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Status and Trends of Land Change in the Great Plains of the United States—1973 to 2000

Professional Paper 1794–B

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

Status and Trends of Land Change in the Great Plains of the United States—1973 to 2000

Edited by Janis L. Taylor, William Acevedo, Roger F. Auch, and Mark A. Drummond

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SALLY JEWELL, Secretary

U.S. Geological Survey
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Cover:
Field of sunflowers in Elbert County, Colorado, about 80 km east of Colorado Springs, Colorado. Photograph taken in 2006.

Inside cover:
Wheat fields, with Sweet Grass Hills in background, in Liberty County, Montana, about 25 km north of Chester, Montana, and about 25 km south of Canadian border. Photograph taken in 2005.

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.

Acting Director, USGS

Preface

U.S. Geological Survey (USGS) Professional Paper 1794–B is the second 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 Great Plains of the United States between 1973 and 2000. Volumes A, C, and D provide similar analyses for the Western United States, the Midwest–South Central 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 Great Plains of the 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 Great Plains of the 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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Contents

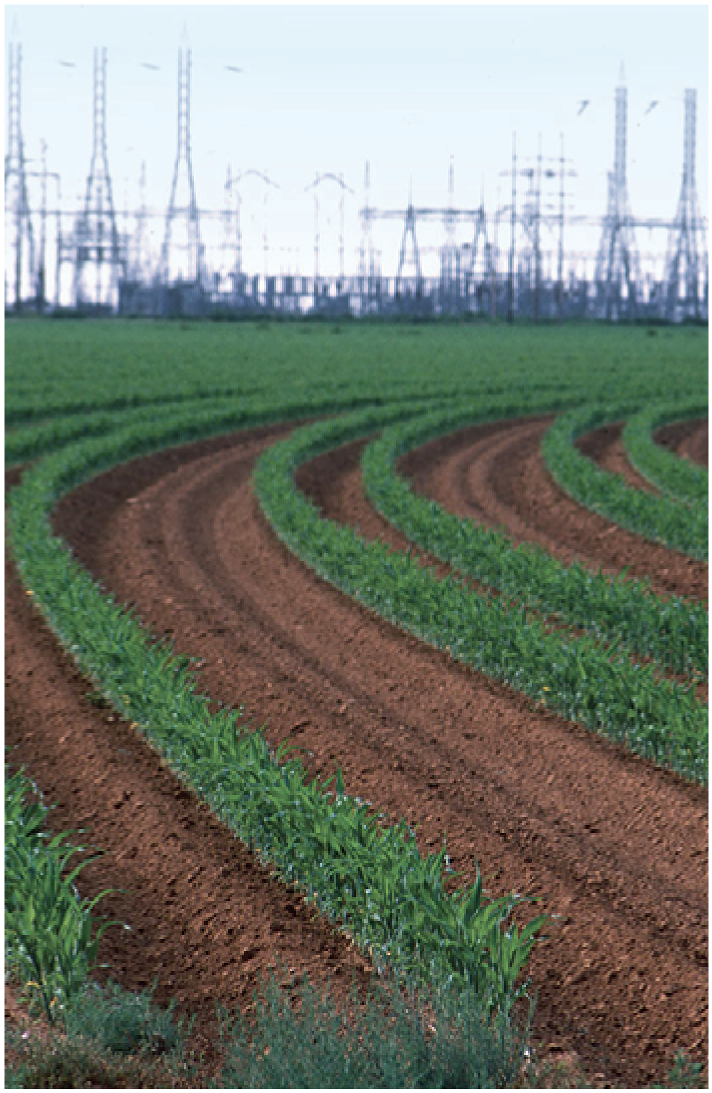
Conversion Factors

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	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 Great Plains of the United States—1973 to 2000

By Mark A. Drummond and Roger F. Auch

Introduction

One of the important stories of the Great Plains of the United States is the geographic and temporal variability of recent land-use and land-cover change, including the underlying causes of land conversion. Because it is an agricultural region, land use in the Great Plains depends in large part on the available natural resources, as well as the inherent suitability of the region for crop production and rangeland grazing. Areas that have favorable soils and climate have had a long history of cultivation, whereas areas that are unsuitable for crops often are used for livestock grazing. Given a range of conditions and land-use regimes across such a large expanse, analysis shows distinct regional characteristics of land change that also vary across relatively short time scales, as human activities intersect with the environmental setting. The prevailing climate and other biological and physical factors (for example, precipitation variability, soil quality, water availability, and topography) affect in complex ways the actions of people and society (for example, public policies, regional and global economic opportunities, population and demographic change, technological advances, and local cultural histories) and, thus, can control the rates and characteristics of land-use and land-cover change.

The Great Plains as a geographic region has been variously defined (Rossum and Lavin, 2000). The region generally lies between the dense forests of the East and the mountains and deserts of the West. The vast, flat-to-rolling plains are used primarily for cropland, rangeland, and settlements. Weather can be extreme, and drought periodically affects the region. Precipitation amounts, which are limited in the western plains that sit in the rain shadow of the Rocky Mountains, increase toward the east, and temperature has a strong north-south gradient. The northeastern and extreme northern parts of the Great Plains are glaciated areas that have numerous “prairie pothole” wetlands, and they have more cropland than the western plains. The western plains primarily are a semiarid shortgrass steppe in which both streamside and groundwater irrigation from the High Plains (Ogallala) aquifer are important in places. Shrubland and forest are more prevalent in the southeastern part of the Great Plains where land-use practices and fire suppression have encouraged woody encroachment (Engle and others, 2008). Few large cities are situated in the interior plains, and population loss is a concern in numerous communities. Most large population centers in the Great Plains are on the fringes of the plains, especially in the southeastern part.

Beyond these broad generalizations, many areas within this expansive region have contrasting socioeconomic and environmental characteristics that potentially can have different effects on their land-use/land-cover trends. Ecoregions—that is, areas that are similar in their biotic-, abiotic-, terrestrial-, and aquatic-ecosystem components, with humans considered as part of the biota (McMahon and others, 2001)—serve as useful entities for studying regional land-use/land-cover change, as they can encapsulate both the similarities and differences in the range of potential land-use/land-cover changes that are likely to occur regionally (Gallant and others, 2004).

