seen later in the study period. For example, the CRP may explain the increase of grassland/shrubland seen in the Driftless Area Ecoregion between 1986 and 1992; however, farmland abandonment and changes in agricultural production patterns caused by the farm crisis of the 1980s may have been a larger contributing factor in gains seen in grassland/shrubland.

Mining Land-Cover Class

Mining made up only 0.1 percent of the Midwest–South Central United States at the beginning of the study period (1973). By 2000, the areal percentage in mining had doubled, although it still remained among the least extensive land-cover classes. The South Central Plains and Arkansas Valley Ecoregions both contain areas of petroleum and natural-gas production. Increases in oil and gas extraction accounted for most of the gains in mining during the study period (fig. 13), despite the fact that the processing (refining plants) and distribution (storage) of hydrocarbon products are mapped as developed. Aggregate mining was common in several ecoregions that experienced increased urbanization within the northern parts of the Midwest–South Central United States (for example, the Eastern Corn Belt Plains, Central Corn Belt Plains, Southeastern Wisconsin Till Plains, Southern Michigan/Northern Indiana Drift Plains, and Erie Drift Plains Ecoregions). Significant iron-ore production characterized mining in the Northern Lakes and Forests Ecoregion. Although critical to energy production, manufacturing, and urban growth, mining made up a minimal amount of land area in the Midwest–South Central United States.

Barren Land-Cover Class

Barren land made up the smallest land-cover class in the Midwest–South Central United States during the study period, accounting for a mere 0.03 percent in 2000. Regionally, no significant gains or losses of barren land occurred during the study period, and only minor fluctuations took place between the barren land-cover class and the water and wetland land-cover classes. Such changes likely were due to natural fluctuations in the region's climate and precipitation regimes, especially along large river channels where substantial changes in sand bars could often be mapped.

Figure 13. Natural-gas extraction site in northwestern Louisiana, in South Central Plains Ecoregion. These gas wells typically were one-half hectare to slightly more than one hectare (one to three acres) of mostly open space, needed for movement of equipment around well head and for pipeline infrastructure.

Summary

Land-use/land-cover changes can impact a region in various ways, including water quality and quantity, wildlife habitat change, land-atmosphere interactions, and changes in carbon stocks and cycles. Land change in the Midwest–South Central United States during the study period was chiefly related to forest harvesting and also to increased urbanization, as well as, to a much lesser extent, to wetland loss owing to agricultural expansion in some ecoregions. Intensive and areally substantial forest-management practices led to periodic changes in forest land cover in a number of ecoregions. Increases in developed land usually occurred in the suburban and exurban periphery of already established urban areas, which are concentrated heavily in the industrial parts of the Midwest–South Central United States region. Although the agriculture land-cover class decreased slightly overall in the Midwest–South Central United States region, geographic variability in the agriculture land-cover class was more evident at the ecoregional scale. Early in the study period, southern wetland losses mostly were because of land-use change (for example, the conversion of forested wetlands to agricultural land or the cutting of ship channels through coastal marshland to support oil and natural gas extraction, both of which took place in the Mississippi Alluvial Plain Ecoregion), whereas northern wetlands were affected more by climate variability (interannual weather fluctuations), mainly during the second half of the study period. Although small in overall regional extent at any one time, the transitional land-cover classes (mainly mechanically disturbed and nonmechanically disturbed) provided much of the overall land-cover change in the Midwest–South Central United States.

The stories of land-use/land-cover change and its impact in the Midwest–South Central United States can be better understood at a finer geographical scale. The change of focus from the much larger Midwest–South Central United States region to smaller, more homogenous ecoregions allows specific stories of land-use/land-cover change to emerge. The remaining chapters in this report, which contain summaries of change for each of the 17 individual Midwest–South Central United States ecoregions, document the rates, types, and drivers of late-20th century land-use/land-cover change in the Midwest–South Central United States.

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Northern Forests Ecoregions

Status and Trends of Land Change in the Midwest–South Central United States—1973 to 2000
Edited by Roger F. Auch and Krista A. Karstensen
U.S. Geological Survey Professional Paper 1794–C, 2015

Chapter 1

Northern Minnesota Wetlands Ecoregion

By Kristi L. Sayler

Ecoregion Description

The Northern Minnesota Wetlands Ecoregion is a relatively small ecoregion that covers about 24,427 km^2 (9,431 mi^2) of northern Minnesota along the Canadian border (fig. 1) (Omernik, 1987; Wiken and others, 2011). The ecoregion is bounded by the Northern Lakes and Forests, North Central Hardwood Forests, and Lake Agassiz Plain Ecoregions. The Northern Minnesota Wetlands Ecoregion has a considerable amount of federal, state, and tribal lands in the form of national parks, forests, and wildlife refuges, state forest and game production areas, and Indian reservations. The ecoregion is composed mostly of level marshlands covered by swamp and boreal-forest vegetation. At one time this region was covered by broad glacial lakes, and much of the ecoregion is still covered by standing water (Wiken and others, 2011). During the process of glacial retreat about 10 thousand years ago, the high water table that resulted from the giant glacial lakes saturated the vegetation and created an environment that lacked oxygen, which is needed for aerobic decomposition; thus, instead of decomposing completely, vegetation accumulated in layers to create the one of the largest peatland complexes in North America (Vileisis, 1997).

The landscape of the Northern Minnesota Wetlands Ecoregion is a mosaic of wetlands (fig. 2), water, and forest, with scattered agricultural areas. Three large lakes that remain from the time of the glaciers are within this ecoregion: Lake of the Woods, which covers the northern part of Lake of the Woods County in the northern part of the ecoregion, is a remnant of Glacial Lake Agassiz (Gustafson, 1997); Upper Red Lake and Lower Red Lake, which are in north-central

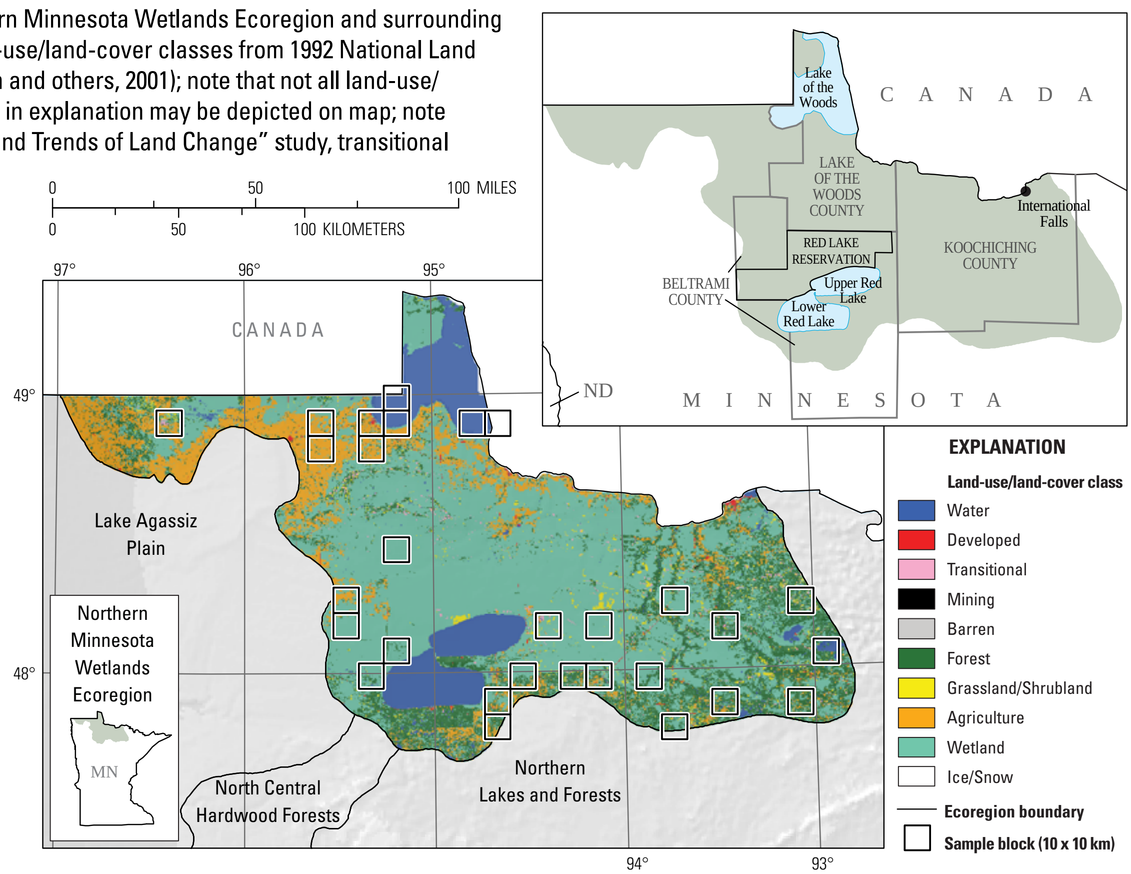

Figure 1. Map of Northern Minnesota Wetlands Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown is part of one Great Plains ecoregion, Lake Agassiz Plain. See appendix 3 for definitions of land-use/land-cover classifications.

Beltrami County, cover part of the Red Lake Reservation. The elevation ranges from 314 to 450 m, with little variation. The ecoregion has a severe, humid, midlatitude continental climate, marked by warm summers and cold winters. The mean annual temperature is about 2°C, with a mean summer temperature of 16°C and a mean winter temperature of -12°C (Wiken and others, 2011). The mean annual precipitation of the ecoregion is 599 mm (24 in.), ranging from 550 to 700 mm (22–28 in.), with most of the precipitation falling during the summer growing season (Wiken and others, 2011).

Forestry is an important land use in the Northern Minnesota Wetlands Ecoregion. By the late 1800s, most of the northern Minnesota forests had been logged, and the state was supplying much of the timber needed for building in the United States (Borchert, 1959). Today, most of the timber harvested in the area is used for pulp and paper mills (fig. 3). The Boise Paper mill in International Falls, Minnesota, which is the largest city in the ecoregion (population in 2000, 6,703; U.S. Census Bureau, 2013), is the city's largest employer.

Agriculture is concentrated in the northwestern part of the Northern Minnesota Wetlands Ecoregion where wetlands have been drained to produce more useable farmland. The major crops are wheat, barley, oats, sunflowers, rye, flax, and corn. Some specialty crops, such as wild rice, bluegrass seed, and seed potatoes, also are grown. In 2000, the land cover of the ecoregion was estimated at about 37 percent forest, 30 percent wetland, 18 percent agriculture, 12 percent water, and 2 percent or less each of grassland/shrubland, mining, and developed.

Figure 2. Mosaic of wetlands and forest, in Beltrami County, Minnesota.

Figure 3. Large forest clearing, in Koochiching County, Minnesota.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Northern Minnesota Wetlands Ecoregion between 1973 and 2000 is estimated at 8.2 percent (table 1). Compared to the other Midwest–South Central United States ecoregions, change in the Northern Minnesota Wetlands Ecoregion was moderate to moderately high (fig. 4): an estimated 3.4 percent of the ecoregion changed once during the study period, and 4.8 percent changed multiple times (table 1). Most areas that changed multiple times showed the different stages of land cover as forests were harvested and regrown, namely forest, mechanically disturbed, and grassland/shrubland. The total change per time period ranged from 2.3 percent of the ecoregion between 1973 and 1980 to 4.3 percent between 1992 and 2000 (table 2). When normalized to account for uneven time periods, the period between 1986 and 1992 had the greatest rate of change, at 0.7 percent per year (table 2; fig. 5).

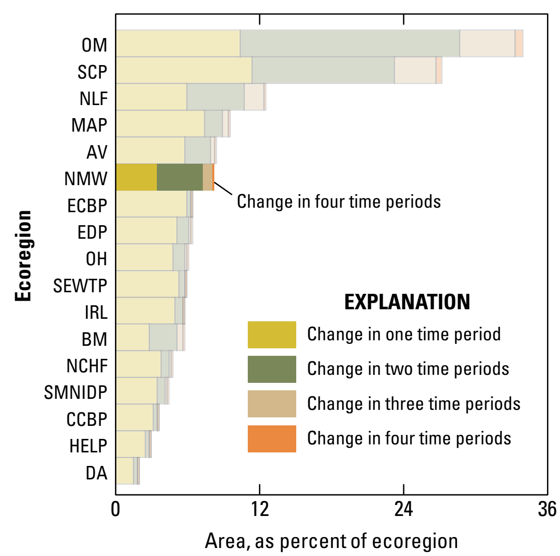

Figure 4. Overall spatial change in Northern Minnesota Wetlands Ecoregion (NMW; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Northern Minnesota Wetlands Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

The forest, mechanically disturbed, and grassland/shrubland land-cover classes changed most during the study period (table 3). Forest had an estimated net decrease of 2.1 percent of the ecoregion area (517 km^2), a 5.4 percent decrease from its 1973 area, with most of the decrease occurring as forest converted to mechanically disturbed (fig. 6). Mechanically disturbed had an estimated net increase of 1.0 percent of the ecoregion area (243 km^2), a more than doubling of the 1973 percentage (fig. 6). Most of the increase in mechanically disturbed land was from conversions from forested land.

The most common land-cover conversion for all time periods between 1973 and 2000 was from forest to mechanically disturbed (table 4). This conversion, as well as the others associated with the timber harvest-and-regrowth cycle, make up most of the top five land-cover conversions and about 75 percent of all the major land-cover changes in the Northern Minnesota Wetlands Ecoregion during the study period (table 4).

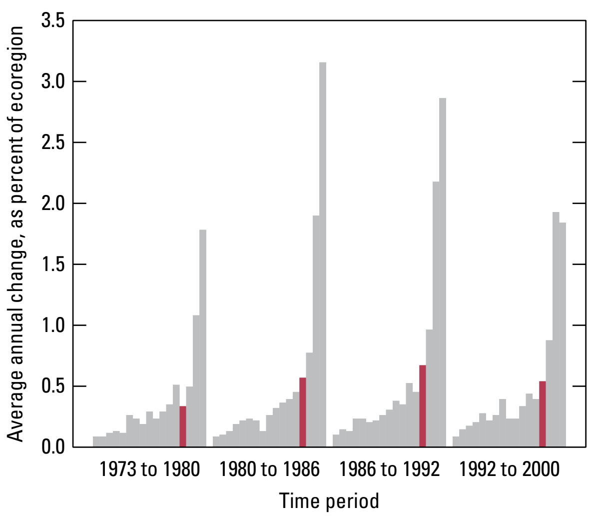

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Northern Minnesota Wetlands Ecoregion are represented by red bars in each time period.

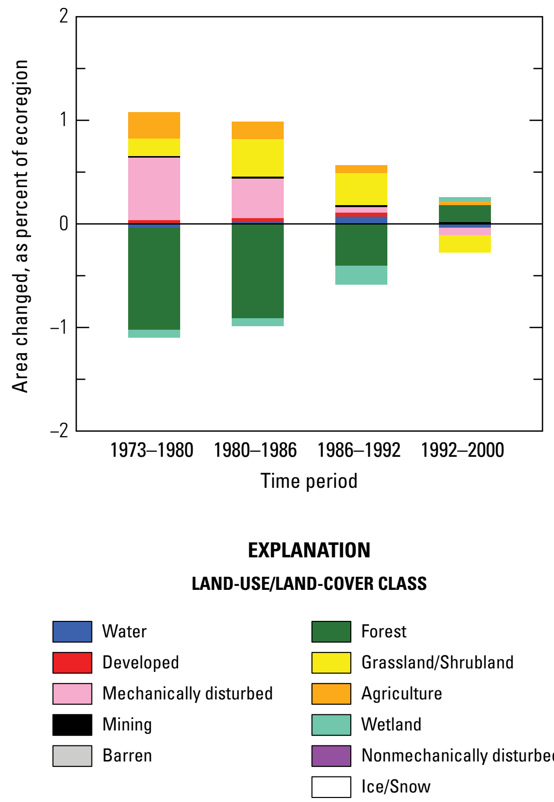

Figure 6. Normalized average net change in Northern Minnesota Wetlands Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Table 1. Percentage of Northern Minnesota Wetlands Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (91.8 percent), whereas 8.2 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	3.4	0.7	2.7	4.1	0.5	13.8
2	3.8	1.3	2.4	5.1	0.9	24.0
3	1.0	0.5	0.5	1.4	0.3	33.2
4	0.0	0.0	0.0	0.0	0.0	37.8
Overall spatial change	8.2	2.3	5.9	10.5	1.6	18.9

Table 2. Raw estimates of change in Northern Minnesota Wetlands Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	2.3	0.9	1.4	3.2	0.6	26.1	0.3
1980–1986	3.4	1.4	2.1	4.8	0.9	27.0	0.6
1986–1992	4.0	1.3	2.7	5.3	0.9	22.1	0.7
1992–2000	4.3	1.3	3.0	5.6	0.9	21.0	0.5
Estimate of change, in square kilometers							
1973–1980	556	215	341	770	145	26.1	79
1980–1986	836	335	501	1,170	226	27.0	139
1986–1992	978	320	657	1,298	216	22.1	163
1992–2000	1,047	326	721	1,372	220	21.0	131

Table 3. Estimated area (and margin of error) of each land-cover class in Northern Minnesota Wetlands Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Nonmechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	11.6	7.2	0.3	0.2	0.6	0.2	0.0	0.0	0.0	0.0	38.7	6.3	1.2	0.9	17.5	6.5	30.2	6.3	0.0	0.0
1980	11.5	7.1	0.3	0.2	1.2	0.6	0.0	0.0	0.0	0.0	37.7	6.1	1.3	0.8	17.8	6.5	30.1	6.3	0.0	0.0
1986	11.5	7.1	0.3	0.3	1.6	0.7	0.1	0.0	0.0	0.0	36.8	6.0	1.7	0.9	17.9	6.5	30.0	6.3	0.0	0.0
1992	11.6	7.1	0.4	0.3	1.6	0.6	0.1	0.0	0.0	0.0	36.4	6.0	2.0	0.9	18.0	6.5	29.8	6.3	0.0	0.0
2000	11.6	7.1	0.4	0.3	1.6	0.5	0.1	0.0	0.0	0.0	36.6	6.0	1.8	0.9	18.1	6.5	29.9	6.3	0.0	0.0
Net change	0.0	0.1	0.1	0.1	1.0	0.4	0.0	0.0	0.0	0.0	–2.1	0.6	0.7	0.4	0.5	0.3	–0.3	0.2	0.0	0.0
Gross change	0.3	0.1	0.1	0.1	3.3	1.1	0.0	0.0	0.0	0.0	4.0	1.2	1.6	0.6	0.8	0.3	1.0	0.3	0.0	0.0
Area, in square kilometers																				
1973	2,822	1,751	66	52	136	59	9	4	7	9	9,460	1,548	282	210	4,280	1,578	7,367	1,550	0	0
1980	2,815	1,746	74	59	287	152	11	4	7	9	9,219	1,501	325	205	4,342	1,590	7,348	1,547	0	0
1986	2,821	1,745	83	69	382	169	12	5	6	8	8,998	1,458	414	220	4,383	1,593	7,328	1,541	0	0
1992	2,842	1,744	90	76	396	145	16	7	6	8	8,899	1,465	488	217	4,403	1,593	7,286	1,542	0	0
2000	2,832	1,746	92	78	379	130	18	8	5	7	8,943	1,458	452	216	4,411	1,593	7,295	1,540	0	0
Net change	10	21	26	27	243	103	9	5	–2	2	–517	151	170	87	131	83	–71	57	0	0
Gross change	80	35	27	27	813	262	11	5	2	2	980	297	402	141	200	83	240	77	0	0

Table 4. Principal land-cover conversions in Northern Minnesota Wetlands Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	239	149	101	1.0	43.1
	Mechanically disturbed	Grassland/Shrubland	64	31	21	0.3	11.4
	Forest	Agriculture	61	30	20	0.2	10.9
	Mechanically disturbed	Forest	48	25	17	0.2	8.6
	Wetland	Mechanically disturbed	47	26	18	0.2	8.5
	Other	Other	98	n/a	n/a	0.4	17.5
		Totals	556			2.3	100.0
1980–1986	Forest	Mechanically disturbed	328	163	110	1.3	39.3
	Mechanically disturbed	Grassland/Shrubland	124	65	44	0.5	14.9
	Mechanically disturbed	Forest	123	89	60	0.5	14.8
	Forest	Agriculture	54	27	18	0.2	6.4
	Wetland	Mechanically disturbed	52	29	19	0.2	6.2
	Other	Other	154	n/a	n/a	0.6	18.5
		Totals	836			3.4	100.0
1986–1992	Forest	Mechanically disturbed	329	118	80	1.3	33.7
	Mechanically disturbed	Forest	179	114	77	0.7	18.3
	Mechanically disturbed	Grassland/Shrubland	167	74	50	0.7	17.1
	Grassland/Shrubland	Forest	85	62	42	0.3	8.7
	Wetland	Mechanically disturbed	65	43	29	0.3	6.6
	Other	Other	153	n/a	n/a	0.6	15.6
		Totals	978			4.0	100.0
1992–2000	Forest	Mechanically disturbed	308	110	74	1.3	29.5
	Mechanically disturbed	Forest	221	89	60	0.9	21.1
	Grassland/Shrubland	Forest	150	65	44	0.6	14.4
	Mechanically disturbed	Grassland/Shrubland	126	75	50	0.5	12.1
	Wetland	Mechanically disturbed	68	36	24	0.3	6.5
	Other	Other	173	n/a	n/a	0.7	16.6
		Totals	1,047			4.3	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	1,205	469	316	4.9	35.3
	Mechanically disturbed	Forest	571	256	173	2.3	16.7
	Mechanically disturbed	Grassland/Shrubland	481	220	148	2.0	14.1
	Grassland/Shrubland	Forest	297	141	95	1.2	8.7
	Wetland	Mechanically disturbed	231	117	79	0.9	6.8
	Other	Other	631	n/a	n/a	2.6	18.5
		Totals	3,416			14.0	100.0

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Chapter 2

Northern Lakes and Forests Ecoregion

By Tamara S. Wilson and Christy L. Ryan

Ecoregion Description

The Northern Lakes and Forests Ecoregion covers 189,889 km^2 (73,316 mi^2) across the northern parts of Minnesota, Wisconsin, and Michigan along the Great Lakes (fig. 1) (Omernik, 1987; Wiken and others, 2011). The ecoregion is bordered by the Northern Minnesota Wetlands Ecoregion to the northwest and the North Central Hardwood Forests Ecoregion to the west and south, as well as the Southern Michigan/Northern Indiana Drift Plains and Huron/Erie Lake Plains Ecoregions to the south. Much of the ecoregion was covered by the Laurentide ice sheet during the Pleistocene Wisconsin-age glaciation (Albert, 1995), which greatly influenced modern topography. It is a region of nutrient-poor glacial soils, coniferous and northern-hardwood forests, undulating till plains, morainal hills, broad lacustrine basins,

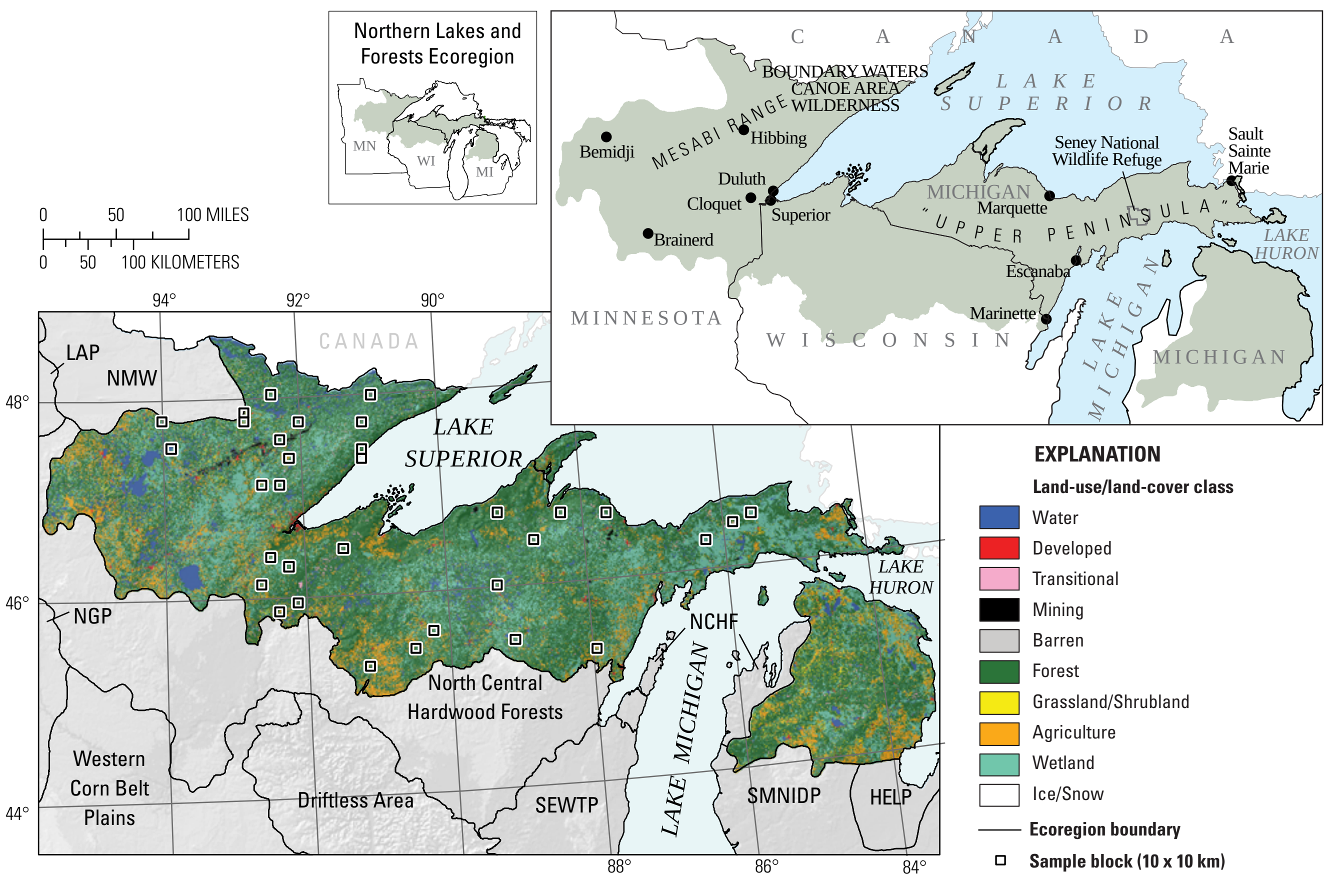

Figure 1. Map of Northern Lakes and Forests Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of three Great Plains ecoregions: Lake Agassiz Plain (LAP), Northern Glaciated Plains (NGP), and Western Corn Belt Plains. See appendix 3 for definitions of land-use/land-cover classifications.

and extensive sandy outwash plains (U.S. Environmental Protection Agency, 2013). Lakes and wetlands are widespread across the ecoregion.

A moist-to-humid, midlatitude boreal climate characterizes the Northern Lakes and Forests Ecoregion. Summers are warm, with average high temperatures of 25°C to 28°C, and winters are cold, with average low temperatures of -20°C to -12°C (Keys and others, 1995). The Great Lakes strongly influence the climate and biota of the ecoregion, affecting the timing and amount of precipitation and also the length of the growing season, as well as moderating temperature extremes. Annual precipitation ranges from about 660 to 910 mm (26 to 36 in.) across the ecoregion (Omernik and others, 2000). In late spring and summer, lake temperatures generally are cooler than the surrounding atmosphere, preventing air temperatures from rising higher than they would without the lake effect in this continental region; the reverse effect moderates winter temperatures.

Mixed broadleaf-coniferous forests cover the ecoregion. Native tree species include jack pine (*Pinus banksiana*), balsam fir (*Abies balsamea*), black spruce (*Picea mariana*), and white spruce (*Picea glauca*). Common hardwoods include quaking aspen (*Populus tremuloides*), bigtooth aspen (*Populus grandidentata*), sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), yellow birch (*Betula alleghaniensis*), paper birch (*Betula papyrifera*), American basswood (*Tilia americana*), and oak (*Quercus* spp.) (Schulte and others, 2007). Wetland and riparian species are prolific and include a variety of sedges (*Carex* spp.) and sphagnums (*Sphagnum* spp.) (Schulte and others, 2007). Agriculture is limited by sandy soils, low temperatures, and a short frost-free period, unlike conditions in the agriculture-dominated ecoregions to the south (Omernik and others, 2000). Where agriculture is possible, hay, corn, and soybeans are the most common crops. Livestock grazing also accounts for a large part of the agricultural lands in the ecoregion (fig. 2).

Most of the ecoregion is sparsely populated; the largest cities (and their 2000 populations) are Duluth, Minnesota (86,918); Superior, Wisconsin (27,368); and Marquette, Michigan (19,661) (U.S. Census Bureau, 2012). Most towns in the ecoregion are small, with much of the development concentrated around the many lakes there. The economy primarily is based on forestry, mining, and seasonal tourism.

The Northern Lakes and Forests Ecoregion has had a long history of iron, copper, and sand and gravel aggregate mining. Following the discovery of iron and copper in the 1840s, the population grew rapidly. More mineral wealth was amassed from Michigan's "Upper Peninsula" alone than was made from the California Gold Rush (Dunbar and May, 1995). Copper mining began to decline in the late 19th century because of competition from Arizona and Montana. Michigan's last operating copper mine closed in 1997 (Michigan Department of Natural Resources, 2011). Mining of iron ore remains important, particularly in the Mesabi Range (fig. 3), in Hibbing, Minnesota, home of the world's largest open-pit iron mine (Minnesota Department of Natural Resources, 2011). Minnesota is the largest producer of iron ore and taconite (an iron-bearing sedimentary rock) in the United States (Minnesota Department of Natural Resources, 2011). Most of the mining in other parts of the ecoregion consists of rock quarries and sand and gravel pits that produce construction materials (fig. 4).

Nationally, the clearing of forests for fuel, timber, and other wood products, as well as the opening the land for crops, led to a widespread loss of forest land that lasted through the early 1900s (U.S. Geological Survey, 1998). This pattern occurred in the Northern Lakes and Forests Ecoregion, as timber harvesting and forest regrowth were the dominant land-cover changes during the late 20th century. Trees in the ecoregion primarily were harvested for wood pulp and construction materials, and the forests had fairly rapid rates of regrowth. This ecoregion has been one of the most intensively logged geographic areas in the United States. Logging often was followed by slash burning practices until fire suppression was implemented in the 1930s (Rhemtulla and others, 2009). Since then, many areas have been allowed to regrow "naturally;" however, pre–European settlement conditions have not yet been achieved (Schulte and others, 2007).

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Northern Lakes and Forests Ecoregion between 1973 and 2000 is estimated at 12.2 percent (23,166 km^2) (table 1). Compared to other Midwest–South Central United States ecoregions, change in the Northern Lakes and Forests Ecoregion was the third highest (fig. 5): about 5.4 percent (10,254 km^2) of the area changed only once during the study period, 5.0 percent (9,494 km^2) changed twice, 1.7 percent (3,228 km^2) changed three times, and 0.1 percent (190 km^2) changed four times

Figure 2. Corn field next to grazing livestock in Northern Lakes and Forests Ecoregion.

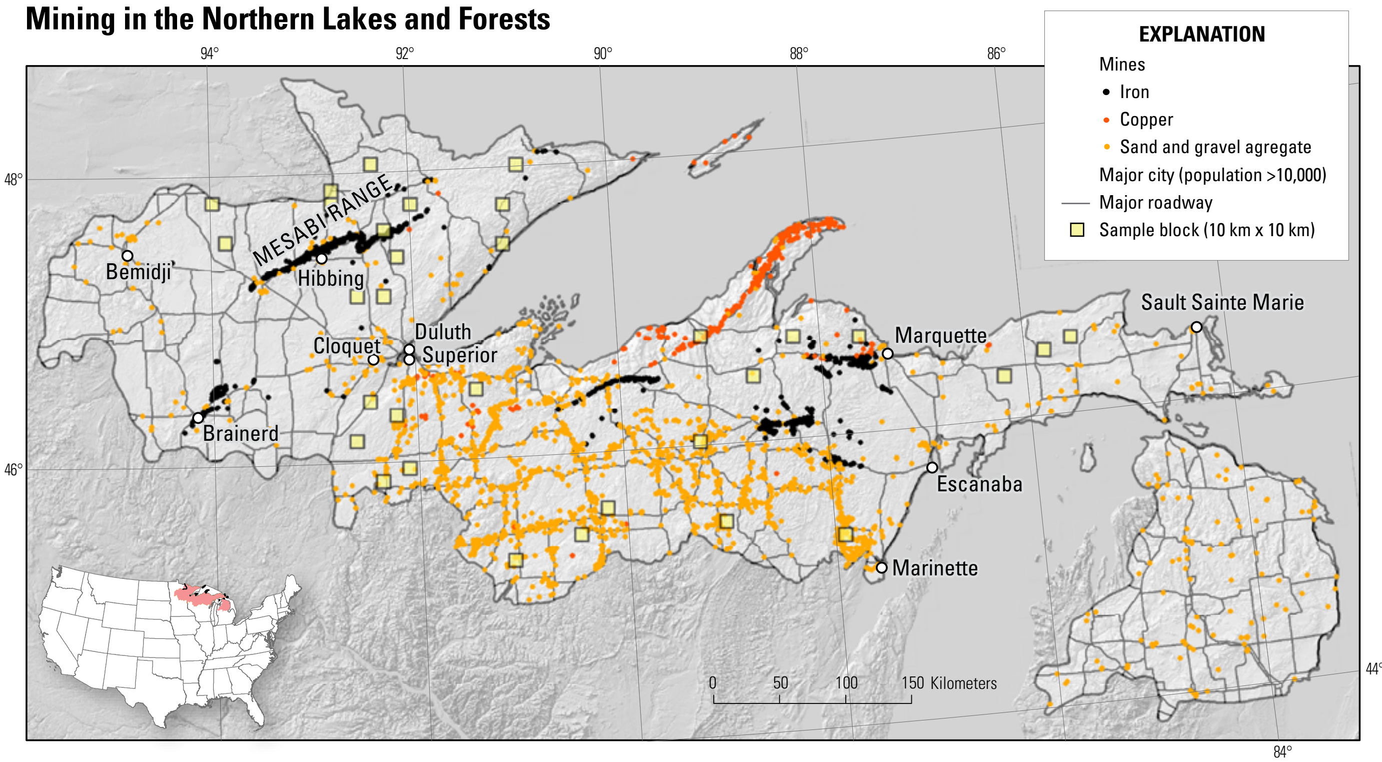

Figure 3. Map showing locations of known mines (historical and current) and major population centers (that is, cities and towns having populations greater than 10,000) in Northern Lakes and Forests Ecoregion (National Atlas of the United States, 2004; U.S. Geological Survey, 2005).

(table 1). Change during the study period increased from 3.5 percent of the ecoregion (6,612 km^2) between 1973 and 1980 to 7.0 percent (13,316 km^2) between 1992 and 2000 (table 2). When normalized to an average annual rate to account for uneven time periods, the period between 1986 and 1992 experienced the greatest amount of change, at 1.0 percent (1,816 km^2) (table 2; fig. 6).

In 2000, forest was the predominant land-cover class in the Northern Lakes and Forests Ecoregion, accounting for 61.7 percent (117,165 km^2) of the land area (table 3; fig. 7). Other major land-cover classes include wetland (18.9 percent; 35,974 km^2), water (7.4 percent; 14,020 km^2), agriculture

Figure 4. Sand and gravel mining activity in Northern Lakes and Forests Ecoregion.

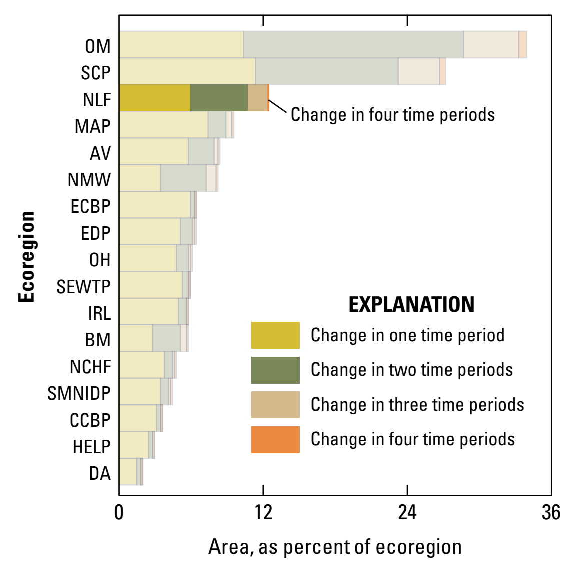

Figure 5. Overall spatial change in Northern Lakes and Forests Ecoregion (NLF; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Northern Lakes and Forests Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

(5.8 percent; 10,929 km^2), mechanically disturbed (3.0 percent; 5,630 km^2), and grassland/shrubland (2.2 percent; 4,242 km^2) (table 3). Between 1973 and 2000, significant net changes in land-cover classes in relation to total ecoregion area included losses of forest (2.8 percent; 5,408 km^2) and wetland (0.2 percent; 333 km^2), as well as gains in mechanically disturbed (which more than doubled, from 1.4 to 3.0 percent, expanding by 3,058 km^2), grassland/shrubland (0.9 percent; 1,653 km^2), agriculture (0.3 percent; 538 km^2), developed (0.2 percent; 302 km^2), and water (0.1 percent; 122 km^2) (table 3; fig. 8).

At least 71.2 percent (28,259 km^2) of all land-cover conversions between 1973 and 2000 were associated with timber harvest and forest regeneration (table 4); note that land-cover change from grassland/shrubland to forest can have multiple origins and, thus, cannot be entirely associated with timber harvest and forest regeneration. Forest cutting (forest to mechanically disturbed, 15,585 km^2) and subsequent forest regeneration (mechanically disturbed to forest, 6,534 km^2), as well as successional regrowth (mechanically disturbed to grassland/shrubland, 6,140 km^2; grassland/shrubland to forest, 5,030 km^2) are included in this estimate (table 4). The largest loss of forest occurred during the period between 1992 and 2000, when 5,420 km^2 of forest was cut (table 4).

Wildland fire events (nonmechanical disturbance) also can influence land-cover change in the Northern Lakes and Forests Ecoregion, as shown in table 4. The lightning-ignited “Seney fire,” which started in August 1976 within Seney National Wildlife Refuge on Michigan’s “Upper Peninsula” (Anderson, 1982), is represented by the conversion from forest to nonmechanically disturbed in the period between 1973 and 1980 (table 4). This fire accounted for 9.3 percent of all changes in that time period, as well as considerable change in the period between 1980 and 1986 (through post–fire recovery) (table 4). Severe drought in the region created unseasonably dry conditions that enabled the fire to spread rapidly, and attempts to extinguish it were hampered by limited access and the presence of standing water and dense brush (Anderson, 1982).

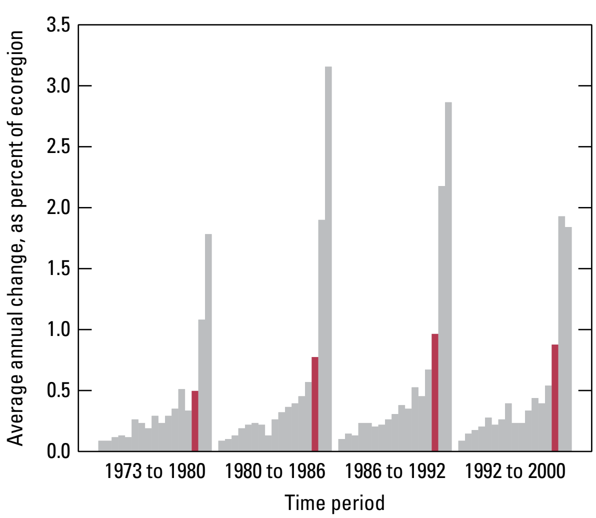

Figure 6. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Northern Lakes and Forests Ecoregion are represented by red bars in each time period.

Figure 7. Forest in Northern Lakes and Forests Ecoregion. As predominant land-cover class in ecoregion, it accounts for about 61.7 percent of ecoregion area in 2000.

The mining land-cover class only accounted for 0.3 percent of the ecoregion in 2000, which is surprisingly low given the extensive mining history of the area. Major mining activities and locations, such as the iron-ore–producing Mesabi Range, were geographically concentrated in certain areas and were not widespread throughout the entire ecoregion, which potentially complicated regional sampling (fig. 3). The economic and environmental effects of mines on the ecoregion likely are much larger than the small size of the land area affected relative to the total area of the ecoregion.

Forest harvest has been the main driver of land-use/land-cover change in the Northern Lakes and Forests Ecoregion since the mid-19th century. Logging increased notably between 1992 and 2000. After normalizing to an annual rate of change to account for the varying lengths in study periods, the amount of forest area cleared per year more than doubled after 1980, after which it remained roughly constant at 630 to 690 km^2 per year. This trend is mirrored in the southeastern United States, but it is the opposite of what has been observed in much of the western United States (figs. 9,10; see also, Drummond and Loveland, 2010; Sleeter and others, 2012).

Land ownership plays a significant role in how forests are managed and protected. Examination of overall spatial change (on a block-by-block basis) and land ownership in the Northern Lakes and Forests Ecoregion shows change occurring on both publicly managed lands and private landholdings (fig. 11). High rates of change are seen on both ownership types; however, the western part of the ecoregion experienced higher overall spatial change during the study period. The exception was wilderness areas that had complete landscape protection, as is reflected by the 1.6 percent change in the block that lies within the Boundary Waters Canoe Area Wilderness (fig. 11). Outside protected areas, the primary factors that limited logging activity likely are related to restricted road access, distance to market, and target-species availability. The west is more populated, and it has larger shipping ports and a denser road network than the east. The 26.2 percent overall spatial change that occurred in a single sample block in the east likely is inflated owing to the 1976 “Seney fire,” which burned over 10 percent of the entire block, and also to subsequent changes related to landscape recovery after the fire.

Because of a long period of high-intensity timber harvest, forest composition and structure have changed significantly. By the end of the study period, forest conditions were marked by lower species diversity, younger trees, smaller average tree diameter, and decreased forest complexity (Rhemtulla and others, 2009). Broad-leafed deciduous species such as aspen (*Populus* spp.) and maple (*Acer* spp.) have become more common, whereas conifer dominance has decreased (Schulte and others, 2007). The replacement of old-growth coniferous forests with early-successional-stage and secondary-growth forests is attributable directly to land-use changes and natural disturbances (Ravenscroft and others, 2010). Much of the old-growth forests that remain are within the Boundary Waters Canoe Area Wilderness.

Homogenization of forest stands decreases overall forest health, resiliency, and sustainability, and it also alters the nutrient cycle, species interactions, habitat quality, and other ecosystem services (Schulte and others, 2007). Future changes in climate are projected to decrease forest productivity (Ravenscroft and others, 2010) by increasing stressors on species at the limits of their range. The Northern Lakes and Forests Ecoregion has been susceptible to catastrophic, drought-induced fire in the past, with fire as a key element in the ecoregion’s dynamic landscape for millennia; however, current temperature trends may accelerate wildfire occurrence and affect tree mortality in the future by increasing fire susceptibility and severity owing to increased fuel loads (Kling and others, 2003). The complex land-ownership mosaic also brings with it a unique set of management challenges that will be pivotal in determining the sustained delivery of ecosystem services under continued patterns of historical land-use/land-cover change.

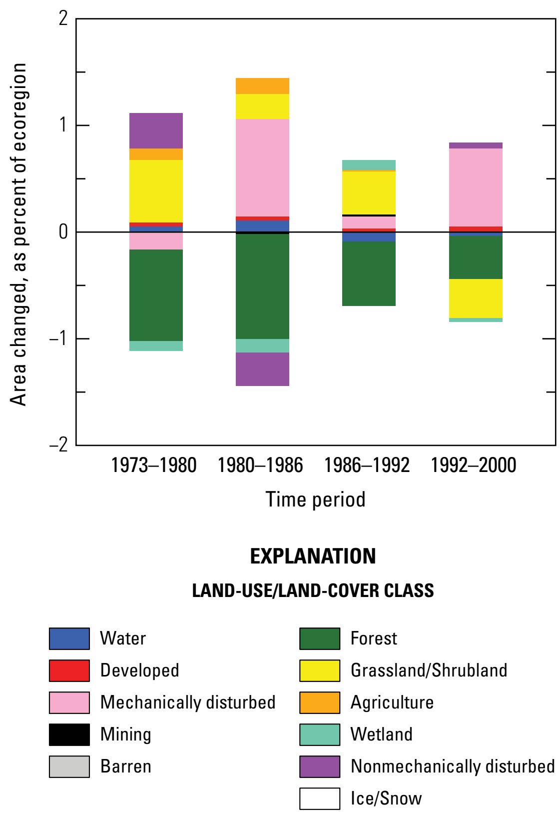

Figure 8. Normalized average net change in Northern Lakes and Forests Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Figure 9. Recent logging activity in Northern Lakes and Forests Ecoregion.

Figure 10. Piles of birch and aspen logs in Northern Lakes and Forests Ecoregion.

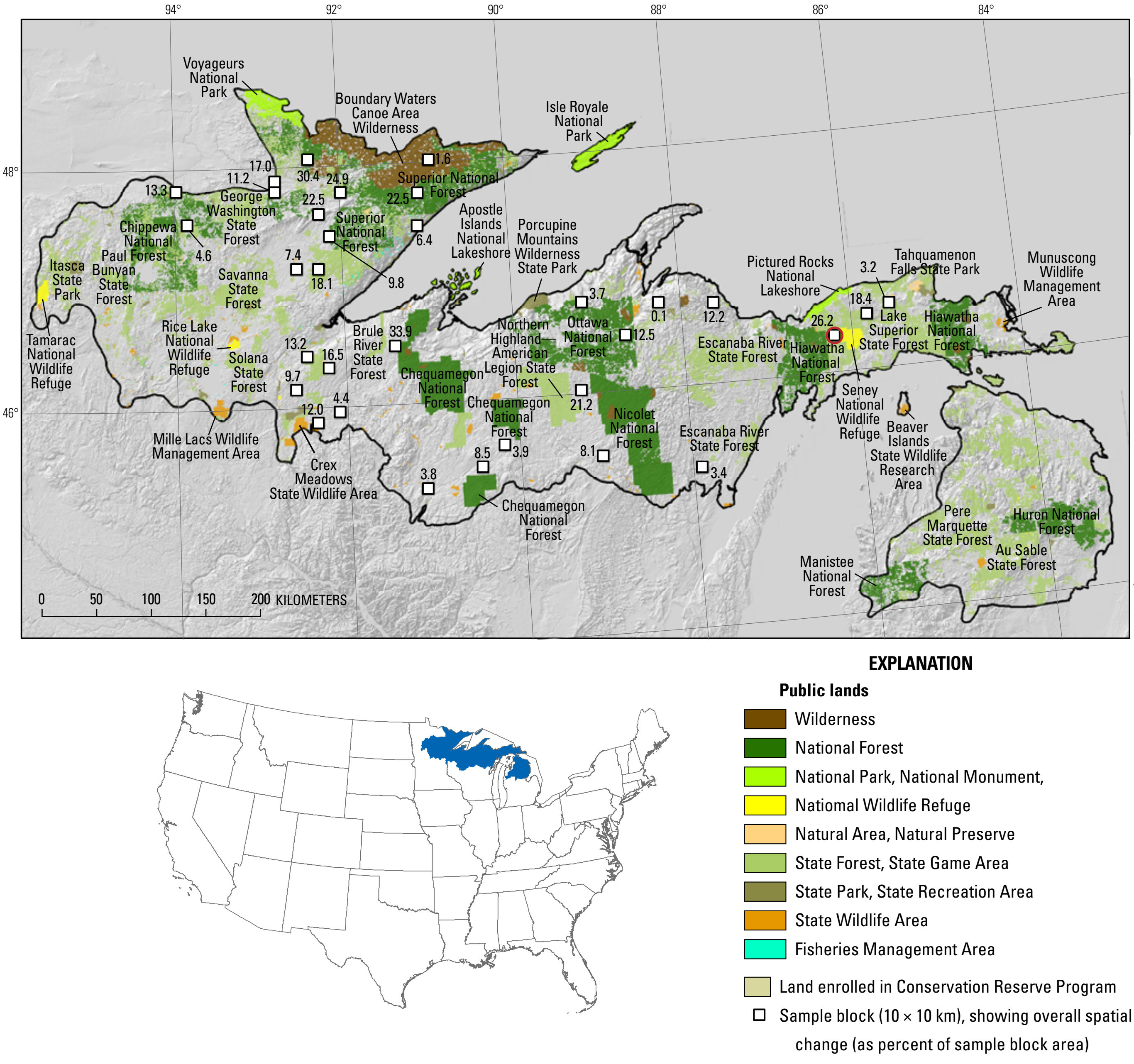

Figure 11. Map of public lands in Northern Lakes and Forests Ecoregion, showing sample-block locations and overall spatial change values (as percent of sample-block area) (U.S. Geological Survey, 2010). Red circle shows location of sample block that has change value of 26.2 percent; "Seney fire," which burned over 10 percent of this block and also parts of Seney National Wildlife Refuge in 1976, likely contributed greatly to this comparatively high change value.

Table 1. Percentage of Northern Lakes and Forests Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (87.5 percent), whereas 12.5 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	5.4	0.9	4.5	6.2	0.6	11.2
2	5.0	1.0	4.0	6.0	0.7	13.4
3	1.7	0.6	1.1	2.3	0.4	22.8
4	0.1	0.1	0.0	0.1	0.0	43.8
Overall spatial change	12.2	2.1	10.1	14.3	1.4	11.8

Table 2. Raw estimates of change in Northern Lakes and Forests Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
			Estimate of change, in percent stratum				
1973–1980	3.5	1.0	2.5	4.5	0.7	19.5	0.5
1980–1986	4.7	1.1	3.6	5.7	0.7	15.7	0.8
1986–1992	5.7	1.0	4.7	6.8	0.7	12.3	1.0
1992–2000	7.0	1.4	5.6	8.4	0.9	13.5	0.9
			Estimate of change, in square kilometers				
1973–1980	6,612	1,899	4,713	8,511	1,287	19	945
1980–1986	8,852	2,054	6,799	10,906	1,391	16	1,475
1986–1992	10,896	1,977	8,919	12,872	1,339	12	1,816
1992–2000	13,316	2,650	10,665	15,966	1,796	13	1,664

Table 3. Estimated area (and margin of error) of each land-cover class in Northern Lakes and Forests Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	7.3	4.2	0.5	0.2	1.4	0.5	0.3	0.4	0.0	0.0	64.5	4.6	1.4	1.1	5.5	1.7	19.1	3.7	0.0	0.0
1980	7.4	4.2	0.6	0.2	1.2	0.5	0.3	0.4	0.0	0.0	63.7	4.5	2.0	0.9	5.6	1.8	19.0	3.7	0.3	0.5
1986	7.5	4.2	0.6	0.2	2.1	0.5	0.2	0.3	0.0	0.0	62.7	4.4	2.2	0.9	5.7	1.8	18.9	3.7	0.0	0.0
1992	7.4	4.2	0.6	0.3	2.2	0.5	0.3	0.3	0.0	0.0	62.1	4.3	2.6	0.9	5.8	1.8	19.0	3.7	0.0	0.0
2000	7.4	4.2	0.7	0.3	3.0	0.7	0.3	0.3	0.0	0.0	61.7	4.3	2.2	1.0	5.8	1.8	18.9	3.7	0.0	0.1
Net change	0.1	0.1	0.2	0.1	1.6	0.7	0.0	0.0	0.0	0.0	–2.8	0.9	0.9	0.5	0.3	0.2	–0.2	0.1	0.0	0.1
Gross change	0.5	0.2	0.2	0.1	4.5	0.8	0.1	0.0	0.0	0.0	6.0	1.1	3.3	0.9	0.6	0.2	0.7	0.2	0.7	1.0
Area, in square kilometers																				
1973	13,899	7,974	1,038	401	2,572	876	516	681	5	5	122,572	8,651	2,589	2,027	10,391	3,306	36,307	7,000	0	0
1980	14,021	8,022	1,083	424	2,268	910	505	677	5	5	120,963	8,503	3,716	1,746	10,606	3,349	36,104	6,967	616	902
1986	14,221	8,040	1,158	453	4,015	940	470	604	5	5	119,102	8,432	4,157	1,616	10,891	3,392	35,869	6,983	0	0
1992	14,070	8,000	1,219	485	4,238	919	495	606	5	5	117,955	8,076	4,916	1,744	10,949	3,387	36,041	6,987	0	0
2000	14,020	8,026	1,340	550	5,630	1,300	499	612	5	5	117,165	8,089	4,242	1,829	10,929	3,384	35,974	6,941	85	124
Net change	122	122	302	182	3,058	1,350	–17	72	0	0	–5,408	1,690	1,653	873	538	448	–333	261	85	124
Gross change	902	299	326	181	8,621	1,560	129	95	1	1	11,345	2,055	6,236	1,623	1,079	422	1,403	337	1,318	1,928

Table 4. Principal land-cover conversions in Northern Lakes and Forests Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	2,219	908	615	1.2	33.6
	Mechanically disturbed	Grassland/Shrubland	1,419	559	379	0.7	21.5
	Mechanically disturbed	Forest	1,108	513	347	0.6	16.8
	Forest	Nonmechanically disturbed	616	902	611	0.3	9.3
	Grassland/Shrubland	Forest	354	348	236	0.2	5.4
	Other	Other	895	n/a	n/a	0.5	13.5
		Totals	6,612			3.5	100.0
1980–1986	Forest	Mechanically disturbed	3,814	927	628	2.0	43.1
	Mechanically disturbed	Grassland/Shrubland	1,090	536	363	0.6	12.3
	Mechanically disturbed	Forest	1,059	491	333	0.6	12.0
	Grassland/Shrubland	Forest	920	391	265	0.5	10.4
	Nonmechanically disturbed	Grassland/Shrubland	315	460	312	0.2	3.6
	Other	Other	1,654	n/a	n/a	0.9	18.7
		Totals	8,852			4.7	100.0
1986–1992	Forest	Mechanically disturbed	4,131	915	620	2.2	37.9
	Mechanically disturbed	Grassland/Shrubland	2,057	686	465	1.1	18.9
	Mechanically disturbed	Forest	1,779	471	319	0.9	16.3
	Grassland/Shrubland	Forest	1,397	492	333	0.7	12.8
	Water	Wetland	275	144	98	0.1	2.5
	Other	Other	1,255	n/a	n/a	0.7	11.5
		Totals	10,896			5.7	100.0
1992–2000	Forest	Mechanically disturbed	5,420	1,285	870	2.9	40.7
	Mechanically disturbed	Forest	2,588	733	496	1.4	19.4
	Grassland/Shrubland	Forest	2,359	812	550	1.2	17.7
	Mechanically disturbed	Grassland/Shrubland	1,574	628	425	0.8	11.8
	Water	Wetland	219	76	51	0.1	1.6
	Other	Other	1,156	n/a	n/a	0.6	8.7
		Totals	13,316			7.0	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	15,585	3,443	2,332	8.2	39.3
	Mechanically disturbed	Forest	6,534	1,611	1,092	3.4	16.5
	Mechanically disturbed	Grassland/Shrubland	6,140	2,043	1,384	3.2	15.5
	Grassland/Shrubland	Forest	5,030	1,520	1,030	2.6	12.7
	Forest	Agriculture	827	338	229	0.4	2.1
	Other	Other	5,559	n/a	n/a	2.9	14.0
		Totals	39,676			20.9	100.0

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Northern Agriculture-Forest Transition Zone Ecoregions

Chapter 3

North Central Hardwood Forests Ecoregion

By Christopher A. Barnes

Ecoregion Description

The North Central Hardwood Forests Ecoregion, about 91,205 km^2 (35,214 mi^2) in size, encompasses parts of Minnesota, Wisconsin, and Michigan (fig. 1) (Omernik, 1987). The ecoregion bridges the predominantly forested ecoregions that neighbor it to the north (Northern Lakes and Forests Ecoregion, Northern Minnesota Wetlands Ecoregion) and the more agricultural ecoregions that surround it to the south and west (Southern Michigan/Northern Indiana Drift Plains, Southeastern Wisconsin Till Plains, Driftless Area, Western Corn Belt Plains, Northern Glaciated Plains, and Lake Agassiz Plain Ecoregions). The ecoregion's growing season generally is longer and warmer than that of the Northern Lakes and Forests Ecoregion, and its more arable and fertile soils support agricultural land use over a larger extent than its northern neighbors. Lakes in the North Central Hardwood Forests Ecoregion typically have higher trophic-state-index values than those in the Northern Lakes and Forests Ecoregion, having higher percentages in the eutrophic and hypereutrophic classes.