To understand the rates, types, and causes of land change, as well as to aid in assessing the consequences of change, the U.S. Geological Survey interpreted and analyzed trends of land-use/land-cover change, using the U.S. Environmental Protection Agency’s Level III Ecoregions (Omernik, 1987; U.S. Environmental Protection Agency, 1999) as the spatial stratification. A statistical sampling approach was used, in part, to account for the large amount of error that can occur in assessing wall-to-wall change for multiple time-steps across large regions (Stehman and others, 2005). For the 17 ecoregions in the Great Plains of the United States, a set of 10 × 10 km sample blocks was randomly selected for each ecoregion from a uniform grid. Within each sample block, land use/land cover was mapped, and its changes were interpreted, at a 60-m resolution using Landsat Multispectral Scanner, Thematic Mapper, and Enhanced Thematic Mapper Plus satellite data for five study dates:1973, 1980, 1986, 1992, and 2000. A detailed explanation of project methodology can be found in appendix 4 (see also, Loveland and others [2002] and Stehman and others [2003]). The approach provides a systematic basis for understanding land-use/land-cover change and can aid in managing and planning for future human-environmental interaction.

Regional Synthesis

The U.S. Geological Survey analyzed land-use/land-cover change for 17 ecoregions in the Great Plains of the United States as part of a national assessment of land change (fig. 1*A*). For purposes of discussion, the 17 Great Plains ecoregions, which cover about 2,231,159 km^2 (861,455 mi^2), have been

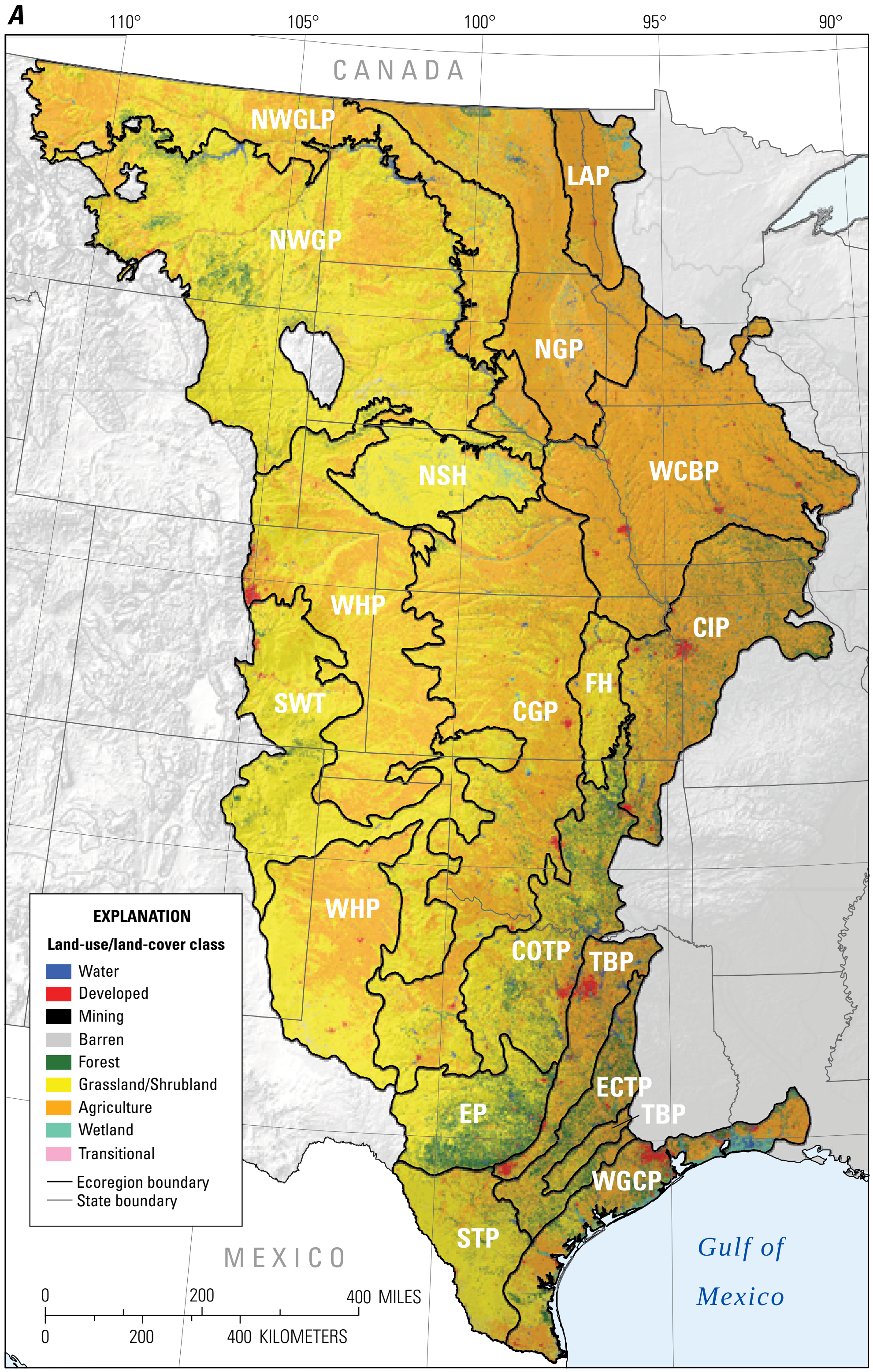


Figure 1. *A*, Map of all 17 ecoregions in Great Plains of United States, showing land-use/land-cover classes from 1992 National Land-Cover Database (Vogelmann and others, 2001); note that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. *B*, Map showing four main Great Plains ecoregion groups, modified from U.S. Environmental Protection Agency's (1997) Level II Ecoregions for Great Plains of United States. Within each ecoregion group, individual ecoregions share many similar physical and biological characteristics. *C*, List of four main Great Plains 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*.

divided into four main groups, within which the ecoregions share many similar physical and biological characteristics: the Western Plains Ecoregions, the Glaciated Plains Ecoregions, the East-Central Plains Ecoregions, and the Southern Plains Ecoregions (fig. 1*B*).

Agriculture and grassland/shrubland are the dominant land-cover classes in the Great Plains ecoregions (fig. 2). A substantial shift between the amount of both agriculture land cover, which includes all cropland and related agricultural uses except rangeland, and grassland/shrubland land cover occurred over the 27-year study period (table 1). Agriculture was the dominant land-cover class mapped in the 1973, 1980, and 1986 study dates. The total percentage of agriculture in the ecoregions increased from 46.0 percent in 1973 to 46.4 percent in both 1980 and 1986. Grassland/shrubland became the dominant land-cover class by 2000 when it reached its greatest extent of 44.4 percent of the ecoregions. Taken together, grassland/shrubland and agriculture make up more than 88 percent of all land cover in the Great Plains ecoregions (fig. 3).

The total extent of forest land cover in the ecoregions was 5.8 percent in 2000, a slight decline from 1973 (5.9 percent). The total extent of water land cover in the ecoregions remained at 1.8 percent between 1973 and 1992, increasing to 2.1 percent in 2000. Developed land cover increased steadily in the ecoregions, increasing from 1.1 percent in 1973 to 1.5 percent in 2000. Wetland land cover was relatively consistent (1.8 percent, decreasing to 1.6 percent in 2000) through the study period (fig. 4), as was barren land cover, which remained at 0.6 percent. All other land-cover classes remained at or below 0.1 percent of the ecoregions (table 1). Because the biological and physical underpinnings, as well as the socioeconomic factors, vary across all the ecoregions, land-use/land-cover change in the Great Plains can be further understood by examining individual ecoregions.

Overall, an estimated 8.4 percent (186,616 km^2) of land cover in the Great Plains ecoregions changed at least once between 1973 and 2000 (table 2). However, the overall amount of change varied substantially across the 17 Great Plains ecoregions (fig. 5). The ecoregion that experienced the highest amount of change was the Northwestern Glaciated Plains Ecoregion, at 14.1 percent, and the ecoregion that experienced the lowest amount of change was the Lake Agassiz Plain Ecoregion, at 1.5 percent. Both of these ecoregions are part of the Glaciated Plains Ecoregions group, which includes areas of Wisconsin-age glaciation and former glacial lakes in the northern and northeastern parts of the Great Plains.

Across the Great Plains, the characteristics of land-cover change varied from ecoregion to ecoregion, depending on both biological and physical factors. For example, the four ecoregions that had overall spatial change amounts of less than 5 percent have contrasting characteristics that constrain land-cover change and enable stability. For example, the Western Corn Belt Plains Ecoregion (3.2 percent overall spatial change) and the Lake Agassiz Plain Ecoregion (1.5 percent overall spatial change) have level topography and glacial-till soils that are well suited for intensive cultivation. Conversely, the Nebraska Sand Hills Ecoregion (4.0 percent overall spatial change) and the Flint Hills Ecoregion (2.2 percent overall spatial change) have hilly topography and poor soils, a combination that constrains cultivation in favor of rangeland use and grassland maintenance. However, both types of characteristics (prime cropland versus historical rangeland) resulted in relatively stable land-use patterns and low rates of change.

Ecoregions that have high rates of spatial change tend to have lands that are marginal for agriculture. Under adverse climatic or economic conditions, these marginal lands either cease to be viable cropland or are subject to other land-change processes. For example, fluctuations between grassland/shrubland and agriculture in the Northwestern Glaciated Plains Ecoregion (14.1 percent overall spatial change) and the Western High Plains Ecoregion (12.5 percent overall spatial change) contributed to the high rates of overall spatial change as marginal lands were brought into and out of production, depending on changing commodity prices, farm practices, and farm-program incentives. Cyclical clearance of mesquite (*Prosopis* spp.), juniper (*Juniperus* spp.), and scrub oak (*Quercus* spp.) for rangeland improvement and to enhance water availability contributed to the high rates of change in four of the ecoregions in the Southern Plains Ecoregions group, particularly in the Southern Texas Plains