The mostly flat landscape of the North Central Hardwood Forests Ecoregion consists of a mosaic of forest and cropland

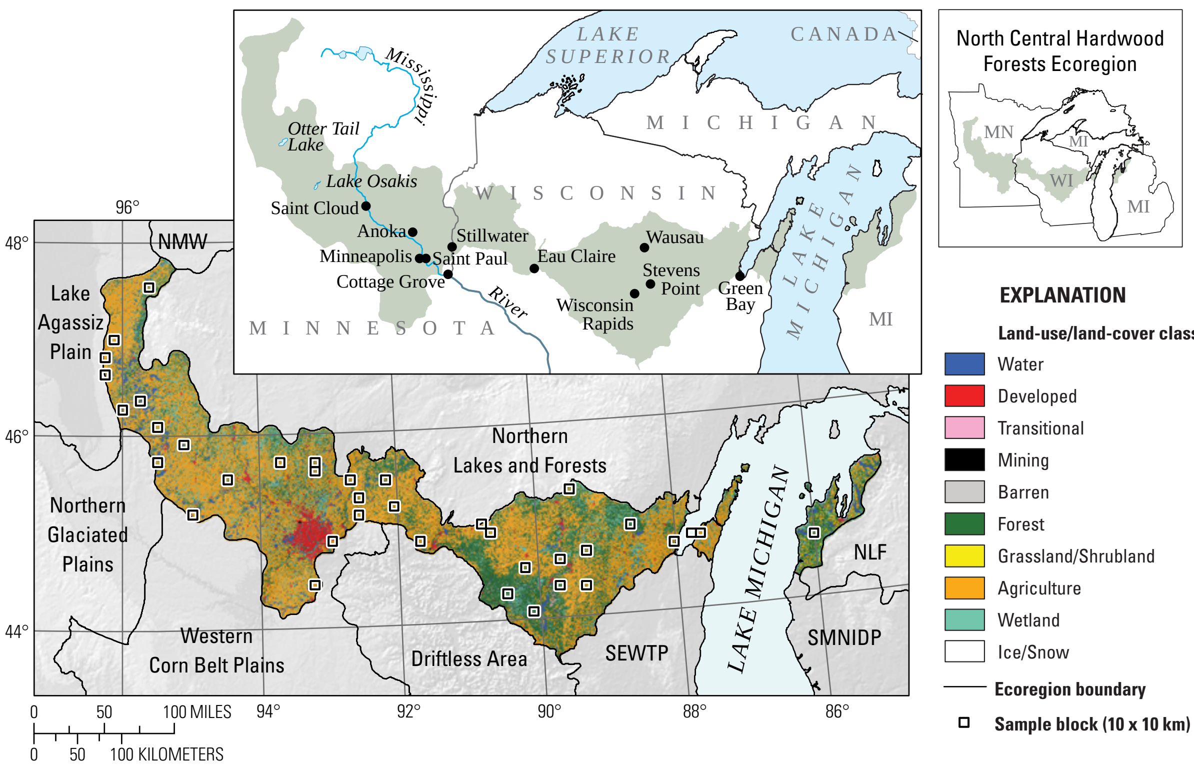

Figure 1. Map of North Central Hardwood Forests Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of three Great Plains ecoregions: Lake Agassiz Plain, Northern Glaciated Plains, and Western Corn Belt Plains. See appendix 3 for definitions of land-use/land-cover classifications.

agriculture, primarily pastureland and dairy operations interspersed with urban, suburban, and rural residential land. Larger cities include Minneapolis, Saint Paul, Saint Cloud, Anoka, and Stillwater, Minnesota, and Eau Claire, Wausau, Wisconsin Rapids, and Stevens Point, Wisconsin. In 2000, the ecoregion's land cover was about 49.8 percent agriculture, 27.1 percent forest, 8.5 percent water, and 8.3 percent wetland (table 1). The ecoregion has a midlatitude humid continental climate, with warm summers, severe winters, and no pronounced dry season. The frost-free period ranges from 140 to 170 days (Wiken and others, 2011), and the mean annual precipitation is 825 mm (32 in.), ranging from a minimum of 760 mm (30 in.) to a maximum of 965 mm (38 in.) (Wiken and others, 2011).

Land cover of the North Central Hardwood Forests Ecoregion prior to European-American settlement was dominated by conifers such as red and white pine (*Pinus resinosa* and *Pinus strobus*, respectively), which regenerated originally when fires were less intense and not so widespread, mixed with hardwood species such as sugar maple (*Acer saccharum*) (Curtis, 1956). Grassland prairies and wetlands were intermixed within forest openings. Pioneer loggers were attracted to the region because of the abundance of white pine, a preferred wood for building; its lightweight, yet strong and durable, characteristics meant it was easy to work with and could be floated down rivers to markets with relative ease (Anderson and others, 1996). Over the last 150 years, the landscape of the North Central Hardwood Forests Ecoregion has experienced major land-cover changes that primarily are due to the extensive and rapid conversion of forests to cropland agriculture and urban development (Anderson and others, 1996). Timber harvesting and agriculture were important economic activities until the turn of the 20th century, when population patterns shifted and people from the farm moved to the city in search of jobs (Robinson, 1915; Borchert, 1987). By 1940, the number of farms, the total acres of farmland, and the percentage of land in farms began to decrease, a trend in agricultural land use that continued throughout the 27-year study period (Anderson and others, 1996). Although timber harvesting continues to be an important economic activity, its extent has decreased, and it is now more focused on different species than it was during its peak from 1898 to 1903, as white pine has become less plentiful (Anderson and others, 1996).

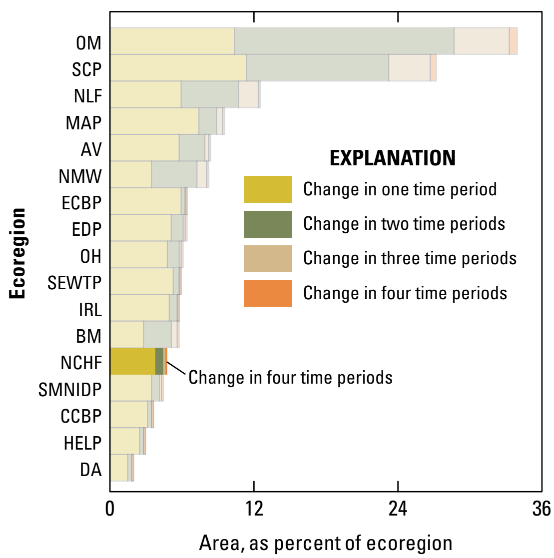

Figure 2. Overall spatial change in North Central Hardwood Forests Ecoregion (NCHF; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in North Central Hardwood Forests Ecoregion (four time periods) labeled for clarity. See table 3 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the North Central Hardwood Forests Ecoregion between 1973 and 2000 is estimated at 4.6 percent (table 2). Compared to other Midwest–South Central United States ecoregions, change in the North Central Hardwood Forest Ecoregion was relatively low (fig. 2): an estimated 3.7 percent of the ecoregion area changed only once during the study period (table 2). The percent of land-cover change gradually increased from 1973 to 2000, from a low of 0.8 percent, between

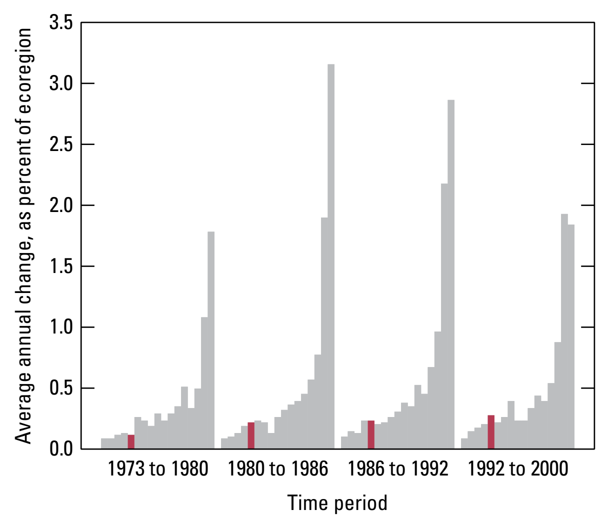

Figure 3. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for North Central Hardwood Forests Ecoregion are represented by red bars in each time period.

1973 and 1980, to a high of 2.2 percent, between 1992 and 2000 (table 3). When normalized to account for uneven time periods, the average annual rate of change in the ecoregion (0.3 percent) was greatest between 1992 and 2000 (table 3).

The agriculture, developed, grassland/shrubland, and forest land-cover classes experienced observable net change during the study period (table 1; fig. 4). The agriculture class showed a net loss of 1,910 km^2 (4.0 percent of its estimated 1973 area) during the study period, and the developed class showed a net increase of 1,642 km^2 (72.6 percent increase from its estimated 1973 area) (table 1). These changes primarily are attributable to metropolitan growth, new rural residential estates, and new lakeshore developments (fig. 5). Accelerating decreases in agriculture land cover in the ecoregion may have been influenced by the timber industry, as well as by the 1985 Farm Bill that established the Conservation Reserve Program (CRP) (table 4). These changes are shown by conversions from agriculture to forest and from agriculture to grassland/shrubland. Grassland/shrubland increased by 21.7 percent, primarily from agriculture. This increase may represent agricultural land being enrolled in the CRP, or perhaps a period of early forest succession. The 0.8 percent loss in forest was caused by small amounts of forest clearance for residential and commercial development, primarily in the suburban regions of Saint Cloud and Minneapolis–Saint Paul, Minnesota, and also Eau Claire and Wisconsin Rapids, Wisconsin.

The leading land-cover conversion during the study period was from agriculture to developed (table 4). The ecoregion lost about 1,296 km^2 of agricultural land to developed land between 1973 and 2000. Agricultural areas of the North Central Hardwood Forests Ecoregion have decreased, coming under increasing pressure from population increases, as well as the demand for executive-style houses

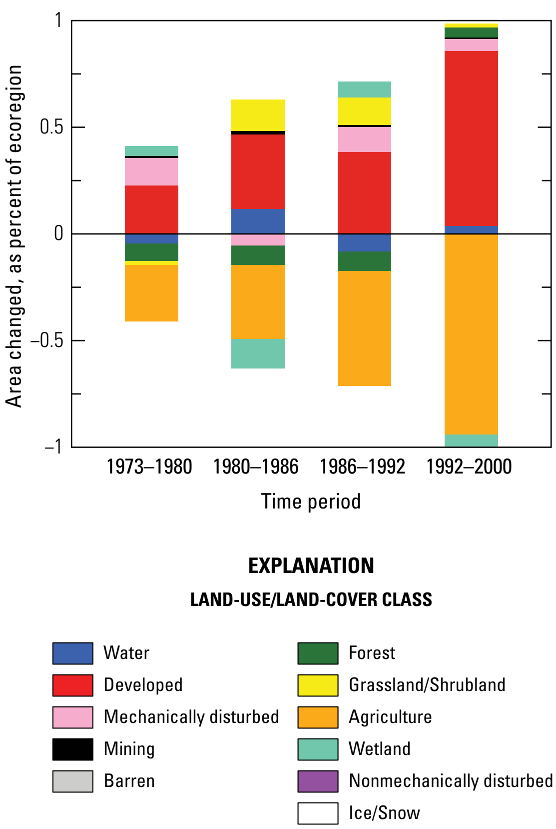

Figure 4. Normalized average net change in North Central Hardwood Forests Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Figure 5. Different types of new developed land cover in North Central Hardwood Forests Ecoregion. *A*, Rural residential development, Cottage Grove, Minnesota. *B*, Lakeshore lots for sale near Lake Osakis, Minnesota. *C*, Signs for development on former agricultural land near Otter Tail Lake, Minnesota.

and new second homes. The major conversion associated with timber harvesting (forest to mechanically disturbed) was the next most common land-cover conversion, indicative of the still-active and still-profitable timber industry (fig. 6*A*). Land-cover changes associated with forest regrowth after harvest (mechanically disturbed to forest; fig. 6*B*) generally fell within the “other” category during the study period (table 4).

Overall, the ecoregion had little land-cover change in relation to other Midwest–South Central United States ecoregions, but this trend may change in the future as the four major urban centers located in this ecoregion continue to increase in population, and the resulting increase in developed land cover may continue to alter the extent of agriculture in the North Central Hardwood Forests Ecoregion.

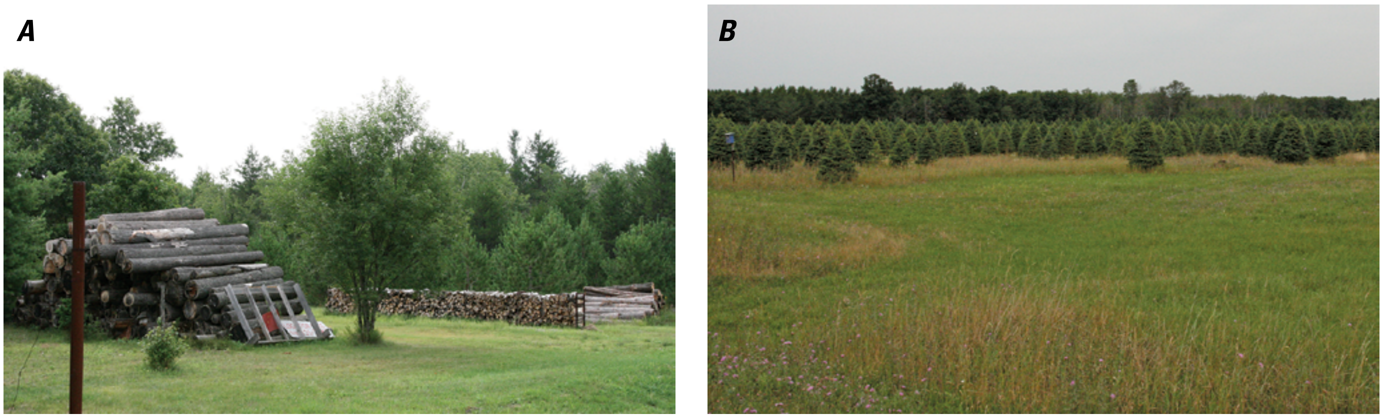

Figure 6. Local timber-harvesting operations near Wisconsin Rapids, Wisconsin, in North Central Hardwood Forests Ecoregion. *A*, Timber logs stacked after harvesting. *B*, Tree farm.

Table 1. Estimated area (and margin of error) of each land-cover class in North Central Hardwood Forests Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Nonmechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	8.5	4.4	2.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	27.3	4.8	1.3	0.5	51.9	5.2	8.4	1.9	0.0	0.0
1980	8.4	4.4	2.7	1.0	0.2	0.2	0.1	0.0	0.0	0.0	27.2	4.8	1.3	0.5	51.7	5.1	8.5	1.9	0.0	0.0
1986	8.5	4.4	3.1	1.2	0.1	0.1	0.1	0.0	0.0	0.0	27.1	4.7	1.4	0.5	51.3	5.1	8.3	1.9	0.0	0.0
1992	8.5	4.4	3.5	1.4	0.2	0.2	0.1	0.0	0.0	0.0	27.1	4.6	1.6	0.5	50.8	5.0	8.4	1.8	0.0	0.0
2000	8.5	4.4	4.3	2.0	0.3	0.2	0.1	0.0	0.0	0.0	27.1	4.6	1.6	0.5	49.8	5.0	8.3	1.9	0.0	0.0
Net change	0.0	0.2	1.8	1.1	0.2	0.2	0.0	0.0	0.0	0.0	–0.2	0.6	0.3	0.2	–2.1	1.2	–0.1	0.2	0.0	0.0
Gross change	0.6	0.3	1.8	1.1	0.8	0.5	0.1	0.0	0.0	0.0	1.5	0.6	0.8	0.3	2.5	1.1	0.7	0.3	0.0	0.0
Area, in square kilometers																				
1973	7,722	3,982	2,263	787	26	20	40	17	1	1	24,915	4,381	1,180	449	47,367	4,711	7,690	1,720	0	0
1980	7,681	3,980	2,478	915	143	157	46	19	1	1	24,842	4,354	1,164	448	47,123	4,684	7,727	1,720	0	0
1986	7,788	3,981	2,802	1,082	98	91	59	30	1	1	24,755	4,265	1,298	476	46,810	4,622	7,594	1,706	0	0
1992	7,713	3,974	3,158	1,307	202	158	66	40	1	1	24,674	4,218	1,420	494	46,315	4,584	7,655	1,676	0	0
2000	7,750	3,969	3,905	1,786	253	181	80	43	1	1	24,714	4,156	1,436	494	45,458	4,598	7,608	1,692	0	0
Net change	28	137	1,642	1,036	227	180	40	29	0	0	–201	589	256	185	–1,910	1,062	–82	153	0	0
Gross change	562	229	1,642	1,036	732	457	55	30	0	0	1,352	549	736	293	2,303	1,019	611	236	0	0

Table 2. Percentage of North Central Hardwood Forests Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (95.4 percent), whereas 4.6 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	3.7	1.2	2.5	4.9	0.8	22.7
2	0.6	0.3	0.3	1.0	0.2	32.4
3	0.2	0.1	0.0	0.3	0.1	51.1
4	0.0	0.0	0.0	0.0	0.0	54.2
Overall spatial change	4.6	1.4	3.1	6.0	1.0	21.0

Table 3. Raw estimates of change in North Central Hardwood Forests Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	0.8	0.3	0.5	1.1	0.2	25.2	0.1
1980–1986	1.3	0.5	0.8	1.8	0.3	23.8	0.2
1986–1992	1.4	0.4	0.9	1.8	0.3	21.5	0.2
1992–2000	2.2	0.7	1.5	2.9	0.5	22.2	0.3
Estimate of change, in square kilometers							
1973–1980	720	267	452	987	182	25	103
1980–1986	1,190	417	773	1,606	283	24	198
1986–1992	1,244	393	851	1,637	267	21	207
1992–2000	2,005	655	1,350	2,660	445	22	251

Table 4. Principal land-cover conversions in North Central Hardwood Forests Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Agriculture	Developed	158	111	75	0.2	21.9
	Forest	Mechanically disturbed	128	156	106	0.1	17.7
	Agriculture	Forest	73	61	42	0.1	10.2
	Grassland/Shrubland	Forest	67	45	31	0.1	9.4
	Water	Wetland	64	43	29	0.1	8.9
	Other	Other	229	n/a	n/a	0.3	31.9
		Totals	720			0.8	100.0
1980–1986	Agriculture	Developed	219	130	89	0.2	18.4
	Wetland	Water	133	61	41	0.1	11.2
	Agriculture	Grassland/Shrubland	126	54	37	0.1	10.6
	Forest	Agriculture	112	116	79	0.1	9.4
	Agriculture	Forest	108	82	56	0.1	9.1
	Other	Other	492	n/a	n/a	0.5	41.4
		Totals	1,190			1.3	100.0
1986–1992	Agriculture	Developed	312	222	151	0.3	25.1
	Forest	Mechanically disturbed	170	154	105	0.2	13.6
	Water	Wetland	154	83	56	0.2	12.4
	Agriculture	Grassland/Shrubland	118	50	34	0.1	9.5
	Mechanically disturbed	Grassland/Shrubland	84	86	58	0.1	6.7
	Other	Other	407	n/a	n/a	0.4	32.7
		Totals	1,244			1.4	100.0
1992–2000	Agriculture	Developed	607	466	317	0.7	30.3
	Forest	Mechanically disturbed	250	180	122	0.3	12.5
	Grassland/Shrubland	Forest	230	142	96	0.3	11.5
	Agriculture	Forest	150	98	66	0.2	7.5
	Agriculture	Grassland/Shrubland	133	69	47	0.1	6.6
	Other	Other	635	n/a	n/a	0.7	31.7
		Totals	2,005			2.2	100.0
1973–2000 (overall)	Agriculture	Developed	1,296	907	616	1.4	25.1
	Forest	Mechanically disturbed	645	429	292	0.7	12.5
	Grassland/Shrubland	Forest	443	180	122	0.5	8.6
	Agriculture	Grassland/Shrubland	429	157	106	0.5	8.3
	Agriculture	Forest	399	274	186	0.4	7.7
	Other	Other	1,947	n/a	n/a	2.1	37.7
		Totals	5,158			5.7	100.0

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Chapter 4

Driftless Area Ecoregion

By Robert P. Glover

Ecoregion Description

The Driftless Area Ecoregion covers about 47,590 km^2 (18,375 mi^2) of southeastern Minnesota, southwestern Wisconsin, and small parts of northeastern Iowa and northwestern Illinois. It is bordered by the following ecoregions: Western Corn Belt Plains Ecoregion to the southwest and west; North Central Hardwood Forests Ecoregion to the north and northeast; Southeastern Wisconsin Till Plains Ecoregion to the east; and Central Corn Belt Plains Ecoregion to the far southeast (fig. 1) (Omernik, 1987). The ecoregion has a humid continental climate that is split between the cool-summer subtype in the north and the warm-summer subtype in the south. Average minimum temperatures range from -17°C to -12°C, and average maximum temperatures range from 27°C to 29°C. The frost-free period ranges from 140 to 170 days (Wiken and others, 2011). Snowfall is common in the winter, and annual precipitation ranges from 813 to 914 mm (31–37 in.) (Wiken and others, 2011; PRISM Climate Group, 2006).

Although evidence of glacial drift is found in the ecoregion, the presence of glacial deposits has not greatly influenced the landscape (Wiken and others, 2011), as it remains hilly with few natural lakes. Because the ecoregion was bypassed by the last continental glacier, it can be better characterized as karst topography, which results from differential weathering and erosion of carbonate rock (Driftless Area Initiative, 2012). The ecoregion contains few wetlands compared to its neighboring glaciated ecoregions (fig. 2). Most of the wetlands are associated with the Mississippi River, the major hydrologic feature of the ecoregion, as well as other rivers and streams.

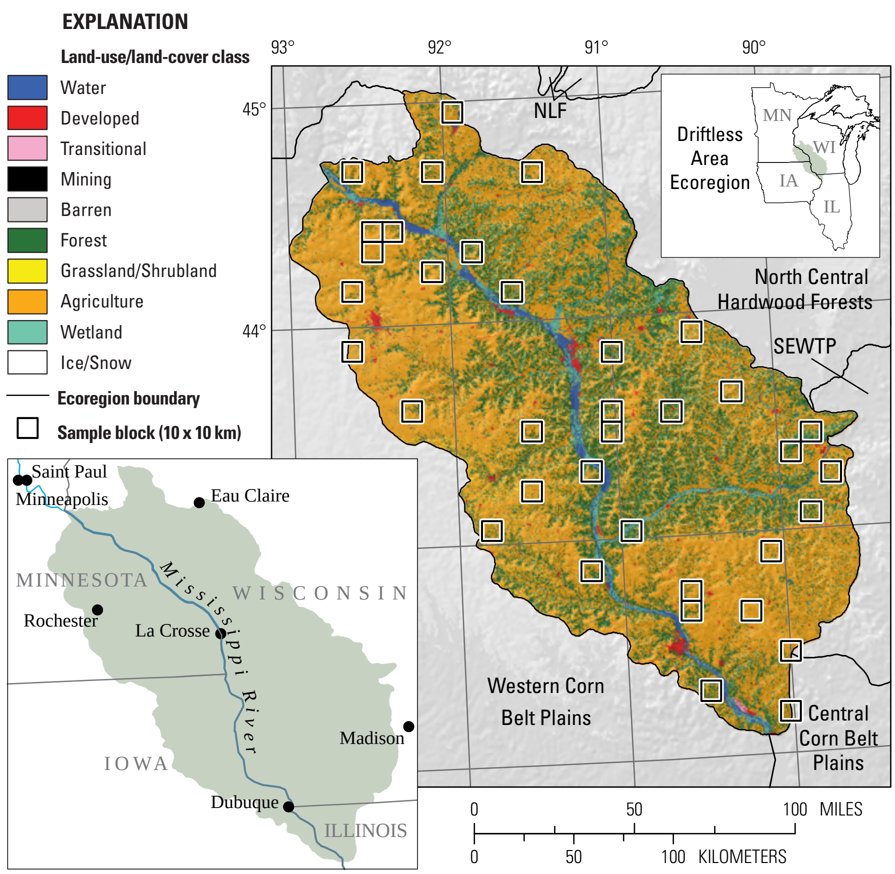

Figure 1. Map of Driftless Area Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown is part of one Great Plains ecoregion, Western Corn Belt Plains. See appendix 3 for definitions of land-use/land-cover classifications.

Historically, tallgrass prairies were the major vegetation type on the plateaus, and wet prairies were the major vegetation type in the valleys. Common prairie species in the ecoregion include little bluestem (*Schizachyrium condensatum*), Indiangrass (*Sorghastrum nutans*), and sideoats grama (*Bouteloua curtipendula*) (Wiken and others, 2011). The hardwood tree species are diverse and include white oak (*Quercus alba*), sugar maple (*Acer saccharum*), and river birch (*Betula nigra*) (Wiken and others, 2011). Land change in the mid-1800s occurred as European settlers altered the natural vegetation by clearing it for agricultural development (McCormick, 2011). The effects of this early land-cover/land-use change were apparent by the early 1900s, when extensive hillside erosion produced large amounts of sediment that accumulated in valleys and streams (McCormick, 2011). Few natural grasslands were present in the ecoregion during the study period, and fire suppression has allowed forests to move into some of the remaining grasslands (Wisconsin Department of Natural Resources, 2012).

Agriculture, which occupies much of the upland areas and, to a lesser extent, the stream valleys, is now the dominant land cover in the ecoregion. Intensive row cropping of corn and soybeans is widespread. In addition to providing foodstuffs for market, these crops help support the livestock industry in the ecoregion, along with hay farming and pasture, which are also common agricultural land uses throughout the ecoregion (figs. 3, 4, 5). However, agricultural runoff and erosion from row cropping has affected the quality of streams and freshwater ecosystems in the ecoregion (McCormick, 2011).

The Driftless Area Ecoregion is a rural ecoregion with a few small towns and cities in the river valleys. The largest population centers in the ecoregion (2000 populations) are Dubuque, Iowa (89,143); Rochester, Minnesota (124,277); and La Crosse, Wisconsin (126,838) (U.S. Census Bureau, 2001). Metropolitan areas located outside of, but near to, the Driftless Area Ecoregion include (2000 populations) Minneapolis–Saint Paul, Minnesota (2,968,806), and Madison (426,526) and Eau Claire (148,337), Wisconsin (U.S. Census Bureau, 2001).

Figure 2. Stream valley in Driftless Area Ecoregion, showing typical combination of grassland/shrubland, wetland, and agriculture land covers. Buffer areas between streams and agricultural land varied throughout ecoregion.

Figure 4. Example of agriculture land use in Driftless Area Ecoregion, including corn and hay production, as well as livestock grazing on pastureland.

Figure 3. Example of farming up on plateau and in valley and, in between, forested hillside too steep to farm, in Driftless Area Ecoregion.

Figure 5. Contour farming, an erosion-control management practice used in Driftless Area Ecoregion.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Driftless Area Ecoregion between 1973 and 2000 is estimated at 1.8 percent (table 1). Compared to other Midwest–South Central United States ecoregions, change in the Driftless Area Ecoregion was the lowest overall (table 1; fig. 6): about 1.4 percent of the area changed only once during the study period, and about 0.3 percent changed twice. The change per time period was relatively constant, at 0.5 percent of the ecoregion between 1973 and 1986, and 0.6 percent in between 1986 and 2000 (table 2). When normalized to an annual rate of change to account for uneven time periods, the average rate for each time period was 0.1 percent, ranging from 35 to 48 km^2 per year (table 2; fig. 7).

Agriculture land cover experienced the greatest amount of net change between 1973 and 2000 (fig. 8), a 362 km^2 decrease from 64.7 to 63.9 percent of the ecoregion, but it remained the predominant land cover throughout the 27-year study period (table 3). Forest was the second most predominant land cover throughout the study period, covering about 30.8 percent of the land area, but it experienced essentially no net change, expanding into grassland/shrubland in some areas and being cleared for agriculture in other areas. The wetland and developed land-cover classes covered only between 1 and about 2 percent of the land area. All other land-cover classes

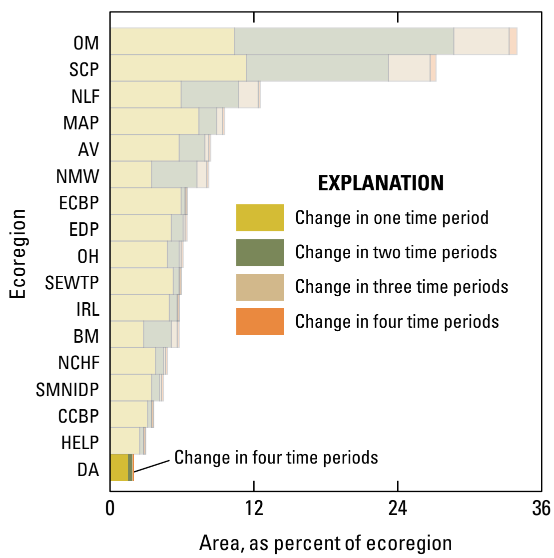

Figure 6. Overall spatial change in Driftless Area Ecoregion (DA; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Driftless Area Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

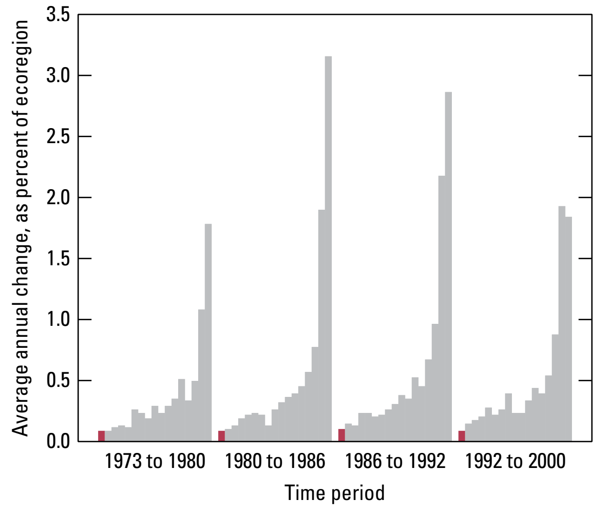

Figure 7. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Driftless Area Ecoregion are represented by red bars in each time period.

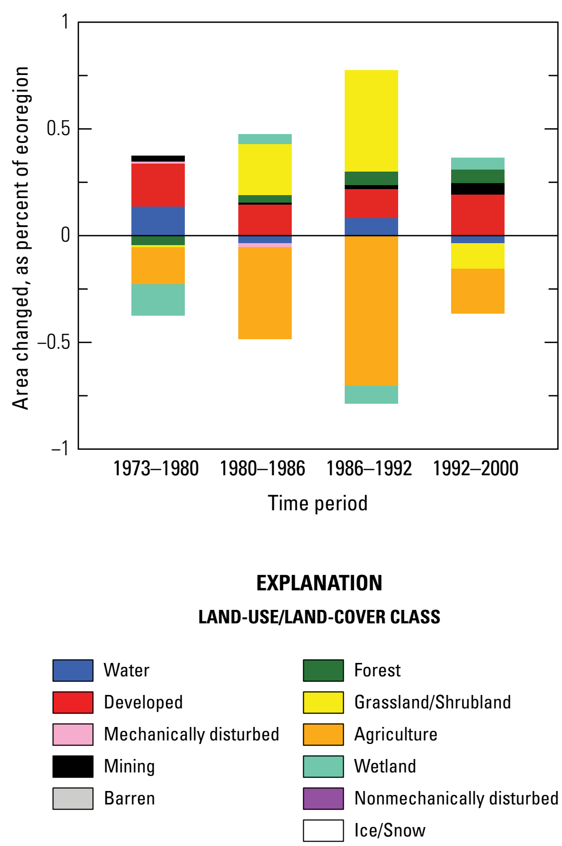

Figure 8. Normalized average net change in Driftless Area Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

each had 1 percent or less of the land area during the study period (table 3). Although few land-cover classes experienced much change, developed expanded by 34.3 percent from its estimated 1973 level, covering 1.3 percent of the ecoregion by 2000. Grassland/shrubland experienced an even larger relative increase of 57.4 percent, but it covered only 0.8 percent of the ecoregion by 2000.

The leading land-cover changes between 1973 and 2000 involved the conversion of agriculture to grassland/shrubland (305 km^2) and to developed (151 km^2) (figs. 9, 10; table 4). These conversions accounted for about 43.7 percent of all change during the study period. Other sources of land-cover change included the conversion of 118 km^2 of wetland to water, as well as the 109 km^2 increase in forest from grassland/shrubland.

Although agriculture was still the predominant land cover in the ecoregion, this land-cover class lost some area to other land-cover classes. The most common conversion (agriculture to grassland/shrubland) may be attributed either to farmland abandonment or to enrollment in the Conservation Reserve Program (CRP). The CRP removed sensitive areas of farmland from production to reduce soil loss and agricultural runoff associated with fertilizers, thereby improving water quality and wildlife habitat (fig. 9).

Although the ecoregion remained predominantly rural, some suburban and exurban development did occur, much of it on agricultural land (fig. 10). The expansion of the nearby Eau Claire and Madison, Wisconsin, and Minneapolis–Saint Paul, Minnesota, metropolitan areas contributed to much of the development within the Driftless Area Ecoregion.

Figure 9. Former agricultural land probably enrolled in Conservation Reserve Program (CRP), in Driftless Area Ecoregion.

Figure 10. Example of exurban development in Driftless Area Ecoregion.

Table 1. Percentage of Driftless Area Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (98.2 percent), whereas 1.8 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	1.4	0.5	0.9	1.9	0.3	24.2
2	0.3	0.2	0.2	0.5	0.1	32.9
3	0.0	0.0	0.0	0.1	0.0	51.8
4	0.0	0.0	0.0	0.0	0.0	64.8
Overall spatial change	1.8	0.5	1.2	2.3	0.4	20.7

Table 2. Raw estimates of change in Driftless Area Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
			Estimate of change, in percent stratum				
1973–1980	0.5	0.2	0.4	0.7	0.1	22.2	0.1
1980–1986	0.5	0.2	0.2	0.7	0.1	31.6	0.1
1986–1992	0.6	0.2	0.4	0.8	0.2	26.3	0.1
1992–2000	0.6	0.2	0.4	0.8	0.1	21.5	0.1
			Estimate of change, in square kilometers				
1973–1980	248	81	167	329	55	22.2	35
1980–1986	216	101	116	317	68	31.6	36
1986–1992	288	112	176	399	76	26.3	48
1992–2000	293	93	200	386	63	21.5	37

Table 3. Estimated area (and margin of error) of each land-cover class in Driftless Area Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mecha-nically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mecha-nically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	0.9	0.6	1.0	0.4	0.0	0.0	0.1	0.0	0.0	0.0	30.8	3.9	0.5	0.2	64.7	4.3	2.1	0.6	0.0	0.0
1980	1.0	0.7	1.1	0.4	0.0	0.0	0.1	0.0	0.0	0.0	30.7	3.9	0.5	0.2	64.6	4.3	2.0	0.6	0.0	0.0
1986	1.0	0.6	1.2	0.4	0.0	0.0	0.1	0.0	0.0	0.0	30.8	3.9	0.6	0.3	64.4	4.3	2.0	0.6	0.0	0.0
1992	1.0	0.7	1.2	0.4	0.0	0.0	0.1	0.0	0.0	0.0	30.8	3.9	0.9	0.5	64.0	4.3	2.0	0.6	0.0	0.0
2000	1.0	0.6	1.3	0.5	0.0	0.0	0.1	0.0	0.0	0.0	30.8	3.9	0.8	0.5	63.9	4.3	2.0	0.6	0.0	0.0
Net change	0.1	0.1	0.3	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.3	0.4	–0.8	0.5	–0.1	0.1	0.0	0.0
Gross change	0.4	0.3	0.3	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.1	0.7	0.5	1.2	0.5	0.4	0.3	0.0	0.0
Area, in square kilometers																				
1973	428	267	466	181	4	4	30	11	2	2	14,639	1,841	242	97	30,782	2,070	997	289	0	0
1980	461	316	514	194	6	6	36	14	2	2	14,629	1,839	238	98	30,741	2,066	962	282	0	0
1986	452	296	549	205	3	2	37	14	2	2	14,639	1,837	295	147	30,639	2,062	974	285	0	0
1992	473	330	581	212	3	2	43	15	2	2	14,654	1,836	409	223	30,472	2,039	955	281	0	0
2000	464	306	626	223	4	4	54	22	2	2	14,670	1,838	381	226	30,421	2,068	967	282	0	0
Net change	36	57	160	53	1	6	24	14	0	0	32	47	139	169	–362	217	–30	59	0	0
Gross change	177	154	160	53	22	11	27	14	0	0	178	30	356	229	563	250	179	154	0	0

Table 4. Principal land-cover conversions in Driftless Area Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for “other” class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class		Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Wetland	Water		58	62	42	0.1	23.4
	Agriculture	Developed		52	29	20	0.1	20.9
	Grassland/Shrubland	Forest		33	18	12	0.1	13.5
	Forest	Agriculture		32	17	11	0.1	13.0
	Agriculture	Grassland/Shrubland		27	13	9	0.1	10.9
	Other	Other		45	n/a	n/a	0.1	18.3
			Totals	248			0.5	100.0
1980–1986	Agriculture	Grassland/Shrubland		84	88	60	0.2	38.8
	Grassland/Shrubland	Forest		30	14	10	0.1	14.0
	Agriculture	Developed		29	14	9	0.1	13.4
	Water	Wetland		21	24	16	0.0	9.5
	Forest	Agriculture		18	9	6	0.0	8.5
	Other	Other		34	n/a	n/a	0.1	15.8
			Totals	216			0.5	100.0
1986–1992	Agriculture	Grassland/Shrubland		139	103	70	0.3	48.4
	Wetland	Water		35	39	27	0.1	12.3
	Agriculture	Developed		29	13	9	0.1	10.2
	Grassland/Shrubland	Forest		26	12	8	0.1	9.0
	Water	Wetland		16	11	7	0.0	5.5
	Other	Other		42	n/a	n/a	0.1	14.7
			Totals	288			0.6	100.0
1992–2000	Grassland/Shrubland	Agriculture		64	70	47	0.1	21.7
	Agriculture	Grassland/Shrubland		55	39	26	0.1	18.7
	Agriculture	Developed		41	18	13	0.1	14.1
	Water	Wetland		25	27	18	0.1	8.6
	Agriculture	Forest		25	14	9	0.1	8.5
	Other	Other		83	n/a	n/a	0.2	28.4
			Totals	293			0.6	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland		305	203	138	0.6	29.2
	Agriculture	Developed		151	52	35	0.3	14.5
	Wetland	Water		118	103	70	0.2	11.2
	Grassland/Shrubland	Forest		109	48	32	0.2	10.5
	Water	Wetland		88	66	45	0.2	8.4
	Other	Other		274	n/a	n/a	0.6	26.3
			Totals	1,045			2.2	100.0

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Chapter 5

Southern Michigan/Northern Indiana Drift Plains Ecoregion

By Steven Kambly

Ecoregion Description

The Southern Michigan/Northern Indiana Drift Plains Ecoregion covers about 73,987 km^2 (28,566 mi^2) from northern Indiana into Michigan's lower peninsula and "Thumb" region (fig. 1) (Omernik, 1987; Wiken and others, 2011). The Huron/Erie Lake Plains Ecoregion lies both north and south of the eastern part of the ecoregion; the Eastern Corn Belt Plains and Central Corn Belt Plains Ecoregions lie to the south; and the Northern Lakes and Forests Ecoregion and a small part of the North Central Hardwood Forests Ecoregion lie to the north. It has a humid continental climate, with average annual precipitation levels ranging from 750 to 990 mm (30 to 39 in.), and it typically is characterized by warm summers and severe winters (Wiken and others, 2011). Average annual minimum and maximum temperatures are –13°C and 29.5°C, respectively, and the annual frost-free period ranges from 140 to 200 days (Wiken and others, 2011).

The Southern Michigan/Northern Indiana Drift Plains Ecoregion is situated between highly productive agricultural

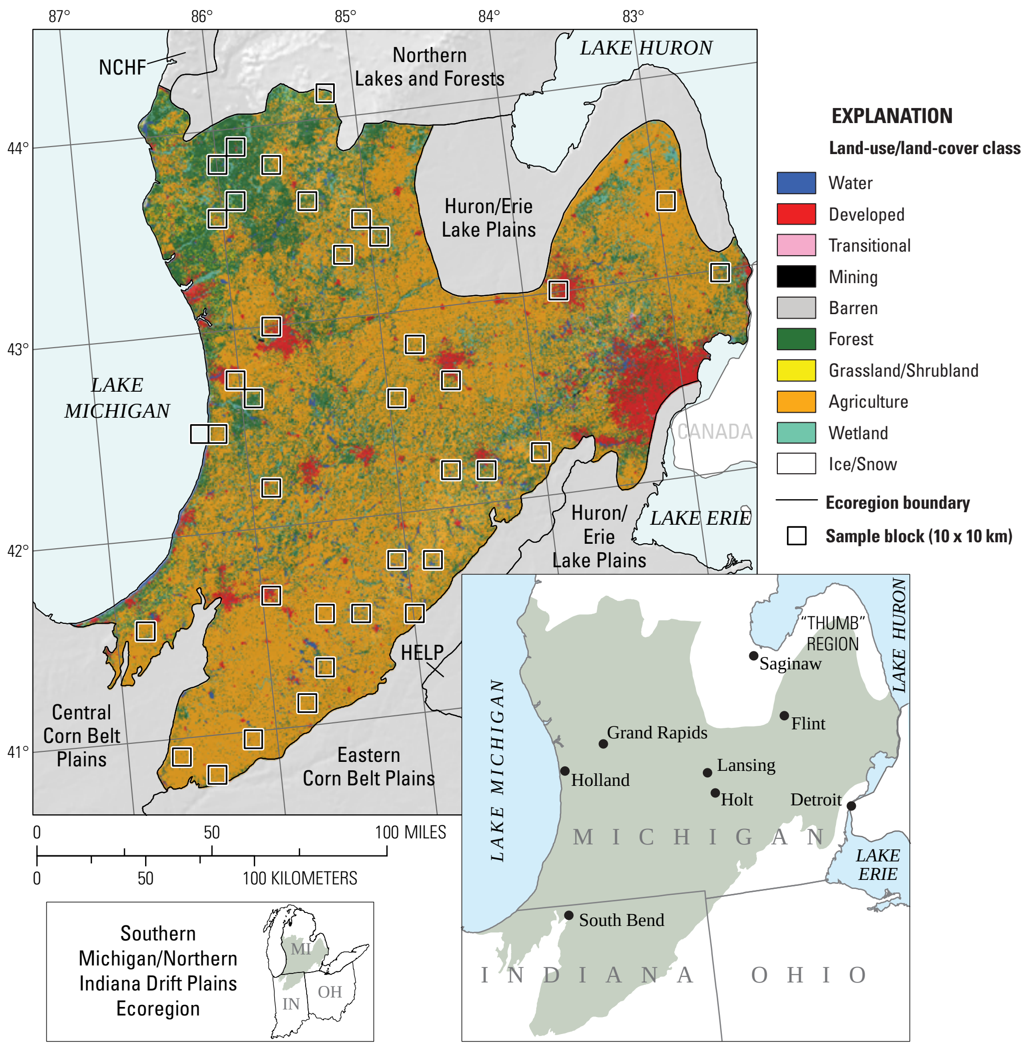

Figure 1. Map of Southern Michigan/Northern Indiana Drift Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

land to the south and east and large expanses of forests, lakes, and wetlands to the north. The landscape of the ecoregion largely is the result of glaciation, and many glacial landforms (including till plains, morainal hills, kames, drumlins, and kettles, as well as paleo–beach ridges and relict dunes) define its topography (U.S. Environmental Protection Agency, 2002). Soils are mostly Alfisols, which are highly suitable for agriculture.

Corn is the most extensively grown crop, followed by soybeans, hay, wheat, dry beans, miscellaneous fruits and vegetables, sugar beets, and potatoes. Corn, soybeans, wheat, and hay are cultivated throughout the ecoregion; sugar beets and dry beans are cultivated primarily in Michigan's "Thumb" region and the lowlands around Saginaw, Michigan (figs. 2,3). Livestock operations include dairying, beef production, and hog, chicken, and turkey farming. Overall, cropland and pastureland constitute most of the landscape in the ecoregion.

Forests, which make up about one-quarter of the ecoregion, largely are deciduous, with four main types: oak-hickory (*Quercus* spp. and *Carya* spp., respectively), American elm–ash–maple (*Ulmus americana, Fraxinus* spp., and *Acer* spp., respectively), aspen-birch (*Populus* spp. and *Betula* spp., respectively), and maple–American beech–birch (*Acer* spp., *Fagus grandifolia*, and *Betula* spp., respectively). In the ecoregion, white pine (*Pinus strobus*) is common among the conifers, although conifers are less common than the deciduous species (U.S. Environmental Protection Agency, 2007). Primarily because of the large-scale clearing of forests for farmland in the latter half of the 1800s, the extent of forest land has decreased substantially from pre–European-settlement levels (Rudy and others, 2008). Furthermore, urbanization in both rural and suburban areas has increased, which may have increased forest fragmentation in the ecoregion.

The cities of South Bend, Indiana, and Detroit, Flint, Lansing, and Grand Rapids, Michigan, contributed to the expansion of developed land throughout the 20th century, as new suburban and exurban development occurred in the outlying regions of these metropolitan areas. This growth was the leading cause of decreases in farmland, forests, and wetlands in the ecoregion (figs. 3,4,5).

Figure 2. Soybeans, major crop in Southern Michigan/Northern Indiana Drift Plains Ecoregion.

Figure 3. Corn field with "developable land" sign, near Holland, Michigan.

Figure 4. Former automobile-manufacturing site that has become vacant land, in Flint, Michigan.

Figure 5. New subdivision near Holt, Michigan.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Southern Michigan/Northern Indiana Drift Plains Ecoregion between 1973 and 2000 is estimated at 4.2 percent. Compared to other Midwest–South Central United States ecoregions, change in the Southern Michigan/Northern Indiana Drift Plains Ecoregion was relatively low (table 1; fig. 6): an estimated 3.5 percent of the ecoregion changed in only one time period, whereas 0.6 and 0.1 percent of the ecoregion changed in two and three time periods, respectively (table 1). The estimated change per time period increased steadily from 0.8 percent of the ecoregion between 1973 and 1980 to 1.6 percent between 1992 and 2000. The normalized estimated annual rates of change also indicate a consistent increase between 1973 and 1992 (from 89 to 171 km^2 per year), with a slight decrease to 152 km^2 per year between 1992 and 2000 (table 2; fig. 7).

Only two land-cover classes, developed and agriculture, had an estimated net change in area of greater than one percent during the study period (table 3). Developed increased by 24.4 percent (1,415 km^2), whereas agriculture decreased by 3.1 percent (1,231 km^2) (table 3). Most of the change in both land-cover classes resulted from conversion of farmland to developed land. In fact, nearly all the conversions of agriculture were to developed, except for small amounts that converted to grassland/shrubland or forest, which had net decreases of 8 percent and 1 percent, respectively, from their 1973 estimated levels.

The most common change during the study period was the conversion of agriculture to developed (fig. 8), which accounted for 25.7 percent of all change detected (table 4). Overall, 945 km^2 of farmland converted to developed land, with almost half of this conversion (420 km^2) occurring between 1992 and 2000. Forest also converted to developed, which was the fifth leading conversion overall; an estimated 288 km^2 changed to developed between 1973 and 2000. The second leading conversion throughout the study period was from grassland/shrubland to forest. Generally, this conversion was an intermediate change, as agriculture initially converted to grassland/shrubland (the fourth leading conversion) before reverting to forest. During the first and last time periods, areas of farmland that converted directly to forest ranked among the top five types of changes (table 4). Between 1973 and 2000, the amount of farmland that converted to grassland/shrubland was estimated at 342 km^2 (table 4), whereas the amount of farmland that converted to forest was estimated at 223 km^2 (these amounts are included as part of the "Other" change class in table 4).

Developed increased more than any other land-cover class during the 27-year study period, from an estimated 7.8 to 9.8 percent of the ecoregion. Increases in developed

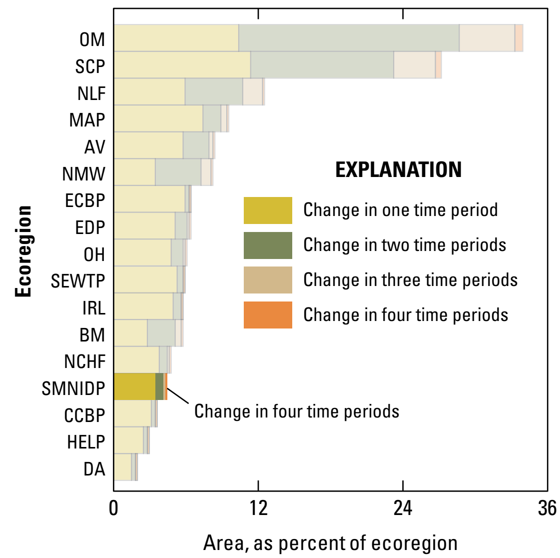

Figure 6. Overall spatial change in Southern Michigan/Northern Indiana Drift Plains Ecoregion (SMNIDP; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Southern Michigan/Northern Indiana Drift Plains Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

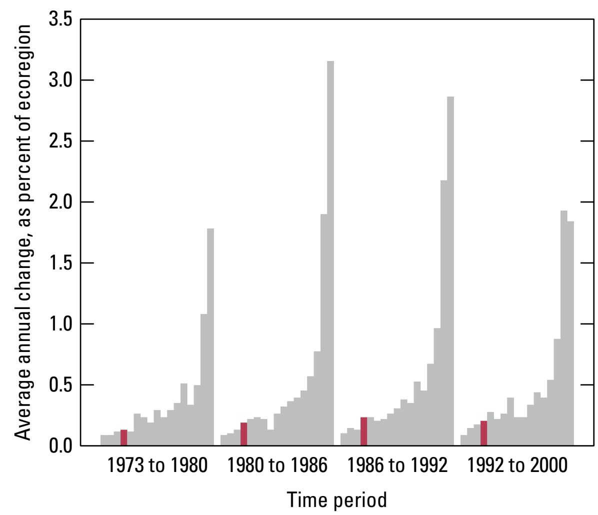

Figure 7. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Southern Michigan/Northern Indiana Drift Plains Ecoregion are represented by red bars in each time period.

occurred most notably in the suburban and exurban counties that surround the cities of Detroit, Flint, Lansing, and Grand Rapids, Michigan. In general, suburban and exurban growth was due to large-scale population shifts from city centers and older suburbs to outlying counties. The building of new communities—characterized by lower density development and following a state-wide trend toward smaller household size—increased the amount of developed land per capita (Michigan Land Use Leadership Council, 2003) and resulted in a decrease in farmland and more natural land covers.