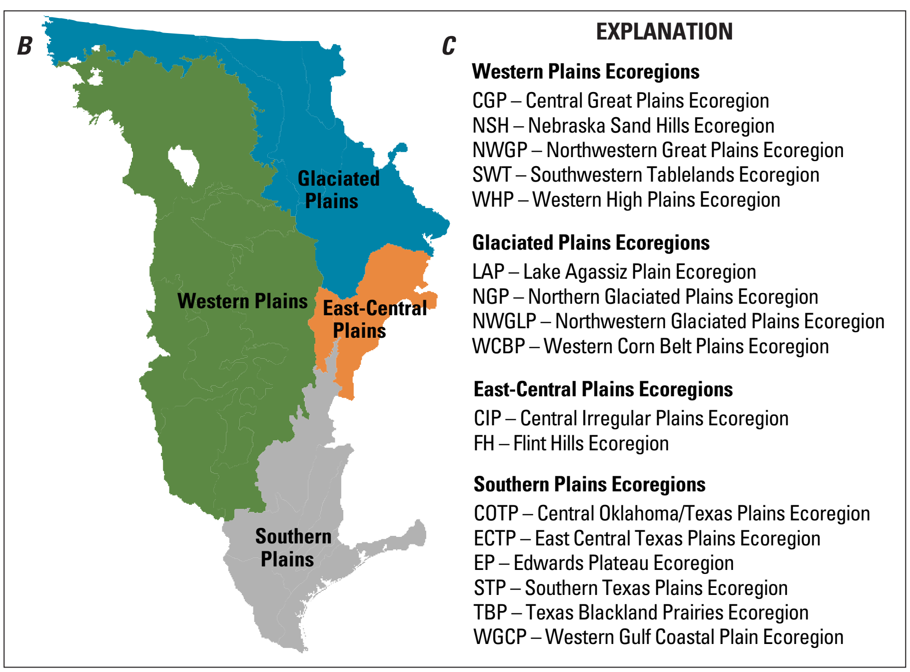


Figure 1.—Continued

Table 1. Areal percentages of land-use/land-cover classes in all 17 Great Plains 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 Great Plains 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	1.8 [0.5]	1.8 [0.5]	1.8 [0.5]	1.8 [0.4]	2.1 [0.5]
Developed	1.1 [0.2]	1.2 [0.2]	1.3 [0.3]	1.4 [0.2]	1.5 [0.2]
Mechanically disturbed	0.0 [<0.1]	0.0 [<0.1]	0.0 [<0.1]	0.1 [<0.1]	0.1 [<0.1]
Mining	0.1 [<0.1]	0.1 [<0.1]	0.1 [<0.1]	0.1 [<0.1]	0.1 [<0.1]
Barren	0.6 [0.3]	0.6 [0.3]	0.6 [0.3]	0.6 [0.3]	0.6 [0.3]
Forest	5.9 [0.4]	5.9 [0.4]	5.8 [0.4]	5.8 [0.4]	5.8 [0.4]
Grassland/Shrubland	42.7 [1.6]	42.2 [1.6]	42.1 [1.2]	44.2 [1.6]	44.4 [1.6]
Agriculture	46.0 [1.6]	46.4 [1.6]	46.4 [1.6]	44.2 [1.6]	43.8 [1.6]
Wetland	1.8 [0.2]	1.8 [0.2]	1.8 [0.2]	1.8 [0.2]	1.6 [0.2]
Nonmechanically disturbed	0.1 [>0.1]	0.0 [0.0]	0.0 [0.0]	0.0 [<0.1]	0.0 [<0.1]

Figure 2. Dryland agriculture in Northwestern Great Plains Ecoregion.

Figure 3. Livestock grazing in Western Gulf Coastal Plain Ecoregion.

Figure 4. Wetland area in Nebraska Sand Hills Ecoregion. Wetlands dot many Great Plains ecoregions, providing vital habitat for birds and other wildlife.

Ecoregion (12.0 percent overall spatial change) where woody vegetation is removed periodically, often through state-funded brush-control programs.

Population changes in smaller cities across the Great Plains, and in the Southern Plains Ecoregions group in particular, affected the conversion of agriculture and grassland/shrubland. For example, in the Texas Blackland Prairies Ecoregion (11.1 percent overall spatial change), urbanization of former agriculture land made up a large component of change. The Western High Plains Ecoregion (12.5 percent overall spatial change) has had the most land enrolled in the Conservation Reserve Program (CRP) since it was enacted by Congress in 1985 to provide economic incentive to convert environmentally sensitive cropland from agriculture to perennial grassland/shrubland cover.

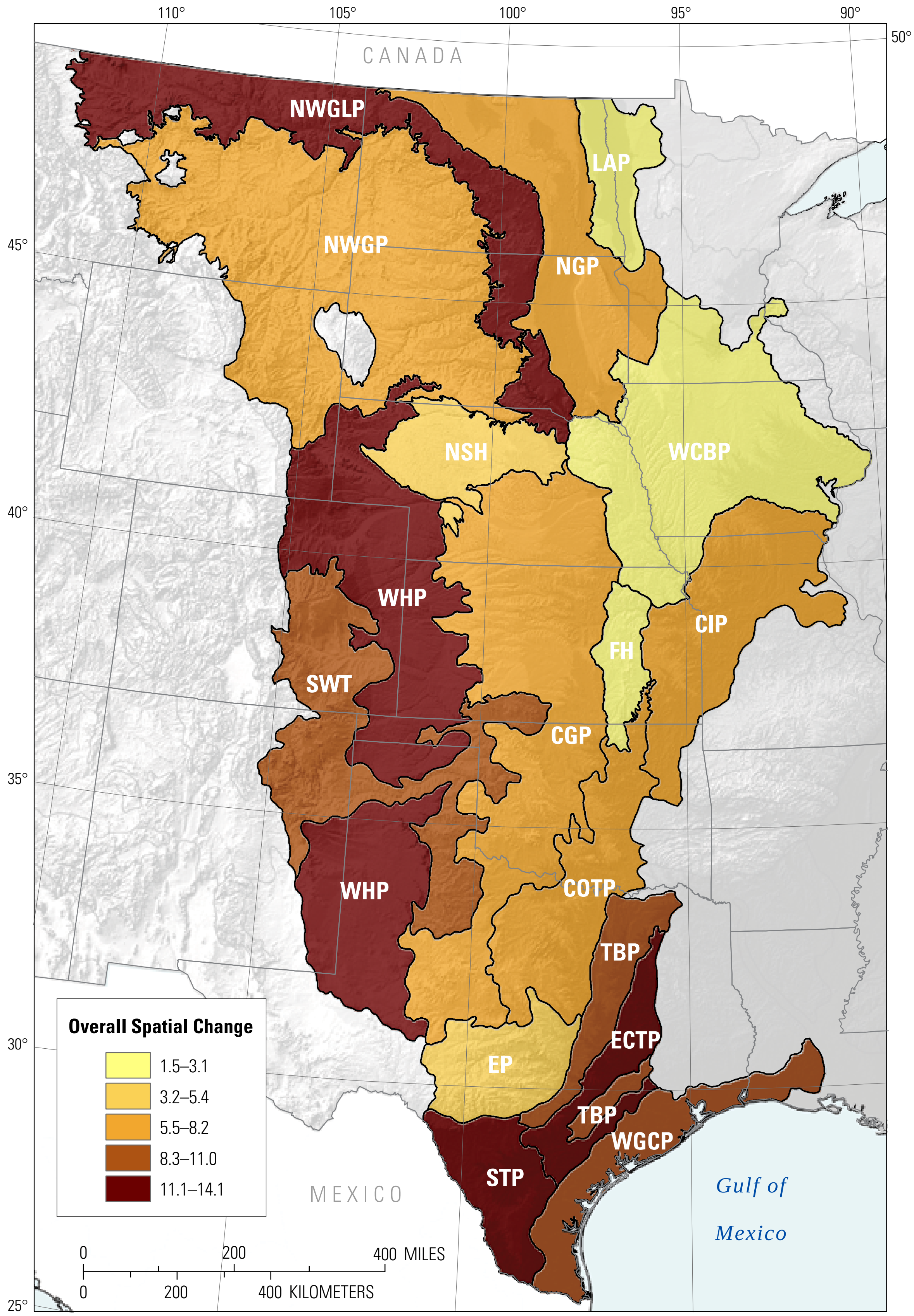


Figure 5. Map showing overall spatial change, as percent of ecoregion area, for each of 17 Great Plains ecoregions over entire study period (1973–2000).

Table 2. Overall spatial change in each Great Plains 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 (km²)	Overall spatial change [margin of error]	
			(km²)	(% of ecoregion)
Western Plains Ecoregions				
Western High Plains Ecoregion		288,752	36,094 [6,641]	12.5 [2.3]
Southwestern Tablelands Ecoregion		159,938	14,075 [3,679]	8.8 [2.3]
Central Great Plains Ecoregion		273,189	22,675 [3,825]	8.3 [1.4]
Northwestern Great Plains Ecoregion		346,883	25,669 [6,938]	7.4 [2.0]
Nebraska Sand Hills Ecoregion		60,541	2,422 [908]	4.0 [1.5]
	Totals	1,129,304	100,934 [11,293]	8.9 [1.0]
Glaciated Plains Ecoregions				
Northwestern Glaciated Plains Ecoregion		160,684	22,656 [3,535]	14.1 [2.2]
Northern Glaciated Plains Ecoregion		141,341	10,459 [1,979]	7.4 [1.4]
Western Corn Belt Plains Ecoregion		216,363	6,924 [1,731]	3.2 [0.8]
Lake Agassiz Plain Ecoregion		40,636	610 [163]	1.5 [0.4]
	Totals	559,024	40,649 [4,472]	7.3 [0.8]
East-Central Plains Ecoregions				
Central Irregular Plains Ecoregion		122,589	8,949 [2,452]	7.3 [2.0]
Flint Hills Ecoregion		27,911	614 [140]	2.2 [0.5]
	Totals	150,500	9,563 [2,408]	6.4 [1.6]
Southern Plains Ecoregions				
Central Oklahoma/Texas Plains Ecoregion		103,412	6,722 [1,241]	6.5 [1.2]
East Central Texas Plains Ecoregion		44,076	5,333 [793]	12.1 [1.8]
Southern Texas Plains Ecoregion		54,744	6,569 [1,369]	12.0 [2.5]
Texas Blackland Prairies Ecoregion		50,501	5,606 [1,313]	11.1 [2.6]
Western Gulf Coastal Plain Ecoregion		80,965	8,016 [1,781]	9.9 [2.2]
Edwards Plateau Ecoregion		58,634	3,225 [704]	5.5 [1.2]
	Totals	392,333	35,470 [2,311]	9.0 [0.8]
All Great Plains ecoregions		2,231,161	186,616 [10,639]	8.4 [0.5]

Water availability in the Great Plains from streams and aquifers, which include the immense High Plains (Ogallala) aquifer and also the Missouri and Platte Rivers, enabled the expansion of intensive irrigation (fig. 6) and contributed to the conversion of grassland/shrubland to agriculture (Dennehy and others, 2002). However, water scarcity in the Western High Plains Ecoregion, caused in some areas by historically high rates of water use, also constrained expansion (fig. 7). Climate variability played a role as well, and changes in precipitation patterns resulted in both wetland conversion and lake expansion in the Northern Glaciated Plains Ecoregion (7.4 percent overall spatial change).

Changes throughout the entire 27-year study period resulted in net increases in grassland/shrubland, developed, water, mining, and mechanically disturbed land-cover classes (table 3; fig. 8). Grassland/shrubland also experienced the greatest amount of gross change, followed closely by agriculture (table 4). Net change in land cover is a measure of the end result of conversions associated with each land-cover class, whereas gross changes indicate the total area of change (table 4), which can be much larger than the net change (for example, timber-harvest cycles and also the cyclic transitions between agriculture and grassland/shrubland). In addition, expansions in some locations often are counteracted by declines in others; the unidirectional, relatively permanent conversion to developed land is a notable exception.

Table 3. Net areal changes in land-use/land-cover classes in all 17 Great Plains ecoregions during each of four time periods and corresponding margin-of-error values for 85-percent confidence interval (in brackets).

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

Land-use/land-cover class	Net change [margin of error] (km^2)			
	1973–1980	1980–1986	1986–1992	1992–2000
Water	–200 [589]	1,278 [749]	–743 [1,486]	5,573 [1,585]
Developed	2,686 [791]	1,628 [370]	2,003 [473]	3,234 [667]
Mechanically disturbed	172 [292]	101 [316]	656 [977]	–48 [1,057]
Mining	286 [112]	386 [183]	323 [142]	412 [127]
Barren	–75 [169]	–367 [233]	499 [540]	–89 [393]
Forest	–1,253 [311]	–567 [376]	–804 [404]	–1,083 [349]
Grassland/Shrubland	–9,780 [3,417]	–2,952 [3,277]	46,853 [7,084]	4,730 [5,262]
Agriculture	9,249 [2,780]	967 [3,268]	–49,506 [7,094]	–9,438 [5,166]
Wetland	305 [529]	–473 [486]	682 [740]	–3,596 [1,332]
Nonmechanically disturbed	–1,390 [1,992]	0 [0]	36 [37]	305 [452]

Figure 6. Irrigation of cropland in Central Great Plains Ecoregion.

Figure 7. Open rangeland in Western High Plains Ecoregion.