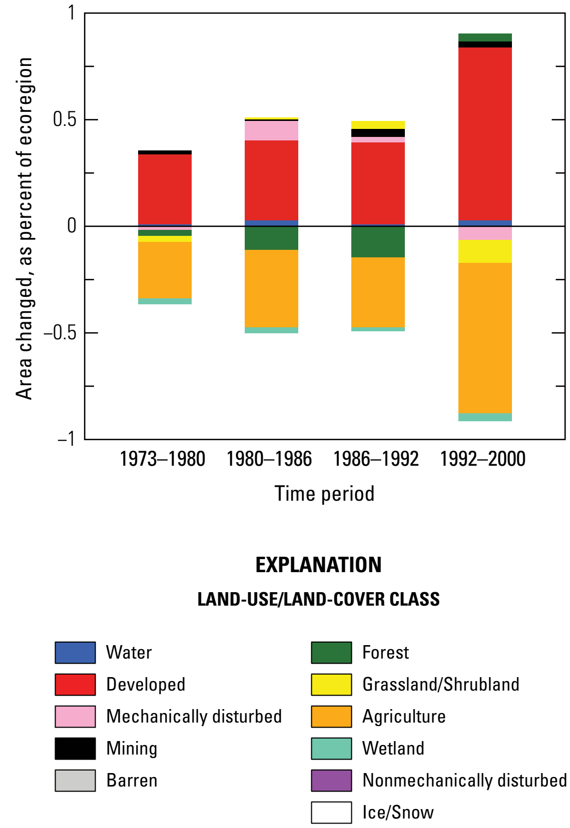

Figure 8. Normalized average net change in Southern Michigan/Northern Indiana Drift Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Table 1. Percentage of Southern Michigan/Northern Indiana Drift Plains Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (95.8 percent), whereas 4.2 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	3.5	0.8	2.7	4.3	0.6	16.1
2	0.6	0.3	0.4	0.9	0.2	28.7
3	0.1	0.1	0.0	0.2	0.1	59.7
4	0.0	0.0	0.0	0.0	0.0	54.6
Overall spatial change	4.2	0.9	3.3	5.1	0.6	14.9

Table 2. Raw estimates of change in Southern Michigan/Northern Indiana Drift Plains Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	0.8	0.2	0.7	1.0	0.1	14.9	0.1
1980–1986	1.1	0.3	0.8	1.4	0.2	17.6	0.2
1986–1992	1.4	0.4	1.0	1.8	0.3	19.7	0.2
1992–2000	1.6	0.5	1.2	2.1	0.3	19.3	0.2
Estimate of change, in square kilometers							
1973–1980	624	137	487	760	93	14.9	89
1980–1986	819	212	607	1,031	144	17.6	136
1986–1992	1,025	297	728	1,321	201	19.7	171
1992–2000	1,216	345	871	1,561	234	19.3	152

Table 3. Estimated area (and margin of error) of each land-cover class in Southern Michigan/Northern Indiana Drift Plains Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mecha-nically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mecha-nically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	4.1	3.9	7.8	3.7	0.0	0.0	0.1	0.0	0.0	0.0	24.4	4.8	1.3	0.4	54.2	6.0	7.9	1.6	0.0	0.0
1980	4.2	3.9	8.2	3.8	0.0	0.0	0.1	0.0	0.0	0.0	24.4	4.8	1.3	0.3	54.0	6.0	7.9	1.6	0.0	0.0
1986	4.2	3.9	8.5	3.9	0.1	0.1	0.1	0.0	0.0	0.0	24.3	4.7	1.3	0.3	53.6	6.1	7.9	1.6	0.0	0.0
1992	4.2	3.9	8.9	4.0	0.2	0.1	0.2	0.1	0.0	0.0	24.1	4.7	1.3	0.3	53.3	6.1	7.8	1.6	0.0	0.0
2000	4.2	3.9	9.8	4.3	0.1	0.1	0.2	0.1	0.0	0.0	24.2	4.7	1.2	0.3	52.6	6.2	7.8	1.6	0.0	0.0
Net change	0.1	0.0	1.9	0.7	0.1	0.1	0.1	0.0	0.0	0.0	–0.2	0.4	–0.1	0.2	–1.7	0.6	–0.1	0.1	0.0	0.0
Gross change	0.1	0.0	1.9	0.7	0.4	0.2	0.1	0.1	0.0	0.0	1.3	0.4	0.8	0.3	2.1	0.6	0.2	0.1	0.0	0.0
Area, in square kilometers																				
1973	3,069	2,879	5,801	2,765	30	32	81	29	0.3	0.4	18,063	3,557	957	261	40,127	4,462	5,858	1,205	0	0
1980	3,077	2,879	6,048	2,802	19	15	95	32	0.3	0.4	18,044	3,549	936	258	39,927	4,462	5,842	1,203	0	0
1986	3,096	2,877	6,325	2,887	89	69	102	36	0.3	0.4	17,964	3,508	936	244	39,658	4,497	5,817	1,206	0	0
1992	3,103	2,878	6,610	2,973	112	74	126	51	0.3	0.4	17,855	3,500	964	226	39,416	4,536	5,801	1,211	0	0
2000	3,121	2,877	7,216	3,194	69	66	145	57	0.3	0.4	17,886	3,501	881	208	38,896	4,623	5,773	1,206	0	0
Net change	52	26	1,415	522	39	75	64	36	0.0	0.0	–177	283	–77	145	–1,231	475	–86	41	0	0
Gross change	79	27	1,415	522	267	153	105	39	0.0	0.0	990	267	586	186	1,539	450	138	48	0	0

Table 4. Principal land-cover conversions in Southern Michigan/Northern Indiana Drift Plains Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Agriculture	Developed	145	49	34	0.2	23.3
	Grassland/Shrubland	Forest	85	52	36	0.1	13.6
	Forest	Developed	83	52	35	0.1	13.3
	Forest	Agriculture	65	23	16	0.1	10.4
	Agriculture	Forest	61	40	27	0.1	9.7
	Other	Other	185	n/a	n/a	0.3	29.7
		Totals	624			0.8	100
1980–1986	Agriculture	Developed	207	114	77.6	0.3	25.3
	Agriculture	Grassland/Shrubland	111	64	43.7	0.1	13.5
	Grassland/Shrubland	Forest	107	70	47.8	0.1	13.0
	Forest	Agriculture	92	52	35.7	0.1	11.3
	Forest	Mechanically disturbed	84	66	44.7	0.1	10.3
	Other	Other	217	n/a	n/a	0.3	26.5
		Totals	819			1.1	100
1986–1992	Agriculture	Developed	173	104	70.4	0.2	16.9
	Forest	Agriculture	134	75	50.6	0.2	13.1
	Agriculture	Grassland/Shrubland	121	54	36.9	0.2	11.8
	Forest	Mechanically disturbed	104	73	49.4	0.1	10.1
	Grassland/Shrubland	Forest	100	60	40.9	0.1	9.8
	Other	Other	393	n/a	n/a	0.5	38.4
		Totals	1,025			1.4	100
1992–2000	Agriculture	Developed	420	198	134.2	0.6	34.5
	Grassland/Shrubland	Forest	153	91	61.7	0.2	12.6
	Forest	Developed	100	60	40.6	0.1	8.2
	Agriculture	Forest	74	39	26.4	0.1	6.1
	Forest	Mechanically disturbed	63	66	44.6	0.1	5.2
	Other	Other	406	n/a	n/a	0.5	33.4
		Totals	1,216			1.6	100
1973–2000 (overall)	Agriculture	Developed	945	387	263.2	1.3	25.7
	Grassland/Shrubland	Forest	444	218	148.0	0.6	12.1
	Forest	Agriculture	354	145	98.2	0.5	9.6
	Agriculture	Grassland/Shrubland	342	161	109.6	0.5	9.3
	Forest	Developed	288	155	105.4	0.4	7.8
	Other	Other	1,310	n/a	n/a	1.8	35.6
		Totals	3,683			5.0	100

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Chapter 6

Erie Drift Plains Ecoregion

By Janis L. Taylor

Ecoregion Description

The Erie Drift Plains Ecoregion covers about 30,622 km^2 (11,820 mi^2), mainly in northeastern Ohio but also in the northwestern corner of Pennsylvania and the southwestern corner of New York (fig. 1). The ecoregion is bordered by the Northern Appalachian Plateau and Uplands, North Central Appalachians, Western Allegheny Plateau, and Eastern Corn Belt Plains Ecoregions, as well as by a long, narrow strip of the Eastern Great Lakes and Hudson Lowlands Ecoregion, which parallels the shoreline of Lake Erie and separates the lake from the northwestern part of the Erie Drift Plains Ecoregion.

The Allegheny Mountains, part of the Appalachian Mountains system, lie to the south and east of the Erie Drift Plains Ecoregion, and fertile, rolling plains lie to the west. Glacially derived features, which are common in the ecoregion, include low round hills, scattered end moraines, kettles, and wetlands (Omernik, 1987; Wiken and others, 2011). Maple, beech, and birch (*Acer* spp., *Fagus grandifolia*, and *Betula* spp., respectively) forests once covered the Erie Drift Plains Ecoregion, but as human populations increased in the eastern United States throughout the 19th century, much of the forest was cleared for agricultural and other uses. Today (2014), the ecoregion is a mix of agricultural, forested, and developed land (fig. 2).

In 1827, the Ohio & Erie Canal connected the Ohio River to Lake Erie through the Cuyahoga River valley and Cleveland, Ohio. The canal stimulated growth in population, agriculture, and industry throughout Ohio. When

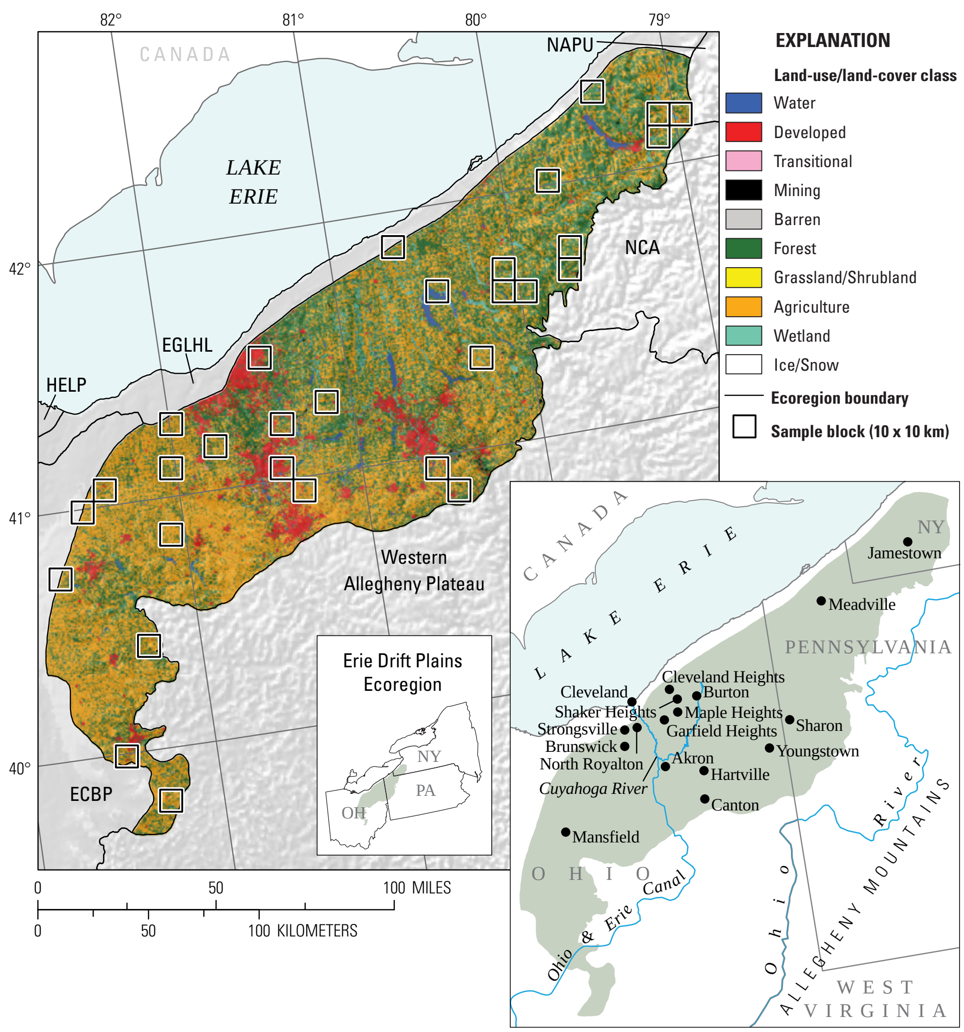

Figure 1. Map of Erie Drift Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status and Trends of Land Change” study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of four Eastern United States ecoregions: Eastern Great Lakes and Hudson Lowlands (EGLHL), Northern Appalachian Plateau and Uplands (NAPU), North Central Appalachians (NCA), and Western Allegheny Plateau. See appendix 3 for definitions of land-use/land-cover classifications.

first developed, this transportation system provided farmers a means to move their agricultural products to, and to acquire other products from, urban markets in the eastern United States. In 1861, the railroad replaced the canal as a major transportation system. Today (2014), the canal is maintained as a water supply for local industries, and a recreational trail system runs along parts of it.

The Cuyahoga River drains a watershed of 2,103 km^2 in northeastern Ohio; most of this watershed is in the Erie Drift Plains Ecoregion. From its headwaters near Burton, Ohio, the Cuyahoga River flows 161 km southwest and then north before entering Lake Erie at Cleveland, Ohio. This watershed provides fresh water for more than 15 percent of Ohio's population (1.6 million people) (U.S. Environmental Protection Agency, 2013). In the late 1960s, the Cuyahoga River was considered the most polluted river in the nation—a symbol of industrial neglect of the environment. In 1969, the river became infamous when kerosene-laden oil from industrial spills, which was floating on the river, caught fire. This fire spurred efforts to develop clean-water legislation, resulting in the Environmental Protection Act of 1970 and the Clean Water Act of 1972. Today, the Cuyahoga River is designated as one of the Environmental Protection Agency's American Heritage Rivers (Cuyahoga American Heritage River Program, 2001).

Transportation improvements in the Erie Drift Plains Ecoregion have supported a diverse economy, with strengths in manufacturing and agriculture. Major crops grown in the ecoregion include corn, soybeans, wheat, and oats (Woods and others, 1999), as well as market produce such as sweet corn, sweet peppers, pumpkins, onions, mustard greens, kale, and herbs (fig. 3). Beef production and dairy farming are common in rural areas. Lake Erie has a moderating effect on air temperatures, and vineyards and wineries line its shore (U.S. Department of Agriculture, 2012). In addition, apple and peach orchards, as well as maple-sugar-refining operations, thrive in this area. All contribute to the diversity of agricultural goods produced in the ecoregion.

The major urban areas in or near the ecoregion are Cleveland, Akron, Mansfield, Youngstown, and Canton, Ohio; Sharon and Meadville, Pennsylvania; and Jamestown, New York. Cleveland, the second largest city and the leading industrial city in Ohio, sits just north of the ecoregion. The location of Cleveland on the shores of Lake Erie accounts for its success as a transportation, industrial, and commercial center, and the city is at the center of a very large metropolitan statistical area that encompasses multiple counties. Although Cleveland is not located in the Erie Drift Plains Ecoregion, most of its growing suburbs are; these include Maple Heights, Garfield Heights, Shaker Heights, Cleveland Heights, North Royalton, Strongsville, and Brunswick, Ohio (fig. 4).

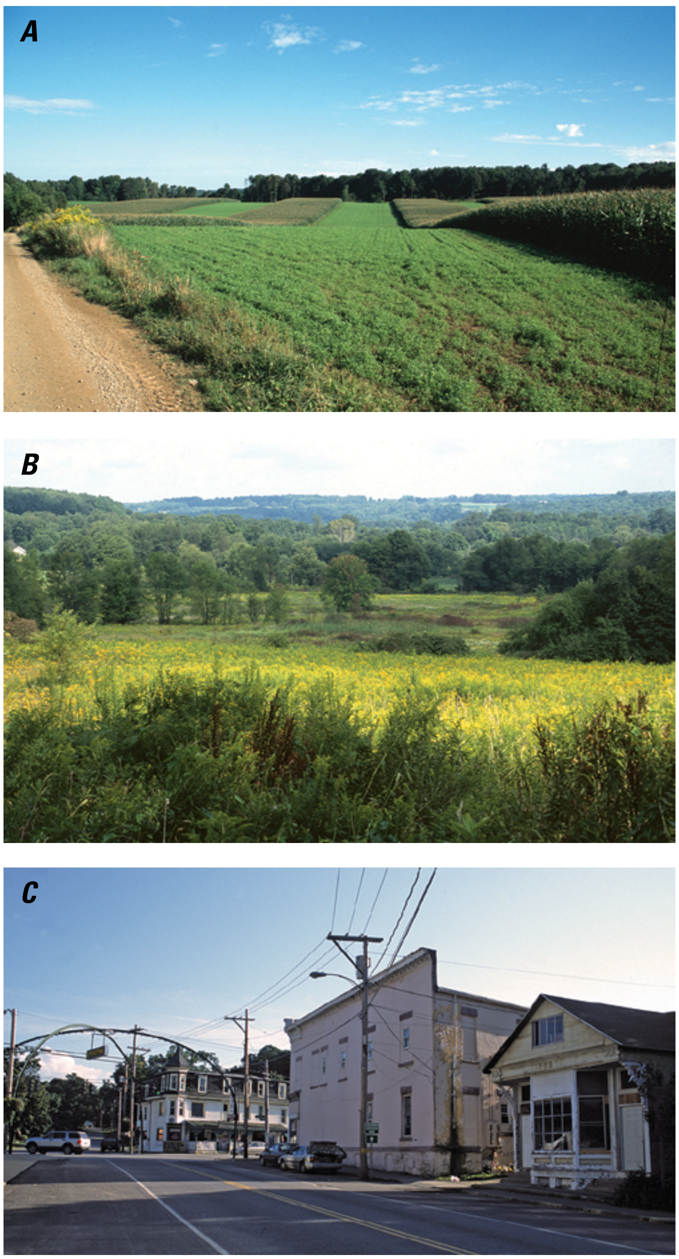

Figure 2. Examples of (*A*) agriculture, (*B*) forest, and (*C*) developed land-cover classes in Erie Drift Plains Ecoregion.

Figure 3. Agricultural field with newly emerged vegetable crop, near Hartville, Ohio.

Figure 4. New urban development, located between Cleveland and Akron, Ohio.

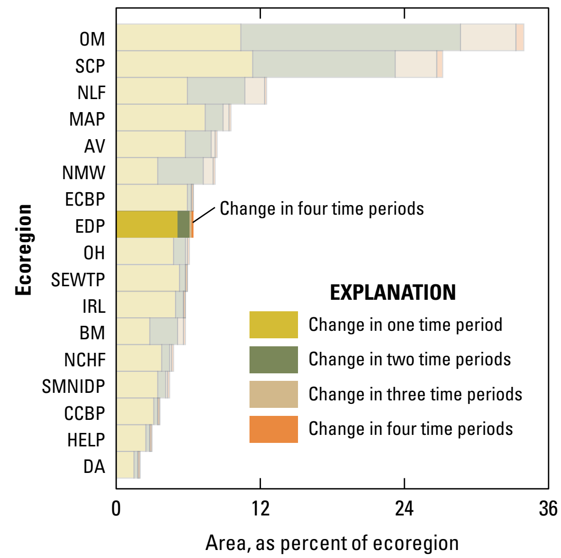

Figure 5. Overall spatial change in Erie Drift Plains Ecoregion (EDP; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Erie Drift Plains Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Erie Drift Plains Ecoregion between 1973 and 2000 is estimated at 6.1 percent (1,860 km^2) (table 1). Compared to other Midwest–South Central United States ecoregions, change in the Erie Drift Plains Ecoregion was moderate (table 1; fig. 5): about 4.9 percent of the area changed in one time period, and 1.1 percent changed in two time periods (table 1). Total change in each time period ranged from 1.6 percent (477 km^2) between 1973 and 1980 to 2.2 percent (677 km^2) between 1986 and 1992 (table 2). After normalizing change per period to an annual rate to account for uneven time periods, change ranged from a low of 0.2 percent (68 km^2) per year in the periods between 1973 and 1980 and between 1992 and 2000 to a high of 0.4 percent (113 km^2) per year in the period between 1986 and 1992 (table 2; fig. 6).

Forest, agriculture, and developed land-cover classes accounted for about 94.5 percent (28,970 km^2) of the ecoregion area during the 27-year study period. The extent of forest decreased by about 2.0 percent (209 km^2), from 37.5 percent (11,491 km^2) in 1973 to 36.8 percent (11,282 km^2) in 2000. Agriculture decreased by 5.3 percent (768 km^2), from 47.6 percent (14,562 km^2) in 1973 to 45.0 percent (13,794 km^2) in 2000. Developed changed the most during the study period, with an increase of 33.9 percent (986 km^2), from 9.5 percent (2,908 km^2) in 1973 to 12.7 percent (3,894 km^2) in 2000 (table 3; fig. 7).

Overall, agriculture and forest land-cover conversions were the two most common conversions during the study period. An estimated 3.0 percent (925 km^2) of either agriculture or forest that was mapped in 1973 had converted to developed by 2000, with forest providing most of this conversion in the first time period (1973–1980) and then agriculture losing more

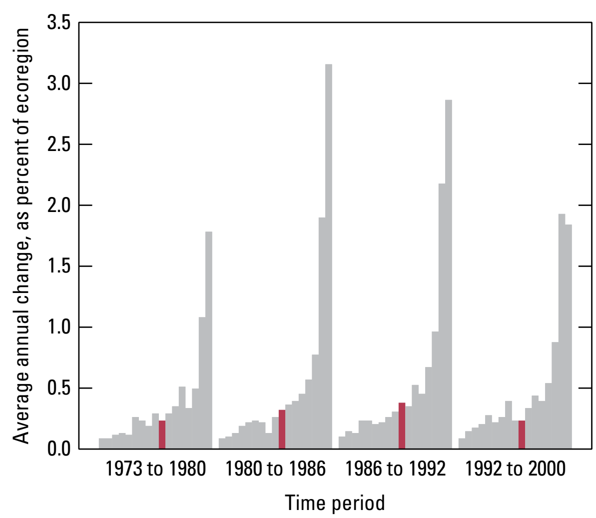

Figure 6. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Erie Drift Plains Ecoregion are represented by red bars in each time period.

land in the last three time periods (1980–1986, 1986–1992, and 1992–2000) (table 4). This unidirectional land-cover change to developed was driven by increases in population in the counties that lie along major highways. The third most common land-cover conversion was from grassland/shrubland to forest (215 km^2) (table 4). This type of conversion may indicate agricultural abandonment in the past, as grassland/shrubland often results when agricultural land is idled, and then, commonly, trees eventually occupy these grassland/shrubland areas.

On the basis of interpretation of 30 sample blocks in the ecoregion, the highest rates of change were determined in the sample blocks in the urban corridor along major highways between Cleveland, Akron, and Youngstown (fig. 8). Generally speaking, the sample blocks that were adjacent to previously developed areas were changing the fastest. The surrounding areas were a combination of agricultural fields and forested lands; change was minimal within these areas during the study period.

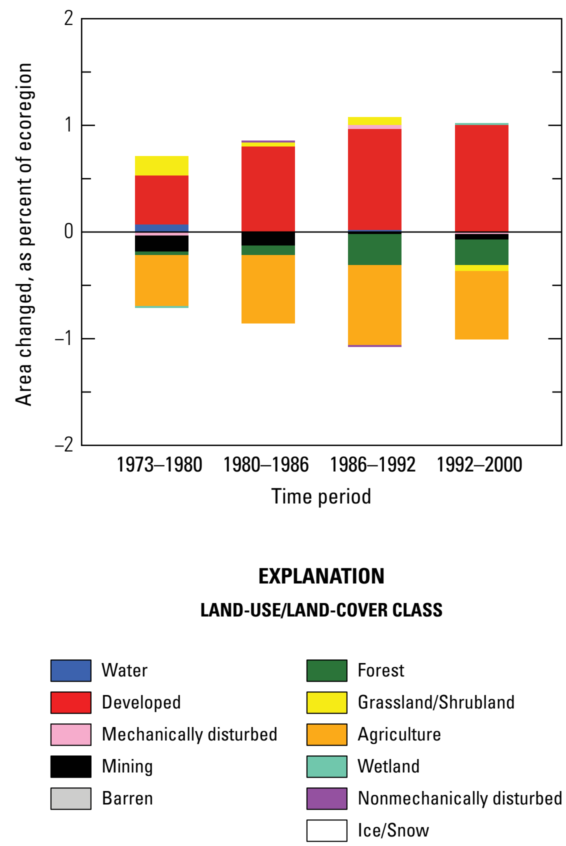

Figure 7. Normalized average net change in Erie Drift Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

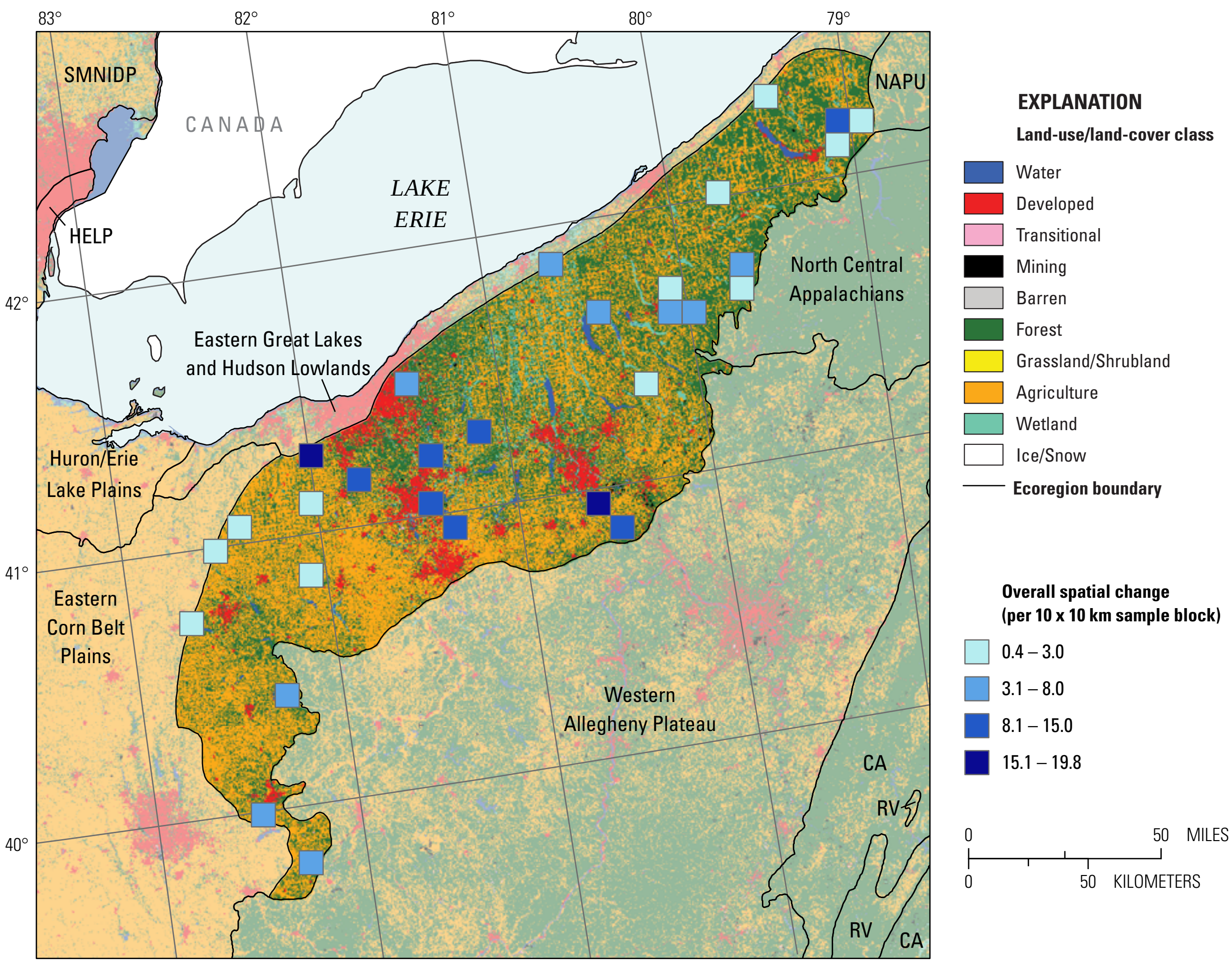

Figure 8. Map of Erie Drift Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001) and locations of 10 x 10 km sample blocks (squares). When sample blocks are ranked by percentage of overall spatial change between 1973 and 2000, geographic pattern emerges: sample blocks that had highest amounts of change are located mostly in urban corridors southeast of Cleveland (see fig. 1 for location). Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2; also shown are parts of six Eastern United States ecoregions: Central Appalachians (CA), Eastern Great Lakes and Hudson Lowlands, Northern Appalachian Plateau and Uplands (NAPU), North Central Appalachians, Ridge and Valley (RV), and Western Allegheny Plateau. See appendix 3 for definitions of land-use/land-cover classifications. Note that not all land-use/land-cover classes shown in explanation may be depicted on map (colors that indicate land-use/land-cover classes in surrounding ecoregions are subdued); note also that, for this “Status and Trends of Land Change” study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes.

Table 1. Percentage of Erie Drift Plains Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (93.9 percent), whereas 6.1 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	4.9	1.2	3.7	6.1	0.8	16.3
2	1.1	0.3	0.8	1.4	0.2	20.0
3	0.1	0.1	0.1	0.2	0.0	33.0
4	0.0	0.0	0.0	0.0	0.0	57.1
Overall spatial change	6.1	1.4	4.7	7.5	0.9	15.5

Table 2. Raw estimates of change in Erie Drift Plains Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	1.6	0.4	1.1	2.0	0.3	18.0	0.2
1980–1986	1.9	0.5	1.4	2.3	0.3	16.8	0.3
1986–1992	2.2	0.6	1.6	2.8	0.4	19.0	0.4
1992–2000	1.9	0.5	1.4	2.3	0.3	17.3	0.2
Estimate of change, in square kilometers							
1973–1980	477	127	350	604	86	18.0	68
1980–1986	572	142	430	714	96	16.8	95
1986–1992	677	190	486	867	129	19.0	113
1992–2000	570	146	424	716	98	17.3	71

Table 3. Estimated area (and margin of error) of each land-cover class in Erie Drift Plains Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Nonmechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	1.9	1.3	9.5	3.8	0.1	0.1	0.6	0.3	0.0	0.0	37.5	3.5	0.6	0.3	47.6	4.9	2.3	0.6	0.0	0.0
1980	2.0	1.3	10.0	3.8	0.1	0.0	0.4	0.2	0.0	0.0	37.5	3.5	0.7	0.4	47.1	4.9	2.3	0.6	0.0	0.0
1986	2.0	1.3	10.8	4.0	0.1	0.0	0.3	0.2	0.0	0.0	37.4	3.6	0.7	0.5	46.4	4.9	2.3	0.6	0.0	0.0
1992	2.0	1.3	11.7	4.1	0.1	0.1	0.3	0.2	0.0	0.0	37.1	3.6	0.8	0.5	45.7	4.9	2.3	0.6	0.0	0.0
2000	2.0	1.3	12.7	4.3	0.1	0.0	0.3	0.1	0.0	0.0	36.8	3.7	0.8	0.5	45.0	4.9	2.3	0.6	0.0	0.0
Net change	0.1	0.1	3.2	1.2	0.0	0.0	–0.3	0.2	0.0	0.0	–0.7	0.7	0.2	0.3	–2.5	0.8	0.0	0.0	0.0	0.0
Gross change	0.1	0.1	3.2	1.2	0.3	0.1	0.4	0.2	0.0	0.0	2.0	0.5	0.9	0.3	2.8	0.8	0.1	0.0	0.0	0.0
Area, in square kilometers																				
1973	576	398	2,908	1,154	31	21	178	93	0.7	1.0	11,491	1,080	169	103	14,562	1,505	707	182	0	0
1980	598	397	3,051	1,178	18	11	136	73	0.0	0.1	11,480	1,084	222	129	14,415	1,492	703	182	0	0
1986	600	399	3,295	1,218	22	11	99	51	0.0	0.0	11,449	1,089	229	138	14,220	1,500	703	182	5	7
1992	607	398	3,586	1,261	34	20	96	49	0.8	1.1	11,357	1,112	248	139	13,992	1,496	701	181	0	0
2000	608	398	3,894	1,322	30	11	80	44	0.0	0.0	11,282	1,119	232	148	13,794	1,491	702	181	0	0
Net change	32	16	986	359	–1	14	–98	69	–0.7	1.0	–209	209	63	79	–768	258	–5	8	0	0
Gross change	40	16	986	359	96	42	135	72	2.3	3.2	603	164	279	78	870	237	21	9	10	13

Table 4. Principal land-cover conversions in Erie Drift Plains Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" classes are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Developed	67	36	24	0.2	13.9
	Agriculture	Developed	63	32	21	0.2	13.2
	Mining	Grassland/Shrubland	56	38	25	0.2	11.8
	Grassland/Shrubland	Forest	42	22	15	0.1	8.9
	Agriculture	Grassland/Shrubland	35	19	13	0.1	7.4
	Other	Other	213	n/a	n/a	0.7	44.7
		Totals	477			1.6	100
1980–1986	Agriculture	Developed	139	68	45.6	0.5	24.3
	Forest	Developed	98	45	30.6	0.3	17.1
	Grassland/Shrubland	Forest	73	33	22.0	0.2	12.7
	Agriculture	Grassland/Shrubland	44	27	18.2	0.1	7.6
	Mining	Grassland/Shrubland	43	32	21.3	0.1	7.6
	Other	Other	175	n/a	n/a	0.6	30.7
		Totals	572			1.9	100
1986–1992	Agriculture	Developed	149	76	51.6	0.5	22.1
	Forest	Developed	137	77	52.0	0.4	20.3
	Agriculture	Grassland/Shrubland	69	30	20.1	0.2	10.1
	Agriculture	Forest	49	27	18.0	0.2	7.2
	Grassland/Shrubland	Forest	44	29	19.8	0.1	6.5
	Other	Other	228	n/a	n/a	0.7	33.7
		Totals	677			2.2	100
1992–2000	Agriculture	Developed	165	61	41.1	0.5	28.9
	Forest	Developed	108	47	32.0	0.4	18.9
	Grassland/Shrubland	Forest	56	25	17.2	0.2	9.8
	Mining	Grassland/Shrubland	29	23	15.2	0.1	5.0
	Agriculture	Forest	28	9	5.9	0.1	5.0
	Other	Other	185	n/a	n/a	0.6	32.5
		Totals	570			1.9	100
1973–2000 (overall)	Agriculture	Developed	516	207	140.1	1.7	22.5
	Forest	Developed	409	173	117.3	1.3	17.8
	Grassland/Shrubland	Forest	215	96	65.0	0.7	9.4
	Agriculture	Grassland/Shrubland	166	62	42.2	0.5	7.2
	Mining	Grassland/Shrubland	146	103	69.3	0.5	6.4
	Other	Other	843	n/a	n/a	2.8	36.7
		Totals	2,296			7.5	100

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Midwest Agricultural Ecoregions


For Sale

Status and Trends of Land Change in the Midwest–South Central United States—1973 to 2000
Edited by Roger F. Auch and Krista A. Karstensen
U.S. Geological Survey Professional Paper 1794–C, 2015

Chapter 7

Southeastern Wisconsin Till Plains Ecoregion

By Mark S. Brooks

Ecoregion Description

The Southeastern Wisconsin Till Plains Ecoregion covers about 30,999 km^2 (11,969 mi^2) (fig. 1) (Omernik, 1987; Wiken and others, 2011). With the exception of a small part that extends into northern Illinois, most of the ecoregion is in southeastern Wisconsin. It is bordered by the North Central Hardwood Forests Ecoregion to the north, the Driftless Area Ecoregion to the west, the Central Corn Belt Plains Ecoregion to the south, and Lake Michigan to the east.

The topography of the ecoregion primarily was formed by glacial processes during Wisconsin-age glaciation. Glacial landforms, including irregular till plains, end moraines, kettles, and drumlins, are responsible for the rolling hills (figs. 2, 3, 4) and lowland plains in the ecoregion. Many wetlands and lakes of various sizes dot the landscape. The soils are a lime-rich till, overlain in most areas by a silt-loam loess cap that varies in thickness from about a meter on hilltops to more than 122 m in the lowland plains (Wisconsin Department of Natural Resources, 2011).

The ecoregion has a humid continental climate, with an average January temperature of –11°C and an average July

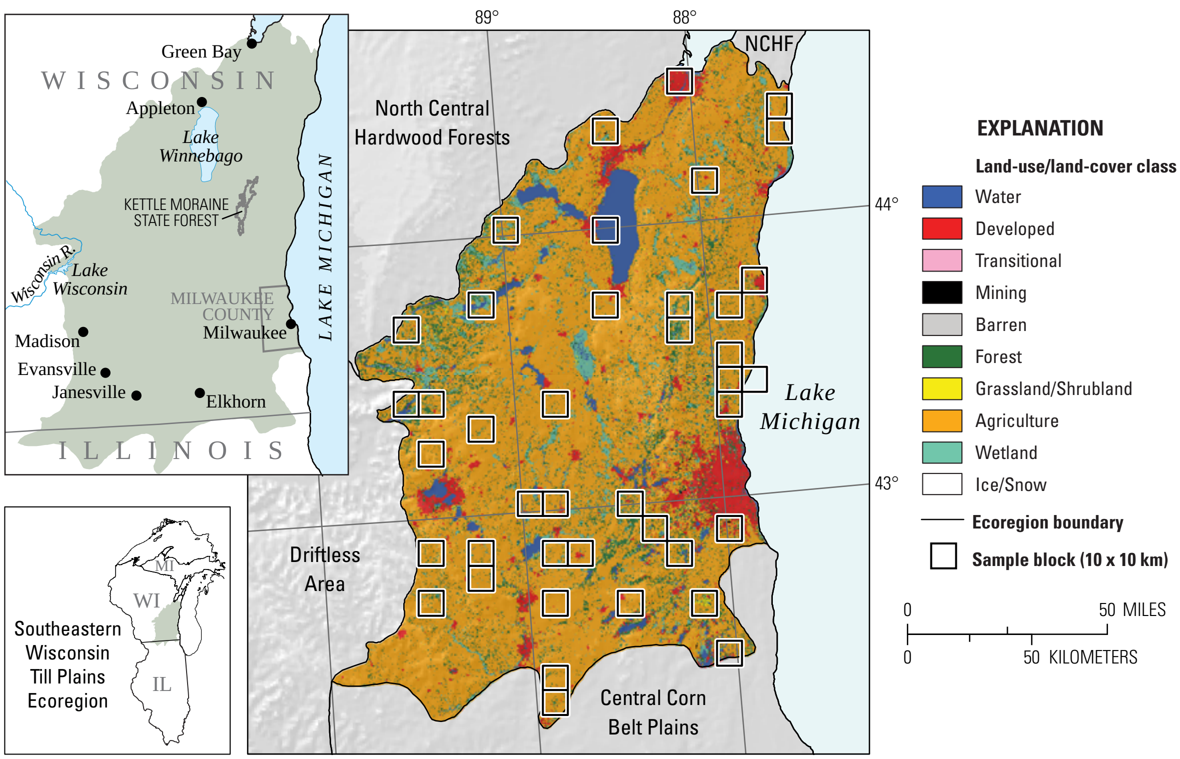

Figure 1. Map of Southeastern Wisconsin Till Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

temperature of 21°C. The average annual precipitation is about 840 mm (33 in.), with an average annual snowfall of 1,320 mm (52 in.) per year (Wisconsin State Climatology Office, 2011). The waters of Lake Michigan have a moderating effect on temperatures near the shoreline, and so summers are somewhat cooler and winters are warmer along the lake when compared to areas further inland.

Prior to European-American settlement, the ecoregion's upland vegetation was a mix of prairie, oak forests (*Quercus* spp.), savanna, and maple-dominated forests (*Acer* spp.). Wet-mesic prairies, southern sedge meadows, emergent marshes, and calcareous fens were present in lowland areas. Today (2014), agricultural land-use practices and developed land have redefined the landscape because they have replaced much of the original vegetation. Forests remain on steeper terrain not suitable for agriculture (Wisconsin Department of Natural Resources, 2011), and wetlands constituted about 7 percent of the ecoregion during the study period.

Dairy farming is the leading agricultural activity, and major food products include milk and cheese. Corn, hay, and other forage crops support dairy operations. Other crops include soybeans (figs. 5, 6), potatoes, wheat, barley, tobacco, beets, beans, peas, cucumbers, apples, cherries, and cranberries (U.S. Department of Agriculture, 2008). The diverse industrial base includes the manufacturing of tractors and other farm machinery, as well as engines, turbines, and construction equipment.

Figure 2. South-facing view of rolling, forested upland areas, with Lake Wisconsin, Wisconsin, in distance.

Figure 3. Kettle depression in Kettle Moraine State Forest, Wisconsin.

Figure 4. Looking north along waterway just south of Elkhorn, Wisconsin.

Figure 5. Irrigated soybean field and large grain-storage complex, east of Evansville, Wisconsin.

Figure 6. Expansive fields of soybeans and corn, east of Janesville, Wisconsin.

The population of the ecoregion increased notably during the study period. Major cities within the ecoregion include (2000 populations) Milwaukee (596,974), Madison (208,054), Green Bay (102,313), and Appleton (70,087), Wisconsin. However, although the city of Milwaukee and Milwaukee County continued to have the highest population totals within the ecoregion, the populations of both decreased during the study period (U.S. Census Bureau, 2011; Wisconsin Department of Administration, 2011).

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Southeastern Wisconsin Till Plains Ecoregion between 1973 and 2000 is estimated at 5.7 percent (table 1). Compared to other Midwest–South Central United States ecoregions, change in the Southeastern Wisconsin Till Plains Ecoregion was moderate (fig. 7), with an estimated 0.4 percent changing in two or more time periods; however, most of the land (about 94.3 percent) did not change during the study period (table 1). Estimated change per time period varied slightly between 1973 and 2000. The first three time periods (1973–1980, 1980–1986, 1986–1992) showed similar amounts of change, whereas the last time period (1992–2000) had the greatest amount of change (table 2). When normalized to an average annual rate of change to account for uneven time periods, the first three time periods showed a minimal change of about 0.2 percent (66.0 to 68.6 km^2) per year (table 2; fig. 8), which increased to 0.3 percent (79.5 km^2) per year in the last time period (1992–2000).

The estimated area of most land-cover classes changed less than 1 percent during the study period, the exceptions being agriculture and developed, the only land-cover classes that experienced observable net change. These land-cover classes had the most significant net losses and net gains during the study period, with a net loss of about 4.2 percent (1,301 km^2) of agricultural land and a net gain of about 4.0 percent (1,242 km^2) of developed land (table 3). In 2000, agriculture was the predominant land cover at about 61.9 percent of the ecoregion, followed by forest at about 11.9 percent of the ecoregion, with almost no net change between 1973 and 2000. Developed expanded to cover an estimated 10.4 percent of the ecoregion, whereas wetland and water accounted for about 7.1 and 6.2 percent of the ecoregion, respectively (table 3).

The leading land-cover conversions between 1973 and 2000 primarily involved changes in the agriculture, forest, grassland/shrubland, and developed land-cover classes (table 4; fig. 9). An estimated 996 km^2 of agricultural land converted to developed land. Forested land and grassland/shrubland also converted to developed land, with a loss of about 110 km^2 and 97 km^2, respectively. Other leading conversions were 206 km^2 of agriculture to grassland/shrubland (possibly the result of farmland abandonment), as well as an estimated 97 km^2

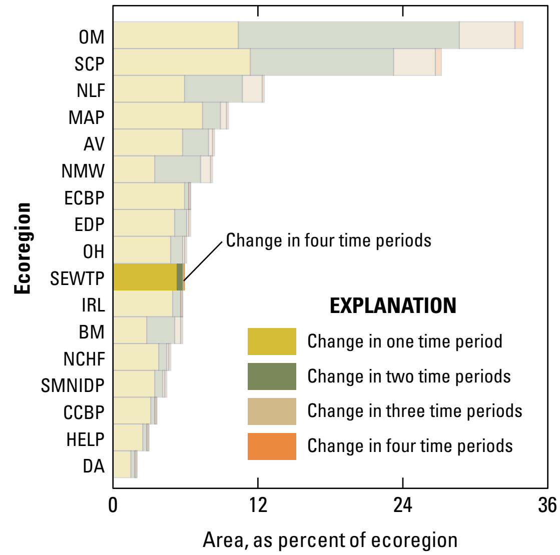

Figure 7. Overall spatial change in Southeastern Wisconsin Till Plains Ecoregion (SEWTP; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Southeastern Wisconsin Till Plains Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

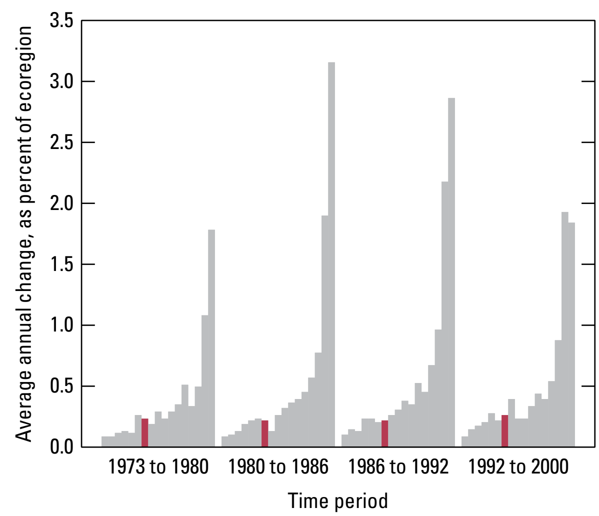

Figure 8. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Southeastern Wisconsin Till Plains Ecoregion are represented by red bars in each time period.

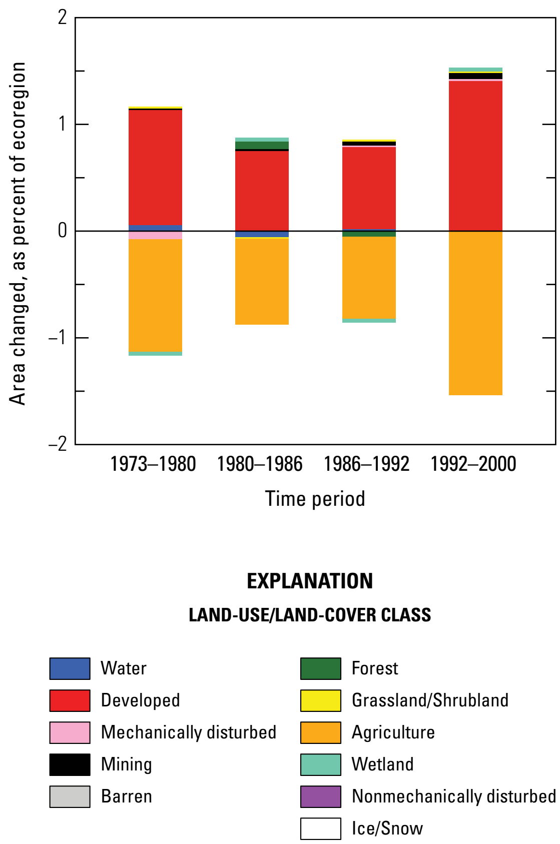

Figure 9. Normalized average net change in Southeastern Wisconsin Till Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

of grassland/shrubland to forest (table 4). However, because of the different types of changes affecting these land-cover classes, grassland/shrubland and forest had almost no overall net change between 1973 and 2000 (table 3).

The Southeastern Wisconsin Till Plains Ecoregion experienced moderate population growth during the study period, and the resulting expansion of residential and commercial development (fig. 10) led to decreases in farmland. Grassland/shrubland and forest also have decreased overall because of losses to developed without replacements coming from agriculture (conversions from agriculture to grassland/shrubland) and grassland/shrubland (conversions from grassland/shrubland to forest). Agriculture remained the dominant land-cover class between 1973 and 2000, despite its decrease of about 6.3 percent.

Figure 10. Exurban residential development, north of Appleton, Wisconsin.

Table 1. Percentage of Southeastern Wisconsin Till Plains Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (94.3 percent), whereas 5.7 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	5.2	1.2	4.0	6.5	0.8	15.9
2	0.4	0.1	0.3	0.6	0.1	23.1
3	0.0	0.0	0.0	0.0	0.0	32.1
4	0.0	0.0	0.0	0.0	0.0	73.2
Overall spatial change	5.7	1.3	4.4	7.0	0.9	15.4

Table 2. Raw estimates of change in Southeastern Wisconsin Till Plains Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	1.5	0.5	1.1	2.0	0.3	20.3	0.2
1980–1986	1.3	0.3	1.0	1.6	0.2	17.0	0.2
1986–1992	1.3	0.4	0.9	1.6	0.3	20.0	0.2
1992–2000	2.1	0.5	1.6	2.5	0.3	16.3	0.3
Estimate of change, in square kilometers							
1973–1980	480	143	337	623	98	20.3	69
1980–1986	397	99	298	497	68	17.0	66
1986–1992	395	116	279	511	79	20.0	66
1992–2000	636	152	484	788	103	16.3	80

Table 3. Estimated area (and margin of error) of each land-cover class in Southeastern Wisconsin Till Plains Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Nonmechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	6.2	3.0	6.4	2.4	0.1	0.1	0.2	0.1	0.0	0.0	11.8	2.1	2.2	0.8	66.1	4.5	7.1	1.7	0.0	0.0
1980	6.2	3.0	7.4	2.7	0.0	0.0	0.2	0.1	0.0	0.0	11.8	2.1	2.2	0.8	65.0	4.6	7.0	1.7	0.0	0.0
1986	6.2	3.0	8.2	2.9	0.0	0.0	0.2	0.1	0.0	0.0	11.9	2.1	2.2	0.8	64.2	4.7	7.1	1.7	0.0	0.0
1992	6.2	3.0	9.0	3.1	0.0	0.0	0.2	0.1	0.0	0.0	11.9	2.1	2.2	0.8	63.4	4.8	7.0	1.7	0.0	0.0
2000	6.2	3.0	10.4	3.3	0.1	0.0	0.3	0.1	0.0	0.0	11.9	2.1	2.2	0.8	61.9	4.9	7.1	1.7	0.0	0.0
Net change	0.0	0.0	4.0	1.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.3	0.0	0.2	–4.2	1.1	0.0	0.1	0.0	0.0
Gross change	0.3	0.1	4.0	1.1	0.2	0.1	0.2	0.1	0.0	0.0	0.7	0.3	0.7	0.2	4.3	1.1	0.3	0.1	0.0	0.0
Area, in square kilometers																				
1973	1,915	917	1,973	738	25	26	50	18	10.0	7.9	3,671	649	679	240	20,489	1,399	2,186	537	0	0
1980	1,933	916	2,309	846	2	2	56	21	10.0	7.9	3,673	652	684	238	20,159	1,433	2,175	537	0	0
1986	1,916	917	2,540	890	3	2	60	24	10.0	7.9	3,696	654	681	238	19,905	1,459	2,187	537	0	0
1992	1,922	916	2,779	949	11	7	71	30	10.0	7.9	3,680	649	683	242	19,664	1,487	2,178	535	0	0
2000	1,923	916	3,215	1,016	20	14	87	35	10.1	7.9	3,681	648	686	254	19,187	1,533	2,188	532	0	0
Net change	8	14	1,242	339	–5	29	36	18	0.1	0.1	10	94	7	50	–1,301	335	2	20	0	0
Gross change	84	29	1,242	339	64	31	48	18	0.1	0.1	232	84	217	76	1,328	330	94	33	0	0

Table 4. Principal land-cover conversions in Southeastern Wisconsin Till Plains Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Agriculture	Developed	265	108	74	0.9	55.2
	Agriculture	Grassland/Shrubland	50	26	18	0.2	10.4
	Forest	Developed	29	18	12	0.1	6.0
	Grassland/Shrubland	Developed	23	13	9	0.1	4.8
	Grassland/Shrubland	Forest	23	12	8	0.1	4.8
	Other	Other	90	n/a	n/a	0.3	18.8
		Totals	480			1.5	100
1980–1986	Agriculture	Developed	185	73	49.6	0.6	46.4
	Agriculture	Grassland/Shrubland	51	24	16.3	0.2	12.9
	Grassland/Shrubland	Forest	27	14	9.4	0.1	6.9
	Grassland/Shrubland	Developed	26	14	9.8	0.1	6.6
	Agriculture	Forest	22	21	14.1	0.1	5.5
	Other	Other	86	n/a	n/a	0.3	21.7
		Totals	397			1.3	100
1986–1992	Agriculture	Developed	175	63	42.9	0.6	44.2
	Agriculture	Grassland/Shrubland	52	22	14.7	0.2	13.2
	Forest	Developed	37	27	18.1	0.1	9.4
	Grassland/Shrubland	Forest	25	23	15.5	0.1	6.3
	Grassland/Shrubland	Developed	25	11	7.6	0.1	6.3
	Other	Other	82	n/a	n/a	0.3	20.7
		Totals	395			1.3	100
1992–2000	Agriculture	Developed	372	103	69.8	1.2	58.5
	Agriculture	Grassland/Shrubland	53	35	23.7	0.2	8.3
	Forest	Developed	28	18	12.1	0.1	4.4
	Grassland/Shrubland	Developed	23	10	6.9	0.1	3.7
	Grassland/Shrubland	Forest	21	12	7.9	0.1	3.4
	Other	Other	139	n/a	n/a	0.4	21.8
		Totals	636			2.1	100
1973–2000 (overall)	Agriculture	Developed	996	285	194.3	3.2	52.2
	Agriculture	Grassland/Shrubland	206	81	55.4	0.7	10.8
	Forest	Developed	110	58	39.4	0.4	5.8
	Grassland/Shrubland	Developed	97	40	27.4	0.3	5.1
	Grassland/Shrubland	Forest	97	47	32.2	0.3	5.1
	Other	Other	403	n/a	n/a	1.3	21.1
		Totals	1,909			6.2	100

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Chapter 8

Huron/Erie Lake Plains Ecoregion

By Steven Kambly

Ecoregion Description

The Huron/Erie Lake Plains Ecoregion consists of two separate, noncontiguous parts, which cover 27,362 km^2 (10,565 mi^2) in Michigan, Ohio, and Indiana (fig. 1) (Omernik, 1987; Wiken and others, 2011). The northern part, which lies along the coast of Michigan's "Thumb" region and includes several counties south and west of Saginaw Bay, in Lake Huron, is bounded by the Northern Lakes and Forests Ecoregion and the Southern Michigan/Northern Indiana Drift Plains Ecoregion. The southern part, which extends from the western shoreline of Lake Erie (from Sandusky, Ohio, to metropolitan Detroit, Michigan) southwest towards Fort Wayne, Indiana, is bounded by the Southern Michigan/Northern Indiana Drift Plains, Eastern Corn Belt Plains, and Eastern Great Lakes and Hudson Lowlands Ecoregions. The climate of the ecoregion is humid continental; the average annual precipitation ranges from about 700 to 915 mm (29–36 in.), and the annual frost-free period ranges from 150 to 200 days (Wiken and others, 2011).

The Huron/Erie Lake Plains Ecoregion, which is underlain by glacial lakebed deposits, is "a broad, fertile, nearly flat plain punctuated by relic sand dunes, beach ridges, and end moraines" (U.S. Environmental Protection Agency, 2002, p. 11). American elm–ash (*Ulmus americana* and *Fraxinus* spp., respectively) swamps and American beech (*Fagus grandifolia*) forests, along with the mixed oak (*Quercus* spp.) forests and oak savannas that are found on drier, sandier soils, were widespread before the large-scale clearing of forests and draining of wetlands for agriculture in the 19th century (fig. 2) (U.S. Environmental Protection Agency, 2002).

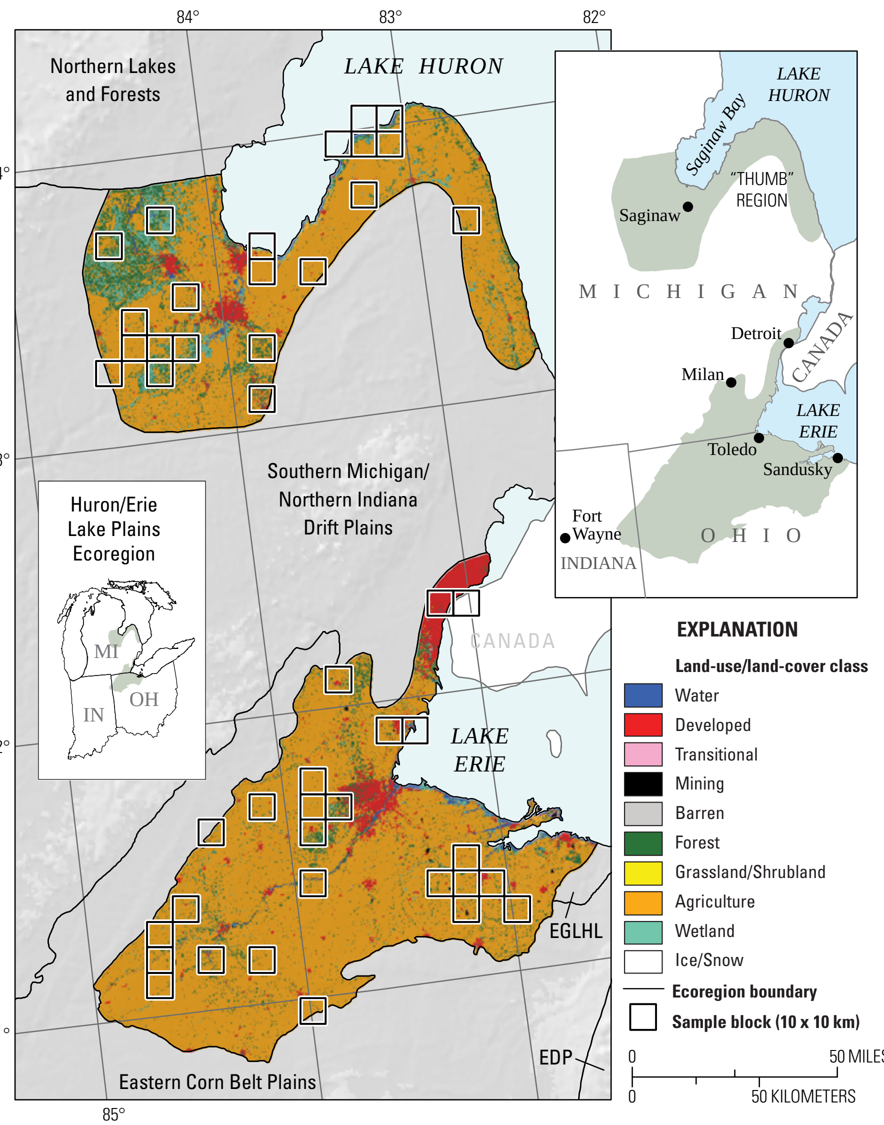

Figure 1. Map of Huron/Erie Lake Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown is part of one Eastern United States ecoregion, Eastern Great Lakes and Hudson Lowlands (EGLHL). See appendix 3 for definitions of land-use/land-cover classifications.

The ecoregion is farmed intensively, with corn, soybeans, and wheat as its major crops, but it also is known for various vegetable crops, sugar beets, and dry beans (fig. 3). Sugar-beet production in the lowlands around Saginaw, Michigan, and in the northern part of Michigan's "Thumb" region increased during the 27-year study period, and the area is a major source of the nation's sugar-beet supply. Michigan's dry-bean production is second only to that of North Dakota.

The Huron/Erie Lake Plains Ecoregion includes the metropolitan areas of Detroit, Michigan, and Toledo, Ohio, both of which experienced industrial decline (fig. 4) and slow population growth and (or) population loss during the study period (Frey, 2012). Large-scale population shifts from city centers to outlying areas (fig. 5) led to increased suburban and exurban development, primarily through the conversion of farmland and forests. Moreover, low-density development patterns, combined with smaller household sizes, have resulted in a far more rapid expansion of urbanized land than would be expected from slow-growing (or decreasing) population levels (Michigan Land Use Leadership Council, 2003).

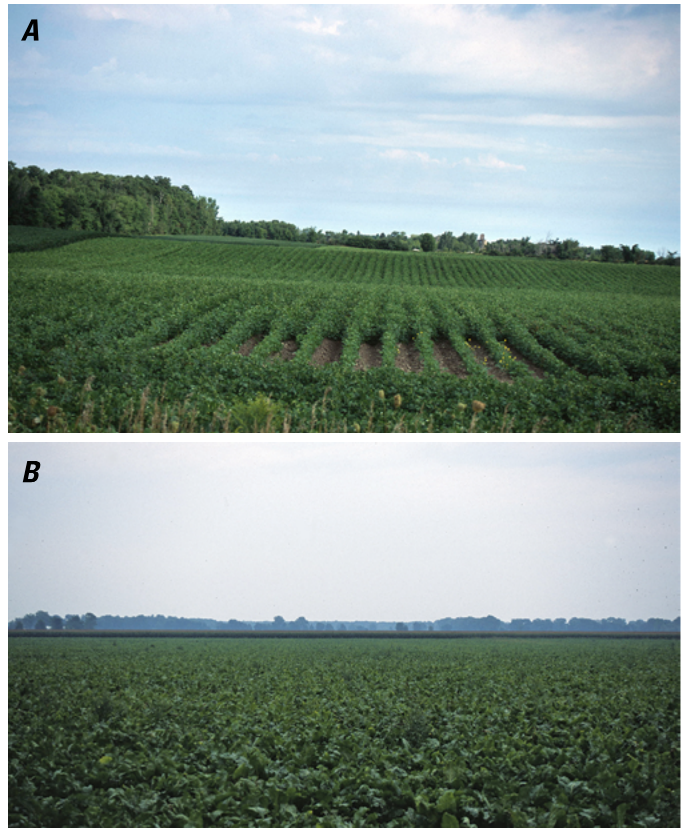

Figure 3. Crops grown in lake plains of Michigan's "Thumb" region, in Huron/Erie Lake Plains Ecoregion. *A*, Dry beans. *B*, Sugar beets.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Huron/Lake Erie Plains Ecoregion between 1973 and 2000 is estimated at 2.7 percent (table 1). About 2.3 percent of the ecoregion changed only once during the study period, whereas about 0.4 percent changed twice. An estimated 97.3 percent of the land area did not change. Compared to other Midwest–South Central United States ecoregions, change in the Huron/Erie Lake Plains Ecoregion was low, indicating that the ecoregion remained relatively stable during the study period (fig. 6): the estimated percent change per time period increased overall from 0.6 percent between 1973 and 1980 to 1.1 percent between 1992

Figure 2. Oak savanna and mixed-oak forest, which are found on dry, sandy soils in Huron/Erie Lake Plains Ecoregion.

Figure 4. Industrial abandonment in southwestern Detroit, Michigan.

and 2000 (table 2; fig. 7). The normalized average annual change rate ranged from 23 to 38 km^2 per year (table 2).

Only two land-cover classes, developed and agriculture, had greater than 1 percent change during the study period (table 3). Most change in the ecoregion occurred as a result of conversion from agriculture to developed. Overall, agriculture decreased by an estimated 350 km^2 (a 1.9 percent loss), nearly as much as the increase in developed (361 km^2). Some loss of agricultural land, however, was caused by conversions from agriculture to grassland/shrubland, which may have resulted from farmland abandonment. Forest land decreased by 2.4 percent from its 1973 base (0.3 percent of the ecoregion area; table 3), primarily because of conversions from forest to developed. The percentages of areal change for the remaining land-cover classes were minimal (fig. 8).

The 18.6 percent increase in developed land (from its 1973 base amount) between 1973 and 2000 was the result of conversions from agriculture, forest, mechanically disturbed, and other more natural land covers. The most common conversion throughout all time periods was from agriculture to developed. Between 1973 and 2000, conversions from agriculture to developed increased significantly, from 57 km^2 in the first time period to 100 km^2 in the last time period for an estimated total of 277 km^2 (table 4). About 68 km^2 of forest converted to developed as well, the third most common conversion during the study period.

Forest to mechanically disturbed, the fourth most common conversion during the study period, mainly resulted from timber harvesting on state forest lands in the northwestern part of the ecoregion. This is in contrast to areas in the eastern and southern parts of the ecoregion, which largely were farmland interspersed with relatively small areas of privately owned forest.

Agriculture to grassland/shrubland was the fifth most common conversion between 1973 and 2000. Furthermore, most grassland/shrubland, having converted from farmland, eventually converted to forest. The decrease in agriculture through conversions to grassland/shrubland was an estimated 50 km^2. When combined with conversions directly to forest (42 km^2, included as part of the "Other" class in the "1973–2000 (overall)" section of table 4), agriculture decreased by 92 km^2, which is much less than the estimated 277 km^2 of agriculture that converted to developed during the study period.

Figure 5. New exurban housing near Milan, Michigan.

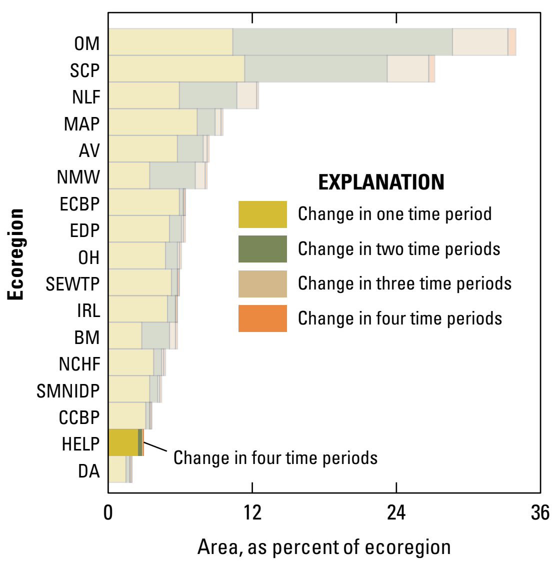

Figure 6. Overall spatial change in Huron/Erie Lake Plains Ecoregion (HELP; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Huron/Erie Lake Plains Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

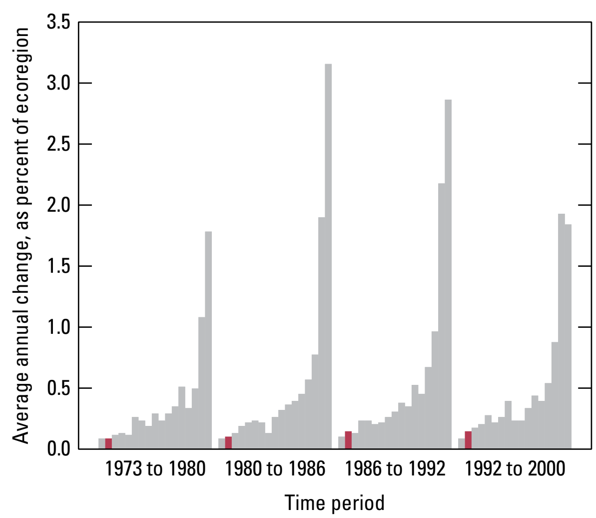

Figure 7. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Huron/Erie Lake Plains Ecoregion are represented by red bars in each time period.

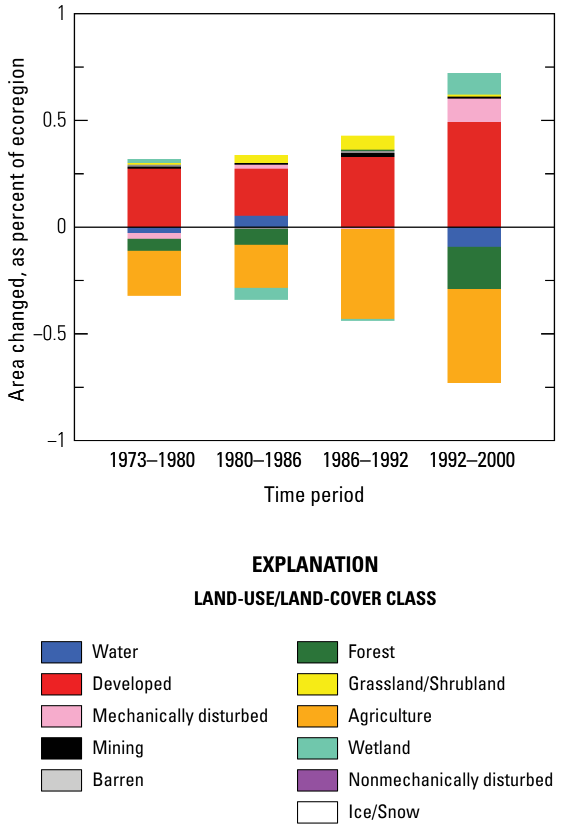

Figure 8. Normalized average net change in Huron/Erie Lake Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Wetland to water and water to wetland were the second and sixth most common conversions, respectively, during the study period. Although wetlands were drained extensively prior to the 20th century to facilitate the growth of farms, new settlements, and transportation routes, large areas of wetlands are now protected within publicly owned lands; about 3.5 percent of the ecoregion remained as wetlands during the study period (table 3).

Expansion of developed at the expense of agriculture and forest was the most significant land-cover change between 1973 and 2000. More land converted to developed, which increased by about 18.6 percent during the study period, than to any other land-cover class. Most of the decrease in agriculture and forest during the study period was attributable to the advance of developed land into suburban and rural settings.

Figure 9. Wetlands in Huron/Erie Lake Plains Ecoregion. Once pervasive, many are now largely concentrated on public lands.

Table 1. Percentage of Huron/Erie Lake Plains Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (97.2 percent), whereas 2.8 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	2.3	0.7	1.6	3.0	0.5	21.1
2	0.4	0.2	0.2	0.5	0.1	34.6
3	0.0	0.0	0.0	0.1	0.0	53.8
4	0.0	0.0	0.0	0.0	0.0	0.0
Overall spatial change	2.7	0.8	1.8	3.5	0.6	21.2

Table 2. Raw estimates of change in Huron/Erie Lake Plains Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	0.6	0.3	0.3	0.9	0.2	30.5	0.1
1980–1986	0.6	0.2	0.4	0.7	0.1	22.5	0.1
1986–1992	0.8	0.3	0.6	1.1	0.2	23.5	0.1
1992–2000	1.1	0.4	0.7	1.5	0.3	23.5	0.1
Estimate of change, in square kilometers							
1973–1980	164	74	91	238	50	30.5	23
1980–1986	154	51	103	205	35	22.5	26
1986–1992	231	79	151	310	54	23.5	38
1992–2000	303	104	198	407	71	23.5	38

Table 3. Estimated area (and margin of error) of each land-cover class in Huron/Erie Lake Plains Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	9.6	6.2	7.0	3.3	0.1	0.1	0.2	0.1	0.0	0.0	12.8	2.7	0.2	0.1	66.6	5.0	3.4	1.1	0.0	0.0
1980	9.6	6.2	7.3	3.4	0.0	0.0	0.2	0.1	0.0	0.0	12.8	2.7	0.2	0.1	66.4	5.0	3.4	1.1	0.0	0.0
1986	9.6	6.2	7.5	3.4	0.1	0.1	0.2	0.1	0.0	0.0	12.7	2.7	0.3	0.1	66.2	5.1	3.4	1.0	0.0	0.0
1992	9.7	6.2	7.8	3.4	0.0	0.0	0.2	0.1	0.0	0.0	12.7	2.7	0.3	0.1	65.8	5.1	3.4	1.0	0.0	0.0
2000	9.6	6.2	8.3	3.5	0.2	0.1	0.2	0.1	0.0	0.0	12.5	2.6	0.3	0.1	65.4	5.1	3.5	1.1	0.0	0.0
Net change	0.0	0.1	1.3	0.6	0.1	0.1	0.0	0.0	0.0	0.0	–0.3	0.2	0.1	0.1	–1.3	0.5	0.1	0.1	0.0	0.0
Gross change	0.3	0.2	1.4	0.6	0.3	0.2	0.1	0.0	0.0	0.0	0.6	0.3	0.3	0.1	1.4	0.5	0.3	0.2	0.0	0.0
Area, in square kilometers																				
1973	2,629	1,696	1,920	913	19	16	45	24	8.5	8.2	3,506	744	61	27	18,235	1,366	939	290	0	0
1980	2,623	1,695	1,997	926	9	8	47	24	9.0	8.7	3,491	743	65	30	18,177	1,378	944	292	0	0
1986	2,640	1,699	2,055	930	15	16	49	25	6.3	5.5	3,473	741	75	32	18,120	1,386	928	287	0	0
1992	2,641	1,692	2,144	935	13	10	55	26	7.8	7.2	3,477	745	92	33	18,005	1,392	928	284	0	0
2000	2,616	1,690	2,281	958	42	36	57	26	7.6	7.1	3,423	722	94	33	17,885	1,398	956	291	0	0
Net change	–13	24	361	166	23	30	12	8	–0.8	1.3	–83	67	32	17	–350	133	18	24	0	0
Gross change	89	46	374	164	74	47	23	12	4.9	6.2	171	69	76	24	380	130	92	48	0	0

Table 4. Principal land-cover conversions in Huron/Erie Lake Plains Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for “other” classes are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Agriculture	Developed	57	40	27	0.2	34.6
	Forest	Agriculture	14	5	4	0.1	8.6
	Forest	Developed	14	13	9	0.1	8.4
	Water	Wetland	11	12	8	0.0	6.9
	Mechanically disturbed	Forest	8	9	6	0.0	5.1
	Other	Other	60	n/a	n/a	0.2	36.4
		Totals	164			0.6	100
1980–1986	Agriculture	Developed	50	23	15.9	0.2	32.7
	Wetland	Water	20	16	11.0	0.1	13.1
	Forest	Mechanically disturbed	12	13	8.8	0.0	7.8
	Agriculture	Grassland/Shrubland	12	6	4.1	0.0	7.5
	Forest	Agriculture	10	4	2.9	0.0	6.2
	Other	Other	50	n/a	n/a	0.2	32.6
		Totals	154			0.6	100
1986–1992	Agriculture	Developed	70	36	24.5	0.3	30.2
	Agriculture	Forest	25	27	18.3	0.1	11.0
	Forest	Developed	20	15	10.4	0.1	8.7
	Agriculture	Grassland/Shrubland	20	11	7.7	0.1	8.6
	Wetland	Water	15	10	6.6	0.1	6.5
	Other	Other	81	n/a	n/a	0.3	35.1
		Totals	231			0.8	100
1992–2000	Agriculture	Developed	100	39	26.6	0.4	33.0
	Forest	Mechanically disturbed	39	34	23.3	0.1	12.8
	Water	Wetland	37	24	16.5	0.1	12.3
	Forest	Developed	26	23	15.9	0.1	8.6
	Grassland/Shrubland	Forest	14	10	6.9	0.1	4.7
	Other	Other	87	n/a	n/a	0.3	28.7
		Totals	303			1.1	100
1973–2000 (overall)	Agriculture	Developed	277	111	75.6	1.0	32.5
	Water	Wetland	69	47	31.9	0.3	8.1
	Forest	Developed	68	51	34.8	0.2	7.9
	Forest	Mechanically disturbed	66	62	42.1	0.2	7.7
	Agriculture	Grassland/Shrubland	50	21	14.4	0.2	5.9
	Other	Other	322	n/a	n/a	1.2	37.8
		Totals	851			3.1	100

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Chapter 9

Eastern Corn Belt Plains Ecoregion

By Roger F. Auch

Ecoregion Description

The Eastern Corn Belt Plains Ecoregion covers about 83,533 km^2 (32,252 mi^2), mainly in central Indiana, western and central Ohio, and southeastern Michigan but also in an extremely small part of Kentucky. The ecoregion is roughly rectangular in shape, except for the narrow band that extends northeast away from Fort Wayne, Indiana, into Michigan, and a southern part that extends south-southeast of Indianapolis, Indiana, to the suburbs of Louisville, Kentucky, that lie near the Ohio River (fig. 1). Neighboring ecoregions include the Southern Michigan/Northern Indiana Drift Plains and Huron/Erie Lake Plains Ecoregions to the north, the Eastern Great Lakes and Hudson Lowlands Ecoregion to the extreme northeast, the Erie Drift

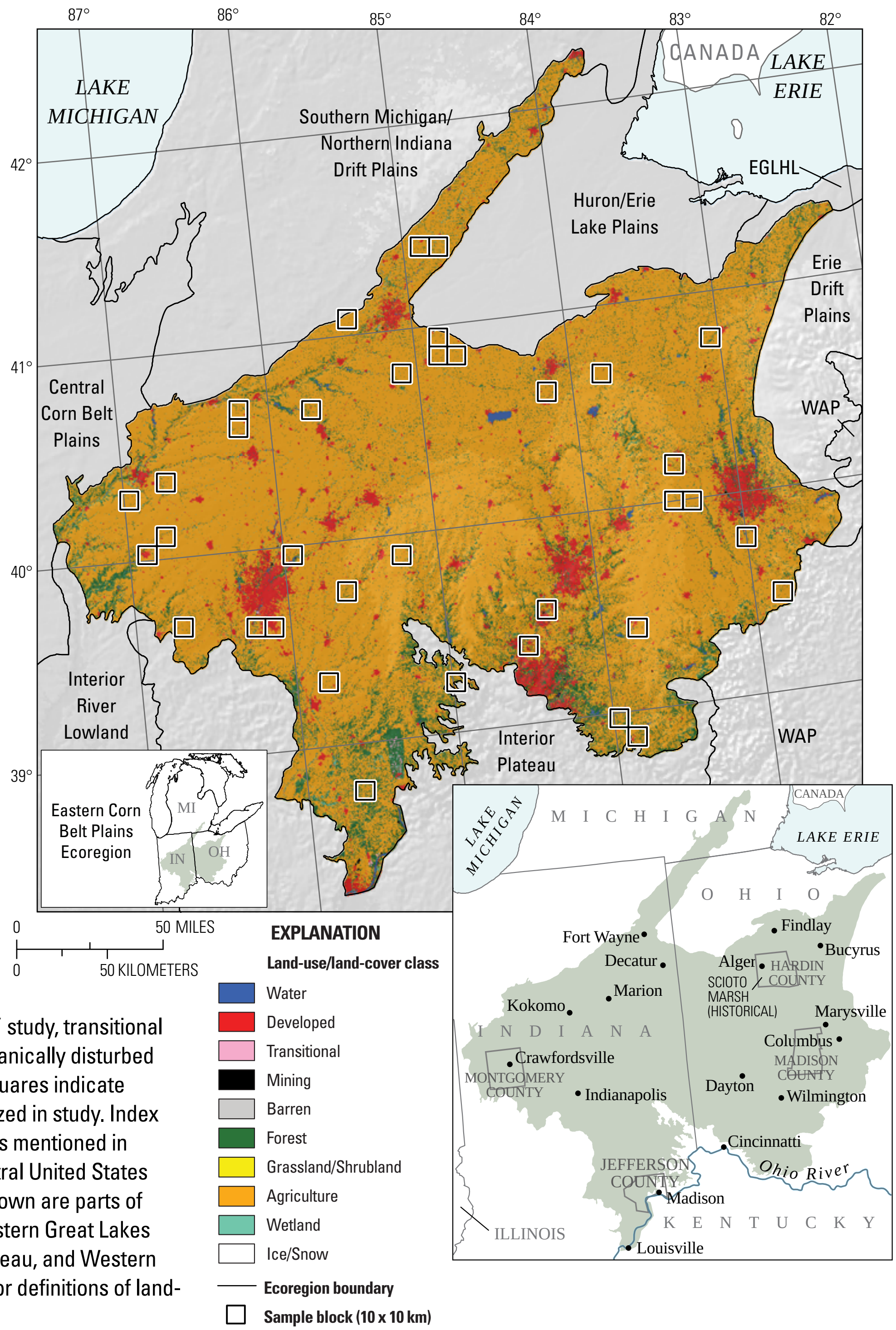

Figure 1. Map of Eastern Corn Belt Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of three Eastern United States ecoregions: Eastern Great Lakes and Hudson Lowlands (EGLHL), Interior Plateau, and Western Allegheny Plateau (WAP). See appendix 3 for definitions of land-use/land-cover classifications.

Plains and Western Allegheny Plateau Ecoregions to the east, the Interior Plateau Ecoregion to the south, the Interior River Lowland Ecoregion to the southwest, and the Central Corn Belt Plains Ecoregion to the west. The climate is considered warm temperate and fully humid. Average annual precipitation ranges from 816 to 1,080 mm (32–42.5 in.), with precipitation generally increasing from north to south (Woods and others, 1998). Glaciation has played a major role in shaping the landforms of the ecoregion, with more level and rolling Wisconsin-age till plains in the north and pre–Wisconsin-age deposits along the southern periphery (Woods and others, 1998).

The land cover of the Eastern Corn Belt Plains Ecoregion at the turn of the 19th century was predominantly composed of forest. Upland forest consisted of American beech (*Fagus grandifolia*), mixed oak (*Quercus* spp.), and oak–sugar maple (*Quercus* spp. and *Acer saccharum*, respectively) communities. Forest in wetter areas (forested wetlands) was composed of elm-ash (*Ulmus* spp. and *Fraxinus* spp., respectively) communities (Woods and others, 1998). The land cover also included prairie grasslands, many of which were considered “wet prairies” where the soil remained saturated or inundated for much of the growing season. The soils under most of the forest and prairies were rich for agricultural use when the first European-American settlers arrived in the ecoregion during the first few decades of the 19th century.

Figure 3. Corn and soybean crops growing in Eastern Corn Belt Plains Ecoregion. *A*, Corn growing on both sides of road, north of Kokomo, Indiana. *B*, Soybean field and typical farmstead in background, in Montgomery County, Indiana.

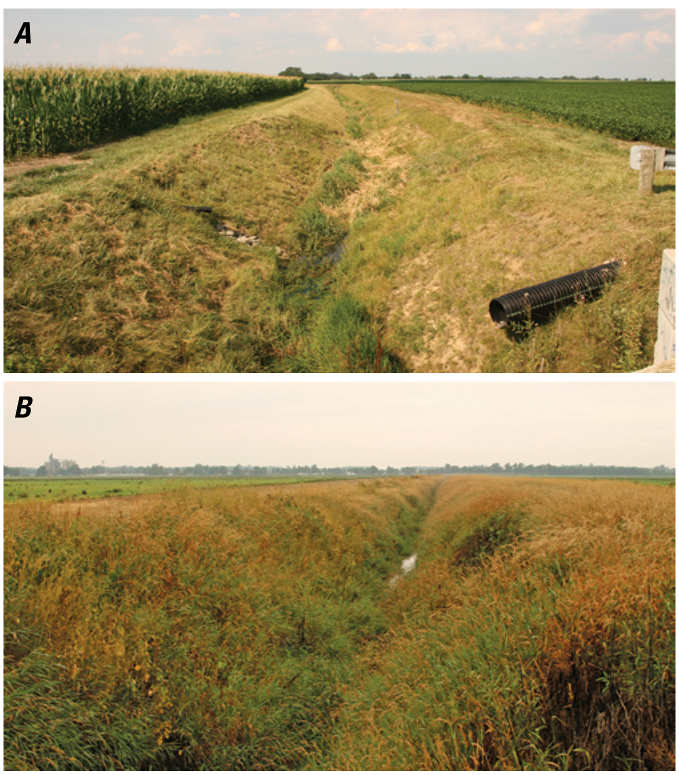

Figure 2. Drainage systems in Eastern Corn Belt Plains Ecoregion. *A*, Typical drainage ditch (this one is in Madison County, Ohio), with outlet of tile drainage system in foreground. *B*, Larger and deeper drainage system, in Hardin County, Ohio, needed to convert former Scioto Marsh (historical) to fertile cropland in 1800s.

Most of the original land covers of the Eastern Corn Belt Plains Ecoregion were converted to anthropogenic land uses during the 1800s, primarily to agriculture. Later in the 19th century and continuing throughout the 20th century, conversions to developed increased, although, during the study period, agriculture remained the predominant land cover. The conversion of upland forest to agriculture or developed was straightforward, but the conversion of forested wetland areas or wet prairies took more effort. Wetter areas were drained in major reclamation efforts, using drain tiles and drainage ditches that, in many places, became a common landscape feature (figs. 2*A*,*B*). Most of the wetland drainage was completed by the 1920s, although it continued into the late 20th century (Prince, 1997). Forest often remained along riparian watercourses in dissected upland areas such as along the southern periphery of the ecoregion, and some were kept as woodlots for landowner use. Many of these woodlots have unnatural geometrical shapes (for example, squares and rectangles).

Agriculture continued to occupy most of the Eastern Corn Belt Plains Ecoregion during the 27-year study period. The ecoregion is a national leader in corn and soybean production (figs. 3*A*,*B*), although other crops such as alfalfa

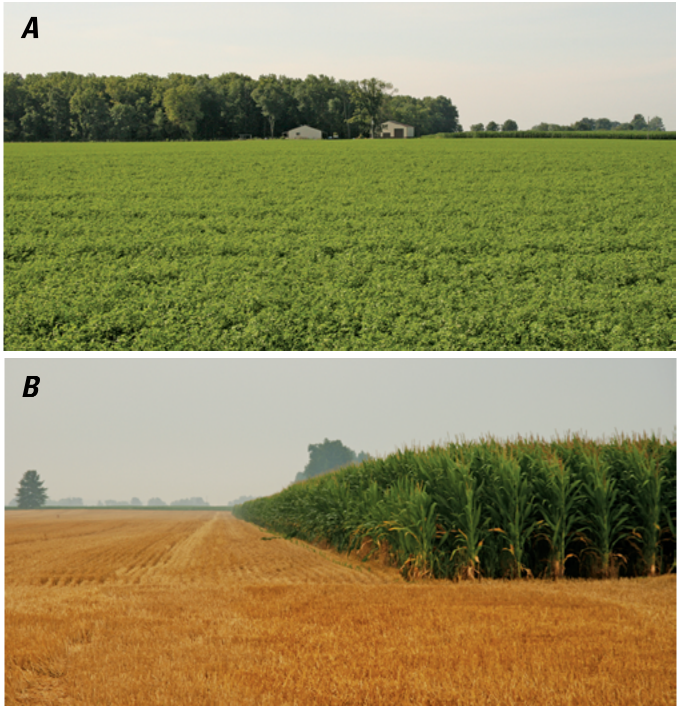

Figure 4. Alfalfa-hay and wheat crops growing in Eastern Corn Belt Plains Ecoregion. *A*, Large alfalfa field, northeast of Crawfordsville, Indiana. *B*, Wheat stubble next to corn field, southwest of Bucyrus, Ohio.

hay and wheat also are grown (figs. 4*A*,*B*). Livestock production primarily consisted of hogs (fig. 5) and, to a more limited extent, beef and dairy cattle. Agricultural land within the Eastern Corn Belt Plains Ecoregion also included small areas of intensively used pastureland.

Forest and developed were secondary land covers found in the ecoregion during the study period. Patches of forest commonly were present across the agricultural landscape, but they usually were isolated from one another by farmland (fig. 6). Only along substantial riparian corridors would forest be more contiguous (fig. 7). Developed was present across a hierarchy of populated places, ranging from large metropolitan areas such as Indianapolis, Indiana, and Cincinnati, Dayton, and Columbus, Ohio; to medium-sized cities such as Fort Wayne, Indiana; to smaller micropolitan areas such as Findlay and Bucyrus, Ohio, and Madison, Decatur, and Marion, Indiana (figs. 8*A*,*B*,*C*). Most of these cities grew as manufacturing centers during the 19th and first half of the 20th centuries, although Columbus and Indianapolis also are state capitals. Exurban development was common on the fringes of these variously sized urban areas (figs. 9*A*,*B*). All other land-cover classes were very small at the ecoregion scale.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Eastern Corn Belt Plains Ecoregion between 1973 and 2000 is estimated at 6.3 percent (table 1). Compared to other Midwest–South Central United States ecoregions, the Eastern Corn Belt Plains Ecoregion was above median ranking (fig. 10), and it had more change than most of its neighboring ecoregions. About 5.9 percent of the ecoregion changed only once during the study period, and 0.3 percent changed more than once (table 1). Examples of multiple changes include areas once used for agriculture that reverted to grassland/shrubland and then to forest in the next time period or at a later date, as well as sites around metropolitan areas that experienced large-scale, active land disturbance related to development or preliminary construction in one time period, followed by subsequent time periods in which development either was completed or not finished. In the latter case, the land cover reverted to grassland/shrubland to be held as possible speculation for future development.

The period between 1992 and 2000 had the greatest amount of change, whereas the period between 1980 and 1986

Figure 5. Farmstead with large grain bins and several modern hog-confinement buildings, south of Fort Wayne, Indiana.

Figure 6. Squared-off patch of forest amidst landscape of cultivated fields, in Madison County, central Ohio.

Figure 7. Riparian forest along stream, in western Jefferson County, Indiana.

Figure 8. Developed land in Eastern Corn Belt Plains Ecoregion. *A*, Street scene in small town of Alger, Ohio. *B*, Fairly new high-growth area north of Cincinnati, Ohio. *C*, Car manufacturing plant, built sometime during study period (1973–2000) just outside of Marysville, Ohio.

Figure 9. Exurban development in Eastern Corn Belt Plains Ecoregion. *A*, Single-family (nonfarm) residence east of Decatur, Indiana, near Indiana-Ohio border. *B*, Exurban subdivision outside of Wilmington, Ohio.

had the least amount of change (table 2). When the uneven time periods were normalized to an average annual rate of change, the period between 1986 and 1992 had the second highest change (0.3 percent), and the period between 1973 and 1980 had the third highest change (0.2 percent). The last time period remained the period with the highest change (0.4 percent), and the second time period had the lowest change (0.1 percent) (table 2; fig. 11).

The agriculture and developed land-cover classes experienced the most net change during the study period, and changes in both classes were closely linked. Agriculture decreased by an estimated 5.2 percent of the ecoregion (4,338 km^2, a 6.5 percent decrease from its estimated 1973 level), and developed increased by an estimated 5.1 percent (4,245 km^2, a 92.3 percent increase from its estimated 1973 level) (table 3). Other, more minor net changes included forest decreasing by 0.5 percent (411 km^2, a 3.8 percent change from its estimated 1973 level), grassland/shrubland increasing by 0.3 percent (239 km^2), and water increasing by 0.2 percent of the ecoregion (126 km^2) (table 3; fig. 12).

Developed land increased during the study period (figs. 13*A*,*B*). Agricultural land was the main source of new developed land, contributing an estimated 3,708 km^2, followed by forested land that was converted to developed land (403 km^2). A substantial amount of the new developed land (2,031 km^2; table 3) was added during the last time period (1992–2000). Agriculture to developed was the leading land-cover change in the Eastern Corn Belt Plains Ecoregion (table 4; fig. 14).

Agriculture also changed to grassland/shrubland (388 km²). The only notable source of new farmland was the conversion of 171 km² of forest to agriculture. The change of agriculture to grassland/shrubland land cover in the Eastern Corn Belt Plains Ecoregion occurred mostly in smaller areas where farming had been discontinued and the land reverted to “brush” (grassland/shrubland) and then possibly to forest during the study period (fig. 15). However, the amount of land converted from agriculture to grassland/shrubland increased during the last two time periods (1986–1992, 1992–2000), a time when the federal Conservation Reserve Program (CRP) was in effect. Land enrolled in the CRP could return to agriculture, if desired, at a future date.

Land uses and land covers in the Eastern Corn Belt Plains Ecoregion remained mostly stable during the study period (1973–2000). Although agricultural land decreased

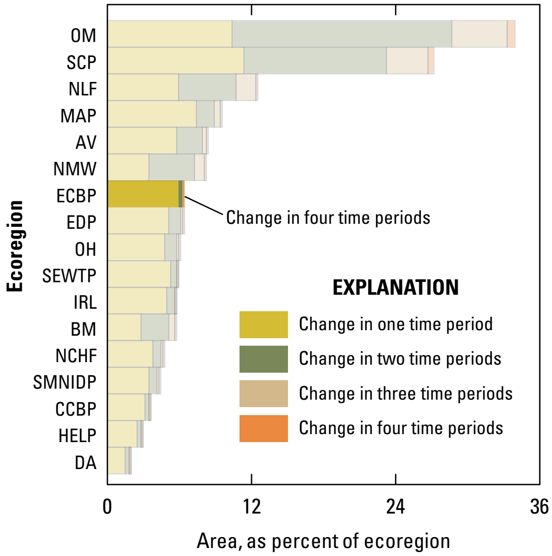

Figure 10. Overall spatial change in Eastern Corn Belt Plains Ecoregion (ECBP; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Eastern Corn Belt Plains Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

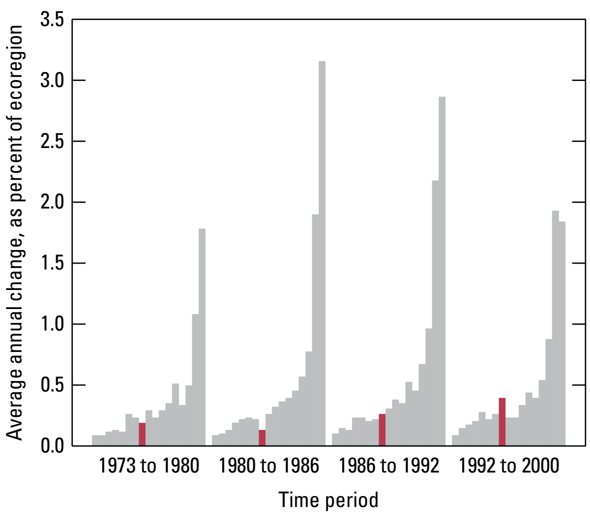

Figure 11. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Eastern Corn Belt Plains Ecoregion are represented by red bars in each time period.

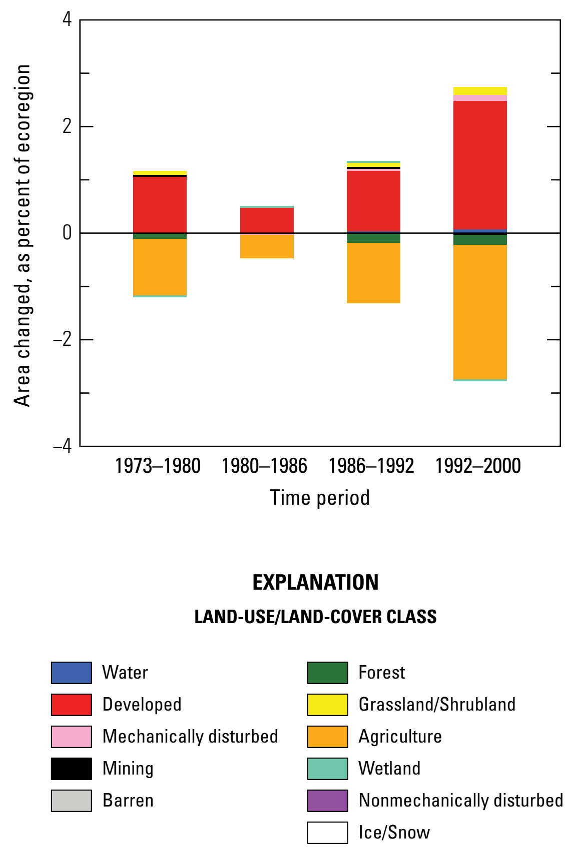

Figure 12. Normalized average net change in Eastern Corn Belt Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

by an estimated 5 percent of the ecoregion during the study period, it still remained by far the leading land cover, occupying an estimated 75 percent of the ecoregion in 2000. Agriculture was lost to developed, grassland/shrubland, mining, water, and forest land covers, but it was only noticeably replaced by forest land cover. Most losses of agricultural land were to newly developed land, which was the largest single type of change in the Eastern Corn Belt Plains Ecoregion, resulting in an estimated conversion of 3,708 km^2 (table 4). The last time period (1992–2000) had the most change from agriculture to developed: 1,760 km^2, or annualized to 220 km^2 per year. In a study of construction projects in 44 central Indiana counties (three-fourths of which were in the Eastern Corn Belt Plains Ecoregion, including the counties in the Indianapolis metropolitan area) during the 1990s, 59 percent were residential, 13.5 percent were commercial, 9 percent were in warehousing, 5 percent were in educational facilities, and 5 percent were in manufacturing, indicating sustained suburban growth in the ecoregion (Nunn, 2002). In Ohio, the population of "fringe metropolitan counties" (that is, counties that are less urbanized than a core urban county but are closely linked to one) increased by 14 percent during the 1990s, compared to 2 percent in core urban counties (Clark and others, 2003), indicating continued deconcentration of urbanization in those parts of the ecoregion.

Figure 13. Developed land cover in Eastern Corn Belt Plains Ecoregion. *A*, New residential development across road from long-established rural cemetery, on northeast side of Indianapolis, Indiana, metropolitan area. *B*, New minimill steel plant that uses steel scrap for its feedstock, north-northeast of Fort Wayne, Indiana.

Figure 14. Conversion from agriculture to developed land cover, most common type of change in Eastern Corn Belt Plains Ecoregion, that occurred on south side of metropolitan Indianapolis, Indiana.

Figure 15. Conversion from agriculture to grassland/shrubland land cover that occurred southeast of metropolitan Cincinnati, Ohio, on southern margin of Eastern Corn Belt Plains Ecoregion.

Table 1. Percentage of Eastern Corn Belt Plains Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (93.7 percent), whereas 6.3 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	5.9	2.5	3.4	8.4	1.7	29.0
2	0.3	0.2	0.2	0.5	0.1	32.6
3	0.0	0.0	0.0	0.0	0.0	45.9
4	0.0	0.0	0.0	0.0	0.0	76.7
Overall spatial change	6.3	2.7	3.6	8.9	1.8	28.7

Table 2. Raw estimates of change in Eastern Corn Belt Plains Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	1.3	0.8	0.5	2.1	0.5	40.3	0.2
1980–1986	0.7	0.3	0.5	1.0	0.2	24.4	0.1
1986–1992	1.6	0.6	1.0	2.1	0.4	25.3	0.3
1992–2000	3.1	1.5	1.5	4.6	1.0	33.9	0.4
Estimate of change, in square kilometers							
1973–1980	1,115	662	453	1,777	450	40.3	159
1980–1986	597	214	383	811	145	24.4	99
1986–1992	1,305	487	818	1,792	331	25.3	218
1992–2000	2,570	1,282	1,288	3,852	871	33.9	321

Table 3. Estimated area (and margin of error) of each land-cover class in Eastern Corn Belt Plains Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	0.6	0.3	5.5	1.8	0.0	0.0	0.1	0.0	0.0	0.0	13.0	2.3	0.1	0.0	80.2	3.2	0.4	0.2	0.0	0.0
1980	0.6	0.3	6.6	2.2	0.0	0.0	0.1	0.1	0.0	0.0	12.9	2.3	0.2	0.1	79.2	3.4	0.4	0.2	0.0	0.0
1986	0.6	0.3	7.0	2.3	0.0	0.0	0.1	0.1	0.0	0.0	12.9	2.3	0.2	0.1	78.7	3.5	0.4	0.2	0.0	0.0
1992	0.7	0.3	8.2	2.6	0.1	0.1	0.1	0.1	0.0	0.0	12.7	2.3	0.3	0.1	77.6	3.8	0.4	0.2	0.0	0.0
2000	0.7	0.3	10.6	3.6	0.2	0.1	0.1	0.1	0.0	0.0	12.5	2.3	0.4	0.1	75.0	4.6	0.4	0.2	0.0	0.0
Net change	0.2	0.1	5.1	2.4	0.1	0.1	0.0	0.0	0.0	0.0	–0.5	0.4	0.3	0.1	–5.2	2.4	0.0	0.0	0.0	0.0
Gross change	0.2	0.1	5.1	2.4	0.2	0.1	0.2	0.1	0.0	0.0	0.7	0.4	0.5	0.2	5.4	2.4	0.0	0.0	0.0	0.0
Area, in square kilometers																				
1973	493	219	4,598	1,471	29	27	54	39	2.7	3.2	10,890	1,910	101	40	67,005	2,675	361	177	0	0
1980	501	220	5,492	1,810	24	29	82	54	2.7	3.2	10,795	1,914	152	60	66,125	2,829	359	177	0	0
1986	516	225	5,869	1,945	11	12	88	50	2.7	3.3	10,779	1,914	155	53	65,752	2,936	361	177	0	0
1992	553	232	6,812	2,200	61	63	95	59	2.8	3.4	10,644	1,911	215	65	64,786	3,155	364	178	0	0
2000	619	261	8,843	3,039	131	93	83	47	6.7	9.0	10,479	1,913	340	111	62,667	3,873	364	178	0	0
Net change	126	75	4,245	1,984	102	92	29	21	4.1	5.9	–411	316	239	93	–4,338	1,982	3	4	0	0
Gross change	133	77	4,245	1,984	175	106	130	78	4.1	5.9	597	313	392	128	4,488	1,965	11	5	0	0

Table 4. Principal land-cover conversions in Eastern Corn Belt Plains Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for “other” class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Agriculture	Developed	823	646	439	1.0	73.8
	Agriculture	Grassland/Shrubland	69	43	29	0.1	6.2
	Forest	Agriculture	65	28	19	0.1	5.8
	Forest	Developed	40	38	25	0.0	3.6
	Mechanically disturbed	Developed	29	27	18	0.0	2.6
	Other	Other	89	n/a	n/a	0.1	8.0
		Totals	1,115			1.3	100
1980–1986	Agriculture	Developed	324	159	108.1	0.4	54.3
	Grassland/Shrubland	Forest	56	41	28.2	0.1	9.4
	Agriculture	Grassland/Shrubland	50	18	12.3	0.1	8.4
	Forest	Agriculture	44	21	14.3	0.1	7.3
	Forest	Developed	30	16	10.9	0.0	5.0
	Other	Other	93	n/a	n/a	0.1	15.6
		Totals	597			0.7	100
1986–1992	Agriculture	Developed	801	336	228.3	1.0	61.4
	Forest	Developed	131	120	81.3	0.2	10.1
	Agriculture	Grassland/Shrubland	109	44	29.6	0.1	8.3
	Agriculture	Mechanically disturbed	56	59	40.2	0.1	4.3
	Forest	Agriculture	37	14	9.7	0.0	2.8
	Other	Other	171	n/a	n/a	0.2	13.1
		Totals	1,305			1.6	100
1992–2000	Agriculture	Developed	1,760	896	608.7	2.1	68.5
	Forest	Developed	202	143	96.9	0.2	7.8
	Agriculture	Grassland/Shrubland	161	69	46.8	0.2	6.3
	Agriculture	Mechanically disturbed	125	90	61.2	0.1	4.8
	Mechanically disturbed	Developed	54	57	38.7	0.1	2.1
	Other	Other	269	n/a	n/a	0.3	10.5
		Totals	2,570			3.1	100
1973–2000 (overall)	Agriculture	Developed	3,708	1,726	1,172.8	4.4	66.4
	Forest	Developed	403	303	205.6	0.5	7.2
	Agriculture	Grassland/Shrubland	388	134	91.2	0.5	7.0
	Agriculture	Mechanically disturbed	206	152	103.3	0.2	3.7
	Forest	Agriculture	171	45	30.4	0.2	3.1
	Other	Other	710	n/a	n/a	0.9	12.7
		Totals	5,587			6.7	100

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Chapter 10

Central Corn Belt Plains Ecoregion

By Daniel G. Sorenson

Ecoregion Description

The Central Corn Belt Plains Ecoregion (Omernik, 1987; Wiken and others, 2011), which covers about 98,794 km^2 (38,145 mi^2), is bordered by (clockwise, from the northeast) the Southern Michigan/Northern Indiana Drift Plains, Eastern Corn Belt Plains, Interior River Lowland, Western Corn Belt Plains, Driftless Area, and Southeastern Wisconsin Till Plains Ecoregions (fig. 1). Most of the ecoregion is in the state of Illinois, but the ecoregion also extends into northwestern Indiana and southeastern Wisconsin (fig. 1). The northern border is at Racine, Wisconsin, where the ecoregion follows the southwestern shore of Lake Michigan to Gary, Indiana. To the west, the ecoregion extends to the Mississippi River at Moline, Illinois, and, to the east, it ends just north of Interstate 70 near Terre Haute, Indiana. Most of the ecoregion is covered by Wisconsin-age glaciated till, and its natural vegetation consists of extensive prairie communities intermixed with oak-hickory (*Quercus* spp. and *Carya* spp., respectively) forests (Wiken and others, 2011).

In the early 19th century, level upland areas were covered by tallgrass prairies composed of species such as big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium condensatum*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*) (Woods

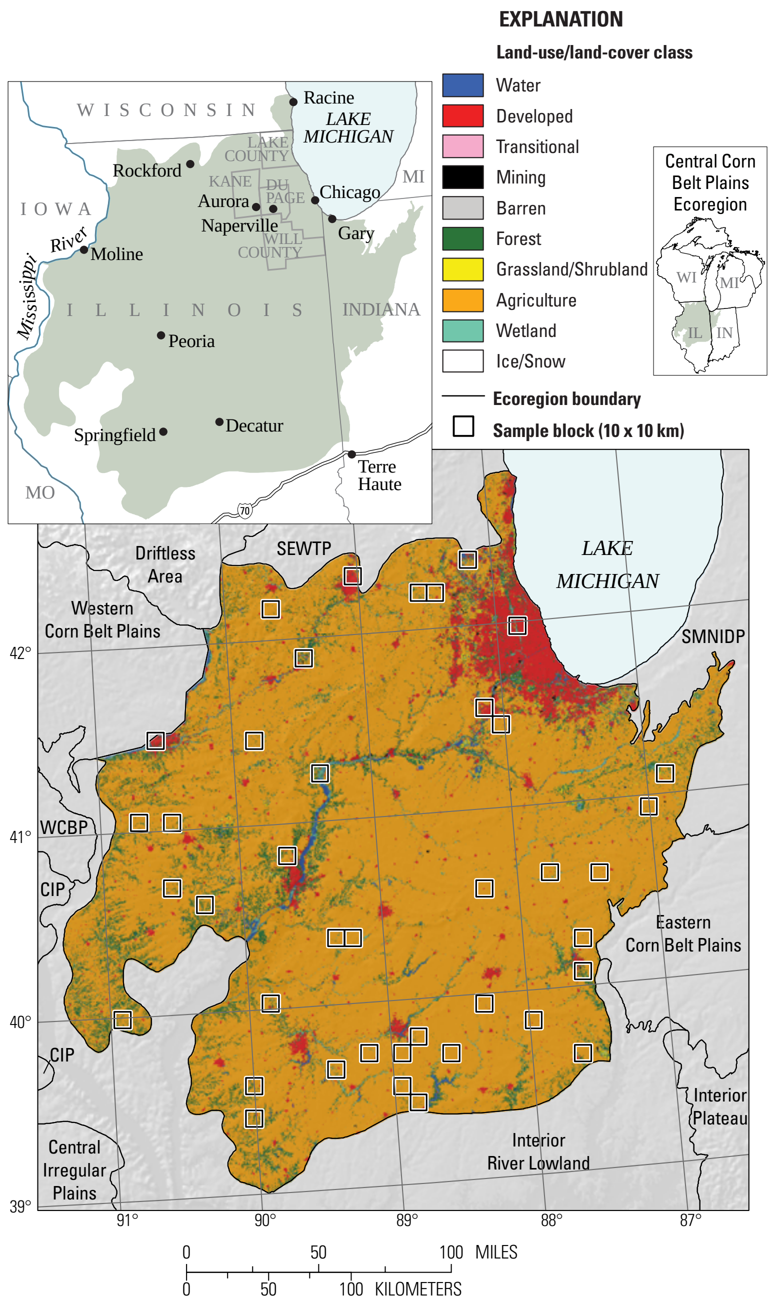

Figure 1. Map of Central Corn Belt Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of two Great Plains ecoregions (Central Irregular Plains [CIP] and Western Corn Belt Plains [WCBP]) and one Eastern United States ecoregion (Interior Plateau). See appendix 3 for definitions of land-use/land-cover classifications.

and others, 2006). After the early 19th century, the native vegetation gradually was replaced by agricultural crops (Wiken and others, 2011). In 1820, about 59 percent of Illinois was prairie, and 37.5 percent was forest (Iverson, 1988). By 2000, about 76 percent of Illinois was agricultural land, and only 11.5 percent was forest (Illinois Interagency Landscape Classification Project, 2002). The predominant crops grown today (2014) are corn and soybeans (figs. 2,3), but forage for livestock also is cultivated. Hogs and pigs are the predominant livestock, with some beef and dairy cattle, sheep, and poultry; however, livestock does not have as much of an economic effect on the Central Corn Belt Plains Ecoregion as it does in surrounding ecoregions (Woods and others, 2006).

Soils in the Central Corn Belt Plains Ecoregion typically are dark and rich, formed beneath the tallgrass prairies. On the broad, flat upland areas, Mollisols are common, especially on loess-covered till, whereas on the forested slopes and ridges, Alfisols are common (Omernik and Gallant, 1988). Poorly drained soils, ponds, and marshes were common in the early 19th century, especially on low-lying, flat lands. As the ecoregion was developed for agriculture, much of these areas were tilled, ditched, and connected to drainage systems, eliminating much of the once-plentiful aquatic habitats (Woods and others, 2006). Elevations range from about 122 m in the south to about 305 m on a few hills in the north (Omernik and Gallant, 1988). The average length of the growing season varies from 160 days in the north to about 180 days in the south (Angel, 2002). Most of the precipitation falls during the growing season, with average annual precipitation ranging from 813 to 1,117 mm (32–44 in.) (Omernik and Gallant, 1988).

The Central Corn Belt Plains Ecoregion is highly populated, with a 2000 population of about 12.1 million. The most densely populated part of the ecoregion is adjacent to Lake Michigan and includes the city of Chicago, Illinois. Chicago is the largest city in the ecoregion, with a 2000 population of 2,896,016. However, many small- to medium-sized cities are scattered throughout the ecoregion, most notably (2000 populations) Rockford, Illinois (150,115); the Chicago suburbs of Aurora (142,115) and Naperville (128,358), Illinois; Peoria (112,892), Springfield (111,454), and Decatur (81,860), Illinois; and Gary, Indiana (102,746) (U.S. Census Bureau, 2000).

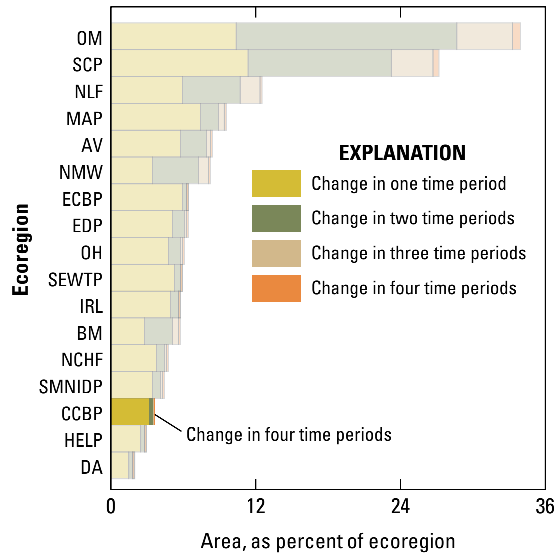

Figure 4. Overall spatial change in Central Corn Belt Plains Ecoregion (CCBP; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Central Corn Belt Plains Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Figure 2. Typical corn field in northern Illinois.

Figure 3. Soybeans, a major crop in Central Corn Belt Plains Ecoregion.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Central Corn Belt Plains Ecoregion between 1973 and 2000 is estimated at 3.4 percent (table 1). Compared to other Midwest–South Central United States ecoregions, the Central Corn Belt Plains Ecoregion had one of the lowest amounts of change (fig. 4). Overall, an estimated 3.2 percent of the ecoregion changed in one time period, and 0.2 percent changed in two time periods (table 1). The amount of area that changed in either three or all four time periods was so small that it was statistically insignificant (table 1).

When normalized to account for the varying lengths of time periods, the estimated average annual change remained stable for the first three time periods, at 0.1 percent of the ecoregion, but increased in the last time period (table 2; fig. 5). The amount of change was 0.7 percent (726 km^2) between 1973 and 1980 and 0.7 percent (713 km^2) between 1980 and 1986. The amount increased slightly between 1986 and 1992 to 0.8 percent (784 km^2), and it almost doubled (1.4 percent; 1,352 km^2) between 1992 and 2000 (tables 2,4).

Agriculture was the predominant land-cover class in the Central Corn Belt Plains Ecoregion. In 2000, agriculture constituted an estimated 75.3 percent of the ecoregion. Only two other land-cover classes were notable: developed, at 11.6 percent, and forest, at 9.3 percent. All other land-cover classes combined represented only 3.9 percent of the ecoregion (table 3).