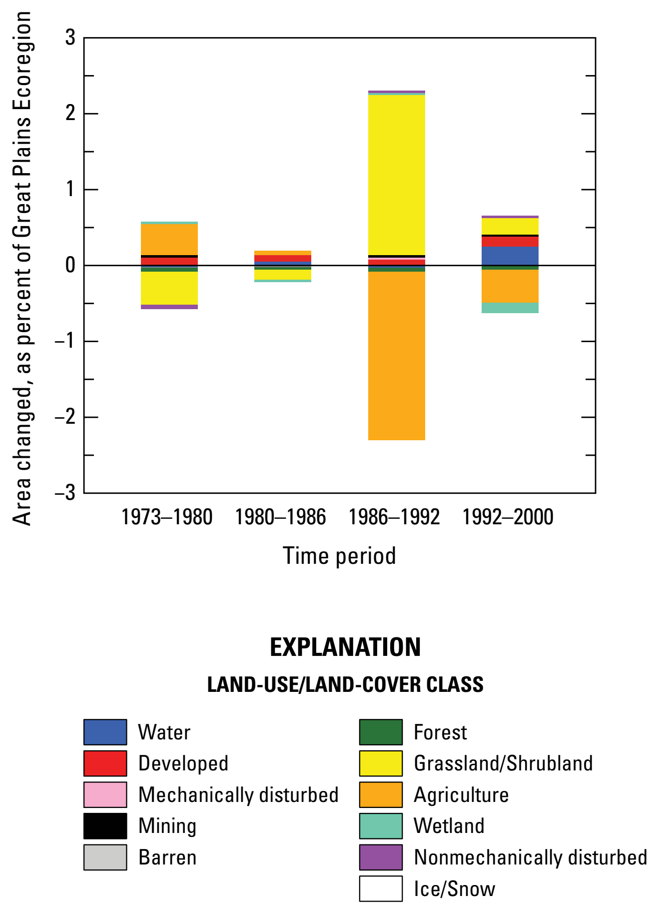


Figure 8. Estimated net change in all 17 Great Plains ecoregions by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use/land-cover classifications.

Table 4. Gross spatial changes and net areal changes in land-use/land-cover classes in all 17 Great Plains ecoregions for entire study period (1973 to 2000) and corresponding margin-of-error values for 85-percent confidence interval (in brackets).

[Percentages are of total area in all Great Plains 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	14,833 [2,360]	0.7 [0.1]	5,908 [1,802]	14.7
Developed	9,602 [1,789]	0.4 [0.1]	9,551 [2,012]	38.3
Mechanically disturbed	4,524 [1,384]	0.2 [0.1]	880 [436]	136.5
Mining	2,372 [452]	0.1 [<0.1]	1,407 [389]	116.6
Barren	2,636 [917]	0.1 [<0.1]	–33 [611]	–0.2
Forest	11,999 [1,369]	0.5 [0.1]	–3,706 [911]	–2.8
Grassland/Shrubland	159,861 [10,634]	7.2 [0.5]	38,851 [9,938]	4.1
Agriculture	156,841 [10,648]	7.0 [0.5]	–48,728 [9,812]	–4.8
Wetland	12,917 [2,125]	0.6 [0.1]	–3,081 [1,356]	–7.7
Nonmechanically disturbed	1,766 [2,065]	0.1 [0.1]	–1,049 [2,042]	–75.5

Agriculture Land-Cover Class

The agriculture land-cover class, one of two primary land-cover classes in the Great Plains ecoregions, declined 2.2 percent (49,086 km^2) between 1973 and 2000, which was the greatest amount of net change, and it had a gross change of 7.0 percent (156,841 km^2), the second highest amount (table 4). Only three ecoregions had a net gain in agriculture throughout the entire study period: the Nebraska Sand Hills Ecoregion (1.5 percent), the Southern Texas Plains Ecoregion (1.0 percent), and the Edwards Plateau Ecoregion (0.6 percent). In most ecoregions, agriculture expanded between 1973 and 1980, a period in which overseas grain exports provided new economic opportunities and public policies encouraged farmers to expand their land in cultivation. Some expansion continued between 1980 and 1986 in several ecoregions, although at a slower rate. The earlier gains in agriculture were more than offset between 1986 and 2000 by conversions from agriculture to grassland/shrubland. In the Edwards Plateau Ecoregion, forest clearance and agricultural expansion were the leading changes between 1973 and 2000.

Between 1973 and 1986, much of the increase in agriculture occurred in the Western Plains Ecoregions group, which had substantial amounts of land that was marginal for cultivation. Conversely, ecoregions that had an advantageous climate, as well as level topography and suitable soils (for example, the Western Corn Belt Plains and Lake Agassiz Plain Ecoregions), tended to be relatively stable or have small declines in agriculture. The largest decline in agriculture between 1973 and 1986 occurred in the Texas Blackland Prairies Ecoregion, which also had a substantial increase in development that continued throughout the entire study period.

Between 1986 and 1992, when the Conservation Reserve Program (CRP) took effect, all ecoregions lost agriculture land cover, and most continued to decline between 1992 and 2000. The total amount of CRP land in the United States reached a plateau in the early 1990s. The extent of CRP lands varied across the Great Plains: the Western High Plains Ecoregion had the most land enrolled in the program (9.5 percent), and the Edwards Plateau Ecoregion had the least (0.0 percent) (U.S. Department of Agriculture, 1920–2002 [various years]). Although the most common conversion during the 27-year study period was from agriculture to grassland/shrubland (106,603 km^2), agriculture declines also were caused by urbanization, land abandonment, reservoir construction, wetland expansion, and mining. The trends of change during all four time periods indicate that land cover in the Great Plains ecoregions is capable of significant fluctuation, which is enabled by both their underlying biological and physical factors and the pressures of land-use and socioeconomic change (fig. 9).