Most of the change in the Central Corn Belt Plains Ecoregion involved agriculture and developed land-cover classes, with conversions from agricultural land to developed

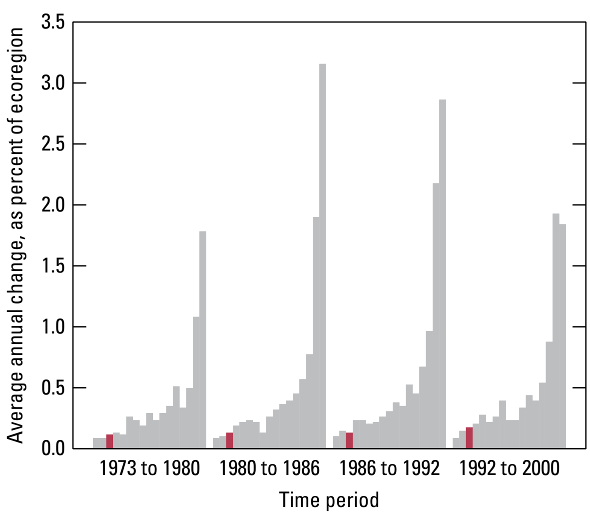

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Central Corn Belt Plains Ecoregion are represented by red bars in each time period.

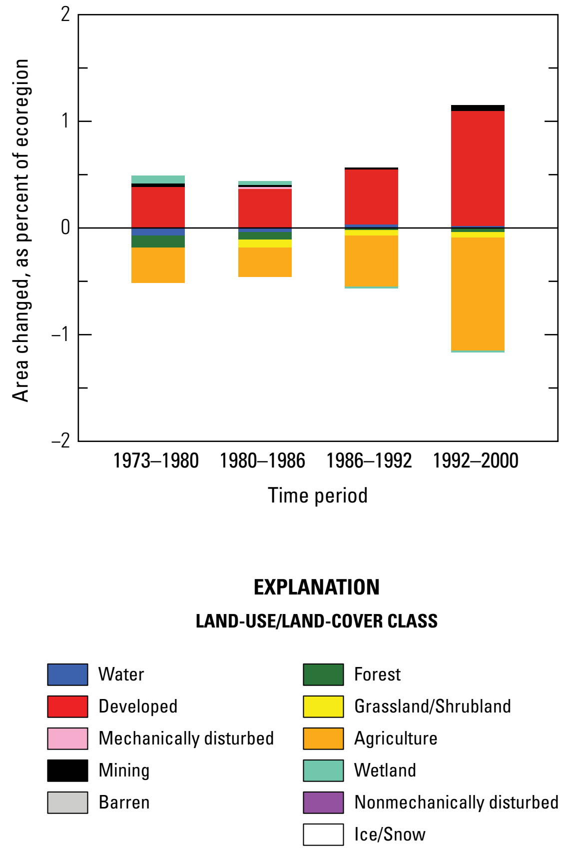

Figure 6. Normalized average net change in Central Corn Belt Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

land constituting the leading type of change in all time periods. Agriculture accounted for 75.4 percent of all changes that occurred in the ecoregion during the study period. The conversion from agriculture to developed made up 92.3 percent of all change from agriculture to another land-cover class (and 91.6 percent of all change of the developed land-cover class listed in table 4). Growth of the developed land-cover class stayed nearly constant between the first and second time periods, but it increased modestly during the third time period and doubled during the last time period (fig. 6).

The main story of land-use/land-cover change in the Central Corn Belt Plains Ecoregion between 1973 and 2000 was the increase in developed land at the expense of agriculture (table 3; fig. 6). One of the primary drivers of change was the increase in population over the 27-year study period: the population for the ecoregion in 1970 was 10.5 million; by 2000, the estimated population was 12.1 million, a 15.2 percent increase (U.S. Census Bureau, 2000). Much of this growth occurred in the suburbs of Chicago. The population increase for the counties surrounding Chicago between 1970 and 2000 was about 61.0 percent for Kane County, 68.4 percent for Lake County, 83.7 percent for DuPage County, and 101.4 percent for Will County (U.S. Census Bureau, 2000). Between 1972 and 1997, land that could be classified as urban in the Chicago suburbs increased by about 49 percent (Wang, 2002). The results of this study (table 4) also show an increased rate of new development in the 1990s (1992–2000) when compared to the earlier time periods.

One reason for the lower rate of development in the earlier time periods may have been the poor performance of the Illinois economy during the 1970s and early 1980s, although the slower rate of Illinois economic growth, when compared to the national rate, was more pronounced in the early 1980s than in the 1970s (Bryan, 1991). Some of the slower growth was attributed to Illinois' larger (when compared to the rest of the United States) manufacturing base, such as metals and machinery. During this time, manufacturing decreased because of changes in technology, combined with more competition (and less demand) for manufactured goods from abroad. Other industries such as retail trade, finance, insurance, real estate, and services also grew more slowly when compared to national rates at this time. The high-wage, high-cost business climate, as well as the high tax rates in Illinois, may have encouraged the relocation of some of these industries to other regions in the United States such as the South and the West (Merriman and Yin, 2011). In the early 1970s, meat packing, one of the most well known industries in Illinois, declined as the Chicago stockyards shut down. Direct sales of livestock from breeders to packers, along with the improvement of interstate trucking highways, changed the meat-packing industry: instead of shipping mature animals to the central stockyards, commercial feedlots were developed locally, and new packing plants were constructed nearby. In addition, large refrigerated trucks transported the products to supermarkets via the interstate-highway system, eliminating the need for large, urban stockyards to be located near railroads (Wade, 2005). From about 1985 to the early 1990s, the gross state product, as well as employment and personal income levels, all stabilized (Bryan, 1991). With the stabilization of the Illinois economy, the rate of development increased (fig. 6).

The Illinois farm economy also performed poorly in the early 1980s. Between 1980 and 1986, Illinois lost thousands of farms and, with them, many farm jobs (Sander, 1989). Farm technologies and greater efficiencies made it possible to produce crops using less manpower. However, the new methods required extensive investment in modern tractors, grain storage, irrigation systems, and other technologies. Because the farm economy had prospered in the 1970s, many farmers borrowed heavily to pay for new equipment and land. During this time, farmers also had expanded their land because the demand for American agricultural commodities was high, and the weak dollar made American food products more affordable than in the past for other countries. Although interest rates were low and the cost of land was reasonable, this generally inflationary time caused interest rates and farm land values to rise rapidly by the end of the decade. However, in the 1980s the economy worsened. Foreign demand declined, especially after the grain embargo of the Soviet Union, and foreign competition grew. The value of the dollar increased, making American goods more expensive overseas. At the same time, domestic demand slowed because of the weakened economy. Farmers had trouble selling their products at the same prices as before, and when farm income declined, a farm financial crisis occurred. Furthermore, many farmers were saddled with high-interest loans tied mostly to devaluated land prices. Some farmers no longer could pay the debt they owed, and many of them lost their farms (Anderlik and Walser, 1999).

Nevertheless, although the farm economy was weak and the amount of land in agricultural production had decreased (table 3), the production of corn and soybeans increased. In 1973, Illinois produced 981,590,000 bushels of corn, but by 2000 the number had increased to 1,668,550,000 bushels, a 70 percent gain (U.S. Department of Agriculture, 2011). The same type of increase can be seen for soybeans: in 1973, Illinois yielded 287,595,000 bushels of soybeans, but by 2000 soybean production had increased by 59.9 percent to 459,800,000 bushels (U.S. Department of Agriculture, 2011). Factors that may have contributed to the increase in crop yields were seed genetics, new producer-level management techniques, and—especially in the 1990s—favorable weather and growing conditions (Tannura and others, 2008).

Table 1. Percentage of Central Corn Belt Plains Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (96.6 percent), whereas 3.4 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	3.2	1.2	2.0	4.4	0.8	25.8
2	0.2	0.1	0.1	0.3	0.1	27.8
3	0.0	0.0	0.0	0.0	0.0	61.7
4	0.0	0.0	0.0	0.0	0.0	80.8
Overall spatial change	3.4	1.2	2.1	4.6	0.8	25.0

Table 2. Raw estimates of change in Central Corn Belt Plains Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	0.7	0.3	0.5	1.0	0.2	25.0	0.1
1980–1986	0.7	0.2	0.5	0.9	0.1	20.7	0.1
1986–1992	0.8	0.4	0.4	1.2	0.2	31.2	0.1
1992–2000	1.4	0.6	0.8	2.0	0.4	29.3	0.2
Estimate of change, in square kilometers							
1973–1980	726	267	459	992	182	25.0	104
1980–1986	713	217	496	930	148	20.7	119
1986–1992	784	359	426	1,143	244	31.2	131
1992–2000	1,352	581	771	1,933	396	29.3	169

Table 3. Estimated area (and margin of error) of each land-cover class in Central Corn Belt Plains Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Nonmechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	1.6	0.8	9.2	4.3	0.0	0.0	0.2	0.1	0.0	0.0	9.5	2.0	0.7	0.3	77.4	6.0	1.4	0.9	0.0	0.0
1980	1.6	0.8	9.6	4.4	0.0	0.0	0.2	0.1	0.0	0.0	9.4	2.0	0.7	0.3	77.1	6.0	1.4	0.9	0.0	0.0
1986	1.5	0.8	10.0	4.5	0.0	0.0	0.2	0.1	0.0	0.0	9.3	2.0	0.7	0.3	76.8	6.0	1.5	1.0	0.0	0.0
1992	1.6	0.8	10.5	4.6	0.0	0.0	0.2	0.1	0.0	0.0	9.3	2.0	0.6	0.2	76.3	6.2	1.5	1.0	0.0	0.0
2000	1.6	0.8	11.6	4.9	0.0	0.0	0.3	0.1	0.0	0.0	9.3	2.0	0.6	0.2	75.3	6.3	1.4	1.0	0.0	0.0
Net change	0.0	0.1	2.4	1.1	0.0	0.0	0.1	0.1	0.0	0.0	–0.2	0.1	–0.2	0.1	–2.2	1.1	0.1	0.1	0.0	0.0
Gross change	0.2	0.2	2.4	1.1	0.1	0.1	0.2	0.1	0.0	0.0	0.5	0.1	0.4	0.1	2.5	1.1	0.2	0.2	0.0	0.0
Area, in square kilometers																				
1973	1,608	837	9,075	4,290	16	23	155	85	0	0	9,383	1,973	719	281	76,483	5,899	1,355	845	0	0
1980	1,545	780	9,464	4,341	2	3	179	94	0	0	9,290	1,968	733	275	76,155	5,949	1,426	936	0	0
1986	1,513	757	9,833	4,401	13	14	205	107	0	0	9,223	1,957	663	267	75,879	5,976	1,465	992	0	0
1992	1,547	776	10,347	4,573	15	17	218	113	0	0	9,216	1,944	608	246	75,411	6,101	1,433	957	0	0
2000	1,560	777	11,422	4,835	16	13	266	140	0	0	9,180	1,940	560	240	74,359	6,267	1,431	954	0	0
Net change	–48	126	2,347	1,118	0	27	111	66	0	0	–203	141	–159	89	–2,124	1,119	76	123	0	0
Gross change	243	207	2,352	1,119	88	55	150	84	0	0	468	142	372	121	2,439	1,094	185	207	0	0

Table 4. Principal land-cover conversions in Central Corn Belt Plains Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Agriculture	Developed	325	194	132	0.3	44.8
	Forest	Agriculture	83	45	31	0.1	11.4
	Water	Wetland	77	101	69	0.1	10.6
	Agriculture	Grassland/Shrubland	59	34	23	0.1	8.1
	Forest	Developed	43	28	19	0.0	5.9
	Other	Other	139	n/a	n/a	0.1	19.1
		Totals	726			0.7	100.0
1980–1986	Agriculture	Developed	285	134	91	0.3	40.0
	Forest	Agriculture	69	46	31	0.1	9.7
	Grassland/Shrubland	Forest	51	36	25	0.1	7.2
	Water	Wetland	48	68	46	0.0	6.7
	Forest	Developed	46	44	30	0.0	6.4
	Other	Other	214	n/a	n/a	0.2	30.0
		Totals	713			0.7	100.0
1986–1992	Agriculture	Developed	446	277	189	0.5	56.9
	Grassland/Shrubland	Forest	46	38	26	0.0	5.9
	Agriculture	Grassland/Shrubland	36	22	15	0.0	4.6
	Wetland	Water	36	47	32	0.0	4.6
	Forest	Developed	32	22	15	0.0	4.1
	Other	Other	188	n/a	n/a	0.2	24.0
		Totals	784			0.8	100.0
1992–2000	Agriculture	Developed	983	533	363	1.0	72.7
	Forest	Developed	66	58	40	0.1	4.9
	Grassland/Shrubland	Forest	40	29	20	0.0	3.0
	Agriculture	Grassland/Shrubland	34	17	12	0.0	2.5
	Mining	Developed	31	24	16	0.0	2.3
	Other	Other	198	n/a	n/a	0.2	14.6
		Totals	1,352			1.4	100.0
1973–2000 (overall)	Agriculture	Developed	2,039	1,023	697	2.1	57.0
	Forest	Agriculture	192	82	56	0.2	5.4
	Forest	Developed	187	126	86	0.2	5.2
	Agriculture	Grassland/Shrubland	171	79	54	0.2	4.8
	Grassland/Shrubland	Forest	162	89	61	0.2	4.5
	Other	Other	824	n/a	n/a	0.8	23.0
		Totals	3,575			3.6	100.0

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Status and Trends of Land Change in the Midwest–South Central United States—1973 to 2000
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Chapter 11

Interior River Lowland Ecoregion

By Krista A. Karstensen and Roger F. Auch

Ecoregion Description

The Interior River Lowland Ecoregion encompasses 93,272 km^2 (36,012 mi^2), mainly in southern and western Illinois, but it also extends into southwestern Indiana, northwestern Kentucky, eastern Missouri, and a tiny part of southeastern Iowa (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1999). The ecoregion is bordered by eight other ecoregions: the Central Corn Belt Plains Ecoregion to the north, the Eastern Corn Belt Plains Ecoregion to the northeast, the Interior Plateau Ecoregion to the east and southeast, the

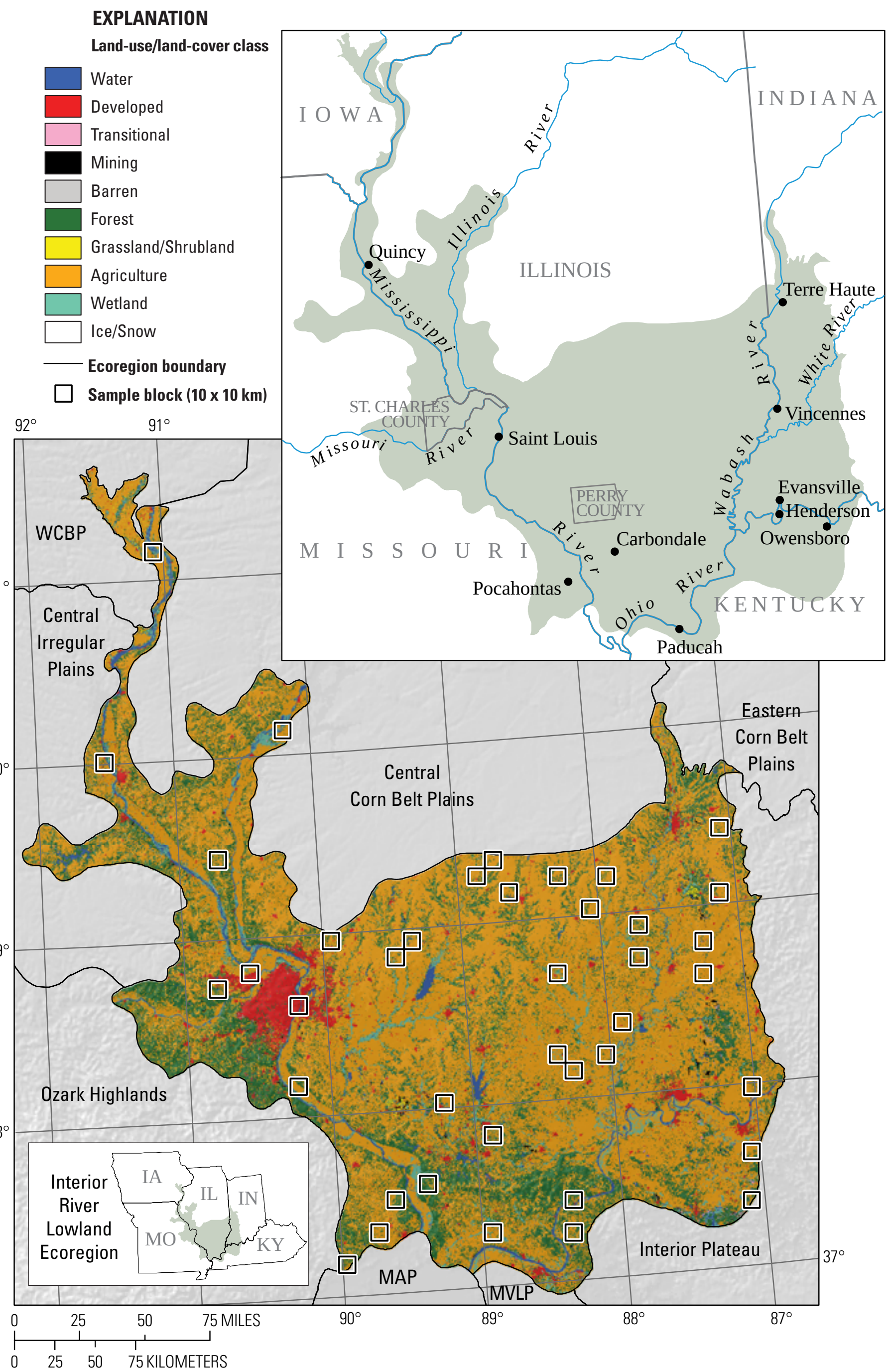

Figure 1. Map of Interior River Lowland Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status and Trends of Land Change” study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of two Great Plains ecoregions (Western Corn Belt Plains [WCBP] and Central Irregular Plains) and two Eastern United States ecoregions (Mississippi Valley Loess Plains [MVLP] and Interior Plateau). See appendix 3 for definitions of land-use/land-cover classifications.

Mississippi Valley Loess Plains and the Mississippi Alluvial Plain Ecoregions to the south, the Ozark Highlands Ecoregion to the southwest, the Central Irregular Plains Ecoregion to the west, and the Western Corn Belt Plains Ecoregion to the far northwest. The Interior River Lowland Ecoregion includes a large stretch of the Mississippi River, and its confluences with the Missouri and Illinois Rivers are located in the ecoregion, as is the confluence of the Wabash River with the Ohio River. In addition, the Ohio–Mississippi River confluence lies just outside the southern part of the ecoregion.

The Interior River Lowland Ecoregion is underlain by noncalcareous, clastic sedimentary rocks and deposits (Woods and others, 1998). The unstratified glacial deposits found north of the White River in Indiana indicate that pre–Wisconsin-age ice once covered much of the Interior River Lowland Ecoregion. Geomorphic characteristics also include terraced valleys filled with alluvium, as well as glacial-outwash, eolian, and lacustrine deposits (Woods and others, 1998). The ecoregion has a midlatitude continental climate, with hot summers and cold winters. Mean annual precipitation ranges from 860 to 1,320 mm (34–52 in.), depending on location (Wiken and others, 2011). Natural vegetation is composed primarily of bottomland and upland forests (fig. 2*A*), although in places the vegetation mosaic includes prairie grasslands (fig. 2*B*) that are dominated by bluestem grasses (for example, *Andropogon gerardii* and *Schizachyrium scoparium*), in addition to areas of herbaceous marshes (Woods and others, 2006). Bottomland forests include sweetgum (*Liquidambar styraciflua*) and various oak species that thrive in wetter environments (for example, pin oak [*Quercus palustris*], swamp white oak [*Quercus bicolor*]); along the Mississippi River, a greater variety of trees can be found, including silver maple (*Acer saccharinum*), American elm (*Ulmus Americana*), green ash (*Fraxinus pennsylvanica*), sycamore (*Platanus occidentalis*), honey locust (*Gleditsia triacanthos*), black walnut (*Juglans nigra*), and hickory (*Carya* spp.). Upland forests include other types of oaks (for example, post oak [*Quercus stellata*], white oak [*Quercus alba*], black oak [*Quercus velutina*]), as well as shagbark hickory (*Carya ovata*) and, in more mesic sites, yellow-poplar (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and northern red oak (*Quercus rubra*) (Wiken and others, 2011).

Figure 2. Forest and prairie landscapes in Interior River Lowland Ecoregion. *A*, Mostly forested landscape among woody bluffs southwest of Carbondale, Illinois, east of Mississippi River. *B*, Native-prairie restoration east of Vincennes, Indiana.

Figure 3. Different farming conditions in Interior River Lowland Ecoregion, primarily resulting from local differences in topography. *A*, Corn fields in irregular landscape, just north of Pocahontas, Missouri. *B*, Flat field near farmstead in Perry County, Illinois, showing soybeans emerging from stubble that remains from previous harvest.

Although land use in the Interior River Lowland Ecoregion is more varied than that of neighboring ecoregions (Woods and others, 1998), agricultural land use historically has been a vital economic resource for this ecoregion. The drained alluvial soils are farmed for feed grains and soybeans, whereas the valley upland areas are used for forage crops, pasture, and woodlots that support mixed uses of farming livestock and crop production (Woods and others, 1998) (fig. 3). This ecoregion provides a key component of national energy resources, as it contains the second largest coal reserve and the largest reserve of bituminous coal in the United States (Varanka and Shaver, 2007); however, use of this coal has diminished recently because of its high sulfur content (Milici and Dennen, 2009) (fig. 4). Developed land in the Interior River Lowland Ecoregion was dominated by (2000 populations) the Saint Louis, Missouri (2,603,607), Evansville, Indiana–Henderson, Kentucky (296,195), and Terre Haute, Indiana (149,192), metropolitan areas, along with smaller cities that had populations of less than 100,000 (Paducah and Owensboro, Kentucky, and Quincy, Illinois) (Demographia, 2003).

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Interior Lowland Ecoregion between 1973 and 2000 is estimated at 5.5 percent (table 1). Compared to other Midwest–South Central United States ecoregions, change in the Interior Lowland Ecoregion was moderate (fig. 5): an estimated 5 percent of the ecoregion changed in one time period. However, the percentage of the ecoregion that changed multiple times was low: about 0.5 percent of the area changed twice, and 0.1 percent changed three times (table 1).

Figure 4. Coal mining, still operating in 2003 in some areas of Interior River Lowland Ecoregion, such as this one located in southwestern Indiana.

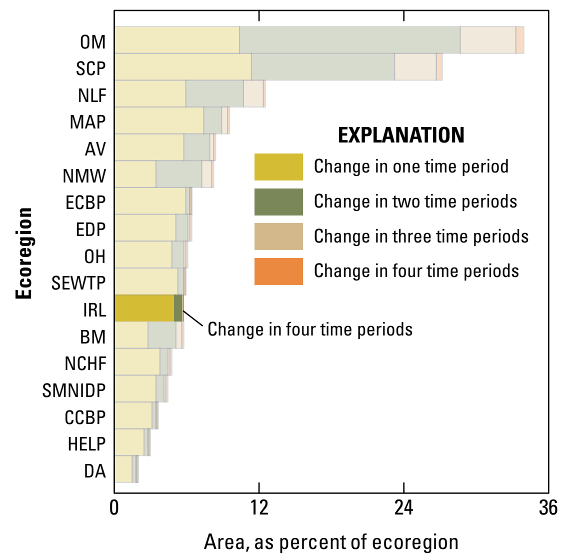

Figure 5. Overall spatial change in Interior River Lowland Ecoregion (IRL; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Interior River Lowland Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

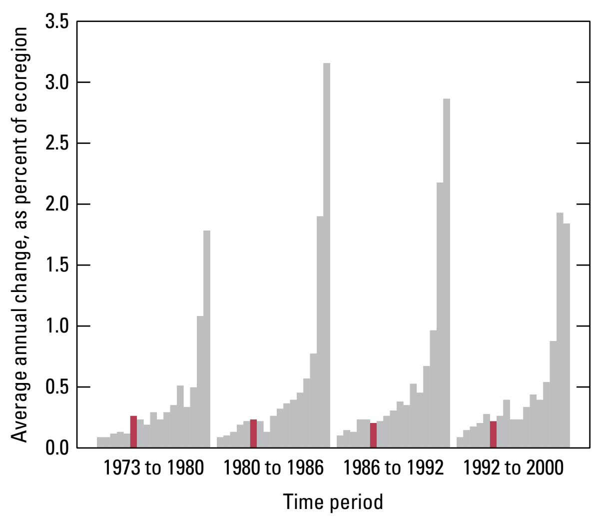

Figure 6. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Interior River Lowland Ecoregion are represented by red bars in each time period.

The estimated area that changed in the ecoregion was highest between 1973 and 1980 (1.8 percent), and it slowly decreased until a slight peak was reached between 1992 and 2000 (1.7 percent) (table 2). When normalized to an annual rate to account for unequal time periods, land-cover change still was highest between 1973 and 1980 (0.3 percent). The remaining time periods had an annual rate of change of 0.2 percent (table 2; fig. 6). During the entire 27-year study period, conversions from forest to agriculture and from agriculture to developed were predominant (table 4).

Agriculture was the primary land-cover class in the ecoregion, increasing to an estimated 65.0 percent of the ecoregion by 1986 but decreasing marginally to 64.6 percent by 2000 (table 3); however, cropland use was highly intensive, and urbanization was expanding, driven by several economic sectors and industries (Varanka and Shaver, 2007). Forest was the next highest land-cover class in the ecoregion, with estimated values of 22.7 percent in 1973 and 20.4 percent in 2000. Developed had a small but steady increase, from 5.4 percent in 1973 to 7.0 percent in 2000 (table 3).

Developed expanded the most in the ecoregion, with an estimated increase of 1.6 percent (1,503 km^2, a 30-percent net increase from its estimated 1973 level) between 1973 and 2000 (table 3; fig. 7). Initially, developed expanded slowly (fig. 8) before peaking with the greatest rate of expansion between 1992 and 2000, which also was the period with the second highest overall amount of change (1.7 percent; table 2). The largest net decrease occurred in forest, with an estimated net decrease of 2.3 percent (2,114 km^2, a 10-percent net decrease from its estimated 1973 level); forest primarily was cleared for agricultural expansion (fig. 9).

Overall, the greatest change during the study period was the conversion from forest to agriculture (2,113 km^2). However, this conversion did not result in a substantial net increase in agriculture because, during the same time period, agriculture was converting to developed. Conversion from agriculture to developed was the second most common change (1,186 km^2). The loss of agriculture was masked by a low net amount of change (0.7 percent).

During the study period, the Interior River Lowland Ecoregion was a rich natural environment that had a low-to-moderate demand for competing land uses, which maintained the stability and growth of the ecoregion despite a relatively small population change (Varanka and Shaver, 2007). Although increased urbanization was one of the primary reasons for change in the ecoregion, population may not have been the only driver of change for the developed land-cover class. Similar to population patterns in other cities in the Midwest–South Central United States (for example, Chicago, Illinois, and Cleveland, Ohio), population growth in Saint Louis, Missouri, decreased during the study period, despite an increase in metropolitan land area. This pattern is indicative of the socioeconomic and demographic drivers of land change that played an integral role in the net increases of the developed land-cover class in the ecoregion.

Figure 7. New housing development near Missouri River, part of metropolitan Saint Louis area in St. Charles County, Missouri.

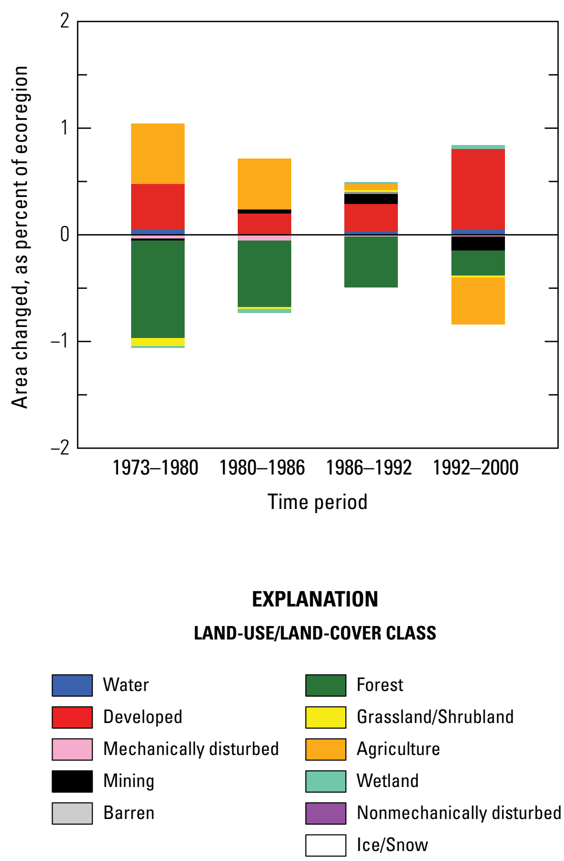

Figure 8. Normalized average net change in Interior River Lowland Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

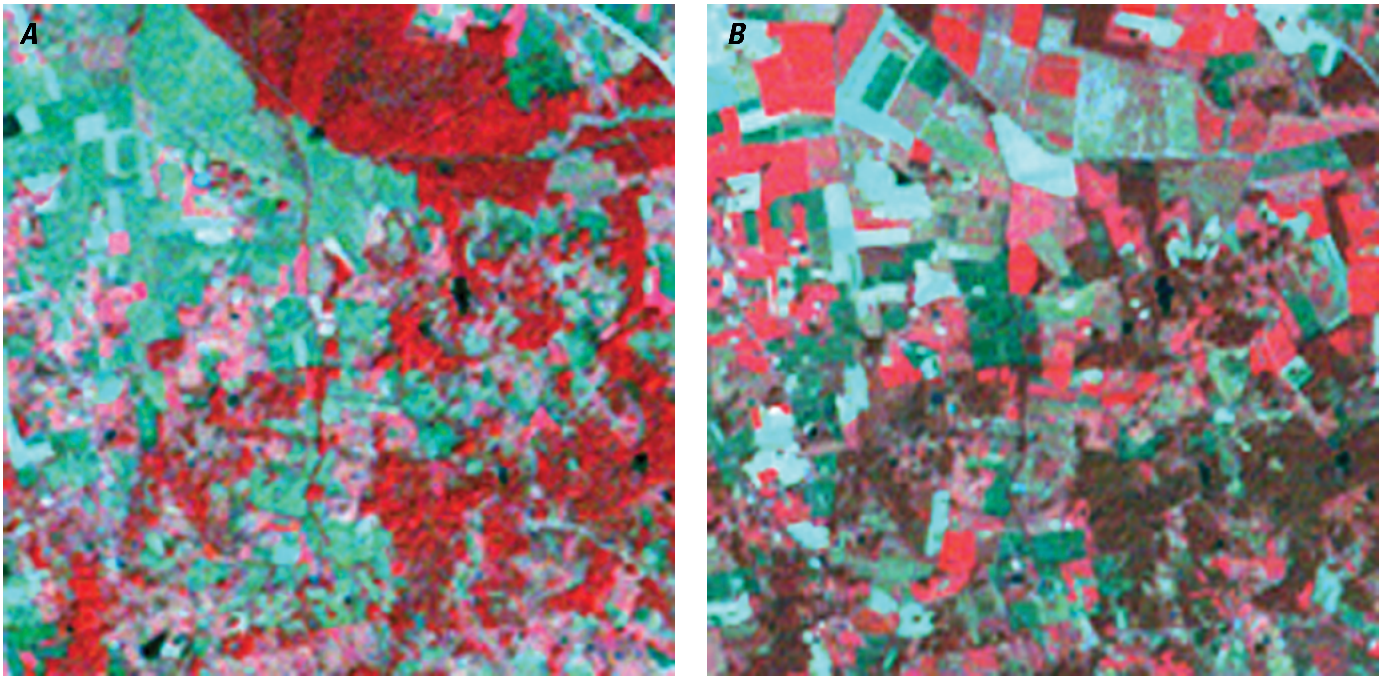

Figure 9. Landsat imagery of area about 10 km south of Owensboro, Kentucky, showing changes in land-cover class from forest (dark reds) to agriculture (greens and blues). Note that these are early Landsat (MSS) images and, thus, are of lower visual quality because of their coarser resolution. *A*, Image from late September 1972, showing large areas of forest and mostly harvested farm fields that surround them. *B*, Image from late September 1981 of same area as *A*, showing that forested areas have been cleared and converted to agricultural use, especially in northeastern part of image but also in several other parts of image.

Table 1. Percentage of Interior River Lowland Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (94.5 percent), whereas 5.5 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	5.0	1.4	3.6	6.3	0.9	18.7
2	0.5	0.2	0.3	0.7	0.2	30.7
3	0.1	0.0	0.0	0.1	0.0	38.1
4	0.0	0.0	0.0	0.0	0.0	72.2
Overall spatial change	5.5	1.5	4.0	7.0	1.0	18.2

Table 2. Raw estimates of change in Interior River Lowland Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
			Estimate of change, in percent stratum				
1973–1980	1.8	0.7	1.1	2.5	0.5	26.2	0.3
1980–1986	1.4	0.4	1.0	1.8	0.3	19.4	0.2
1986–1992	1.2	0.4	0.8	1.6	0.3	22.0	0.2
1992–2000	1.7	0.7	1.1	2.4	0.5	26.8	0.2
			Estimate of change, in square kilometers				
1973–1980	1,712	659	1,053	2,372	449	26.2	245
1980–1986	1,277	364	913	1,641	248	19.4	213
1986–1992	1,095	353	742	1,449	241	22.0	183
1992–2000	1,631	643	988	2,274	438	26.8	204

Table 3. Estimated area (and margin of error) of each land-cover class in Interior River Lowland Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
									Area, in percent stratum											
1973	2.6	0.8	5.4	3.0	0.1	0.1	0.1	0.1	0.0	0.0	22.7	3.4	0.5	0.3	64.0	3.9	4.6	1.3	0.0	0.0
1980	2.7	0.8	5.8	3.2	0.1	0.1	0.1	0.1	0.0	0.0	21.8	3.4	0.4	0.3	64.6	3.9	4.5	1.3	0.0	0.0
1986	2.7	0.8	6.0	3.3	0.0	0.0	0.1	0.1	0.0	0.0	21.1	3.4	0.4	0.3	65.0	4.0	4.5	1.3	0.0	0.0
1992	2.7	0.8	6.2	3.3	0.0	0.0	0.2	0.2	0.0	0.0	20.7	3.4	0.4	0.3	65.1	4.0	4.5	1.3	0.0	0.0
2000	2.8	0.8	7.0	3.6	0.0	0.0	0.1	0.1	0.0	0.0	20.4	3.4	0.4	0.3	64.6	4.1	4.6	1.3	0.0	0.0
Net change	0.2	0.1	1.6	1.2	–0.1	0.1	0.0	0.1	0.0	0.0	–2.3	0.7	–0.1	0.2	0.7	1.3	0.0	0.2	0.0	0.0
Gross change	0.3	0.1	1.6	1.2	0.3	0.2	0.5	0.4	0.0	0.0	2.8	0.7	0.4	0.2	3.6	1.1	0.3	0.2	0.0	0.0
									Area, in square kilometers											
1973	2,463	760	5,008	2,829	103	71	118	110	15	13	21,164	3,214	470	251	59,682	3,622	4,248	1,224	0	0
1980	2,516	769	5,400	2,967	81	71	92	86	15	13	20,307	3,189	413	259	60,210	3,652	4,238	1,224	0	0
1986	2,523	761	5,580	3,034	30	19	128	97	15	13	19,726	3,180	396	244	60,662	3,687	4,211	1,217	0	0
1992	2,563	758	5,816	3,104	20	15	222	187	17	15	19,285	3,136	417	241	60,719	3,692	4,213	1,219	0	0
2000	2,616	757	6,511	3,311	15	9	100	65	22	20	19,050	3,131	408	244	60,299	3,850	4,250	1,252	0	0
Net change	153	106	1,503	1,088	–88	69	–18	95	7	8	–2,114	646	–62	164	617	1,175	2	156	0	0
Gross change	259	99	1,521	1,088	323	152	506	365	7	8	2,585	618	365	171	3,394	982	267	149	0	0

Table 4. Principal land-cover conversions in Interior River Lowland Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Agriculture	856	377	257	0.9	50.0
	Agriculture	Developed	304	355	242	0.3	17.8
	Forest	Mechanically disturbed	59	57	39	0.1	3.5
	Grassland/Shrubland	Forest	58	68	47	0.1	3.4
	Agriculture	Forest	57	23	16	0.1	3.3
	Other	Other	378	n/a	n/a	0.4	22.1
		Totals	1,712			1.8	100.0
1980–1986	Forest	Agriculture	603	221	150	0.6	47.2
	Agriculture	Developed	138	98	67	0.1	10.8
	Wetland	Agriculture	103	113	77	0.1	8.1
	Grassland/Shrubland	Forest	65	81	55	0.1	5.1
	Agriculture	Wetland	48	68	47	0.1	3.7
	Other	Other	320	n/a	n/a	0.3	25.0
		Totals	1,277			1.4	100.0
1986–1992	Forest	Agriculture	409	174	118	0.4	37.4
	Agriculture	Developed	170	102	70	0.2	15.5
	Agriculture	Mining	143	151	103	0.2	13.1
	Mining	Agriculture	43	45	31	0.0	3.9
	Forest	Developed	42	32	22	0.0	3.9
	Other	Other	288	n/a	n/a	0.3	26.3
		Totals	1,095			1.2	100.0
1992–2000	Agriculture	Developed	574	454	309	0.6	35.2
	Forest	Agriculture	245	94	64	0.3	15.0
	Mining	Agriculture	139	169	115	0.1	8.5
	Forest	Developed	120	106	72	0.1	7.3
	Agriculture	Forest	118	64	43	0.1	7.3
	Other	Other	435	n/a	n/a	0.5	26.7
		Totals	1,631			1.7	100.0
1973–2000 (overall)	Forest	Agriculture	2,113	601	409	2.3	37.0
	Agriculture	Developed	1,186	890	606	1.3	20.8
	Forest	Developed	243	181	124	0.3	4.3
	Agriculture	Forest	236	84	57	0.3	4.1
	Agriculture	Mining	210	170	116	0.2	3.7
	Other	Other	1,727	n/a	n/a	1.9	30.2
		Totals	5,716			6.1	100.0

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South Central Highlands Ecoregions

Status and Trends of Land Change in the Midwest–South Central United States—1973 to 2000
Edited by Roger F. Auch and Krista A. Karstensen
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Chapter 12

Ozark Highlands Ecoregion

By Krista A. Karstensen

Ecoregion Description

The Ozark Highlands Ecoregion, which covers about 108,332 km^2 (41,827 mi^2), includes parts of southern Missouri, northern Arkansas, and northeastern Oklahoma, as well as the extreme southeastern corner of Kansas (fig.1) (Omernik, 1987; Wiken and others, 2011). Neighboring ecoregions are the Central Irregular Plains Ecoregion to the west and north, the Interior River Lowlands Ecoregion to the northeast, the Mississippi Alluvial Plain Ecoregion to the southeast, and the

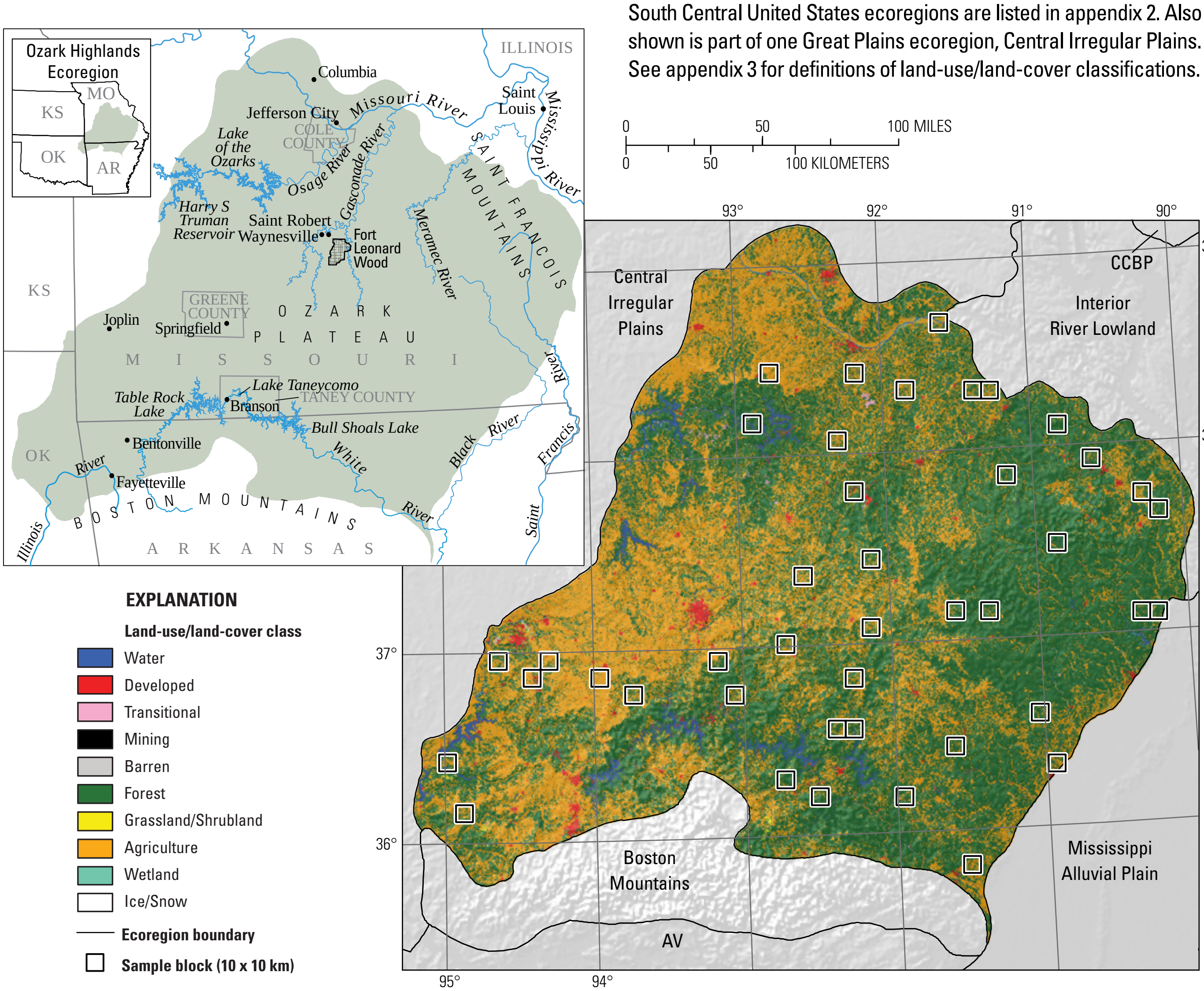


Figure 1. Map of Ozark Highlands Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status and Trends of Land Change” study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown is part of one Great Plains ecoregion, Central Irregular Plains. See appendix 3 for definitions of land-use/land-cover classifications.

Boston Mountains Ecoregion to the south (fig. 1). Elevations in the ecoregion range from 76 to 274 m, and local relief ranges from 15 to 244 m (Woods and others, 2004). Urban areas in the ecoregion include the cities of Bentonville and Fayetteville, Arkansas, and Jefferson City, Columbia, Springfield, Joplin, and Branson, Missouri.

The ecoregion is part of the Ozark Plateaus physiographic province, which consists of a structural dome of sedimentary and igneous rocks (Davis and Bell, 1998). The sedimentary rocks generally dip away from the igneous core of the Saint Francois Mountains in southeastern Missouri to form the Salem-Springfield Plateaus (formerly known as the "Salem Plateau" and the "Springfield Plateau" [Fenneman, 1938]) section of the Ozark Plateaus physiographic province. The Salem-Springfield Plateaus are underlain by limestone and dolomite, which have formed the karst topography responsible for the ecoregion's unique hydrologic features such as losing streams, springs, seeps, and fens (U.S. Forest Service, 2010). The soils that have formed in this geologic landscape have shaped both the natural vegetation and the agricultural character of the Ozark Highlands Ecoregion (L. Handley, U.S. Geological Survey, written commun., 2010).

The Ozark Highlands Ecoregion generally has a mesic temperature regime, with annual precipitation of about 1,070 to 1,240 mm (42–49 in.) (Woods and others, 2004). The continental climate of the ecoregion is affected by prevailing easterly storm systems, as well as Gulf of Mexico moisture sources and occasional incursions of polar fronts (Jacobson and Primm, 1997).

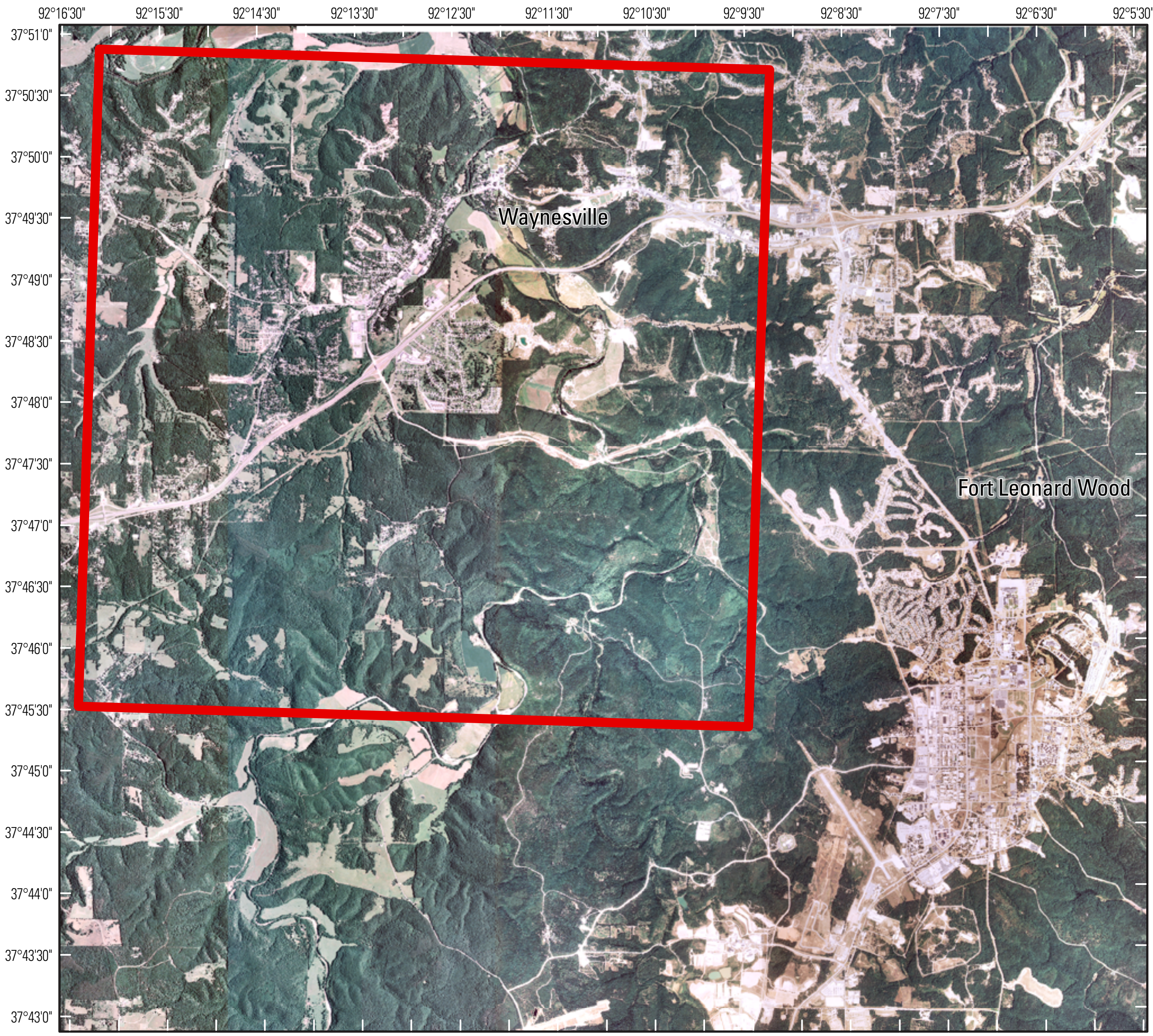
Several river systems drain the ecoregion; these include the Osage, Gasconade, Meramec, Saint Francis, Black, White, and Illinois Rivers. Most rivers drain either radially away from south-central Missouri or northward from the Boston Mountains (Petersen and others, 1998). The annual mean streamflow of individual streams within the ecoregion varies substantially from year to year. Minimum monthly streamflows generally occur in the summer and autumn (July to October), and maximum monthly streamflows typically occur in spring (March to May) (Adamski and others, 1995).

The Ozark Highlands Ecoregion has some of the largest freshwater springs in North America, providing habitat for a wide variety of endemic species such as the Ozark shiner (*Notropis ozarcanus*) (The Nature Conservancy, 2003). Although the ecoregion has some small sinkhole ponds, it has few natural lakes (U.S. Forest Service, 2010). The 1941 initiation of the Missouri Pond Program (Missouri Department of Conservation, 2012) had a noticeable effect on the ecoregion. Missouri farmers embraced the program as a way to provide water for their livestock, as well as for recreational and domestic uses, and sportsmen also were encouraged by its provision of fish- and waterfowl-habitat incentives (Missouri Department of Conservation, 2012). This conservation effort likely is responsible for creating many of the farm ponds across the ecoregion. The Ozark Highlands Ecoregion also has several substantial reservoirs along large rivers; these include Lake Taneycomo, Bull Shoals Lake, Table Rock Lake, Lake of the Ozarks, and Harry S Truman Reservoir. These large water bodies provide recreational boating and fishing activities and generally attract many tourists during the summer months. For example, most of the shoreline of Lake of the Ozarks, one of the largest manmade lakes in the Midwest–South Central United States, is privately owned and is occupied by vacation homes, hotels, condominiums, and restaurants.

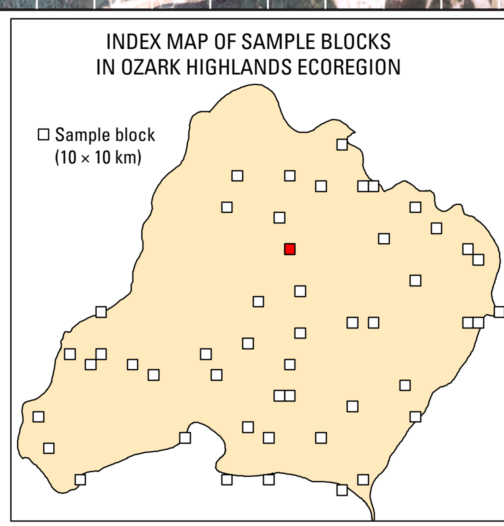
Land cover in the Ozark Highlands Ecoregion is characterized primarily by forest in the east and agriculture in the west (figs.1,2). The oak–hickory (*Quercus* spp. and *Carya* spp.) forest in the ecoregion provided a profitable environment for the timber boom of the late 1800s, which lasted until 1920. During this period, the ecoregion experienced cutover, and controlled forest burns were suppressed. Between 1960 and 1993, upland areas increasingly were used for grazing and row crops; valley slopes were used for woodland grazing and managed timber; and valley bottoms were cleared for pasture and row crops, with some reversion to forest (Jacobson and Primm, 1997). The agricultural crisis in the Midwest that occurred during the 1980s (Demissie, 1986) had an adverse effect on the ecoregion. Throughout this period, the acreage harvested for crops, as well as the number of cattle sold, decreased substantially until recovery in the early 1990s. Most farm income in the Ozark Highlands Ecoregion in the early 2000s was from the sale of cattle, poultry, or hogs (Woods and others, 2004).

In 2000, developed land accounted for an estimated 2.1 percent of the ecoregion, mostly around major urban areas. Springfield, Missouri, was the largest city in the ecoregion in 2000 (population 151,580). The other urban areas (Jefferson City, Columbia, Joplin, Branson, Bentonville, and Fayetteville) had less than 100,000 residents each in 2000. The developed land in the Ozark Highlands Ecoregion had diverse sources of growth. For example, in Branson, Missouri, which had a resident population of only 6,050 people in 2000 (U.S. Census Bureau, 2001), local recreational and entertainment opportunities attract upwards of 7 million tourists annually (Lambe, 2008). The small cities of Saint Robert and Waynesville, Missouri, grew rapidly starting in 1960 following growth of the Fort Leonard Wood military installation. One sample block included in this ecoregion analysis is about 1.5 km from the military installation's border (fig. 3); the

Figure 2. Hay land and pastureland south of Jefferson City, in Cole County, Missouri.



Base from The National Map, U.S. Geological Survey
North American Datum of 1983 (NAD 83)
UTM Zone 15, Universal Transverse Mercator projection



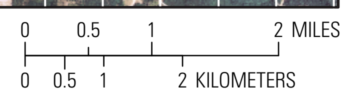


Figure 3. Aerial photograph of area surrounding Waynesville, Missouri, showing its proximity to Fort Leonard Wood military installation. Red outline in aerial photograph shows area of sample block 304; red square in index map shows location of sample block 304 in Ozark Highlands Ecoregion.

sample block includes Waynesville, which is one of the larger towns adjacent to the Fort Leonard Wood military installation. The addition of many military personnel at any one location may potentially affect the footprint (overall areal extent) of land-use and land-cover change, not only for the military installation itself but also for the surrounding community (Karstensen and Loveland, 2008).

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) between 1973 and 2000 in the Ozark Highlands Ecoregion is estimated at 5.9 percent (table 1). Compared to the other Midwest–South Central United States ecoregions, change in the Ozark Highlands Ecoregion was moderate (fig. 4): about 4.8 percent of the ecoregion changed once during the study period, 1.1 percent changed twice, and 0.1 percent changed three times (table 1). The amount of change varied slightly between 1973 and 2000, with the total change per time period (as percent of the ecoregion) ranging from 1.5 to 2.0 percent (table 2). When normalized to account for uneven time periods, the average annual rate of change for the first three time periods (1973–1980, 1980–1986, and 1986–1992) was 0.3 percent, and, for the fourth time period (1992–2000), it was 0.2 percent (table 2; fig. 5). This decrease of overall change in the middle of the study period may be due to the agricultural crisis in the Midwest that occurred in the 1980s.

The forest and agriculture land-cover classes experienced the highest amount of change during the study period (table 3; fig. 6). Despite covering an estimated 60,893 km^2 of the ecoregion in 2000, forest had a net loss of 3.9 percent (2,484 km^2, 2.3 percent of the ecoregion area). Agriculture, which covered about 39,820 km^2 in 2000, had a net gain of about 5 percent (1,881 km^2, 1.7 percent of the ecoregion area). Grassland/shrubland and developed had the third and fourth highest amount of land in 2000, covering 2.8 percent and 2.1 percent of the ecoregion, respectively (table 3).

Neighboring ecoregions also experienced an overall net decrease in forest (Karstensen, 2008, 2009a,b; Sayler, 2009); however, forest loss in the Ozark Highlands Ecoregion was due to agricultural expansion, whereas the driving forces of land-cover change in the other ecoregions may have been more complex. For example, in the Boston Mountains Ecoregion to the south, which had a total net forest loss of 1.7 percent of ecoregion area between 1973 and 2000, agricultural expansion also occurred (a net increase of 0.7 percent of ecoregion area). Forest loss in the Boston Mountains Ecoregion, however, more likely is attributable to forest-logging practices and, thus, is associated with the mechanically disturbed land-cover class (rather than agriculture). A neighboring ecoregion that also showed an increase in agricultural land (an increase of 0.7 percent of ecoregion area) from forested land was the Interior River Lowland Ecoregion to the northeast.

The three leading land-cover-class conversions between 1973 and 2000 in the Ozark Highlands Ecoregion were (1) forest to agriculture, (2) agriculture to grassland/shrubland, and (3) grassland/shrubland to forest (table 4). Overall, the most common type of conversion in each time period was from forest to agriculture: between 1973 and 2000, an

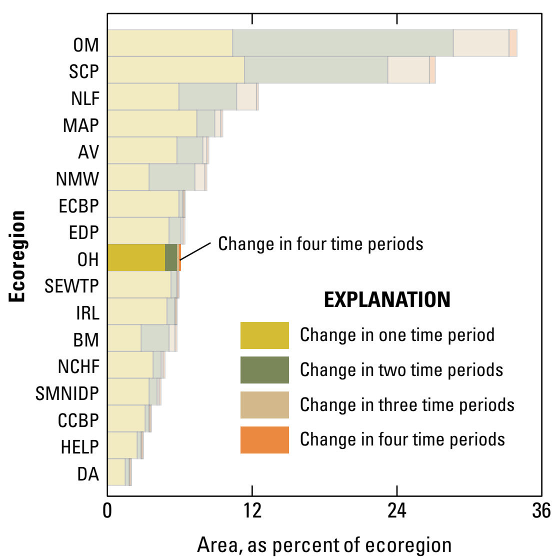


Figure 4. Overall spatial change in Ozark Highlands Ecoregion (OH; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Ozark Highlands Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

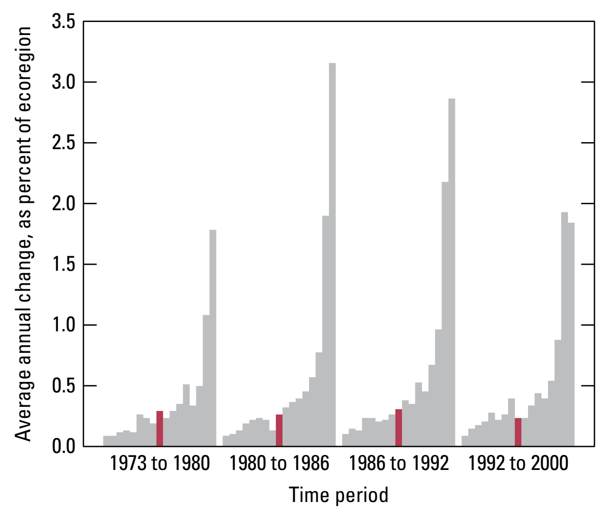


Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Ozark Highlands Ecoregion are represented by red bars in each time period.

estimated 2,593 km^2 were converted from forest to agriculture. This conversion may have resulted in a larger net increase in agriculture if agricultural land had not been reverting to grassland/shrubland at the same time (table 4). This may have been the result of the Conservation Reserve Program (CRP), which offered financial incentives for farmers to retire marginal agricultural land and convert it to native grasses or trees, usually for ten years' duration (Johnson and Maxwell, 2001).

Changes in forest practices were one of the drivers of land change in the ecoregion. Most large-scale timber operations in the Ozark Highlands Ecoregion began in the late 1800s with the construction of railroads. At the end of this timber-boom period (1920), most of the marketable shortleaf pine (*Pinus echinata*) was depleted, thereby shifting production to smaller companies that made railroad ties, stave bolts, firewood, and charcoal (Cunningham and Hauser, 1989; Stevens, 1991; Jacobson and Primm, 1997). Increases in timber production from the mid-1950s to the early 1970s represented renewed cutting of second-growth forests (Cunningham and Hauser, 1989; Jacobson and Primm, 1997). This study has shown that the period between 1973 and 1980 had the greatest amount of forested land when compared to the other three time periods, which may be indicative of the second-growth forests that were allowed to reach maturity before periods of increased agricultural expansion and less frequent burning.

In the late 1960s and early 1970s, net farm income in the Ozark Highlands Ecoregion increased significantly owing to both an increase in domestic prices and the growth in export markets (Demissie, 1986). This trend was common in the Midwest–South Central United States region, and overall agricultural expansion occurred in the region primarily because of the availability of abundant credit from various sources, as well as high rates of inflation and low real-estate interest rates. In particular, net farm income in Missouri doubled

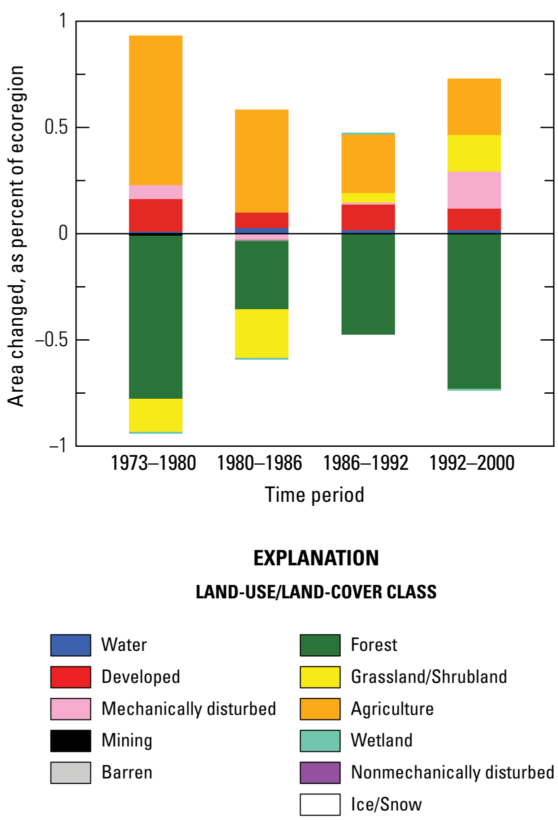


Figure 6. Normalized average net change in Ozark Highlands Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

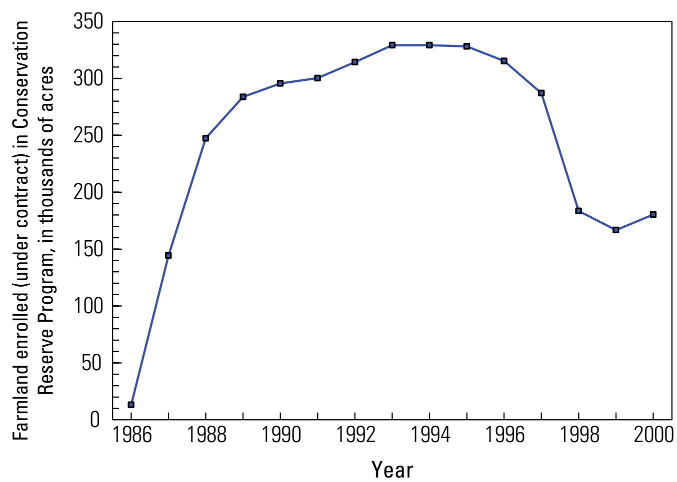


Figure 7. Cumulative enrollment (acres under contract) in Conservation Reserve Program between 1986 and 2000 in counties within Ozark Highlands Ecoregion (U.S. Department of Agriculture, 2010). Enrollments initially increased before declining in late 1990s.

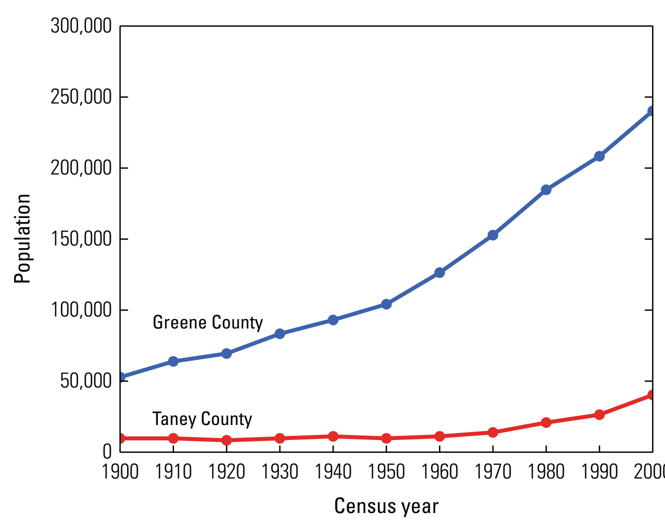


Figure 8. Population growth in Greene and Taney Counties, Missouri, during 20th century (U.S. Census Bureau, 1994, 2000). Growth of these counties is due primarily to increasing populations of Springfield and Branson, Missouri.

between 1964 and 1974 (Demissie, 1986), a trend that may be recorded in this study's statistics as the conversion, between 1973 and 1980, of the greatest amount of area from forest to agriculture, which likely is due to the clearing of forested land for primarily cattle- and poultry-based agricultural expansion.

Agro-economic markets are subject to change, and, during the study period, many farmers assumed heavy debt loads, becoming financially vulnerable to sudden shifts in economic forces (Stam and Dixon, 2004). In the early 1980s, economic conditions reversed as total farm debt increased, land values became inflated, and export markets contracted. In addition, substantial problems with farm lenders arose. The farm economic crisis is important to note primarily because, in the early 1980s, agriculture was still a predominant land-cover class in the ecoregion despite decreased agricultural production. Moreover, an increase in the amount of agricultural land that was abandoned may have taken place in the ecoregion during the two time periods (1980–1986, 1986–1992) in which the farm economic crisis occurred. Although CRP enrollment in the Ozark Highlands Ecoregion decreased in the later 1990s, the program may have contributed to the patterns of land-cover change across the ecoregion (fig.7). Conversions from agriculture to grassland/shrubland recorded in this study indicate agricultural abandonment, deintensification, or enrollment of agricultural land in the CRP. During the third and fourth time periods (1986–1992, 1992–2000), farmers likely either placed marginal agricultural land under CRP contracts or maintained less intensive management practices for various reasons, including economic ones.

The predominant land-cover change in the Ozark Highlands Ecoregion is attributable to the cutting of forests for agricultural expansion, as is shown in this study's statistics: in each of the four time periods, forest decreased and agriculture increased. Despite the economic hardships that affected farms in the 1980s, agricultural land increased during the study period. Cattle, poultry, and hogs continued to be the primary livestock produced and sold, and corn continued to be the primary agricultural crop throughout the ecoregion. Although changes in developed land were locally substantial during the study period (as exemplified by population growth around metropolitan Springfield and Branson [fig. 8]), the ecoregion as a whole showed little net change in developed land (table 3) because the number of urban areas in the ecoregion was limited.

In evaluating future land-cover change in the Ozark Highlands Ecoregion, the tradeoffs between agricultural and forest land uses should be considered, as well as the rapid growth of the larger cities in the ecoregion. The growing population will place greater demands on resources, which will, in turn, result in future demands on land cover and land use throughout the ecoregion.

Table 1. Percentage of Ozark Highlands Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (94.1 percent), whereas 5.9 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	4.8	0.5	4.2	5.2	0.3	7.3
2	1.1	0.3	0.8	1.3	0.2	16.5
3	0.1	0.0	0.1	0.1	0.0	29.6
4	0.0	0.0	0.0	0.0	0.0	57.7
Overall spatial change	5.9	0.7	5.3	6.6	0.4	7.5

Table 2. Raw estimates of change in Ozark Highlands Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	2.0	0.4	1.7	2.4	0.2	11.9	0.3
1980–1986	1.5	0.2	1.3	1.8	0.2	10.0	0.3
1986–1992	1.8	0.3	1.5	2.1	0.2	11.0	0.3
1992–2000	1.8	0.3	1.6	2.1	0.2	9.5	0.2
Estimate of change, in square kilometers							
1973–1980	2,201	386	1,816	2,587	263	11.9	314
1980–1986	1,665	245	1,420	1,910	167	10.0	277
1986–1992	1,955	315	1,640	2,271	215	11.0	326
1992–2000	2,003	278	1,725	2,281	189	9.5	250

Table 3. Estimated area (and margin of error) of each land-cover class in Ozark HIghlands Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	1.2	0.6	1.7	0.8	0.1	0.1	0.1	0.1	0.1	0.1	58.5	4.2	3.0	0.9	35.0	4.2	0.3	0.1	0.0	0.0
1980	1.2	0.6	1.8	0.9	0.2	0.1	0.1	0.1	0.1	0.1	57.7	4.1	2.8	0.8	35.7	4.2	0.3	0.1	0.0	0.0
1986	1.2	0.6	1.9	0.9	0.1	0.1	0.1	0.1	0.1	0.1	57.4	4.1	2.6	0.8	36.2	4.2	0.3	0.1	0.0	0.0
1992	1.3	0.6	2.0	0.9	0.1	0.1	0.1	0.1	0.1	0.1	56.9	4.1	2.7	0.8	36.5	4.2	0.3	0.1	0.0	0.0
2000	1.3	0.6	2.1	1.0	0.3	0.1	0.1	0.1	0.1	0.1	56.2	4.0	2.8	0.8	36.8	4.2	0.3	0.1	0.0	0.0
Net change	0.1	0.0	0.4	0.2	0.2	0.2	0.0	0.0	0.0	0.0	–2.3	0.4	–0.2	0.3	1.7	0.5	0.0	0.0	0.0	0.0
Gross change	0.1	0.0	0.4	0.2	0.8	0.2	0.0	0.0	0.1	0.0	3.1	0.4	1.6	0.3	3.0	0.3	0.0	0.0	0.0	0.0
Area, in square kilometers																				
1973	1,292	617	1,789	849	115	108	74	83	141	99	63,377	4,515	3,247	925	37,939	4,581	358	130	0	0
1980	1,309	613	1,957	950	178	64	63	82	148	95	62,541	4,426	3,081	918	38,698	4,550	357	130	0	0
1986	1,342	616	2,034	971	154	62	65	82	137	89	62,192	4,430	2,828	857	39,226	4,579	356	128	0	0
1992	1,365	618	2,160	1,020	162	69	66	82	134	87	61,684	4,430	2,876	834	39,529	4,590	356	128	0	0
2000	1,387	619	2,273	1,073	346	154	67	82	136	86	60,893	4,336	3,060	890	39,820	4,566	352	127	0	0
Net change	94	38	484	244	230	188	–7	17	–6	25	–2,484	471	–188	361	1,881	543	–6	12	0	0
Gross change	161	54	484	244	827	223	17	17	63	40	3,311	420	1,776	369	3,258	376	52	30	0	0

Table 4. Principal land-cover conversions in Ozark Highlands Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Agriculture	905	189	129	0.8	41.1
	Grassland/Shrubland	Forest	321	158	108	0.3	14.6
	Agriculture	Grassland/Shrubland	241	75	51	0.2	10.9
	Forest	Mechanically disturbed	177	64	43	0.2	8.1
	Grassland/Shrubland	Agriculture	158	100	68	0.1	7.2
	Other	Other	399	n/a	n/a	0.4	18.1
		Totals	2,201			2.0	100.0
1980–1986	Forest	Agriculture	477	117	80	0.4	28.7
	Grassland/Shrubland	Forest	307	115	79	0.3	18.4
	Grassland/Shrubland	Agriculture	193	111	76	0.2	11.6
	Agriculture	Grassland/Shrubland	166	79	54	0.2	10.0
	Forest	Mechanically disturbed	153	62	42	0.1	9.2
	Other	Other	369	n/a	n/a	0.3	22.2
		Totals	1,665			1.5	100.0
1986–1992	Forest	Agriculture	581	134	92	0.5	29.7
	Agriculture	Grassland/Shrubland	367	125	85	0.3	18.8
	Grassland/Shrubland	Agriculture	222	120	82	0.2	11.4
	Grassland/Shrubland	Forest	176	78	53	0.2	9.0
	Forest	Mechanically disturbed	157	69	47	0.1	8.0
	Other	Other	452	n/a	n/a	0.4	23.1
		Totals	1,955			1.8	100.0
1992–2000	Forest	Agriculture	630	130	89	0.6	31.5
	Agriculture	Grassland/Shrubland	375	119	81	0.3	18.7
	Forest	Mechanically disturbed	344	154	105	0.3	17.2
	Grassland/Shrubland	Forest	184	69	47	0.2	9.2
	Grassland/Shrubland	Agriculture	105	43	29	0.1	5.2
	Other	Other	365	n/a	n/a	0.3	18.2
		Totals	2,003			1.8	100.0
1973–2000 (overall)	Forest	Agriculture	2,593	392	267	2.4	33.1
	Agriculture	Grassland/Shrubland	1,148	295	201	1.1	14.7
	Grassland/Shrubland	Forest	987	295	201	0.9	12.6
	Forest	Mechanically disturbed	831	263	180	0.8	10.6
	Grassland/Shrubland	Agriculture	679	324	221	0.6	8.7
	Other	Other	1,586	n/a	n/a	1.5	20.3
		Totals	7,824			7.2	100.0

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Chapter 13

Boston Mountains Ecoregion

By Krista A. Karstensen

Ecoregion Description

The Boston Mountains Ecoregion encompasses about 17,068 km^2 (6,590 mi^2) of rugged, mountainous terrain across northwestern Arkansas and northeastern Oklahoma (fig.1) (Omernik, 1987; Wiken and others, 2011). The ecoregion is bounded on the north by the Ozark Highlands Ecoregion, on the west by the Central Irregular Plains Ecoregion, and on the south by the Arkansas Valley Ecoregion; in addition, a small part of the Mississippi Alluvial Plain Ecoregion adjoins the far-eastern part of the ecoregion.

Overall, the population density in the Boston Mountains Ecoregion is low; for example, one of the larger cities in the ecoregion—Tahlequah, Oklahoma—had population of 14,458 in 2000 (U.S. Census Bureau, 2001). In Arkansas, the principal streams and rivers in the ecoregion include the Mulberry River and Big Piney Creek, which drain the ecoregion to the south; the Buffalo and Little Red Rivers, which drain the ecoregion to the east; and the White and Kings Rivers, which drain the ecoregion to the north. In Oklahoma, the most important hydrologic features in the ecoregion are Tenkiller Ferry Lake and a small reach of the Arkansas River.

The climate of the Boston Mountains Ecoregion generally is humid. Mean annual precipitation is about 1,270 mm (50 in.), and it is, in general, greater in the north than in the south (Woods and others, 2004). Maximum precipitation occurs in spring and autumn, whereas minimum precipitation occurs in midsummer. In the summer, many small streams commonly have little or no flow. Parts of the ecoregion are associated with the carbonate-rock aquifers of the Ozark Plateaus aquifer system (Reilly and others, 2008), and water quality in the Boston Mountains Ecoregion generally has been exceptional;

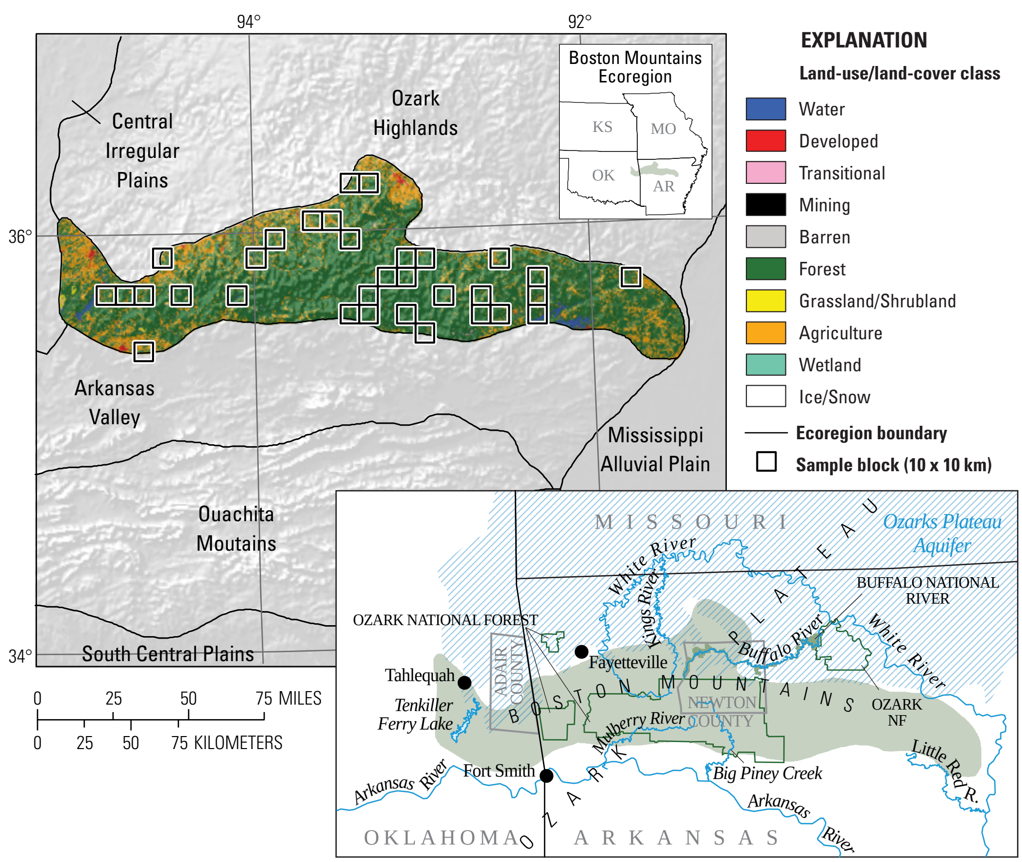

Figure 1. Map of Boston Mountains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown is part of one Great Plains ecoregion, Central Irregular Plains. See appendix 3 for definitions of land-use/land-cover classifications.

however, nutrient concentrations generated in agricultural areas potentially present concerns for the health of freshwater ecosystems (Woods and others, 2004). In addition to forestry and agriculture, the Buffalo National River and parts of the Ozark National Forest help promote the recreational use of streams, lakes, rivers, and forests in the ecoregion.

The mountains in the Boston Mountains Ecoregion are remnants of the old, deeply dissected Ozark Plateau that has been eroded to produce steep-sided valleys separated by high flats and ridges (National Park Service, 2013). The most recent uplift of the Ozark Plateau, which includes the Boston Mountains, occurred about 300 million years ago, and weathering and erosion have been shaping the landscape since that time (Guccione, 2008). Elevations in the Boston Mountains Ecoregion range from about 60 m on valley floors to about 850 m on broad mountaintops, the northern part of the ecoregion typically being higher than the southern part (Woods and others, 2004); local relief in the Boston Mountains ranges from 46 to 274 m (Woods and others, 2004). The Boston Mountains are part of the greater Ozark Plateaus physiographic province, which has the greatest relief of any landform between the Appalachian Mountains to the east and the Rocky Mountains to the west (Guccione, 2008).

The Boston Mountains Ecoregion generally is underlain by gently folded sandstone, shale, cherty dolomite, and limestone. Soils on the upland areas primarily are Ultisols, and soils on terraces and floodplains primarily are Entisols (Woods and others, 2004). In the Boston Mountains Ecoregion, natural vegetation is composed mostly of oak–hickory (*Quercus* spp. and *Carya* spp.) forests that are fundamental to the timber industry, which plays an important role in the socioeconomic condition of the ecoregion. Species within hardwood forests on upland areas include northern red oak (*Quercus rubra*), blackjack oak (*Quercus marilandica*), post oak (*Quercus stellata*), white oak (*Quercus alba*), chinkapin oak (*Quercus muehlenbergii*), black hickory (*Carya texana*), mockernut hickory (*Carya tomentosa*), sugar maple (*Acer saccharum*), birch (*Betula* spp.), and cottonwood (*Populus deltoides*) (Woods and others, 2004; U.S. Department of Agriculture, 2006). Species commonly found on the narrow floodplains and low terraces are southern red oak (*Quercus falcata*), sweetgum (*Liquidambar styraciflua*), willows (*Salix* spp.), and American sycamore (*Platanus occidentalis*) (Woods and others, 2004). Softwood species in the ecoregion include loblolly pine (*Pinus taeda*) and shortleaf pine (*Pinus echinata*).

Land use in the Boston Mountains Ecoregion is associated principally with the forestry and timber industry. Although the generally infertile soils of the ecoregion preclude widespread agricultural land use, areas of low relief are used primarily for pasturelands, hay lands, and livestock farming such as the production of poultry and cattle (Petersen and others, 1998). In this study, conversions from mechanically disturbed to agriculture are associated with the clearing of forested land to create or expand pasturelands or to locate confined animal-feeding operations that are used mostly for poultry production.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Boston Mountains Ecoregion between 1973 and 2000 is estimated at 5.5 percent (table 1). Compared to other Midwest–South Central ecoregions, change in the Boston Mountains Ecoregion was relatively low (fig. 2): an estimated 2.7 percent of the ecoregion changed once during the study period, and 2.3 percent changed twice (table 1). The amount of change varied somewhat between 1973 and 2000, with the total change per time period (as percent of the ecoregion) ranging from 2.0 to 2.7 percent (table 2). The average annual rate of change was highest between 1980 and 1986 (0.4 percent) (table 2; fig. 3).

The forest and mechanically disturbed land-cover classes changed the most during the 27-year study period (1973–2000) (table 3). Forest had an estimated net loss of 2.2 percent from its 1973 base, a loss of 1.7 percent of the ecoregion area (table 3). This equates to an estimated decrease of 288 km^2 of forested land (table 3). Mechanically disturbed had an estimated net gain of 1.0 percent of the ecoregion area or 175 km^2, but this represents a more than 300 percent change from its very low 1973 estimated base (table 3). Forest loss in the ecoregion can be attributed to logging practices (mechanically disturbed land-cover class), as well as some conversion of forest to agriculture (tables 3,4; fig. 4).

In the decade before 1973, the volume of growing stock (that is, living trees of a commercial species that have the potential to produce saw logs) in the Boston Mountains Ecoregion increased for softwood (for example, loblolly pine and shortleaf pine) at a much faster rate than that for hardwoods (Van Sickle, 1970). The gross annual growth for most forests in the Boston Mountains Ecoregion was about 40 percent of the estimated potential (Van Sickle, 1970). Although overall forest productivity was low, mountain slopes and benches in the ecoregion had good hardwood-growing potential (Van Sickle, 1970). Because markets in the ecoregion were poorly developed, improvement cuts—made to improve the form or quality of remaining forest stands—were unprofitable. In 1970, long-range forestry programs were enacted, along with efforts to develop recreational opportunities, to supplement economic productivity (Van Sickle, 1970).

One of the programs that may have affected the ecoregion is the Forestry Incentives Program (FIP). The FIP originally was authorized in 1978 to share as much as 65 percent of the costs of tree planting, timber-stand improvements, and related practices on nonindustrial, privately held forest lands (U.S. Forest Service, 1995). The FIP was intended to ensure the Nation’s ability to meet demands for timber products and to put more forest under a quality-management program. The availability of the program in designated counties was based on a U.S. Forest Service survey of total eligible private timber acreage that was potentially suitable for production of timber products (U.S. Forest Service, 1995). Although it may not necessarily have been the benchmark for shaping land-cover change in the Boston Mountains Ecoregion, the FIP may at least have helped encourage tree growth and implement better management practices on private lands in the latter part of the study period (David Mason, U.S. Forest Service, written commun., 2009).

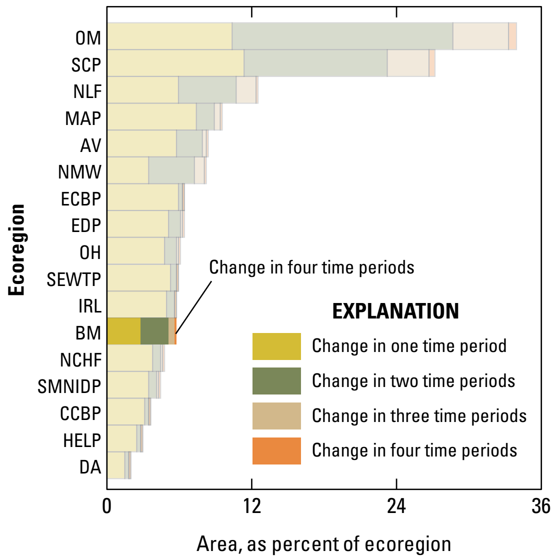

Figure 2. Overall spatial change in Boston Mountains Ecoregion (BM; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Boston Mountains Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

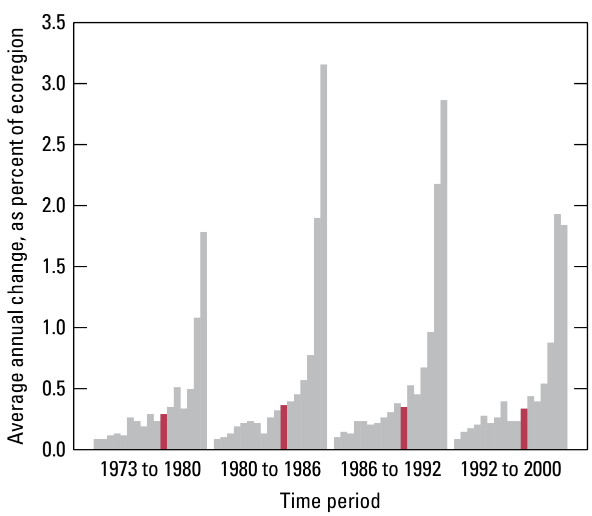

Figure 3. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Boston Mountains Ecoregion are represented by red bars in each time period.

In a 1999 assessment, primary mills—those that process roundwood in log or bolt form or as chipped roundwood—were canvassed to document changes in wood-product output and wood-residue use (Bentley and others, 2002). This assessment complemented the Forest Inventory and Analysis (FIA) Program's periodic inventory of volume and removals from timberland in Arkansas. In 1999, the roundwood-softwood output for all industrial products within census land area in the ecoregion ranged from less than 5 cubic feet per acre in the north and west to 5 to 20 cubic feet per acre in the south and east (Bentley and others, 2002). In the same year, the intensity of roundwood-hardwood output for all manufactured wood products in the ecoregion generally was less than that of softwoods, with most counties in the ecoregion producing less than 5 cubic feet per acre. The overall primary roundwood product for the ecoregion in 1999 was saw logs (Bentley and others, 2002).

The land-cover statistics show typical land-cover conversions affecting the ecoregion that are associated with the timber industry (for example, forest to mechanically disturbed, followed by mechanically disturbed to grassland/shrubland,

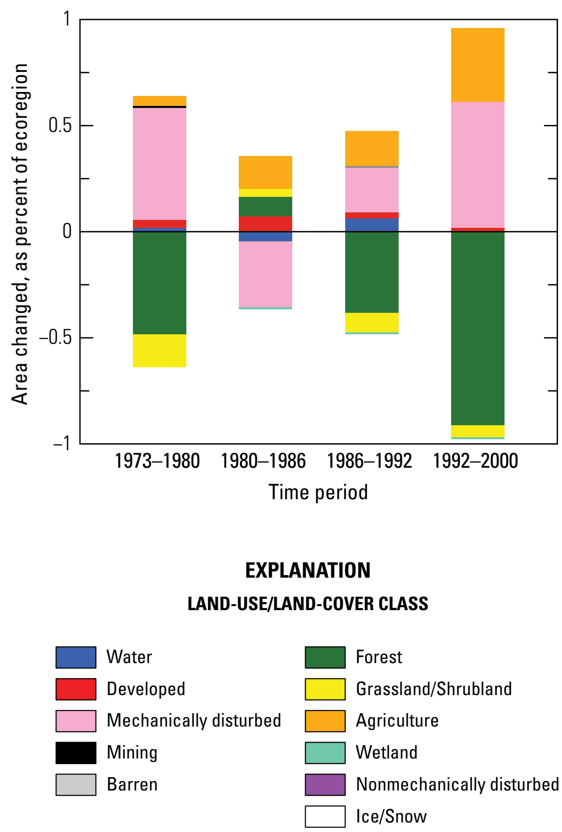

Figure 4. Normalized average net change in Boston Mountains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

and ultimately reverting back to forest). In addition, changes in forest structure have occurred; for example, Heitzman and others (2007) noted that the forest structure in the Boston Mountains recently (1998–2000) has been affected by regional drought, as well as by the red oak borer (*Enaphalodes rufulus*), an insect that permanently damages the wood of living oak trees and causes a decrease in lumber grade (Donley and Acciavatti, 1997). Despite these adverse effects, forest remained the leading land-cover class in all time periods.

Both privately held and publicly held forests are in the ecoregion, and both clearcutting (fig. 5) and thinning (fig. 6) are common timber-management practices. The amount of timberland in the ecoregion increased between the 1988 and 1995 FIA surveys, with most of the timberland being held in private ownership for nonindustrial purposes (Rosson and London, 1997). The rates of growth and removal (in board feet[1] per year) of saw timber on undifferentiated privately held lands were much higher than corresponding rates on National Forest lands and other federal and state lands (U.S. Forest Service, 1995).

The timber industry helped shape the land-cover changes in the Boston Mountains Ecoregion during the 27-year study period (1973–2000). The leading land-cover conversion in all the time periods was from forest to mechanically disturbed (table 4). The Boston Mountains Ecoregion experienced conversion of an estimated 590 km^2 of forest to mechanically disturbed between 1973 and 2000. The second-leading conversion was from grassland/shrubland to forest, which was associated with forest regeneration. Similarly, the third-leading conversion of mechanically disturbed to grassland/shrubland was indicative of new tree growth that followed cutting for timber. Although land-cover changes in the ecoregion were associated largely with forestry practices and the timber industry, it is worth noting that forested land also was cleared for agricultural land use.

[1]A board foot (a unit of volume for measuring lumber) is equal to 30 cm by 30 cm by 2.5 cm (12 in. × 12 in. × 1 in.) (Albritton, 2001).

Figure 5. Clearcutting of forest, Adair County, Oklahoma.

Figure 6. Forest thinning, Newton County, Arkansas.

Table 1. Percentage of Boston Mountains Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (94.5 percent), whereas 5.5 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	2.7	0.6	2.2	3.3	0.4	14.1
2	2.3	0.4	1.9	2.6	0.2	10.5
3	0.5	0.1	0.4	0.6	0.1	17.4
4	0.0	0.0	0.0	0.0	0.0	43.9
Overall spatial change	5.5	0.9	4.7	6.4	0.6	10.4

Table 2. Raw estimates of change in Boston Mountains Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
			Estimate of change, in percent stratum				
1973–1980	2.0	0.5	1.5	2.5	0.3	17.1	0.3
1980–1986	2.1	0.3	1.8	2.5	0.2	10.1	0.4
1986–1992	2.0	0.3	1.7	2.4	0.2	10.3	0.3
1992–2000	2.7	0.5	2.2	3.1	0.3	11.7	0.3
			Estimate of change, in square kilometers				
1973–1980	347	88	259	435	59	17.1	50
1980–1986	364	54	310	418	37	10.1	61
1986–1992	349	53	296	402	36	10.3	58
1992–2000	457	79	378	535	53	11.7	57

Table 3. Estimated area (and margin of error) of each land-cover class in Boston Mountains Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	1.3	0.8	0.9	0.7	0.3	0.2	0.0	0.0	0.0	0.0	77.5	3.5	0.7	0.4	19.3	3.3	0.0	0.0	0.0	0.0
1980	1.3	0.8	0.9	0.7	0.9	0.2	0.0	0.0	0.0	0.0	77.0	3.5	0.6	0.2	19.4	3.3	0.0	0.0	0.0	0.0
1986	1.2	0.8	1.0	0.7	0.6	0.1	0.0	0.0	0.0	0.0	77.1	3.5	0.6	0.1	19.5	3.4	0.0	0.0	0.0	0.0
1992	1.3	0.8	1.0	0.7	0.8	0.2	0.0	0.0	0.0	0.0	76.7	3.5	0.5	0.1	19.7	3.4	0.0	0.0	0.0	0.0
2000	1.3	0.8	1.0	0.7	1.4	0.4	0.0	0.0	0.0	0.0	75.8	3.6	0.4	0.1	20.0	3.4	0.0	0.0	0.0	0.0
Net change	0.1	0.0	0.2	0.1	1.0	0.4	0.0	0.0	0.0	0.0	–1.7	0.5	–0.3	0.3	0.7	0.2	0.0	0.0	0.0	0.0
Gross change	0.2	0.1	0.2	0.1	3.1	0.6	0.0	0.0	0.0	0.0	3.6	0.7	1.3	0.4	1.2	0.2	0.0	0.0	0.0	0.0
Area, in square kilometers																				
1973	216	142	150	114	56	26	1	1	2	3	13,220	602	121	60	3,295	569	7	4	0	0
1980	220	143	155	116	148	29	1	1	2	2	13,137	594	95	27	3,303	571	7	4	0	0
1986	213	141	168	124	95	22	1	1	2	2	13,153	604	100	24	3,329	574	7	4	0	0
1992	225	144	173	126	130	27	2	1	2	3	13,088	598	85	24	3,358	576	6	3	0	0
2000	225	144	176	126	231	73	2	1	2	3	12,932	609	76	23	3,417	574	6	3	0	0
Net change	9	7	26	16	175	74	1	1	0	0	–288	91	–45	53	122	38	–1	1	0	0
Gross change	28	22	30	16	526	95	1	1	1	1	615	125	218	64	213	28	1	1	0	0

Table 4. Principal land-cover conversions in Boston Mountains Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" classes are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	145	30	20	0.9	41.9
	Grassland/Shrubland	Forest	80	58	40	0.5	23.0
	Mechanically disturbed	Grassland/Shrubland	33	19	13	0.2	9.4
	Forest	Agriculture	29	18	12	0.2	8.4
	Agriculture	Grassland/Shrubland	24	12	8	0.1	6.9
	Other	Other	36	n/a	n/a	0.2	10.4
		Totals	347			2.0	100.0
1980–1986	Forest	Mechanically disturbed	84	20	14	0.5	23.0
	Grassland/Shrubland	Forest	68	23	15	0.4	18.6
	Mechanically disturbed	Agriculture	52	18	12	0.3	14.3
	Mechanically disturbed	Grassland/Shrubland	49	13	9	0.3	13.4
	Mechanically disturbed	Forest	45	26	17	0.3	12.4
	Other	Other	67	n/a	n/a	0.4	18.4
		Totals	364			2.1	100.0
1986–1992	Forest	Mechanically disturbed	130	27	18	0.8	37.3
	Grassland/Shrubland	Forest	69	16	11	0.4	19.7
	Mechanically disturbed	Agriculture	38	13	9	0.2	10.8
	Mechanically disturbed	Grassland/Shrubland	31	14	10	0.2	8.8
	Agriculture	Grassland/Shrubland	22	9	6	0.1	6.4
	Other	Other	59	n/a	n/a	0.3	17.0
		Totals	349			2.0	100.0
1992–2000	Forest	Mechanically disturbed	231	73	49	1.4	50.6
	Grassland/Shrubland	Forest	52	16	11	0.3	11.5
	Mechanically disturbed	Agriculture	51	16	11	0.3	11.2
	Mechanically disturbed	Forest	41	18	12	0.2	9.1
	Mechanically disturbed	Grassland/Shrubland	38	13	9	0.2	8.3
	Other	Other	43	n/a	n/a	0.3	9.4
		Totals	457			2.7	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	590	102	69	3.5	38.9
	Grassland/Shrubland	Forest	269	88	59	1.6	17.7
	Mechanically disturbed	Grassland/Shrubland	150	44	30	0.9	9.9
	Mechanically disturbed	Agriculture	147	35	24	0.9	9.7
	Mechanically disturbed	Forest	115	53	36	0.7	7.6
	Other	Other	246	n/a	n/a	1.4	16.2
		Totals	1,517			8.9	100.0

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Chapter 14

Arkansas Valley Ecoregion

By Krista A. Karstensen

Ecoregion Description

The Arkansas Valley Ecoregion covers about 26,606 km^2 (10,273 mi^2) across west-central Arkansas and east-central Oklahoma (fig. 1) (Omernik, 1987; Wiken and others, 2011). Ecoregions that surround the Arkansas Valley Ecoregion are the Central Irregular Plains and Boston Mountains Ecoregions to the north, the Mississippi Alluvial Plain Ecoregion to the east, the Ouachita Mountains Ecoregion to the south, and the Central Oklahoma/Texas Plains Ecoregion to the west. The Arkansas Valley Ecoregion generally is characterized by plains, hills, floodplains, terraces, and scattered mountains (Woods and others, 2005), which differs from the neighboring Boston Mountains and Ouachita Mountains Ecoregions but is similar to the Mississippi Alluvial Plain Ecoregion to the east because both ecoregions include alluvial geology and bottomland plant communities (The Nature Conservancy, 2003).

The Arkansas Valley Ecoregion generally lies in a synclinal valley that essentially coincides with the Arkoma Basin, an oil-and-gas province that developed as layers of sand and mud were deposited in a depression during the Ouachita orogeny, a mountain-building period in the Paleozoic era that resulted in the landforms in the neighboring Ouachita Mountains to the south. Elevations in the Arkansas Valley Ecoregion range from

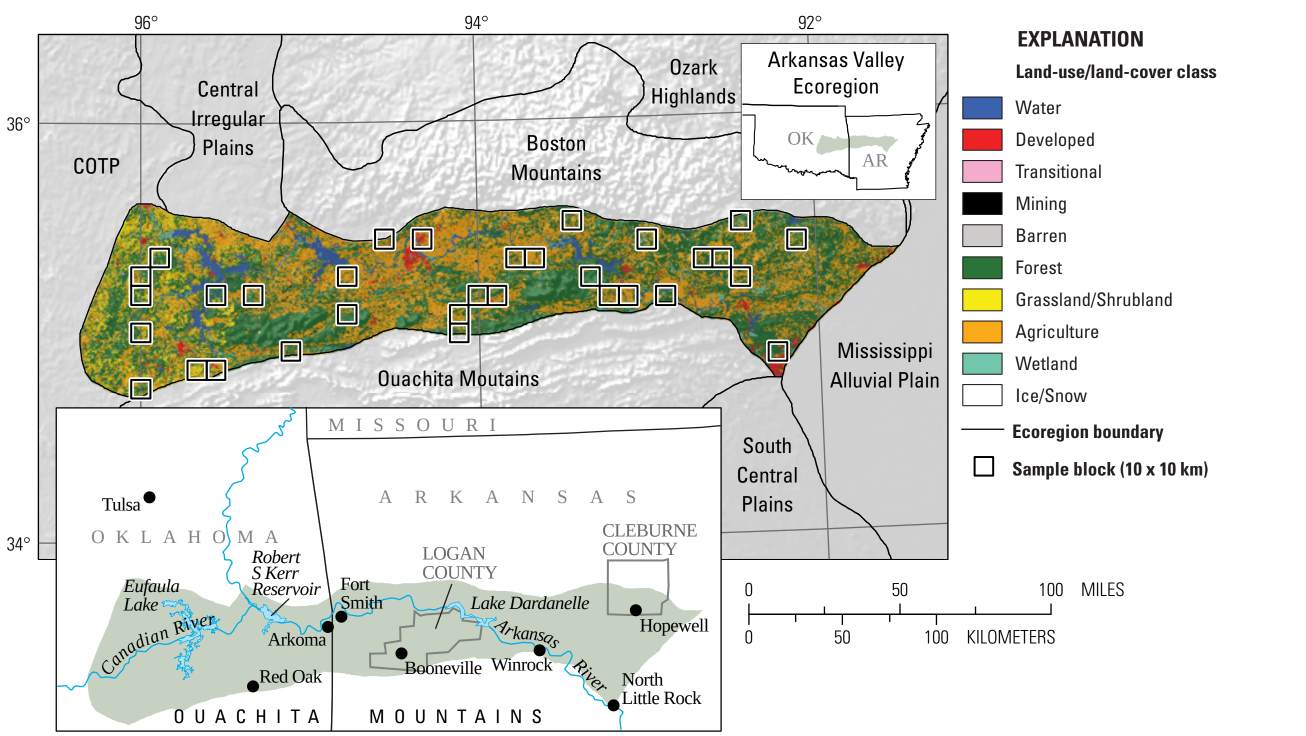

Figure 1. Map of Arkansas Valley Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of two Great Plains ecoregions: Central Irregular Plains and Central Oklahoma/Texas Plains (COTP). See appendix 3 for definitions of land-use/land-cover classifications.

62 to 839 m (Woods and others, 2005) (fig. 2), and local relief ranges from less than 15 to 305 m (Woods and others, 2005).

The two largest urban areas in the Arkansas Valley Ecoregion are Fort Smith and North Little Rock, Arkansas, with populations in 2000 of 80,268 and 60,433, respectively. Fort Smith was established in 1817 as an U.S. Army outpost, and the city continues to have an active military presence, although manufacturing, education, health care, and social services also are important to the economy (U.S. Census Bureau, 2009; City of Fort Smith, Arkansas, 2010).

The climate of the Arkansas Valley Ecoregion is affected by prevailing westerly winds, and weather systems generally move from west to east (Perry, 2005). Summers generally are hot, and winters are moderately cool, typically with no significant snow accumulation. Mean annual precipitation ranges from 1,040 to 1,570 mm (41–62 in.) (Woods and others, 2005).

Two primary river systems drain the Arkansas Valley Ecoregion, the Arkansas River and the Canadian River. The Arkansas River played an important role in westward expansion and the early settlement of the ecoregion. The largest lakes in the ecoregion—Eufaula Lake and Robert S Kerr Reservoir in Oklahoma and Lake Dardanelle in Arkansas—are all reservoirs along these two rivers, and they provide ideal conditions for fishing, camping, and other recreational activities.

The forests of the Arkansas Valley Ecoregion are dominated by oak–hickory and oak–hickory–pine (*Quercus* spp., *Carya* spp., and *Pinus* spp.) woodlands (Woods and others, 2005). Income from the timber industry is substantial, although, historically, such income was judged to be less than its full potential in some areas of the ecoregion (Brinlee and Wilson, 1981), as some of the woodlands were cut several times, and the trees that were left to propagate the stands were of poor quality (Brinlee and Wilson, 1981; Swafford and Allgood, 1981). Two main differences in forest land cover exist between the Arkansas Valley Ecoregion and that of the neighboring Boston Mountains and Ouachita Mountains Ecoregions: (1) forest ownership in the Arkansas Valley Ecoregion primarily is private, with much less publicly held forest land, and (2) more forested land in the Arkansas Valley Ecoregion was cleared for agricultural land use than in the neighboring ecoregions (Karstensen, 2009).

Although some of the wooded steep slopes in the ecoregion are used for woodland grazing, most of the pasturelands and hay lands are on the bottomlands and the more gently sloping upland areas (Woods and others, 2005) (fig. 3). Poultry and livestock production are important agricultural land uses, and extensive cropland is present in the Arkansas River floodplain (Woods and others, 2005).

Figure 2. Valley near Winrock, Arkansas.

Figure 3. Hay field near Booneville, Arkansas.

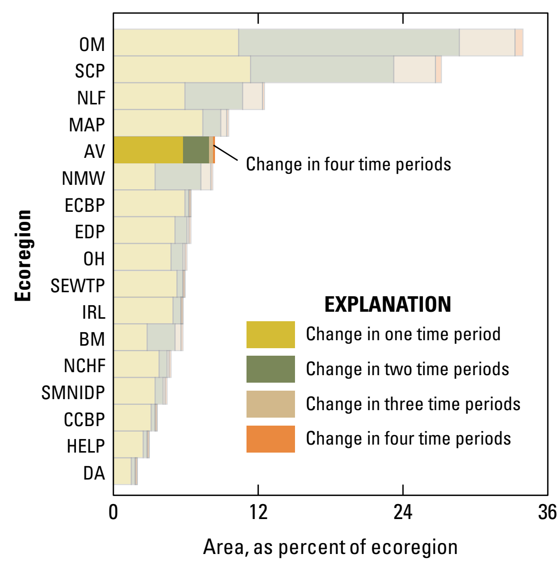

Figure 4. Overall spatial change in Arkansas Valley Ecoregion (AV; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Arkansas Valley Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Arkansas Valley Ecoregion between 1973 and 2000 is estimated at 8.3 percent (table 1). Compared to other Midwest–South Central ecoregions, change in the Arkansas Valley Ecoregion was moderately high (fig. 4): about 5.8 percent of the ecoregion changed once during the study period, 2.1 percent changed twice, 0.4 percent changed three times, and 0.1 percent changed four times (table 1). The amount of change varied for each of the four time periods between 1973 and 2000, with the total change ranging from 2.3 to 3.4 percent of the ecoregion (table 2). The average annual rate of change was highest during the third time period (1986–1992; 0.5 percent) and lowest during the first time period (1973–1980; 0.3 percent) (table 2; fig. 5).

The forest and agriculture land-cover classes changed the most during the 27-year study period (table 3; fig. 6). Forest, which covered an estimated 12,868 km^2 of the ecoregion in 2000, had a 3.7 percent (490 km^2) decrease from its estimated 1973 area, a net loss of 1.8 percent of the ecoregion area. Forest loss in the ecoregion likely can be attributed to timber logging practices, as well as agricultural expansion. Agricultural land, which covered about 10,767 km^2 of the ecoregion in 2000, had a 1.2 percent decrease from its estimated 1973 area, a net loss of 0.5 percent of the ecoregion area. Although agriculture had a net gain from forest in the ecoregion, the overall force behind the small net loss of agriculture was the amount of agricultural land that was converted to developed land, an estimated 231 km^2 (table 4).

In 2000, forest was the dominant land-cover class in the Arkansas Valley Ecoregion (table 3). Most land-cover conversions associated with the forest were related to timber-harvest logging practices, as shown by conversions from forest to mechanically disturbed and, to a lesser extent, from mechanically disturbed to grassland/shrubland (table 4). According to the U.S. Forest Service, the average potential productivity of the forests in the ecoregion was 73 cubic feet per acre in 1995, a value less than that of the Ouachita Mountains Ecoregion but more than that of the Boston Mountains Ecoregion (Rudis, 2001). Forested land in the Arkansas Valley Ecoregion also was cleared for agricultural expansion during the study period, a practice that has been occurring since the early days of settlement in the ecoregion.

Although crop varieties, farm types and sizes, and certain management practices have changed across time, agriculture has long played an important role in the Arkansas Valley Ecoregion. For example, in Logan County, Arkansas, soils that have good natural drainage on hills and in valleys near the floodplain of the Arkansas River were cleared for farming, whereas steep, stony, or wet soils were left as woodland

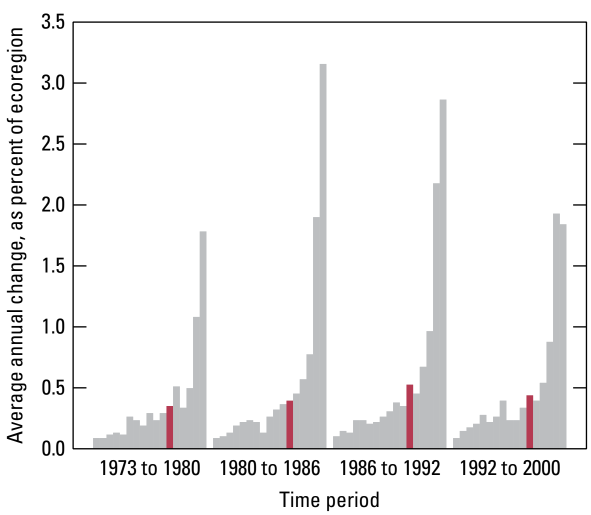

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Arkansas Valley Ecoregion are represented by red bars in each time period.

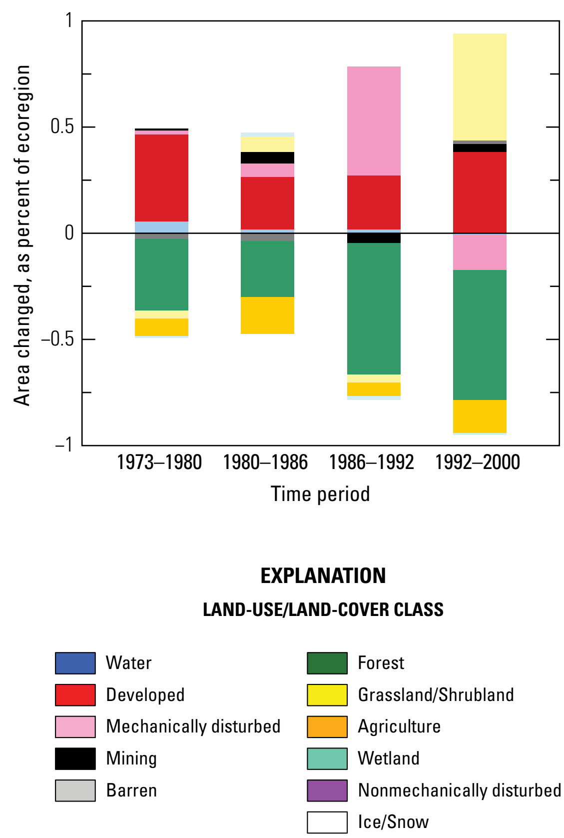

Figure 6. Normalized average net change in Arkansas Valley Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

(Garner and others, 1980). Until 1980, cotton was considered a primary cash crop in the area (Garner and others, 1980); after 1980, farming practices became more diversified, with dairying and the raising of beef cattle, hogs, and poultry becoming more predominant (Garner and others, 1980). Livestock production has been a major source of income in areas of ridges and valleys, whereas soybean cultivation has been the major source of farm income in the bottomlands (Garner and others, 1980). Poultry farming increased around 1970, supporting an increase in livestock farming as litter from the poultry farms could be used as fertilizer on cattle fields (Robert Coats, University of Arkansas, oral commun., 2011).

The predominant land-cover changes in the Arkansas Valley Ecoregion can be attributed to the forestry and agricultural industries, as is shown in the ecoregion statistics in each of the four time periods (and in the overall 27-year study period); however, except for forest cutting, these changes did little to alter the overall land-cover composition of the ecoregion. Although both the forest and agriculture land-cover classes incurred an overall net loss between 1973 and 2000, they remained the leading land-cover classes in the Arkansas Valley Ecoregion.

Figure 7. Mechanical disturbance of forest near Red Oak, Oklahoma.

Figure 8. Forest near Hopewell, in Cleburne County, Arkansas.