Grassland/Shrubland Land-Cover Class

The grassland/shrubland land-cover class had the highest amount of gross change in the Great Plains ecoregions between 1973 and 2000, at 7.2 percent (159,861 km^2); in addition, it had the second highest amount of net change, at 1.7 percent (37,930 km^2) (table 4). In many regards, the characteristics of land-cover change in grassland/shrubland are inverse to those in agriculture (fig. 10). The total area of grassland/shrubland declined between

1973 and 1986 as agriculture expanded, but, after 1986, grassland/shrubland expanded greatly owing to a decline in agriculture land cover. For example, in the semiarid Western High Plains Ecoregion, agriculture gained nearly 1.6 percent from grassland/shrubland as irrigation expanded between 1973 and 1980; however, this was followed by expansion of grassland/shrubland between 1986 and 2000, affecting about 7.5 percent of the ecoregion. Overall, the extent of grassland/shrubland change was highest in the Great Plains ecoregions between 1986 and 1992, supporting the premise that the CRP and other drivers of agricultural abandonment were important forces of grassland/shrubland change, including those changes that stem from the ongoing intensification, industrialization, and consolidation of agriculture.

Across the Great Plains ecoregions, grassland/shrubland converted to developed (3,152 km^2) and to forest (2,958 km^2), although the net result was often an increase in grassland/shrubland because of its gains from agriculture. For example, the Texas Blackland Prairies Ecoregion had a net gain in grassland/shrubland during each time period as agriculture

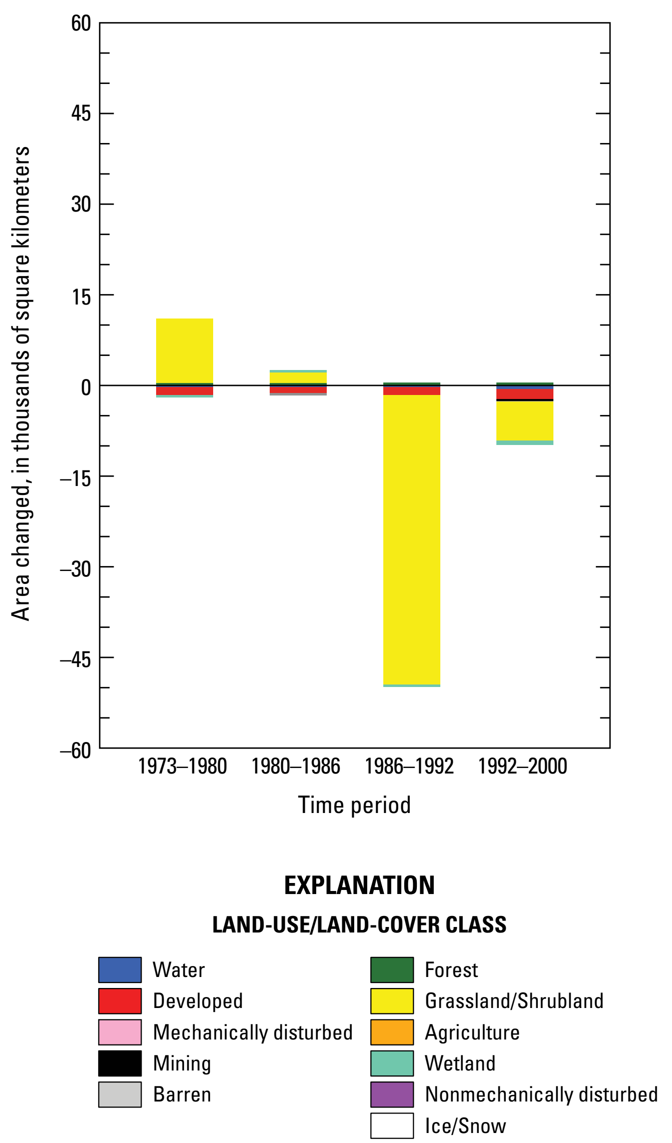


Figure 9. Gross change (area gained from, and lost to, other land-cover classes) in agriculture land-cover class in all 17 Great Plains ecoregions over entire study period (1973–2000). Colored bars above zero axis indicate land-cover classes that lost area to agriculture and amounts of area lost, whereas colored bars below zero axis indicate land-cover classes that gained area from agriculture and amounts of area gained.

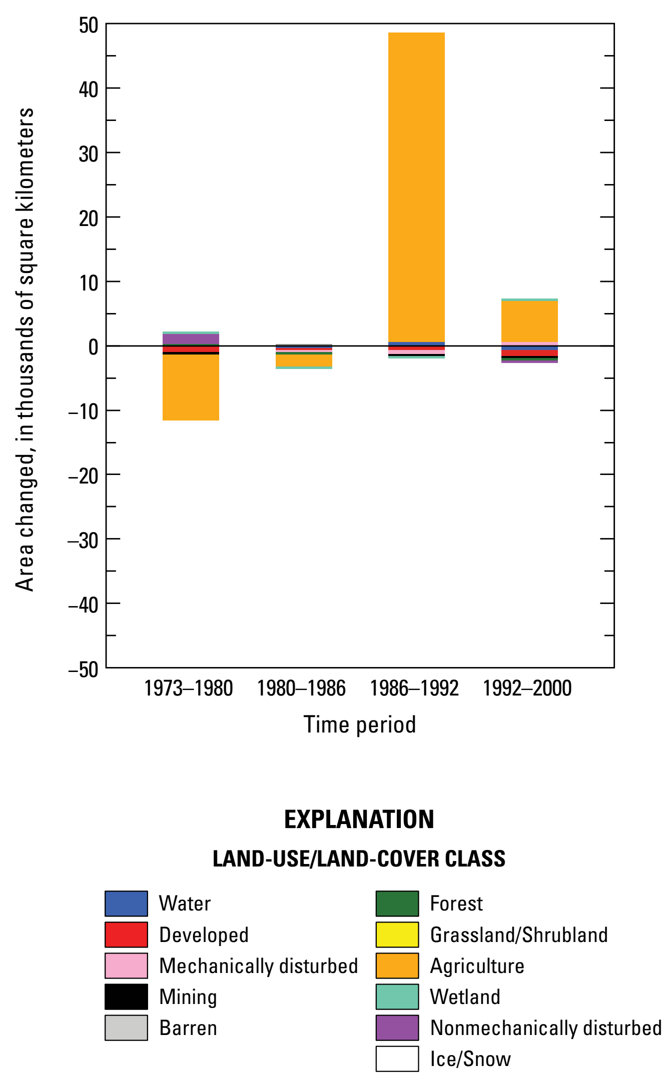


Figure 10. Gross change (area gained from, and lost to, other land-cover classes) in grassland/shrubland land-cover class in all 17 Great Plains ecoregions over entire study period (1973–2000). Colored bars above zero axis indicate land-cover classes that lost area to grassland/shrubland and amounts of area lost, whereas colored bars below zero axis indicate land-cover classes that gained area from grassland/shrubland and amounts of area gained.