Table 1. Percentage of Arkansas Valley Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (91.7 percent), whereas 8.3 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	5.8	0.8	5.0	6.6	0.5	9.3
2	2.1	0.8	1.3	2.9	0.6	26.4
3	0.4	0.3	0.0	0.7	0.2	61.9
4	0.1	0.1	0.0	0.1	0.0	56.0
Overall spatial change	8.3	1.4	6.9	9.7	1.0	11.5

Table 2. Raw estimates of change in Arkansas Valley Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	2.4	0.6	1.8	3.0	0.4	16.0	0.3
1980–1986	2.3	0.6	1.7	3.0	0.4	17.9	0.4
1986–1992	3.1	0.9	2.2	4.0	0.6	20.1	0.5
1992–2000	3.4	0.9	2.5	4.3	0.6	18.2	0.4
Estimate of change, in square kilometers							
1973–1980	644	153	492	797	103	16.0	92
1980–1986	624	165	458	789	112	17.9	104
1986–1992	826	244	581	1,070	166	20.1	138
1992–2000	907	244	663	1,151	165	18.2	113

Table 3. Estimated area (and margin of error) of each land-cover class in Arkansas Valley Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Nonmechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	2.0	1.1	2.3	1.2	0.4	0.2	0.1	0.1	0.1	0.1	50.2	4.2	3.1	1.5	40.9	4.4	0.8	0.3	0.0	0.0
1980	2.1	1.1	2.7	1.4	0.4	0.4	0.1	0.1	0.1	0.1	49.9	4.1	3.1	1.4	40.9	4.4	0.8	0.3	0.0	0.0
1986	2.1	1.1	3.0	1.5	0.4	0.3	0.2	0.1	0.1	0.0	49.6	4.1	3.1	1.4	40.7	4.4	0.8	0.3	0.0	0.0
1992	2.1	1.1	3.2	1.7	0.9	0.7	0.1	0.1	0.1	0.0	49.0	4.1	3.1	1.5	40.6	4.4	0.8	0.3	0.0	0.0
2000	2.1	1.1	3.6	1.8	0.8	0.3	0.2	0.1	0.1	0.1	48.4	4.0	3.6	1.7	40.5	4.3	0.8	0.3	0.0	0.0
Net change	0.1	0.1	1.3	0.7	0.4	0.3	0.1	0.1	0.0	0.0	–1.8	1.0	0.5	0.7	–0.5	0.8	0.0	0.0	0.0	0.0
Gross change	0.4	0.1	1.3	0.7	2.8	1.4	0.2	0.1	0.1	0.1	4.3	1.0	2.2	0.9	2.4	0.6	0.2	0.1	0.0	0.0
Area, in square kilometers																				
1973	540	303	613	328	94	46	33	25	35	19	13,358	1,122	821	390	10,895	1,176	218	77	0	0
1980	554	303	722	375	99	95	33	22	29	19	13,266	1,091	812	385	10,874	1,164	217	78	0	0
1986	559	303	789	399	116	72	48	25	20	12	13,196	1,092	830	380	10,826	1,163	222	77	0	0
1992	564	302	859	440	252	182	38	19	19	12	13,029	1,091	820	387	10,809	1,160	217	78	0	0
2000	562	301	961	489	207	88	48	22	24	14	12,868	1,059	953	457	10,767	1,140	216	80	0	0
Net change	22	18	348	197	113	83	15	15	–11	9	–490	257	131	189	–127	210	–1	12	0	0
Gross change	97	35	352	197	733	375	49	21	34	25	1,139	267	587	249	647	170	48	21	0	0

Table 4. Principal land-cover conversions in Arkansas Valley Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Agriculture	121	37	25	0.5	18.8
	Forest	Mechanically disturbed	98	95	65	0.4	15.2
	Agriculture	Developed	80	71	48	0.3	12.4
	Grassland/Shrubland	Forest	77	51	34	0.3	11.9
	Mechanically disturbed	Grassland/Shrubland	60	36	25	0.2	9.3
	Other	Other	209	n/a	n/a	0.8	32.4
		Totals	644			2.4	100.0
1980–1986	Forest	Mechanically disturbed	112	70	48	0.4	18.0
	Forest	Agriculture	99	28	19	0.4	15.9
	Grassland/Shrubland	Forest	72	30	20	0.3	11.5
	Agriculture	Forest	60	38	26	0.2	9.6
	Agriculture	Grassland/Shrubland	49	32	22	0.2	7.9
	Other	Other	231	n/a	n/a	0.9	37.0
		Totals	624			2.3	100.0
1986–1992	Forest	Mechanically disturbed	242	181	122	0.9	29.4
	Forest	Agriculture	116	26	18	0.4	14.0
	Grassland/Shrubland	Forest	100	58	39	0.4	12.2
	Mechanically disturbed	Forest	68	45	31	0.3	8.3
	Agriculture	Forest	57	34	23	0.2	6.9
	Other	Other	242	n/a	n/a	0.9	29.3
		Totals	826			3.1	100.0
1992–2000	Forest	Mechanically disturbed	198	84	57	0.7	21.8
	Mechanically disturbed	Grassland/Shrubland	185	178	121	0.7	20.4
	Forest	Agriculture	111	30	21	0.4	12.2
	Grassland/Shrubland	Forest	85	49	33	0.3	9.4
	Agriculture	Developed	68	52	35	0.3	7.5
	Other	Other	260	n/a	n/a	1.0	28.7
		Totals	907			3.4	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	650	337	228	2.4	21.7
	Forest	Agriculture	446	84	57	1.7	14.9
	Mechanically disturbed	Grassland/Shrubland	337	232	157	1.3	11.2
	Grassland/Shrubland	Forest	334	117	79	1.3	11.1
	Agriculture	Developed	231	158	107	0.9	7.7
	Other	Other	1,001	n/a	n/a	3.8	33.4
		Totals	3,000			11.3	100.0

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Chapter 15

Ouachita Mountains Ecoregion

By Krista A. Karstensen

Ecoregion Description

The Ouachita Mountains Ecoregion covers about 26,506 km^2 (10,234 mi^2) across west-central Arkansas and southeastern Oklahoma (fig. 1) (Omernik, 1987; Wiken and others, 2011). The ecoregions neighboring the Ouachita Mountains Ecoregion are the Arkansas Valley Ecoregion to the north, the South Central Plains Ecoregion to the south, and the Central Oklahoma/Texas Plains Ecoregion to the west. The vegetation along the west edge of the ecoregion is dynamic, with pine–oak-forest (*Pinus* spp. and *Quercus* spp.), tallgrass-prairie, and oak-savanna communities of the neighboring ecoregions to the west meeting along this edge (The Nature Conservancy, 2003). The boundaries of this “floristic association intergrade” advance and retreat with historic changes in climate (The Nature Conservancy, 2003).

Large urban areas are not common in the Ouachita Mountains Ecoregion. Hot Springs, Arkansas, which lies in the southeastern part of the ecoregion, is home to Hot Springs National Park, and the city had a population of 35,750 in 2000

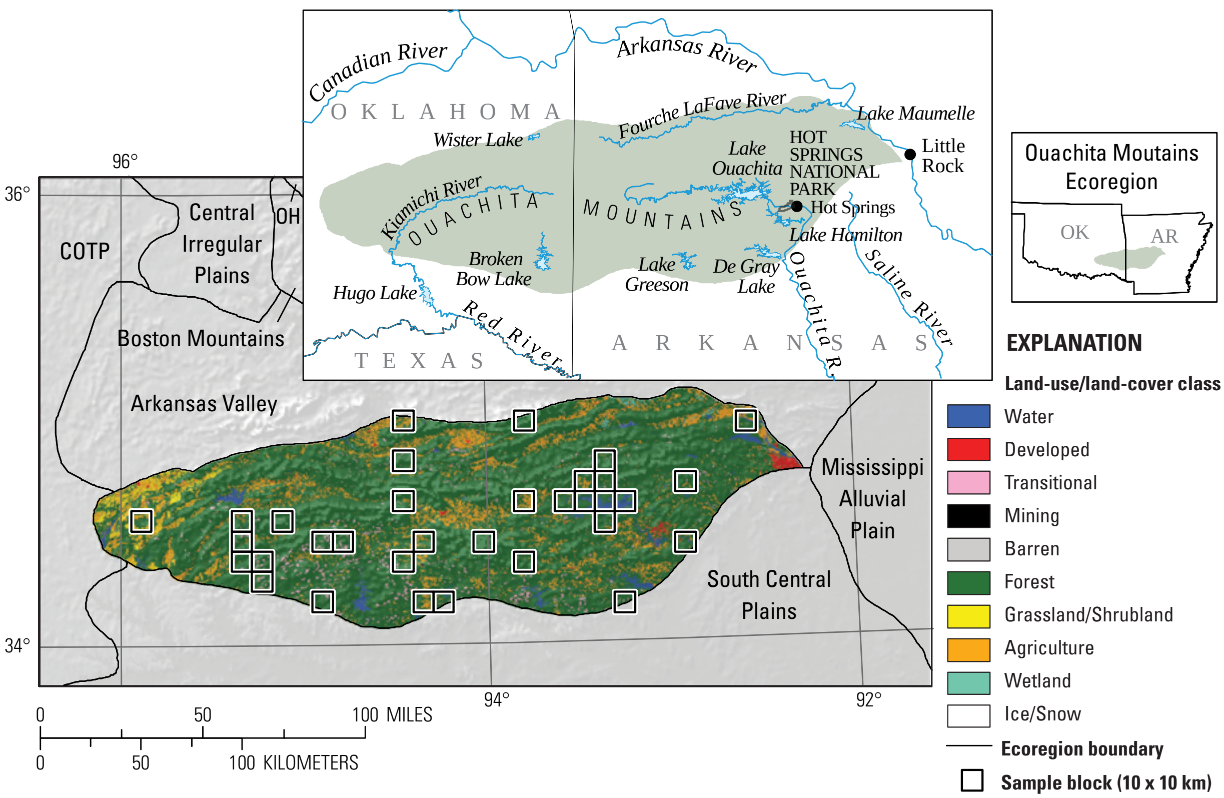

Figure 1. Map of Ouachita Mountains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status and Trends of Land Change” study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of two Great Plains ecoregions: Central Oklahoma/Texas Plains (COTP) and Central Irregular Plains. See appendix 3 for definitions of land-use/land-cover classifications.

(U.S. Census Bureau, 2013). Hot Springs and its satellite retirement communities bring urbanization and recreational pressures to the nearby Saline River and Lake Ouachita (The Nature Conservancy, 2003). The other major urban area in the ecoregion is part of metropolitan Little Rock, Arkansas (population, 583,845 in 2000; U.S. Census Bureau, 2001), whose west edge is in the far-east corner of the ecoregion.

Elevations in the Ouachita Mountains Ecoregion, which range from 88 to 823 m (Woods and others, 2004), are much higher than those of all of the neighboring ecoregions except for the Arkansas Valley Ecoregion, where elevations are comparable (table 1) (Woods and others, 2004, 2005). Overall, the local relief in the Ouachita Mountains Ecoregion, which ranges from 15 to 488 m, is much greater than that of its neighboring ecoregions (table 1) (Woods and others, 2004, 2005). The landforms of the Ouachita Mountains Ecoregion are rooted in an accretionary wedge composed of intensely folded and deformed sandstone, shale, and chert that make up one of the major fold-and thrust-belt mountain ranges of North America (The Nature Conservancy, 2003). During the Paleozoic era, in the mountain-building period referred to as the Ouachita orogeny, an ocean closed as the South American plate collided with the North American plate, and mountains were formed as the intervening marine sediments were folded and faulted (The Nature Conservancy, 2003; Woods and others, 2004).

The Ouachita Mountains Ecoregion is in the humid-subtropical climate zone. The climate of the ecoregion is affected by two different air masses: (1) warm, moist air moving north from the Gulf of Mexico, and (2) cool, dry air moving east from the central Great Plains (The Nature Conservancy, 2003). Summers generally are hot, and winters are moderately cool, typically with no significant snow accumulation. Mean annual precipitation ranges from 1,270 to 1,680 mm (50–66 in.), increasing from west to east (The Nature Conservancy, 2003; Woods and others, 2004). Areas of higher elevation receive more rainfall because of orographic effects. Moderate droughts occur at 15- to 20-year intervals, and floods may occur in any month but are most common in the spring (The Nature Conservancy, 2003).

Several river systems drain the Ouachita Mountains Ecoregion, including the Arkansas, Kiamichi, Ouachita, Fourche LaFave, and Saline Rivers. Lakes in the ecoregion, which are mostly reservoirs, include Lake Ouachita, Lake Maumelle, De Gray Lake, Broken Bow Lake, Wister Lake, Lake Hamilton, Lake Catherine, and Lake Greeson. These waters provide ideal conditions for fishing, camping, and other recreational activities. The exceptional water quality of most hydrologic reaches in the ecoregion has provided habitat for various endemic species (The Nature Conservancy, 2003; Woods and others, 2004).

Land cover in the Ouachita Mountains Ecoregion is composed primarily of loblolly pine (*Pinus taeda*) and shortleaf pine (*Pinus echinata*) forests (fig. 2). Although forest composition has changed across time, forest still remains the dominant land-cover class in the ecoregion. The most significant historical change in forest composition was the conversion of shortleaf pine forests to loblolly pine plantations on industrial lands (Hedrick and others, 2007). Throughout the ecoregion, the understory vegetation also has changed from grasses and forbs to woody species (Hedrick and others, 2007). Forest conditions at the beginning of the 21st century stem from two primary factors: (1) the cutting of the original trees, and (2) the effects of more than 60 years of fire-suppression efforts (Hedrick and others, 2007). Large-scale exploitation of the original forests began in the early 1910s and had largely ended by the 1940s (Smith, 1986). Under U.S. Forest Service stewardship, the period of regeneration that followed the cutting was marked by a strict policy of fire suppression that continued well into the 1980s, resulting in the near-disappearance of the shortleaf pine–bluestem (*Andropogon* spp.) woodland community in the ecoregion by

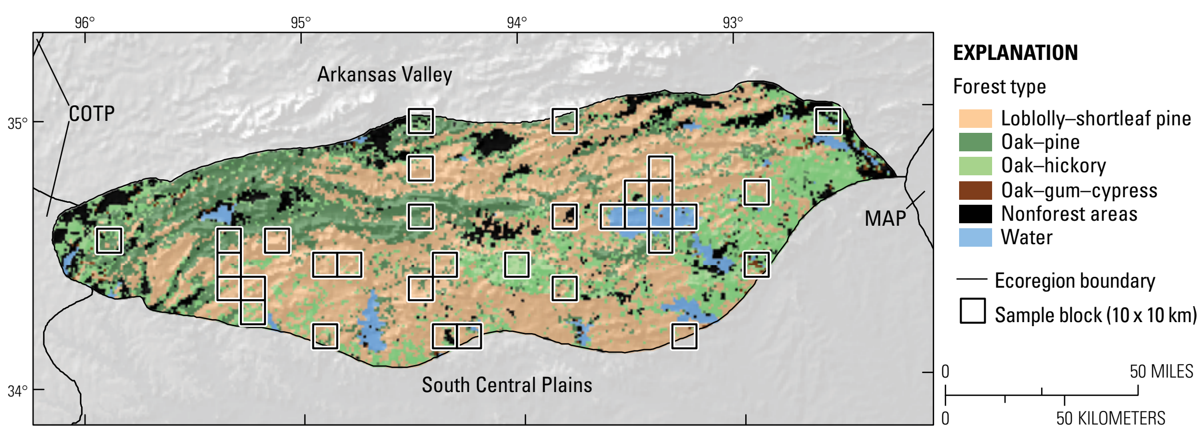

Figure 2. Map of Ouachita Mountains Ecoregion and surrounding ecoregions, showing types of forest land cover in 2002 (National Atlas of the United States, 2002). Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of one Great Plains ecoregion, Central Oklahoma/Texas Plains (COTP).

the 1970s (Arkansas Department of Planning, 1974; Smith, 1986; Hedrick and others, 2007).

Although not as widespread and dominant as forest, agriculture plays a role in the land uses of the Ouachita Mountains Ecoregion. Limited to valley bottoms, the agricultural land uses in the ecoregion primarily are hay lands and pasturelands used for cattle production. Poultry production also is important, and confined-feeding operations for raising fowl are common in the ecoregion.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Ouachita Mountains Ecoregion between 1973 and 2000 is an estimated 33.9 percent (table 2). The Ouachita Mountains Ecoregion not only had the highest overall spatial change of all 17 Midwest–South Central ecoregions (fig. 3), but it also ranked highest in overall spatial change of all 84 Level III ecoregions of the conterminous United States (see appendix 1; see also, U.S. Environmental Protection Agency, 1999): about 10.4 percent of the ecoregion changed once during the study period, 18.2 percent changed twice, 4.7 percent changed three times, and 0.7 percent changed four times (table 2).

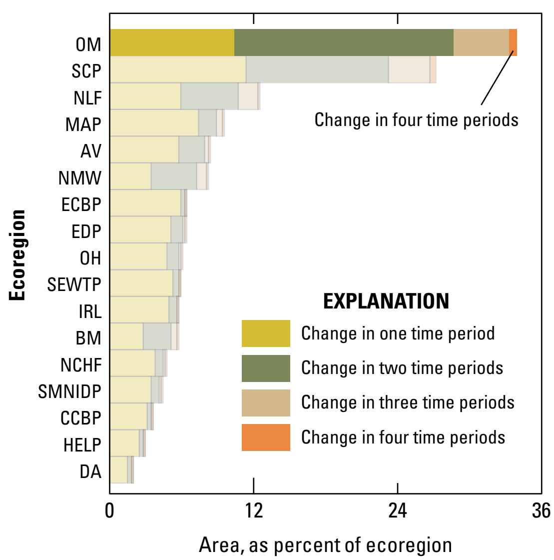

Figure 3. Overall spatial change in Ouachita Mountains Ecoregion (OM; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Ouachita Mountains Ecoregion (four time periods) labeled for clarity. See table 3 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

The amount of change varied between 1973 and 2000, with the total estimated change of any individual time period (as percent of ecoregion area) ranging from 12.5 to 19.0 percent (table 3). The average annual rates of change were highest during the middle two time periods (1980–1986, 1986–1992), at 3.2 and 2.9 percent, respectively (table 3; fig. 4). Overall, land-cover change was the greatest in the second time period (1980–1986) before decreasing slightly in the later time periods.

The forest and mechanically disturbed land-cover classes changed most during the study period (1973–2000) (table 4; fig. 5). Although forest still covered an estimated 20,602 km^2 of the ecoregion in 2000, forest had a net loss of 5.7 percent of the ecoregion's area (1,508 km^2, a 6.8 percent decrease from its 1973 area) (table 4; fig. 6). Forest loss in the ecoregion likely can be attributed to the logging practices associated with the mechanically disturbed land-cover class. Mechanically disturbed land covered about 1,979 km^2 in 2000, and it had a net gain of 3.4 percent of the ecoregion's area (an 85.1 percent increase from its 1973 area). Agriculture and water were the third and fourth most extensive land-cover classes in 2000, covering 2,286 km^2 and 895 km^2 of the ecoregion, respectively (table 4).

The four leading land-cover conversions in the Ouachita Mountains Ecoregion between 1973 and 2000 were the following: (1) forest to mechanically disturbed (fig. 7), (2) mechanically disturbed to forest, (3) grassland/shrubland to forest, and (4) mechanically disturbed to grassland/shrubland (table 5). These land-cover-change statistics show typical land-cover responses to the land-use demands of the logging and timber industry.

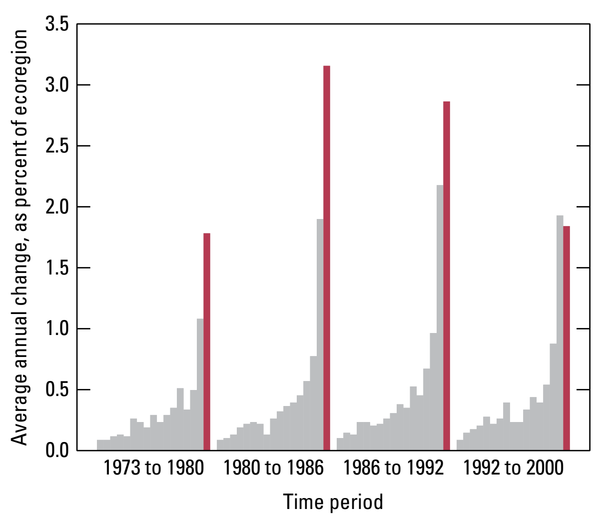

Figure 4. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Ouachita Mountains Ecoregion are represented by red bars in each time period.

Forest harvest plays a large role in the geographic and social aspects of the ecoregion, and the timber industry was the largest economic force in the Ouachita Mountains Ecoregion during the study period. By the late 1920s, forests in the ecoregion were logged completely, and second-growth forests were logged again in the 1940s and 1950s (The Nature Conservancy, 2003). This second-growth logging may have provided the baseline for the forest land-cover class that was mapped during the first time period (1973–1980) because the trees that were cut in the 1950s would have been mature and ready for harvest in the time period between 1973 and 1980 (or in subsequent time periods). In 2000, the Ouachita Mountains still were dominated by forests, but the structure and composition of these forests had changed substantially (Bukenhofer and Hedrick, 2008). Although timber harvesting played an important role in shaping land-use/land-cover change in the Ouachita Mountains Ecoregion, it also is important to note the changes in management practices, as well as in forest composition, that occurred during the study period.

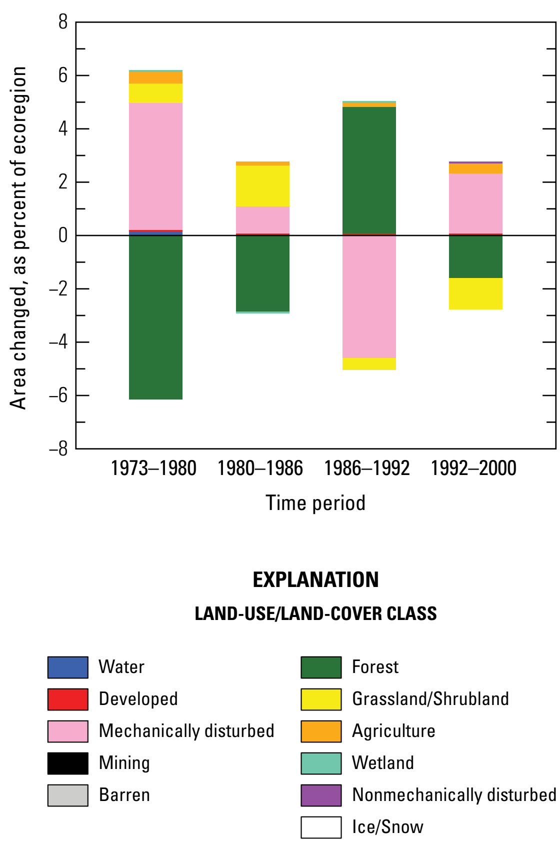

Figure 5. Normalized average net change in Ouachita Mountains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Recent (1989, 2005, and 2008) U.S. Forest Service forest inventory surveys concluded that most of the forest land in the Ouachita Mountains Ecoregion is in private holdings (U.S. Forest Service, 2010).The next leading land owner is the U.S. Forest Service, followed by other federal agencies and state and local governments. Reserved status land in the ecoregion primarily was held by the U.S. Forest Service, the U.S. Fish and Wildlife Service, and the Departments of Defense and Energy (U.S. Forest Service, 2010). In the Ouachita Mountains Ecoregion, the distribution of land ownership in Arkansas was slightly different from that in Oklahoma. Although large timber corporations own most of the land in both states, slightly more private land is held in Oklahoma than in Arkansas, whereas more land is federally managed in Arkansas than in Oklahoma (The Nature Conservancy, 2003; U.S. Forest Service, 2010).

Figure 6. Forest in Ouachita Mountains Ecoregion. Forest made up about 77.7 percent of land cover in ecoregion in 2000.

Figure 7. Logging activity in Ouachita Mountains Ecoregion, showing example of land cover that changed from forest to mechanically disturbed.

During the study period, forests in the ecoregion developed largely in response to the following two factors: (1) the commercial management of the original forests, and (2) the suppression of fires in the forests (Bukenhofer and Hedrick, 2008). Large-scale harvesting of timber started in the 1910s, and, by 1940, most of the original forests had been cut (Smith, 1986). Lead by U.S. Forest Service initiatives, the forest regeneration that followed this period of timber harvesting was marked by a strict policy of wildfire suppression (Bukenhofer and Hedrick, 2008), which remained largely in effect into the beginning of the 21st century (Bukenhofer and Hedrick, 2008). The use of prescribed fire by managers during the late 1990s and early 2000s (on an amount of area that averaged 101 km^2 annually) has been insufficient to maintain a restored (that is, in a pre–logged state) woodland ecosystem in the ecoregion, which then detrimentally affects the health and resiliency of other ecosystems in the ecoregion (Bukenhofer and Hedrick, 2008).

The alteration of stand composition and structure also can affect the forest ecosystem. Between about 1983 and 2003, changes in the Ouachita Mountains Ecoregion were manifested through second-growth forest that mostly was converted to pine plantations (The Nature Conservancy, 2003; see also, fig. 8). These plantations are composed primarily of “improved” loblolly pine, which is not native to the forested-upland ecosystems of the Ouachita Mountains Ecoregion.

Although forest thinning, selective cutting, and clearcutting have played a large role in the fragmentation of forests in the Ouachita Mountains Ecoregion, roads also have contributed significantly to this process. Roads constructed to access forest land can fragment the landscape and contribute to increased sedimentation in streams. However, many roads in the Ouachita Mountains ecoregion were smaller than the minimum mapping unit (60 x 60 m pixel) and, thus, may not be included in the statistics of the ecoregion. Nevertheless, roads played a vital role in certain activities in the ecoregion, such as timber harvesting.

The dominant changes in the Ouachita Mountains Ecoregion involved the forest land-cover class, as shown in the land-cover-conversion statistics in table 4: in three of four time periods, the largest percentage of change was from forest to mechanically disturbed. These changes can be attributed to timber operations (timber harvesting and certain forestry practices), which played a large role in shaping the economic, social, and geographic composition of the ecoregion. Typical conversions associated with timber and forestry practices are from forest to mechanically disturbed and from grassland/shrubland to forest, both of which occurred in each time period (table 4). Overall, forest remained the leading land-cover class in the ecoregion (in terms of areal extent).

Figure 8. Pine plantation in Ouachita Mountains Ecoregion, showing trees of two different ages.

Table 1. Ranges in elevation and in relief for Ouachita Mountains Ecoregion, compared to those for neighboring ecoregions.

[Note that Central Oklahoma/Texas Plains Ecoregion is not in Midwest–South Central United States group of ecoregions but, rather, is in Great Plains of the United States group]

Ecoregion	Range in elevation (m)	Range in relief (m)
Ouachita Mountains Ecoregion	88 to 823	15 to 488
South Central Plains Ecoregion	15 to 168	3 to 107
Central Oklahoma/Texas Plains Ecoregion	183 to 518	15 to 107
Arkansas Valley Ecoregion	76 to 839	>15 to 183

Table 2. Percentage of Ouachita Mountains Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (66.1 percent), whereas 33.9 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	10.4	1.8	8.6	12.1	1.2	11.5
2	18.2	3.2	15.0	21.4	2.2	11.8
3	4.7	1.0	3.6	5.7	0.7	14.8
4	0.7	0.4	0.3	1.1	0.3	42.3
Overall spatial change	33.9	5.2	28.7	39.0	3.5	10.3

Table 3. Raw estimates of change in Ouachita Mountains Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
			Estimate of change, in percent stratum				
1973–1980	12.5	2.1	10.3	14.6	1.4	11.5	1.8
1980–1986	19.0	3.3	15.7	22.3	2.2	11.7	3.2
1986–1992	17.2	2.7	14.4	19.9	1.9	10.8	2.9
1992–2000	14.8	2.6	12.2	17.3	1.7	11.8	1.8
			Estimate of change, in square kilometers				
1973–1980	3,303	560	2,743	3,863	379	11.5	472
1980–1986	5,029	870	4,159	5,899	589	11.7	838
1986–1992	4,551	727	3,824	5,279	493	10.8	759
1992–2000	3,915	683	3,231	4,598	463	11.8	489

Table 4. Estimated area (and margin of error) of each land-cover class in Ouachita Mountains Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mecha-nically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
									Area, in percent stratum											
1973	3.2	2.3	0.5	0.3	4.0	1.0	0.0	0.0	0.1	0.1	83.4	2.7	1.0	0.4	7.6	2.0	0.2	0.1	0.0	0.0
1980	3.4	2.3	0.5	0.4	8.8	1.8	0.0	0.0	0.1	0.1	77.3	2.6	1.7	0.6	8.0	2.1	0.2	0.1	0.0	0.0
1986	3.4	2.3	0.6	0.4	9.8	1.8	0.0	0.0	0.1	0.1	74.5	2.9	3.2	0.8	8.1	2.2	0.2	0.1	0.0	0.0
1992	3.4	2.3	0.7	0.4	5.2	1.1	0.0	0.0	0.1	0.1	79.3	2.8	2.8	1.1	8.3	2.2	0.2	0.1	0.0	0.0
2000	3.4	2.3	0.7	0.4	7.5	1.8	0.0	0.0	0.1	0.1	77.7	2.7	1.6	0.8	8.6	2.3	0.2	0.1	0.1	0.1
Net change	0.1	0.1	0.3	0.2	3.4	1.6	0.0	0.0	0.0	0.0	–5.7	1.5	0.7	0.7	1.1	0.6	0.0	0.0	0.1	0.1
Gross change	0.2	0.1	0.3	0.2	19.1	3.3	0.0	0.0	0.0	0.0	21.4	3.5	6.6	1.5	1.2	0.6	0.0	0.0	0.1	0.1
									Area, in square kilometers											
1973	856	608	122	83	1,069	275	8	6	28	32	22,110	703	258	99	2,003	537	53	30	0	0
1980	892	613	139	94	2,338	473	10	6	26	28	20,486	686	450	147	2,112	564	53	30	0	0
1986	900	613	156	98	2,605	464	12	6	24	28	19,744	758	856	224	2,155	576	53	30	0	0
1992	898	606	173	102	1,387	301	12	5	25	28	21,013	754	748	301	2,197	587	54	30	0	0
2000	895	605	192	113	1,979	474	13	6	30	31	20,602	704	437	209	2,286	623	55	31	17	16
Net change	39	38	71	47	910	415	5	4	2	3	–1,508	408	179	196	284	172	2	2	17	16
Gross change	65	39	71	47	5,070	873	8	4	13	10	5,668	934	1,737	387	330	169	3	3	17	16

Table 5. Principal land-cover conversions in Ouachita Mountains Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	2,134	394	267	8.1	64.6
	Mechanically disturbed	Forest	542	158	107	2.0	16.4
	Mechanically disturbed	Grassland/Shrubland	314	126	86	1.2	9.5
	Grassland/Shrubland	Forest	117	68	46	0.4	3.5
	Forest	Water	19	22	15	0.1	0.6
	Other	Other	177	n/a	n/a	0.7	5.4
		Totals	3,303			12.5	100.0
1980–1986	Forest	Mechanically disturbed	2,438	463	314	9.2	48.5
	Mechanically disturbed	Forest	1,482	361	245	5.6	29.5
	Mechanically disturbed	Grassland/Shrubland	686	184	124	2.6	13.6
	Grassland/Shrubland	Forest	288	124	84	1.1	5.7
	Forest	Agriculture	59	31	21	0.2	1.2
	Other	Other	76	n/a	n/a	0.3	1.5
		Totals	5,029			19.0	100.0
1986–1992	Mechanically disturbed	Forest	2,116	416	282	8.0	46.5
	Forest	Mechanically disturbed	1,313	295	200	5.0	28.8
	Grassland/Shrubland	Forest	543	116	79	2.0	11.9
	Mechanically disturbed	Grassland/Shrubland	425	144	97	1.6	9.3
	Forest	Agriculture	64	30	20	0.2	1.4
	Other	Other	91	n/a	n/a	0.3	2.0
		Totals	4,551			17.2	100.0
1992–2000	Forest	Mechanically disturbed	1,889	455	308	7.1	48.3
	Mechanically disturbed	Forest	1,122	274	185	4.2	28.7
	Grassland/Shrubland	Forest	500	184	125	1.9	12.8
	Mechanically disturbed	Grassland/Shrubland	184	72	48	0.7	4.7
	Forest	Agriculture	112	71	48	0.4	2.9
	Other	Other	108	n/a	n/a	0.4	2.8
		Totals	3,915			14.8	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	7,773	1,337	906	29.3	46.3
	Mechanically disturbed	Forest	5,263	1,017	689	19.9	31.3
	Mechanically disturbed	Grassland/Shrubland	1,608	392	266	6.1	9.6
	Grassland/Shrubland	Forest	1,447	341	231	5.5	8.6
	Forest	Agriculture	356	184	125	1.3	2.1
	Other	Other	350	n/a	n/a	1.3	2.1
		Totals	16,798			63.4	100.0

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South Central Lowlands Ecoregions


PRIVATE PROPERTY
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OR
TRESPASSING
ALLOWED

Chapter 16

Mississippi Alluvial Plain Ecoregion

By Kristi L. Sayler

Ecoregion Description

The Mississippi Alluvial Plain Ecoregion mainly lies in a flat alluvial floodplain that follows the Mississippi River south, from southern Illinois through parts of Missouri, Arkansas, Tennessee, Mississippi, and Louisiana, ending at the Gulf of Mexico; the ecoregion also includes the Red River valley, a finger of land that extends from the confluence of the Red and Mississippi Rivers northwest to Shreveport, Louisiana, and beyond, into the southwest corner of Arkansas (fig. 1) (Omernik, 1987; Wiken and others, 2011). The ecoregion, which covers about 141,895 km^2 (54,786 mi^2), is bounded on the west by the Ozark Highlands, Boston Mountains, Arkansas Valley, Ouachita Mountains, South Central Plains, and Western Gulf Coastal Plain Ecoregions; on the north, by the Interior River Lowland Ecoregion; and on the east by the Mississippi Valley Loess Plains, Southeastern Plains, and Southern Coastal Plain Ecoregions.

The climate of the Mississippi Alluvial Plain Ecoregion is mild in the winter and hot in the summer, with average temperatures being higher in the south than in the north; average annual precipitation

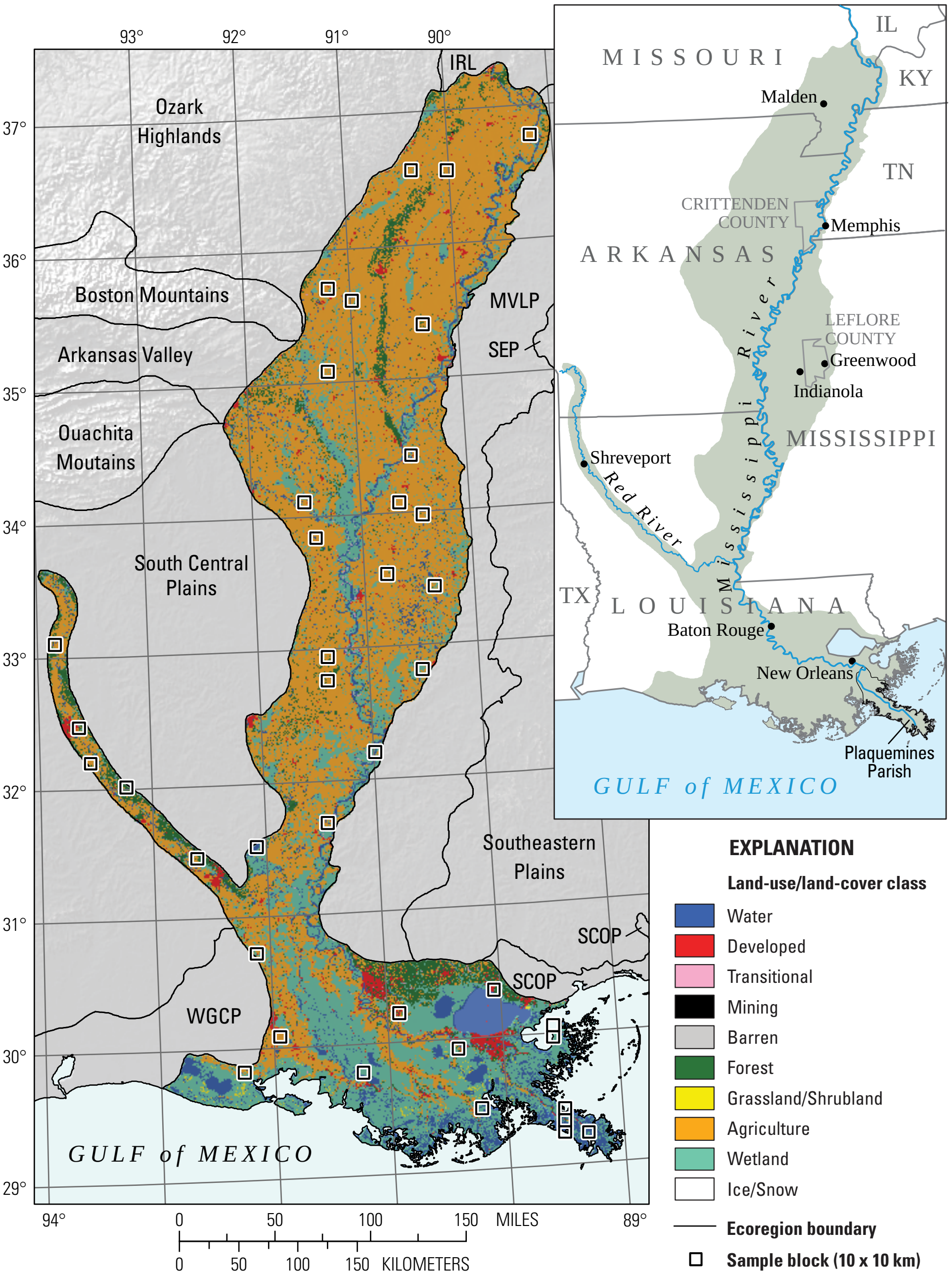

Figure 1. Map of Mississippi Alluvial Plain Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of one Great Plains ecoregion (Western Gulf Coastal Plain [WGCP]) and three Eastern United States ecoregions (Mississippi Valley Loess Plains [MVLP], Southeastern Plains [SEP], and Southern Coastal Plain [SCOP]). See appendix 3 for definitions of land-use/land-cover classifications.

also increases from north to south, ranging from 1,100 to 1,550 mm (43–61 in.). Historically, the ecoregion was covered by bottomland deciduous forests, but the expansion of farming into the ecoregion between the early 1800s and 1935 resulted in about half of the forested lands being lost (Stanturf, 2006). Rapid tree clearing renewed in the 1940s and continued into the early 1970s (McWilliams and Rosson, 1990, p. 491), allowing agriculture to fully occupy most of the ecoregion. The northern and central parts of the ecoregion now (2014) are highly cultivated; soybeans, rice, and cotton are the leading agricultural products (fig. 2). Aquaculture also is important, channel catfish (*Ictalurus punctatus*) being the leading commodity. Cotton production has recovered from low prices and boll weevil (*Anthonomus grandis*) infestations in the 1970s (Firestone, 2001). The southern part of the ecoregion, which is a forested-wetland alluvial plain (fig. 3), includes the cities of New Orleans and Baton Rouge, Louisiana. The mostly deciduous bottomland forests are composed of the following four main species groups: (1) sugarberry–American elm–green ash (*Celtis laevigata*, *Ulmus americana*, and *Fraxinus pennsylvanica*, respectively), (2) sweetgum–Nutall's oak–willow oak (*Liquidambar styraciflua*, *Quercus texana*, and *Quercus phellos*, respectively), (3) bald cypress–water tupelo (*Taxodium distichum* and *Nyssa aquatica*, respectively), and (4) overcup oak–water hickory (*Quercus lyrata* and *Carya aquatica*, respectively) (McWilliams and Rosson, 1990, p. 493).

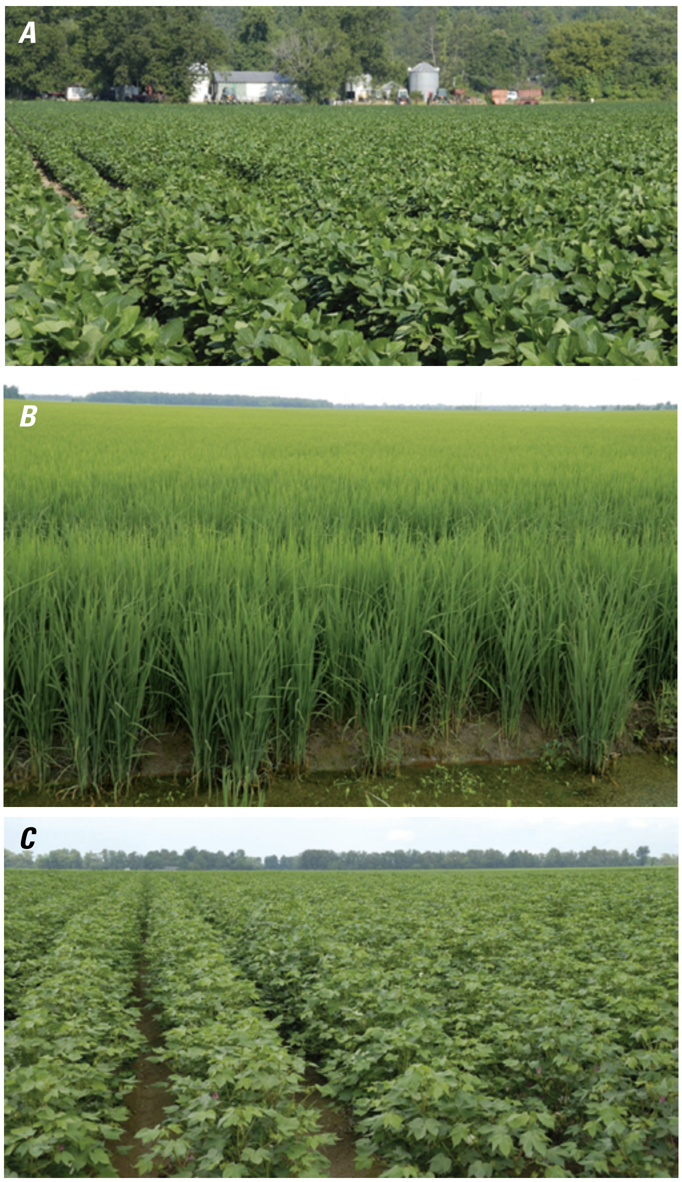

Figure 2. Examples of agricultural land in Mississippi Alluvial Plain Ecoregion, including (*A*) soybean field near Malden, Missouri; (*B*) rice field in Crittenden County, Arkansas, northwest of Memphis, Tennessee; and (*C*) cotton field northeast of Indianola, Mississippi.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Mississippi Alluvial Plain Ecoregion between 1973 and 2000 is estimated at 9.4 percent (table 1). Compared to other Midwest–South Central

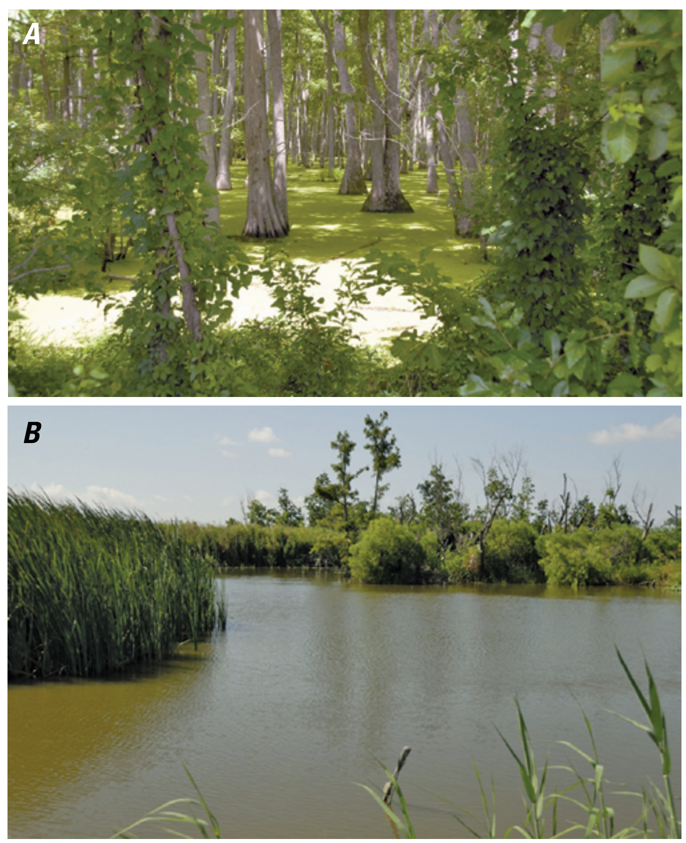

Figure 3. Examples of forested wetland alluvial plain in southern part of Mississippi Alluvial Plain Ecoregion, including (*A*) cypress swamp in Leflore County, Mississippi, near Greenwood, Mississippi, and (*B*) coastal wetland marsh in Plaquemines Parish, Louisiana.

United States ecoregions, change in the Mississippi Alluvial Plain Ecoregion was mixed. The change was higher than in the Boston Mountains, Interior River Lowland, Ozark Highlands, and Arkansas Valley Ecoregions, but it was lower than in the Western Gulf Coastal Plain, Mississippi Valley Loess Plains, and the South Central Plains Ecoregions (fig. 4): an estimated 7.4 percent of the area changed only once during the study period (table 1). The amount of change per time period varied throughout the study, ranging from a low of 2.7 percent to a high of 3.6 percent (table 2). When normalized to an average annual rate to account for uneven time periods, the period between 1973 and 1980 had the greatest amount of change, with a rate of 0.5 percent (721 km^2) per year (table 2; fig. 5).

In 2000, land-cover classes in the Mississippi Alluvial Plain Ecoregion included an estimated 48.7 percent agriculture, 19.4 percent wetland, 16.3 percent water, and 9.6 percent forest, but it was the wetland, water, forest, and developed classes that changed the most during the entire 27-year study period (table 3). The leading land-cover conversion in all time periods was the loss of 4,367 km^2 of wetland to water between 1973 and 2000 (table 4). Overall, wetland decreased by about 10.8 percent (3,344 km^2), largely a result of coastal wetlands lost to water, which increased by 19.0 percent (3,698 km^2) (table 3; fig. 6). The coastal wetlands in the Mississippi Alluvial Plain Ecoregion have been affected greatly by sediment erosion and land subsidence (Morton and others, 2003).

Another substantial amount of change was in the developed land-cover class (fig. 7), which increased by

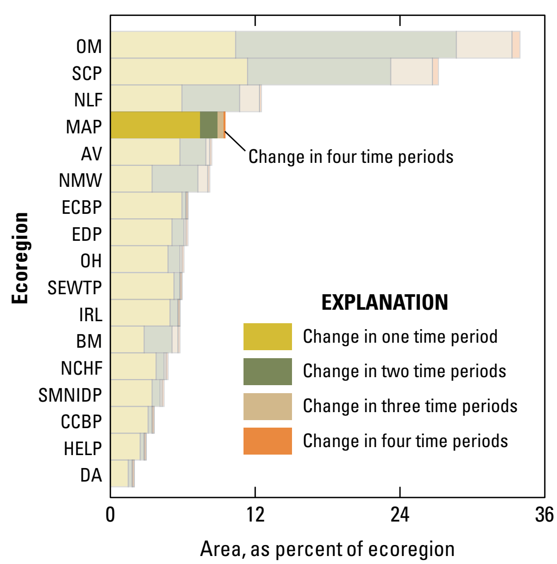

Figure 4. Overall spatial change in Mississippi Alluvial Plain Ecoregion (MAP; darker bars) compared with that of all 17 Midwest–South Central United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Mississippi Alluvial Plain Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

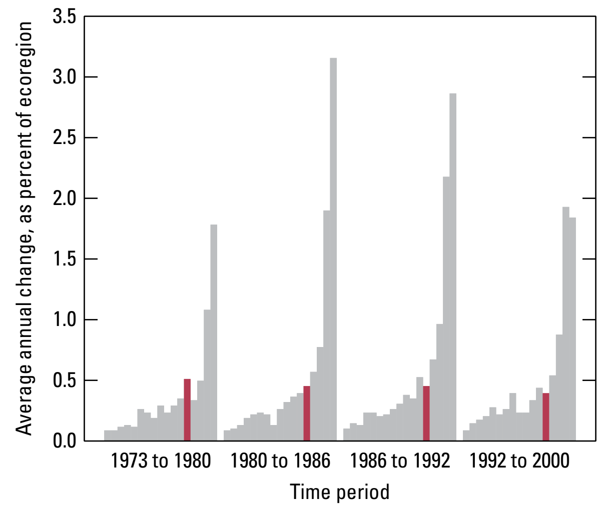

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for Mississippi Alluvial Plain Ecoregion are represented by red bars in each time period.

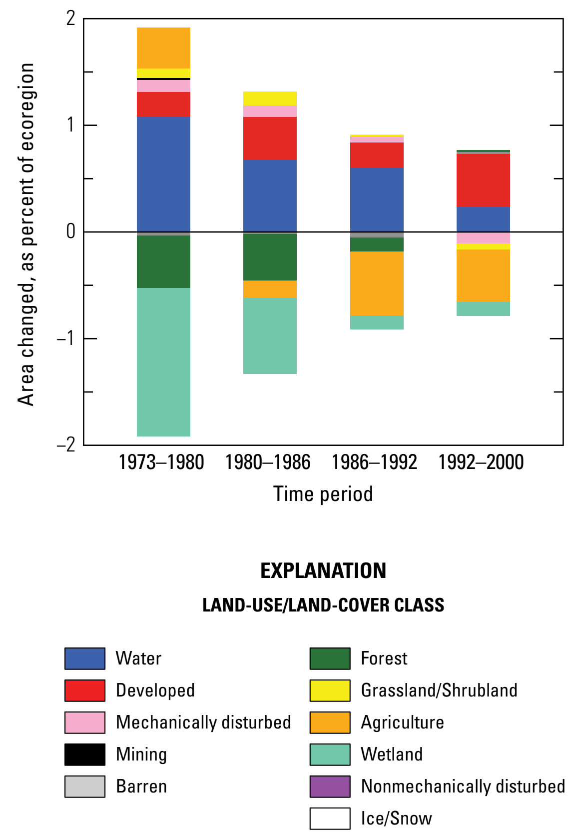

Figure 6. Normalized average net change in Mississippi Alluvial Plain Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

37.7 percent (1,968 km^2) to 5.1 percent of the ecoregion, largely through conversion from agriculture and forest (table 3). Although, when compared to changes in wetland, water, and forest, conversions to developed did not account for as much change, they still played a substantial role in the ecoregion, and they are representative of the growth that occurred around the edges of major cities. Timber harvesting (classified as conversion from forest to mechanically disturbed) was the next most common land-cover conversion in the ecoregion (table 4). A 9.7 percent (1,465 km^2) decrease in forest was caused by increased harvest of upland forests, primarily in the Red River valley of Louisiana and southwestern Arkansas (fig. 8; table 3).

The loss of coastal wetlands owing to storm damage, sediment erosion, and land subsidence was the major driver of land-cover change in the Mississippi Alluvial Plain Ecoregion. The small decrease in forest because of timber harvesting in the Red River valley accounted for much of the remaining change. A small but steady increase in the developed land-cover class around major cities was due primarily to increasing population in the growing metropolitan areas in Louisiana between 1970 and 2000 (CensusScope, 2012).

New home construction west of New Orleans, Louisiana.

Figure 8. Forest harvesting along Red River valley, Louisiana.

Table 1. Percentage of Mississippi Alluvial Plain Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (90.6 percent), whereas 9.4 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	7.4	2.2	5.1	9.6	1.5	20.7
2	1.6	0.7	0.9	2.3	0.5	30.5
3	0.4	0.3	0.1	0.8	0.2	50.7
4	0.1	0.1	0.0	0.1	0.0	61.3
Overall spatial change	9.4	2.7	6.7	12.1	1.8	19.5

Table 2. Raw estimates of change in Mississippi Alluvial Plain Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	3.6	1.5	2.1	5.0	1.0	27.9	0.5
1980–1986	2.7	0.8	1.8	3.5	0.6	21.0	0.4
1986–1992	2.7	1.0	1.7	3.7	0.7	26.1	0.5
1992–2000	3.1	1.2	1.9	4.3	0.8	26.4	0.4
Estimate of change, in square kilometers							
1973–1980	5,046	2,074	2,972	7,120	1,409	28	721
1980–1986	3,763	1,162	2,601	4,926	790	21	627
1986–1992	3,840	1,473	2,367	5,314	1,001	26	640
1992–2000	4,420	1,715	2,704	6,135	1,165	26	552

Table 3. Estimated area (and margin of error) of each land-cover class in Mississippi Alluvial Plain Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	13.7	7.2	3.7	1.8	0.1	0.1	0.0	0.0	0.2	0.1	10.6	3.7	0.3	0.2	49.6	7.6	21.8	5.5	0.0	0.0
1980	14.8	7.9	3.9	1.9	0.2	0.2	0.0	0.0	0.1	0.1	10.1	3.5	0.4	0.2	50.0	7.7	20.4	4.8	0.0	0.0
1986	15.5	8.2	4.3	2.0	0.3	0.3	0.0	0.0	0.1	0.1	9.7	3.3	0.5	0.3	49.8	7.7	19.7	4.6	0.0	0.0
1992	16.1	8.2	4.6	2.1	0.4	0.3	0.0	0.0	0.1	0.0	9.6	3.1	0.6	0.4	49.2	7.7	19.5	4.4	0.0	0.0
2000	16.3	8.3	5.1	2.3	0.3	0.2	0.0	0.0	0.1	0.1	9.6	3.2	0.5	0.3	48.7	7.6	19.4	4.4	0.0	0.0
Net change	2.6	2.1	1.4	0.8	0.2	0.1	0.0	0.0	–0.1	0.1	–1.0	0.7	0.2	0.3	–0.9	0.7	–2.4	2.0	0.0	0.0
Gross change	3.7	2.1	1.4	0.8	0.9	0.5	0.0	0.0	0.3	0.2	2.0	1.0	1.0	0.5	2.8	0.7	4.0	2.0	0.0	0.0
Area, in square kilometers																				
1973	19,498	10,205	5,222	2,504	187	132	30	19	254	144	15,042	5,264	439	276	70,342	10,788	30,882	30,882	0	0
1980	21,032	11,183	5,577	2,631	342	282	45	26	212	132	14,327	4,955	576	328	70,877	10,922	28,906	28,906	0	0
1986	21,998	11,663	6,148	2,769	489	419	54	31	179	108	13,716	4,667	768	421	70,643	10,891	27,899	27,899	0	0
1992	22,850	11,692	6,498	2,937	559	470	54	33	97	68	13,553	4,429	801	505	69,770	10,870	27,712	27,712	0	0
2000	23,196	11,841	7,190	3,242	414	287	40	27	142	97	13,577	4,531	738	400	69,060	10,796	27,538	27,538	0	0
Net change	3,698	2,926	1,968	1,114	227	199	10	25	–112	103	–1,465	1,047	299	423	–1,282	977	–3,344	–3,344	0	0
Gross change	5,247	2,958	1,983	1,113	1,317	761	66	46	376	214	2,872	1,443	1,396	767	3,983	927	5,643	5,643	0	0

Table 4. Principal land-cover conversions in Mississippi Alluvial Plain Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for “other” class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km^2)	Margin of error (+/– km^2)	Standard error (km^2)	Percent of ecoregion	Percent of all changes
1973–1980	Wetland	Water	1,844	1,854	1,259	1.3	36.5
	Wetland	Agriculture	725	403	274	0.5	14.4
	Water	Wetland	419	366	248	0.3	8.3
	Forest	Agriculture	372	209	142	0.3	7.4
	Forest	Mechanically disturbed	298	265	180	0.2	5.9
	Other	Other	1,388	n/a	n/a	1.0	27.5
		Totals	5,046			3.6	100.0
1980–1986	Wetland	Water	1,037	760	517	0.7	27.6
	Forest	Mechanically disturbed	385	395	268	0.3	10.2
	Forest	Developed	266	217	147	0.2	7.1
	Agriculture	Developed	210	174	118	0.1	5.6
	Water	Wetland	178	134	91	0.1	4.7
	Other	Other	1,687	n/a	n/a	1.2	44.8
		Totals	3,763			2.7	100.0
1986–1992	Wetland	Water	702	408	277	0.5	18.3
	Forest	Mechanically disturbed	399	342	232	0.3	10.4
	Grassland/Shrubland	Forest	286	253	172	0.2	7.5
	Mechanically disturbed	Grassland/Shrubland	254	318	216	0.2	6.6
	Agriculture	Water	239	178	121	0.2	6.2
	Other	Other	1,960	n/a	n/a	1.4	51.0
		Totals	3,840			2.7	100.0
1992–2000	Wetland	Water	784	571	388	0.6	17.7
	Water	Wetland	499	312	212	0.4	11.3
	Mechanically disturbed	Forest	408	339	230	0.3	9.2
	Grassland/Shrubland	Forest	405	410	279	0.3	9.2
	Agriculture	Developed	355	325	221	0.2	8.0
	Other	Other	1,970	n/a	n/a	1.4	44.6
		Totals	4,420			3.1	100.0
1973–2000 (overall)	Wetland	Water	4,367	3,057	2,076	3.1	25.6
	Forest	Mechanically disturbed	1,411	1,115	757	1.0	8.3
	Water	Wetland	1,272	853	580	0.9	7.5
	Wetland	Agriculture	1,048	498	339	0.7	6.1
	Agriculture	Developed	922	690	469	0.6	5.4
	Other	Other	8,048	n/a	n/a	5.7	47.1
		Totals	17,069			12.0	100.0

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Chapter 17

South Central Plains Ecoregion

By Mark A. Drummond

Ecoregion Description

The South Central Plains Ecoregion lies at the western margin of the southern pine-forest belt. The ecoregion covers about 155,520 km^2 (60,047 mi^2) of southern Arkansas, northern and western Louisiana, southeastern Oklahoma, and eastern Texas (fig. 1) (Omernik, 1987; Wiken and others, 2011). Neighboring ecoregions include the Ouachita Mountains Ecoregion to the north; the Mississippi Alluvial Plain Ecoregion to the east; the Western Gulf Coastal Plain Ecoregion to the south; and the East Central Texas Plains, Texas Blackland Prairies, and Central Oklahoma/Texas Plains Ecoregions to the west. Much of the South Central Plains Ecoregion lies within the broad southern coastal plain, which is underlain by marine and fluvial sedimentary rocks. Soils are generally acidic, and a significant amount of wetlands are present. Annual precipitation ranges from about 1,140 to 1,520 mm (45–60 in.), and the number of annual frost-free days ranges

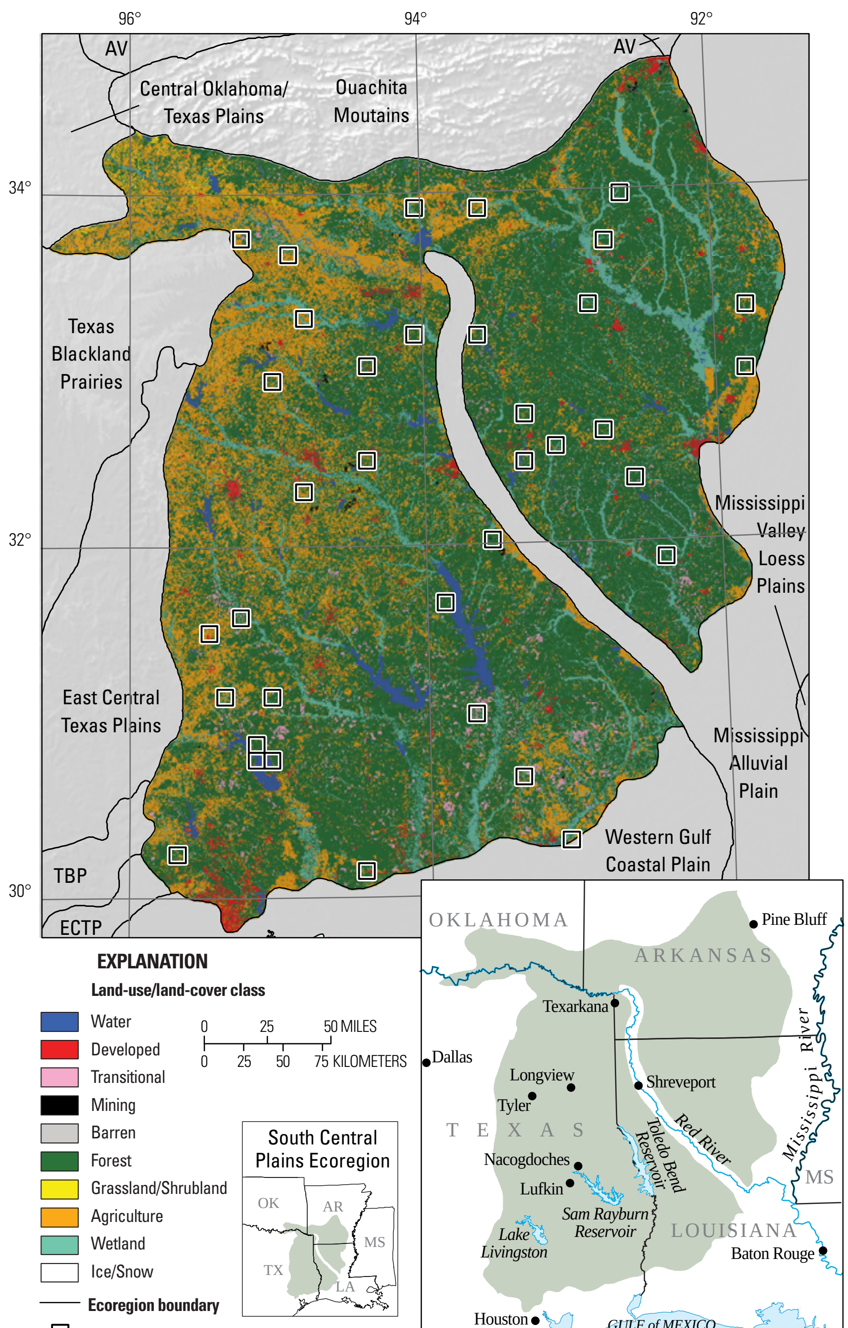


Figure 1. Map of South Central Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 10 x 10 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Midwest–South Central United States ecoregions are listed in appendix 2. Also shown are parts of four Great Plains ecoregions (Central Oklahoma/Texas Plains, East Central Texas Plains [ECTP], Texas Blackland Prairies [TBP], and Western Gulf Coastal Plain) and one Eastern United States ecoregion (Mississippi Valley Loess Plains). See appendix 3 for definitions of land-use/land-cover classifications.

from 200 days in the north to 300 days in the south (Wiken and others, 2011). Climate variability affects the ecoregion in the form of periodic droughts, as well as deluges from tropical storms and hurricanes.

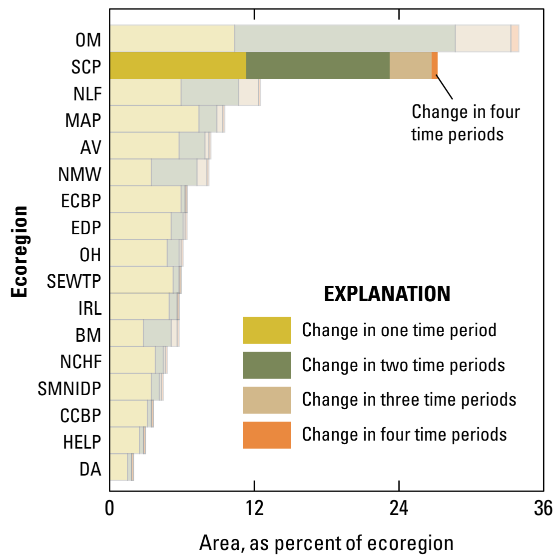
The South Central Plains Ecoregion is characterized, in part, by extensive forest cover; however, much native upland pine and hardwood in the ecoregion has been replaced by even-aged loblolly pine (*Pinus taeda*) and shortleaf pine (*Pinus echinata*) plantations (fig. 2). Bottomland forests are typified by deciduous species, which include water oak (*Quercus nigra*), willow oak (*Quercus phellos*), swamp chestnut oak (*Quercus michauxii*), sweetgum (*Liquidambar styraciflua*), blackgum (*Nyssa sylvatica*), red maple (*Acer rubrum*), bald cypress (*Taxodium distichum*), and water tupelo (*Nyssa aquatica*) (Wiken and others, 2011). Pasturelands and other agricultural lands have been carved out of the upland forests, particularly in the western part of the ecoregion (fig. 3). The valley of the Red River, which divides the ecoregion as it runs towards the Mississippi River, supports most of the cropland, although much of the Red River valley is included in the neighboring Mississippi Alluvial Plain Ecoregion (U.S. Environmental Protection Agency, 1999). Streams are common in the ecoregion, and several large reservoirs are in its western half. The ecoregion generally has no large cities, although the Houston, Texas, suburbs extend into its southwest corner. Other cities and towns include the Shreveport, Louisiana, metropolitan area; Texarkana and Pine Bluff, Arkansas; and Longview, Tyler, Nacogdoches, and Lufkin, Texas. Total population of the ecoregion increased by about 42 percent, from 2.2 million in 1970 to 3.1 million in 2000 (U.S. Census Bureau, 1973, 2013).

The patterns of land-cover change in the South Central Plains Ecoregion are founded by the biological and geological resources of the ecoregion, which include upland forests, bottomland forested wetlands, and oil and gas deposits. The upland areas support timber production (for lumber and pulpwood) and agricultural uses that include pasture and confined-poultry operations, as well as oil and gas production (Daigle and others, 2004). Upland forest areas in the northern part of the ecoregion, which historically have contained a mix of shortleaf and loblolly pine and other native trees, generally have been replaced by commercially operated pine plantations and pasturelands. Upland forest areas in the south half of the ecoregion historically included the westernmost range of the longleaf pine (*Pinus palustris*), which, by the end of the 20th century, was present in less than 5 percent of its original range in the southeastern United States (Earley, 2004). Oil and natural-gas production generally peaked in the early 1970s; however, since about 2000, areas in the central part of the ecoregion

Figure 2. Two areas of even-aged, planted pine in South Central Plains Ecoregion. *A*, Pastureland converted to tree farm. *B*, Young pines (foreground) and mature pine stand (background).

Figure 3. Two areas of agricultural land in South Central Plains Ecoregion. *A*, Pastureland in rolling uplands of western part of ecoregion. *B*, Confined animal-feeding operations (mostly poultry).

(northwestern Louisiana, southwestern Arkansas, and eastern Texas), where the Haynesville shale-gas formation is located, have experienced an increase in drilling activity and well-pad construction (U.S. Bureau of Land Management, 2008).



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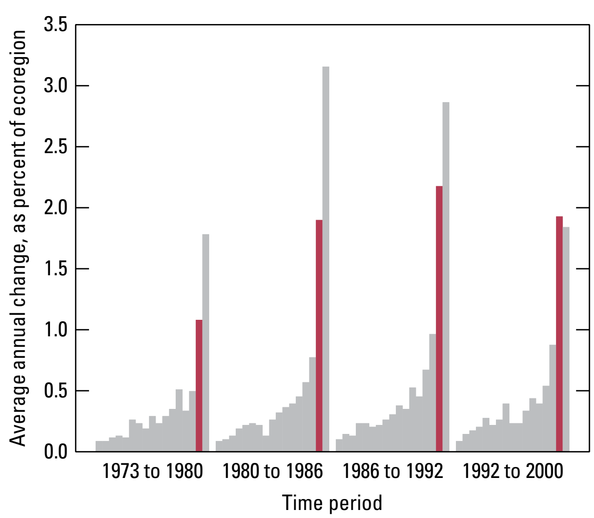

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Midwest–South Central United States ecoregions (gray bars). Estimates of change for South Central Plains Ecoregion are represented by red bars in each time period.

Contemporary Land-Cover Change (1973 to 2000)

Changes in the extent of land cover in the South Central Plains Ecoregion are related to several land-conversion processes, some of which include cycles of forest harvest and regrowth, as well as conversions from agriculture to grassland/shrubland and forest, in addition to urbanization and mining. The overall spatial change (the percentage of land area that changed at least one time) in the South Central Plains Ecoregion between 1973 and 2000 is estimated at 27.1 percent (table 1). The South Central Plains Ecoregion had the second highest overall spatial change of the 17 Midwest–South Central United States ecoregions (fig. 4), and it had the third highest overall spatial change of all 84 Level III ecoregions of the conterminous United States (see appendix 1; see also, U.S. Environmental Protection Agency, 1999). A substantial area of the ecoregion changed multiple times during the study period: the total amount of land area that changed multiple times (15.8 percent) was larger than the amount of area that changed only once (11.3 percent) (table 1), which indicates the cyclic nature

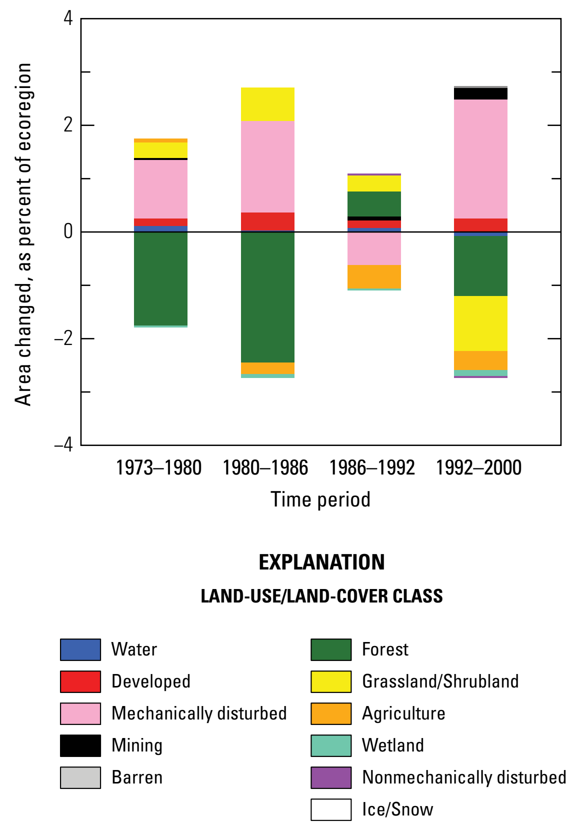

Figure 6. Normalized average net change in South Central Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

of land conversion in the fast-growing pine-plantation areas. The average annual rate of change increased from 1.1 percent between 1973 and 1980, to 1.9 percent between 1980 and 1986, and to 2.2 percent between 1986 and 1992, declining slightly to 1.9 percent between 1992 and 2000 (table 2; fig. 5).

The largest net change in ecoregion area between 1973 and 2000 occurred in the forest land-cover class, which constituted over one-half of the total ecoregion area (an estimated 58.7 percent in 2000) (table 3). Decreases in forest land affected about 4.9 percent (7,579 km^2) of the ecoregion between 1973 and 2000. The four leading land-cover class conversions between 1973 and 2000 involved various stages of forest harvest (mechanically disturbed to forest) and revegetation (mechanically disturbed to forest, mechanically disturbed to grassland/shrubland, and grassland/shrubland to forest), with substantially less activity between 1973 and 1980 than in the subsequent three time periods (table 4). Changes in forest land indicate the significance of lumber and pulpwood in the regional economy. The change from agriculture to forest, the fifth leading land-cover conversion between 1973 and 2000, likely indicates a switch from pasture and hay production to silviculture.

The effects of forestry activities are shown by an increase in mechanically disturbed land, which increased by 4.4 percent of the total ecoregion area between 1973 and 2000 (table 3). Mechanically disturbed land increased from an estimated 2.9 percent (4,563 km^2) of the ecoregion in 1973, to an estimated 7.4 percent (11,480 km^2) of the ecoregion in 2000, suggesting a general acceleration in the rate of forest cutting. However, the rate and timing of tree regrowth caused a variable rate of net change in forest land cover, including a period of small net forest gain (0.5 percent) between 1986 and 1992 that did not reverse the overall trend of forest loss (fig. 6).

Net agricultural land decreases affected nearly 1.0 percent (1,549 km^2) of the ecoregion between 1973 and 2000. Agriculture, which was the second most extensive land-cover class, constituted about 18.2 percent of the ecoregion area in 2000 (table 3). Forest was lost to agriculture between 1973 and 1980, but thereafter forest gained from agriculture (table 4). This change after 1980 likely was due to the conversion of agricultural land to planted-pine plantations as the profitability of timber production increased. Conversion of agriculture to grassland/shrubland—possibly as an intermediate stage in the change to forest land—also occurred, but it was not one of the top conversions (it was included as part of the "Other" change class in table 4). Agriculture also lost to developed (301 km^2), water (92 km^2), and mining (20 km^2) (these also were included as part of the "Other" change class, in the "1973–2000 (overall)" section of table 4). However, most of the expansion to mining occurred on forest land (590 km^2, included as part of the "Other" change class in the "1973–2000 (overall)" section of table 4), and at least some of the increase in mining that occurred after 1986 is related to surface mining of small fields of lignite coal deposits in the central part of the ecoregion. A small part of the mining land-cover class includes the total area of forest land converted to gas- and oil-well pads (fig. 7*A*).

Developed land increased by 53.3 percent between 1973 and 2000, from 1.7 percent of the ecoregion in 1973 to 2.6 percent of the ecoregion in 2000 (fig. 7*B*; table 3). The conversion occurred mostly at the expense of forest (an estimated 1,011 km^2) compared to agriculture (301 km^2) (both of these conversions are included as part of the "Other" change class in the "1973–2000 (overall)" section of table 4). The analysis showed only a small decrease in wetlands, which affected 0.2 percent of the ecoregion (table 3). The area of surface water increased by 0.2 percent as a result of reservoir construction on forest land and agricultural land (table 3). No natural disturbance (nonmechanically disturbed land-cover class) was detected.

Pine-plantation forestry was a major driver of land change in the ecoregion. Tree cutting-and-regrowth cycles accounted for much of the land-cover-class conversions between 1973 and 2000, as well as for the large footprint of overall spatial change. Additionally, the changes from agriculture to forest were driven by the economic opportunities associated with converting marginal farmland to plantation forestry. Despite some conversion from agriculture to forest, the expansion of mechanical disturbance, land development, and mining caused an overall net decrease in forest land cover. Increased demands on the ecoregion in the future could cause an accelerated conversion of natural and seminatural hardwood forest environments to planted-pine environments, which may have undesirable consequences for biomass carbon stocks and ecosystem services (Sohngen and Brown, 2006).

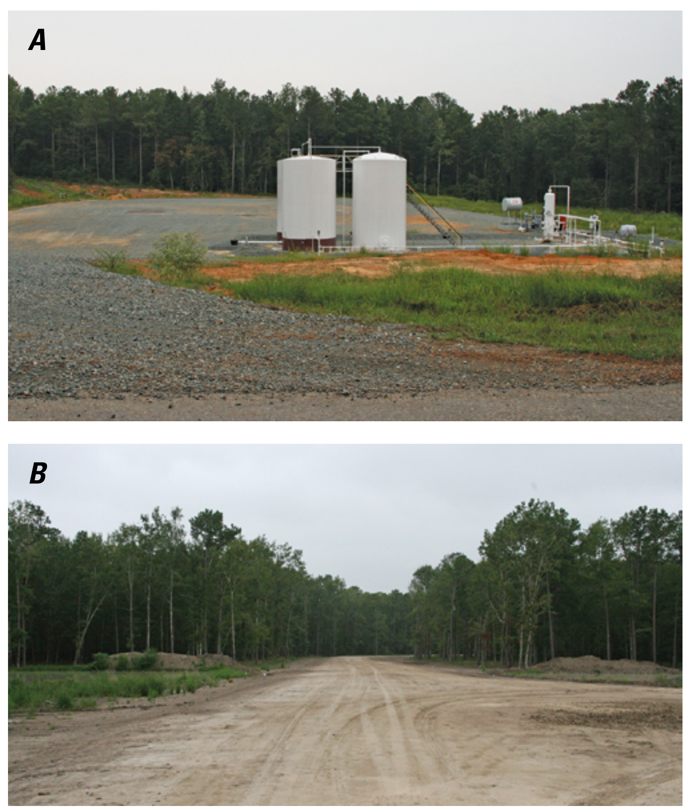

Figure 7. Mining and developed land-cover classes in South Central Plains Ecoregion. *A*, Natural-gas well pad. *B*, Land recently cleared for development.

Table 1. Percentage of South Central Plains Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (72.9 percent), whereas 27.1 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	11.3	1.3	10.0	12.6	0.9	8.0
2	11.8	1.9	10.0	13.7	1.3	10.6
3	3.6	1.0	2.6	4.6	0.7	18.6
4	0.4	0.2	0.2	0.6	0.1	36.5
Overall spatial change	27.1	3.4	23.7	30.5	2.3	8.5

Table 2. Raw estimates of change in South Central Plains Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at 85-percent confidence level.

[Estimates of change per period normalized to annual rate of change for each time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	7.6	1.6	5.9	9.2	1.1	14.7	1.1
1980–1986	11.4	1.8	9.5	13.2	1.2	10.9	1.9
1986–1992	13.0	2.0	11.0	15.0	1.4	10.5	2.2
1992–2000	15.4	2.3	13.1	17.7	1.6	10.1	1.9
Estimate of change, in square kilometers							
1973–1980	11,786	2,554	9,231	14,340	1,735	14.7	1,684
1980–1986	17,667	2,837	14,830	20,504	1,927	10.9	2,944
1986–1992	20,262	3,117	17,145	23,379	2,118	10.5	3,377
1992–2000	23,913	3,556	20,358	27,469	2,416	10.1	2,989

Table 3. Estimated area (and margin of error) of each land-cover class in South Central Plains Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mecha-nically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	3.7	2.8	1.7	0.6	2.9	0.9	0.1	0.1	0.0	0.0	63.6	4.3	0.8	0.3	19.1	4.4	8.1	1.8	0.0	0.0
1980	3.8	2.9	1.8	0.6	4.0	1.1	0.1	0.1	0.0	0.0	61.9	4.1	1.1	0.3	19.2	4.4	8.1	1.8	0.0	0.0
1986	3.8	2.9	2.2	0.7	5.8	1.2	0.1	0.1	0.0	0.0	59.4	4.2	1.7	0.6	19.0	4.4	8.0	1.8	0.0	0.0
1992	3.9	2.9	2.3	0.7	5.1	1.1	0.2	0.1	0.0	0.0	59.9	4.0	2.0	0.5	18.5	4.3	8.0	1.8	0.0	0.0
2000	3.9	2.9	2.6	0.8	7.4	1.4	0.4	0.3	0.0	0.0	58.7	3.8	1.0	0.3	18.2	4.3	7.9	1.8	0.0	0.0
Net change	0.2	0.1	0.9	0.4	4.4	1.4	0.3	0.3	0.0	0.0	–4.9	1.5	0.2	0.3	–1.0	0.4	–0.2	0.2	0.0	0.0
Gross change	0.4	0.3	0.9	0.4	13.8	2.5	0.4	0.3	0.0	0.0	14.3	2.5	4.2	1.3	1.9	0.4	0.7	0.3	0.1	0.1
Area, in square kilometers																				
1973	5,725	4,414	2,598	894	4,563	1,416	116	84	18	20	98,914	6,683	1,191	450	29,728	6,839	12,666	2,829	0	0
1980	5,883	4,480	2,829	965	6,298	1,762	148	113	19	20	96,214	6,437	1,667	418	29,865	6,843	12,598	2,827	0	0
1986	5,929	4,464	3,356	1,070	8,963	1,871	194	90	19	20	92,387	6,477	2,627	869	29,530	6,819	12,515	2,811	0	0
1992	6,083	4,467	3,557	1,108	8,000	1,716	300	140	19	20	93,147	6,252	3,055	817	28,834	6,760	12,479	2,807	46	67
2000	6,007	4,448	3,983	1,224	11,480	2,168	648	445	20	20	91,336	5,929	1,481	394	28,249	6,718	12,315	2,764	0	0
Net change	282	125	1,385	580	6,917	2,115	532	443	2	2	–7,579	2,309	291	518	–1,479	686	–351	337	0	0
Gross change	632	422	1,388	581	21,432	3,875	634	444	2	2	22,274	3,934	6,479	1,980	2,879	652	1,082	506	93	135

Table 4. Principal land-cover conversions in South Central Plains Ecoregion, showing amount of area changed (and margin of error, calculated at 85-percent confidence level) for each conversion during each of four time periods and also during overall study period. See appendix 3 for definitions of land-cover classifications.

[Values given for "other" classes are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	5,917	1,721	1,169	3.8	50.2
	Mechanically disturbed	Forest	3,292	1,265	860	2.1	27.9
	Mechanically disturbed	Grassland/Shrubland	804	278	189	0.5	6.8
	Forest	Agriculture	437	145	99	0.3	3.7
	Grassland/Shrubland	Forest	362	327	222	0.2	3.1
	Other	Other	974	n/a	n/a	0.6	8.3
		Totals	11,786			7.6	100.0
1980–1986	Forest	Mechanically disturbed	8,554	1,817	1,234	5.5	48.4
	Mechanically disturbed	Forest	4,496	1,496	1,016	2.9	25.4
	Mechanically disturbed	Grassland/Shrubland	1,492	840	571	1.0	8.4
	Grassland/Shrubland	Forest	787	240	163	0.5	4.5
	Agriculture	Forest	419	205	140	0.3	2.4
	Other	Other	1,918	n/a	n/a	1.2	10.9
		Totals	17,667			11.4	100.0
1986–1992	Forest	Mechanically disturbed	7,649	1,675	1,138	4.9	37.7
	Mechanically disturbed	Forest	6,717	1,558	1,059	4.3	33.2
	Grassland/Shrubland	Forest	1,792	826	561	1.2	8.8
	Mechanically disturbed	Grassland/Shrubland	1,751	690	468	1.1	8.6
	Agriculture	Forest	538	188	128	0.3	2.7
	Other	Other	1,815	n/a	n/a	1.2	9.0
		Totals	20,262			13.0	100.0
1992–2000	Forest	Mechanically disturbed	10,866	2,166	1,471	7.0	45.4
	Mechanically disturbed	Forest	7,232	1,601	1,088	4.7	30.2
	Grassland/Shrubland	Forest	2,260	787	535	1.5	9.5
	Agriculture	Forest	718	253	172	0.5	3.0
	Mechanically disturbed	Grassland/Shrubland	444	183	124	0.3	1.9
	Other	Other	2,394	n/a	n/a	1.5	10.0
		Totals	23,913			15.4	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	32,986	5,862	3,982	21.2	44.8
	Mechanically disturbed	Forest	21,737	4,729	3,213	14.0	29.5
	Grassland/Shrubland	Forest	5,201	1,390	944	3.3	7.1
	Mechanically disturbed	Grassland/Shrubland	4,491	1,294	879	2.9	6.1
	Agriculture	Forest	1,895	550	373	1.2	2.6
	Forest	Agriculture	1,358	375	254	0.9	1.8
	Other	Other	5,960	n/a	n/a	3.8	8.1
		Totals	73,628			47.3	100.0

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Appendixes 1–4

Appendix 1. Map of Ecoregions in Conterminous United States

This volume—U.S. Geological Survey Professional Paper 1794–C, which covers 17 ecoregions in the Midwest–South Central United States—provides an assessment of the rates and causes of land-use and land-cover change in the Midwest–South Central United States region between 1973 and 2000. The other three volumes of this Professional Paper (1794–A, 1794–B, and 1794–D) provide similar analyses for the Western United States, the Great Plains of the United States, and the Eastern United States regions, respectively.

The map contained in this appendix (fig. 1.1) shows all 84 ecoregions in the conterminous United States, as originally defined by Omernik (1987) and later modified by the U.S. Environmental Protection Agency (1997), in addition to the ecoregions that are contained in the Western United States, Great Plains of the United States, Midwest–South Central United States, and Eastern United States regions. Also shown are the land-use/land-cover classes from the 2001 National Land-Cover Database (Homer and others, 2004).

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Ecoregion Abbreviations Used on Map

[Map is on following pages]

ACPB	Atlantic Coastal Pine Barrens Ecoregion
ANMM	Arizona/New Mexico Mountains Ecoregion
CR	Coast Range Ecoregion
CRK	Canadian Rockies Ecoregion
EGLHL	Eastern Great Lakes and Hudson Lowlands Ecoregion
HELP	Huron/Erie Lake Plains Ecoregion
LPH	Laurentian Plains and Hills Ecoregion
MACP	Middle Atlantic Coastal Plain Ecoregion
MRK	Middle Rockies Ecoregion
MVFP	Montana Valley and Foothill Prairies Ecoregion
MVLP	Mississippi Valley Loess Plains Ecoregion
NAPU	Northern Appalachian Plateau and Uplands Ecoregion
NCA	North Central Appalachians Ecoregion
NCHF	North Central Hardwood Forests Ecoregion
NECZ	Northeastern Coastal Zone Ecoregion
NEH	Northeastern Highlands Ecoregion
NLF	Northern Lakes and Forests Ecoregion
NMW	Northern Minnesota Wetlands Ecoregion
PL	Puget Lowland Ecoregion
SCCCOW	Southern and Central California Chaparral and Oak Woodlands Ecoregion
SCM	Southern California Mountains Ecoregion
SEWTP	Southeastern Wisconsin Till Plains Ecoregion
SFCP	Southern Florida Coastal Plain Ecoregion
TBP	Texas Blackland Prairies Ecoregion
WUM	Wasatch and Uinta Mountains Ecoregion
WV	Willamette Valley Ecoregion

Figure 1.1. Map of ecoregions in conterminous United States.


90°
80°
50°
70°
40°
30°
CANADA
Lake Agassiz Plain
NMW
Northern Lakes and Forests
NCHF
Northern Glaciated Plains
Driftless Area
SEWTP
NLF
HELP
Southern Michigan/ Northern Indiana Drift Plains
Western Corn Belt Plains
Central Corn Belt Plains
Eastern Corn Belt Plains
Erie Drift Plains
Central Irregular Plains
PLAINS
Great
Flint Hills
Interior River Lowland
MIDWEST–SOUTH CENTRAL UNITED STATES
Interior Plateau
Ozark Highlands
Boston Mountains
Arkansas Valley
Ouachita Mountains
Mississippi Alluvial Plain
South Central Plains
TBP
MVLP
East Central Texas Plains
Western Gulf Coastal Plain
EASTERN UNITED STATES
Southeastern Plains
Southwestern Appalachians
Ridge and Valley
Blue Ridge Mountains
Piedmont
Central Appalachians
Western Allegheny Plateau
NCA
NAPU
EGLHL
NEH
Northeastern Highlands
LPH
NECZ
Northern Piedmont
ACPB
MACP
Middle Atlantic Coastal Plain
Southern Coastal Plain
SFCP
ATLANTIC OCEAN
Gulf of Mexico
EXPLANATION
Land-use/land-cover class
Water
Developed
Barren
Forest
Grassland/Shrubland
Agriculture
Wetland
Ice/Snow
Ecoregion boundary
Major ecoregion group boundary

Appendix 2. Abbreviations for Ecoregions in the Midwest–South Central United States

AV	Arkansas Valley Ecoregion
BM	Boston Mountains Ecoregion
CCBP	Central Corn Belt Plains Ecoregion
DA	Driftless Area Ecoregion
ECBP	Eastern Corn Belt Plains Ecoregion
EDP	Erie Drift Plains Ecoregion
HELP	Huron/Erie Lake Plains Ecoregion
IRL	Interior River Lowland Ecoregion
MAP	Mississippi Alluvial Plain Ecoregion
NCHF	North Central Hardwood Forests Ecoregion
NLF	Northern Lakes and Forests Ecoregion
NMW	Northern Minnesota Wetlands Ecoregion
OH	Ozark Highlands Ecoregion
OM	Ouachita Mountains Ecoregion
SCP	South Central Plains Ecoregion
SEWTP	Southeastern Wisconsin Till Plains Ecoregion
SMNIDP	Southern Michigan/Northern Indiana Drift Plains Ecoregion

Appendix 3. Land-Cover Classification System Used in “Status and Trends of Land Change” Study

This analysis of land-use/land-cover change during the 1973–2000 study period is based on land-cover classifications mapped for five study dates—1973, 1980, 1986, 1992, and 2000. The use of moderate-resolution imagery—Landsat Multispectral Scanner, Thematic Mapper, and Enhanced Thematic Mapper Plus—necessitated a land-cover classification system that was fairly general in order to achieve high levels of accuracy and consistency in the interpretations. The classification system also needed to contain classes that could be used as an appropriate surrogate for land use. This classification, which is based on the Anderson Level I classes (Anderson and others, 1976), was used because the classes have been designed as use surrogates, but this system has been further modified by adding two transitional disturbance categories, mechanically disturbed (human induced) and nonmechanically disturbed (natural).

The classification system used consists of the following 11 general land-cover classes: water, developed, mechanically disturbed, mining, barren, forest, grassland/shrubland, agriculture, wetland, nonmechanically disturbed, and ice/snow. Classes are defined as follows:

Water—Areas that are persistently covered with water, such as perennial streams, canals, rivers, lakes, reservoirs, bays, and oceans.

Developed—Areas of intensive use, in which much of the land is covered with structures or other anthropogenically induced, impermeable surfaces (for example, high-density residential, commercial, and industrial areas, as well as roads, highways, and other transportation corridors), or less intensive use, in which the land-cover matrix includes both vegetation and structures (for example, low-density residential areas, recreational facilities, cemeteries, parking lots, and utility corridors). Land that is functionally related to urban or built-up environments (for example, parks and golf courses) is also included.

Mechanically disturbed—Land in an altered and often unvegetated state owing to disturbance by mechanical (that is, human) means. Mechanically disturbed land is in transition from one land-cover class to another. Processes leading to mechanical disturbance include forest clearcutting, earthmoving, scraping, chaining, reservoir drawdown, and other types of anthropogenically induced changes.

Mining—Areas of extractive mining activities that have significant surface expression, including mining buildings and apparatus, quarry pits, evaporation and leach ponds, tailings and overburden piles, and other components related to mining, to the extent that these features can be detected.

Barren—Areas of bare soil, sand, or rock, in which less than 10 percent of the area is vegetated. Barren lands generally are naturally occurring.

Forest—Tree-covered land where the tree-cover density is greater than 10 percent. Cleared forest land is mapped (according to land cover at the time of the imagery) as either mechanically disturbed or grassland/shrubland.

Grassland/Shrubland—Land that is predominately covered with grasses, forbs, or shrubs. Vegetated cover must make up at least 10 percent of the area.

Agriculture—Land, in either a vegetated or an unvegetated state, used for the production of food or fiber. This includes cultivated and uncultivated croplands, hay lands, pasture, orchards, vineyards, and confined-livestock operations. However, forest plantations always are classified as forest, regardless of how the wood products are used.

Wetland—Land where water saturation is the determining factor in soil characteristics, vegetation types, and animal communities. Wetlands usually contain both water and vegetated cover.

Nonmechanically disturbed—Land in an altered and often unvegetated state owing to disturbance by nonmechanical (that is, natural) means. Nonmechanically disturbed land is in transition from one land-cover class to another. Causes of nonmechanical disturbance include fire, wind, floods, animals, and other similar phenomena.

Ice/Snow—Land where the accumulation of snow and ice does not completely melt during the summer period (for example, alpine glaciers and perennial snowfields).

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Appendix 4. Methodology Used in "Status and Trends of Land Change" Study

This appendix describes the methodology used to document the temporal and spatial rates, trends, and types of change documented in this "Status and Trends of Land Change" study. The methodology is based on a statistical sampling approach, manual classification of land use and land cover, and postclassification comparisons of land cover over five different study dates (Loveland and others, 2002). U.S. Environmental Protection Agency's (1999) Level III ecoregions provided the geographic framework for regional land-cover change estimates, and land-use/land-cover change was estimated on an ecoregion-by-ecoregion basis using a probability sample of randomly selected blocks within each of 84 ecoregions across the conterminous United States. For each sample block, five dates of Landsat imagery were interpreted in order to map land use and land cover, using a classification system that consists of 11 general land-cover classes (see appendix 3, entitled "Land-Cover Classification System Used in 'Status and Trends of Land Change' Study"). The resulting land-cover data for each sample block were used to determine change for four time periods, and sample-block data were used to calculate change estimates for each ecoregion.

Sampling Strategy

In this study, a sampling strategy was used as a cost-efficient method for characterizing land-cover change in an area as large as the conterminous United States. The study used a stratified random sample of 2,688 square blocks (fig. 1); a random sample of these blocks was independently selected for each ecoregion analyzed. Because the study used a probability sample, the estimates of land-use/land-cover change that are derived can be considered as categorically representative of the population (Kish, 1987).

The size of each sample block in this study, as well as the sampling density (that is, the number of sample blocks analyzed per ecoregion), was based on a compromise between two conflicting objectives: (1) estimating change in land-cover area, and (2) estimating change in landscape pattern. Larger numbers of smaller sample blocks would result in more precise estimates of change in land-cover area, whereas smaller numbers of larger sample blocks would be more desirable for characterizing landscape pattern.

Size of Samples

In the initial study design, a 20 × 20 km (400 km^2) sample-block size was used, and nine ecoregions were analyzed, each analysis consisting of 9 to 11 sample blocks. On the basis of results from these initial ecoregion analyses, a decision was made to use a higher density of smaller (10 × 10 km; 100 km^2) sample blocks for the remainder of the ecoregion analyses in order to maximize the precision of the land-cover change estimates.

Sampling Density

The sampling density was determined by both the project requirements for precision in the change estimates and the expected characteristics of change within the ecoregion being studied. As precision requirements increase, so must the sampling density. Similarly, a greater sampling density is required when areas of change are expected to be less evenly distributed throughout an ecoregion.

In this study, the target precision level was to map gross overall change to within a ±1% margin of error at an 85% confidence level for each ecoregion. On the basis of this target precision level and the expected characteristics of change within all 84 ecoregions in the conterminous United States, it was determined that between 25 and 48 of the 10 × 10 km sample blocks per ecoregion would likely be needed to adequately characterize overall change in each ecoregion.

Implementation of the Sampling Strategy

The sampling strategy outlined above was fairly straightforward to implement. A regular grid of 10 × 10 km (or, in a few cases, 20 × 20 km) sample blocks was overlain on an ecoregion map of the conterminous United States. Blocks whose centers fell within the boundaries of an ecoregion were highlighted as potentially valid sample blocks for that ecoregion and then were assigned a unique numerical value from 1 to N. A random number generator was then used to select sample blocks, one at a time, until the desired number was reached. Thus, each sample block within an ecoregion had an equal probability of being included in the final sample analysis.

Although the number of sample blocks selected and analyzed was based on both the target precision level and the expected characteristics of change within the ecoregion, unexpected heterogeneity in the distribution of change could still result in the estimates of change having levels of precision that are lower than desired. Should this occur, the sampling strategy allowed for the selection and interpretation of additional sample blocks. The inclusion of these reserve blocks allowed the analysis to achieve change estimates that have acceptable levels of precision. In actuality, for various reasons, no reserve blocks were implemented.

Geographic Framework

A central premise of the study design was the use of a geographic framework to provide regional land-cover change estimates. Geographers have long used regional frameworks because they capture the essence and potential of the landscape without masking the roles of environmental, social, and economic forces (Turner and Meyer, 1991). This "Status and Trends of Land Change" study chose to use ecoregions, as originally defined by Omernik (1987) and later modified by the U.S. Environmental Protection Agency (1999), as the framework from which to tell the regional story of change.

Ecoregions were chosen as the unit of analysis because (1) they provide a means to localize estimates of the rates and driving forces of change, (2) they were developed by synthesizing information on a wide variety of factors (for example, climate, geology, physiography, soils, vegetation, hydrology, and human influences) and, therefore, should reflect both current land-use and land-cover types and future change trajectories, and (3) they provide a framework that can be extended globally.

Landsat Data

Landsat satellite imagery was the primary source of data used for detecting land-cover change in this study. Data from the Landsat Multispectral Scanner (MSS), Thematic Mapper (TM), and Enhanced Thematic Mapper Plus (ETM+) instruments were acquired from the Landsat data archive: Landsat MSS datasets are available from late-1972 through late-1992; Landsat TM data are available from 1982 to 2012; and Landsat ETM+ data are available from 1999 to the present (2015). Each of these products provided a consistent, synoptic, multispectral view of the land surface from which land cover could be interpreted for the period between 1972 and 2000. To analyze trends in land-use/land-cover change throughout this period, five target study dates spaced at semiregular intervals (1973, 1980, 1986, 1992, and 2000) were selected. Landsat imagery corresponding to each 10 × 10 km (or 20 × 20 km) sample block was extracted from full Landsat scenes, resulting in five dates of satellite imagery for each sample block. To reduce expenses, the initial data-acquisition strategy was to use existing geoprocessed Landsat datasets as the primary input data source. Four of the five dates of Landsat MSS, TM, and ETM+ data were available in a geocoded format as a result of processing done for two previous projects: (1) the North American Landscape Characterization (NALC) project produced 1973, 1986, and 1992 geocoded Landsat MSS datasets for the conterminous United States and Mexico (Lunetta and others, 1998), and (2) the 1992 TM and 2000 ETM+ data came from the Multiresolution Landscape Characterization initiative (Loveland and Shaw, 1996). New 1980 Landsat MSS acquisitions were obtained in order to maintain the six- to eight-year interval between the five target dates.

The Landsat MSS, TM, and ETM+ scenes obtained were previously georeferenced to root-mean-square error of 1 pixel or less but to differing map projections. For this study, all scenes were translated to a common Albers equal-area projection. Most of the NALC MSS data had also been terrain-corrected, but approximately one-third of the NALC data (path and rows) had been processed before the implementation of terrain-correction techniques. However, this was not considered a problem because the early NALC scenes were located primarily in areas with negligible terrain variability.

Ancillary Data

Additional ancillary data were acquired to aid interpreters in delineating land use and land cover from the Landsat data. For example, aerial photography was acquired for each sample block to provide a high-resolution data source to help with difficult interpretations. The National Aerial Photography Program (NAPP) generally provided one or two dates of color-infrared (CIR) and (or) black-and-white aerial photographs from 1987 to the present. The National High Altitude Photograph (NHAP) Program generally provided one date of CIR and (or) black-and-white aerial photographs between 1980 and 1986. Although the Landsat imagery was always used as the source material for delineating land use and land cover, these higher resolution aerial photographs were invaluable for assisting in the interpretation of the imagery. Topographic maps, census data, other electronic sources of aerial photographs (for example, Google Earth), and digital raster graphics were among the other sources of information that interpreters found useful when processing the data.

Land-Cover Classification Scheme

The analysis of land use and land cover change during the 1973 to 2000 study period was based on classifications of land cover for the five target dates mentioned previously. The classification system used consists of the following 11 general land-cover classes: water, developed, mechanically disturbed, mining, barren, forest, grassland/shrubland, agriculture, wetland, nonmechanically disturbed, and ice/snow. See appendix 3, entitled “Land-Cover Classification System Used in ‘Status and Trends of Land Change’ Study,” for definitions of these 11 classifications.

Two primary factors affected the design of the classification system. The first factor was recognizing that the use of moderate-resolution Landsat imagery would necessitate a land-cover classification system that was fairly general in order to achieve high interpretation accuracy and consistency. The ability to identify and map land cover would be limited both by the technical specifications of the Landsat MSS, TM, and ETM sensors and by the local and regional landscape characteristics that affect the form and contrast visible in satellite imagery. This would be especially true when interpreting Landsat MSS data.

The second factor involved choosing land-cover classes that captured the land-cover changes of interest. Because the project’s interest was in land-use change, with land cover serving as a surrogate for land use, the decision was to use the Anderson Level I classes (Anderson and others, 1976) because they were designed as use surrogates. However, the Anderson system was selectively modified by adding two disturbance categories, mechanically disturbed (human induced) and nonmechanically disturbed (natural).

Manual Land-Cover Delineation

Land-cover delineation for each sample block began with the creation of a baseline reference land-cover dataset. The 1992 date usually was the starting point owing to the availability of the 30-m-resolution 1992 National Land Cover Data (NLCD) dataset (Vogelmann and others, 2001). The NLCD dataset provided a starting template after the more detailed NLCD classes were aggregated to match the general land-cover classification described above.

The NLCD data first were manually edited on the computer screen, using on-screen interpretation methods, while using the 1992 Landsat TM data and the NAPP aerial photographs as interpretation aids. This cleanup procedure to improve the NLCD classification accuracy was carried out because the NLCD data were created using automated image-processing procedures, and they were not meant for use in local- or ecoregional-scale assessments. A minimum mapping unit of 60 × 60 meters was used for this study. Thus, features having ground footprints less than 60 m wide generally were not mapped, resulting in the exclusion of high-contrast features such as roads, which have a distinct spectral signature but have ground dimensions of less than 60 m.

To carry out the NLCD editing for a particular sample block, the analyst displayed the NLCD data alongside the 1992 Landsat TM data on the computer screen. These data sources, along with hard-copy prints of NAPP aerial photography roughly corresponding to the 1992 date, were visually inspected by the analyst to determine if any corrections were needed in the sample block. The analyst manually delineated polygons that consisted of contiguous blocks of specific land-cover classes. Each of these polygons was then given a code value that corresponded to the land-cover classes outlined in the classification scheme in appendix 3. The process continued until the entire sample block was manually inspected, mapped, and coded by the analyst.

To analyze change, land-cover classes for the 1973, 1980, 1986, and 2000 study dates were backward- or forward-classified using the 1992 land-cover dataset as the template. For example, creation of the 2000 land-cover product began by making an exact copy of the 1992 land-cover product. This copy served as a baseline for the 2000 land-cover product, in which identified changes between 1992 and 2000 were manually edited into the copied image. This baseline 2000 land-cover product was displayed on screen, along with the 1992 Landsat imagery and the 2000 Landsat imagery, allowing the analyst to pan through the entire area of the sample block while examining the 1992 and 2000 Landsat imagery and any relevant aerial photography for valid land-cover changes between the two study dates. Any identified land-cover changes were manually digitized on screen, and the land cover was recoded on the 2000 land-cover product.

Upon completion of the 2000 land-cover product, the same procedures were used to create the 1986, 1980, and 1973 land-cover products. This manual process eliminated errors that may occur between independently created land-cover products that are compared in a subsequent change analysis. Because only manually identified, delineated, and coded land-cover changes were analyzed during this phase, classification errors were greatly reduced.

Statistical Analysis

The resulting land-cover data for each sample block was used in postclassification comparisons to determine change between study years (fig. 2). Sample blocks within each ecoregion were used to generate change statistics for all 84 ecoregions. These statistics were used to determine the predominant types of land-cover conversions occurring within each ecoregion, the estimated rates of change for these conversions, and whether these types and rates of change are constant or variable across time. The analysis of change also involved looking for spatial correlations between conversion types and selected socioeconomic and environmental factors, such as timber production, agricultural yields, precipitation amounts, population levels, proximity to urban development, and overall economic conditions, in order to improve the understanding of potential drivers of change.

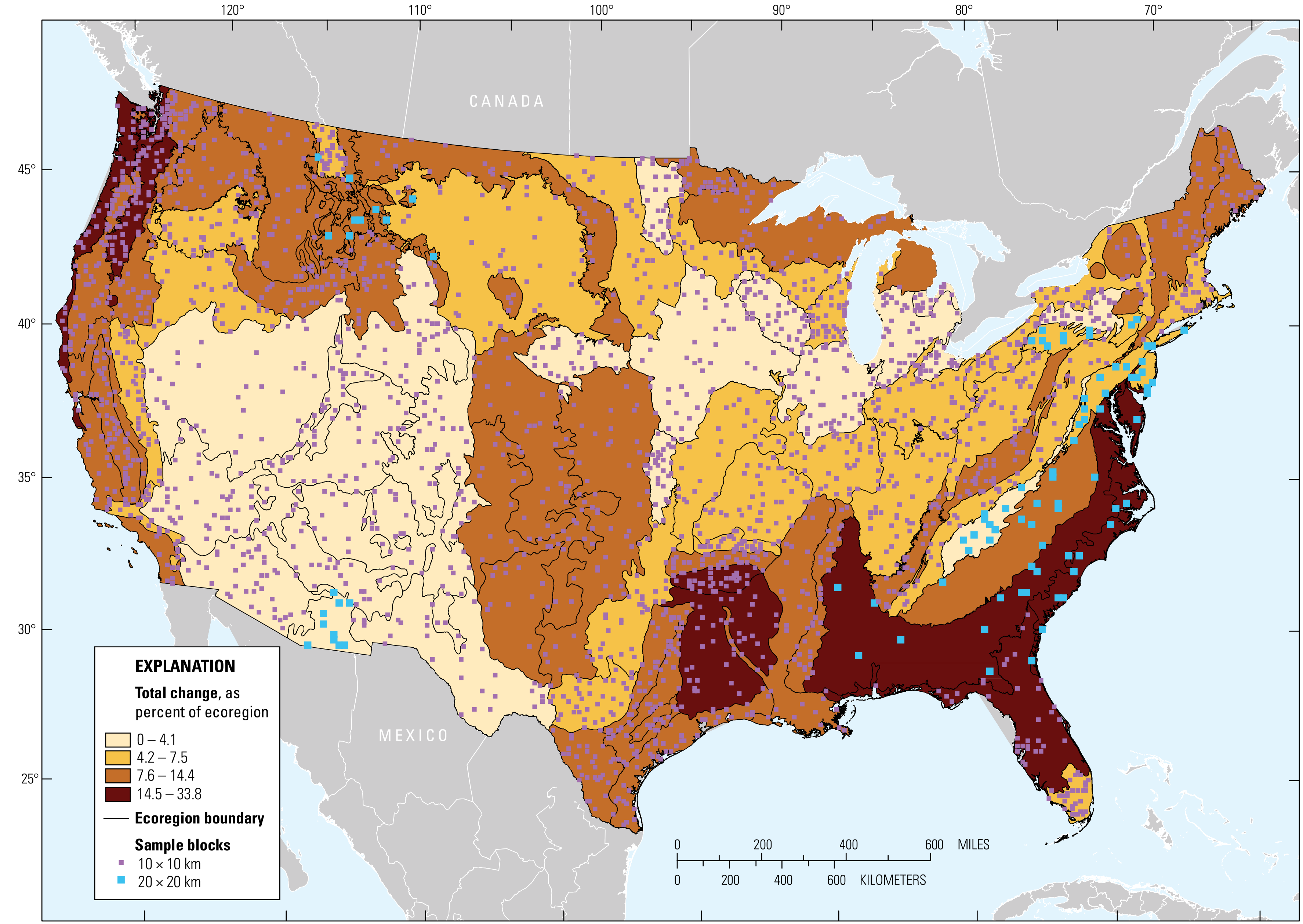

Figure 4.1. Map of ecoregions in conterminous United States, showing locations of 2,688 sample blocks that were used in “Status and Trends of Land Change” study (purple and blue squares indicate locations of 10 × 10 km and 20 × 20 km sample blocks, respectively). Also shown are amounts of total change in each ecoregion between 1973 and 2000, as percent of ecoregion.

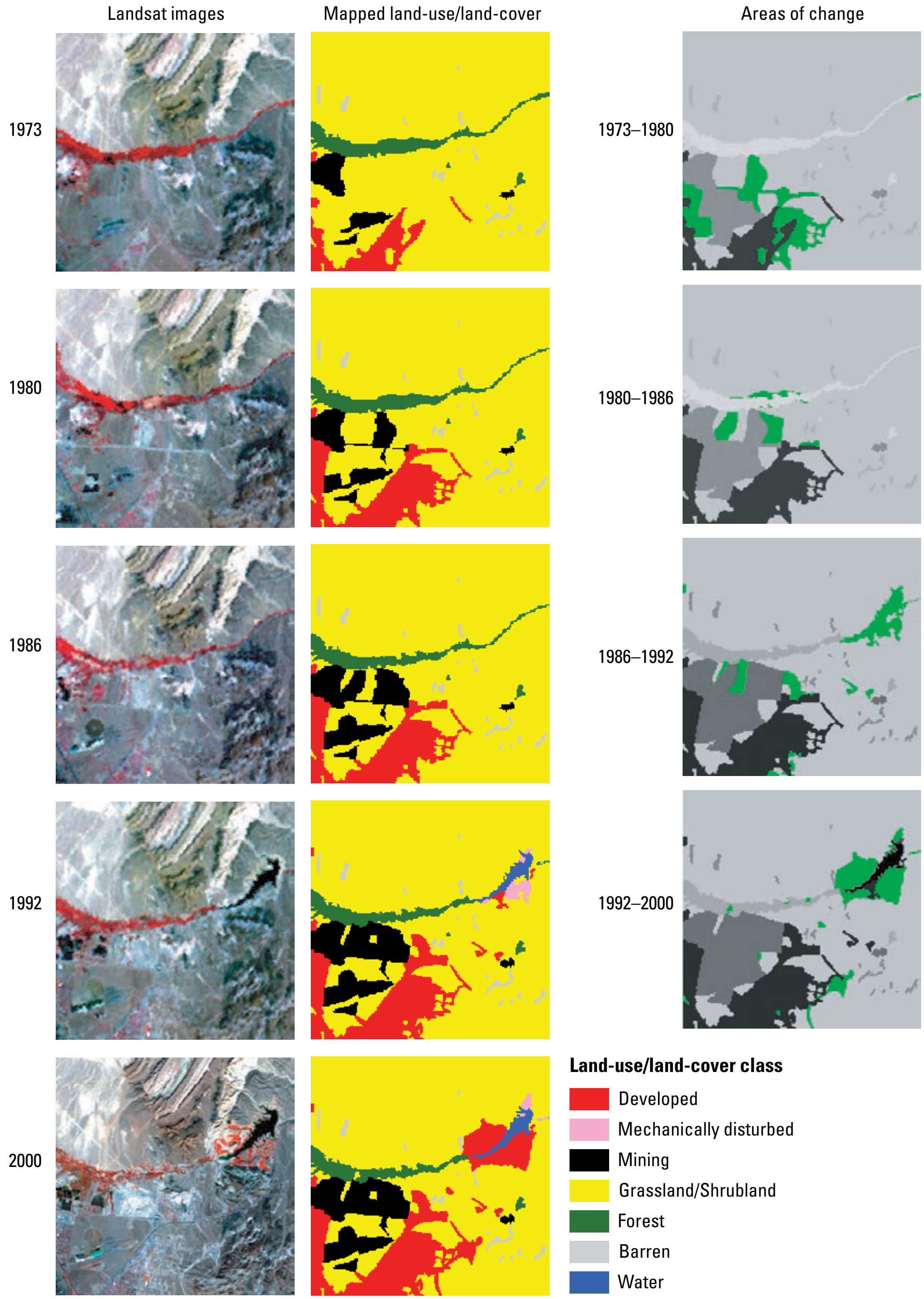

Figure 4.2. Example of data compiled for each sample block, showing sample block 14-0555 (located near Henderson, Nevada, in Mojave Basin and Range Ecoregion, one of Western United States ecoregions). Left column is satellite imagery collected for each of five years analyzed in study (imagery sources for study years: 1973, 1980, and 1986 are Landsat Multispectral Scanner (MSS) images; 1992 is Landsat Thematic Mapper (TM) image; 2000 is Landsat Enhanced Thematic Mapper (ETM) image). Center column is mapped land-use/land-cover data for each study year. Right column shows areas that changed (green areas) in each of four time periods between study years; light- and dark-gray-shaded areas show areas of previous change and represent overall land-change footprint throughout study period.

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