was abandoned or deintensified, despite a relatively large amount of urban expansion. Additional gross land-cover changes involving grassland/shrubland were found primarily in the Southern Plains Ecoregions group as a result of brush removal, a cyclical change that involves the conversion of grassland/shrubland to mechanically disturbed and then back to grassland/shrubland (4,524 km²) (fig. 11).

Grassland/shrubland either increased or was relatively constant in most ecoregions, the exception being small declines in the Central Great Plains Ecoregion (–0.1 percent), the Southern Texas Plains Ecoregion (–0.9 percent), and the Nebraska Sand Hills Ecoregion (–1.4 percent). Decreases in the Southern Texas Plains Ecoregion were caused by brush removal for livestock grazing and invasive-species control, as well as for agricultural expansion and increases in developed land and mining. Grassland/shrubland in the sparsely populated Nebraska Sand Hills Ecoregion declined primarily as cropland expanded along the margins of the ecoregion.

Developed Land-Cover Class

Across the Great Plains ecoregions, new developed land for commercial, industrial, residential, transportation, water treatment, and other similar land uses increased by 0.4 percent (9,551 km²) of the total area between 1973 and 2000 (fig. 12). As a percentage of change, the area of developed land-cover class increased by 38.3 percent from its estimated 1973 extent. New developed land was found primarily around regional and subregional centers of service, retail, and manufacturing that are located in micropolitan (that is, populations of at least 10,000 but less than 50,000) and metropolitan (that is, populations of 50,000 or more) areas. At least 106 micropolitan areas and 46 metropolitan areas are within, or partly within, the Great Plains ecoregions (U.S. Census Bureau, 2003).

Other developed land included recreational areas and, in some cases, additional industrial infrastructure. Some increases in amenity-based development occurred in localized areas, usually around existing or newly built reservoirs. In

Figure 11. Brush clearance in Southern Texas Plains Ecoregion.

Figure 12. Urban expansion in Texas Blackland Prairies Ecoregion.

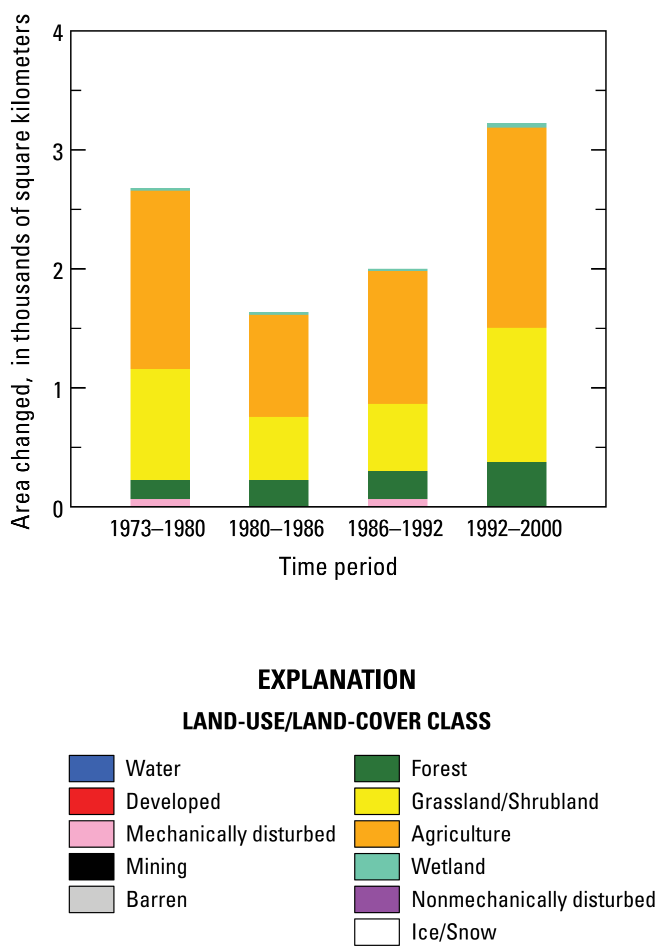


Figure 13. Average annual gains in developed land-cover class from other land-cover classes in all 17 Great Plains ecoregions over entire study period (1973 to 2000). Colored bars indicate land-cover classes that lost area to developed land and amounts of area lost.

addition, several isolated industrial complexes (for example, power plants) were built between 1973 and 2000. Some sections of the original interstate highway system were completed during the first two time periods (1973–1980, 1980–1986), and subsequent additions of major multilane roads to federal and state highway systems occurred throughout the entire study period.

Between 1973 and 2000, 97 percent of the new developed land cover came from three sources (fig. 13): developed gained an estimated 5,176 km^2 from agriculture, an estimated 3,152 km^2 from grassland/shrubland, and an estimated 983 km^2 from forest. The ratios of conversion to new developed land remained relatively stable across the entire study period, although the conversion of forest to developed increased from 6.6 percent during the first time period (1973–1980) to 12.0 percent thereafter.

The Texas Blackland Prairies Ecoregion had the greatest increase in developed land cover, gaining 1,919 km^2 (3.8 percent), which is about 20 percent of the net increase in developed land in the Great Plains ecoregions. The Texas Blackland Prairies Ecoregion includes an axis of large urban areas in Texas, from Dallas in the north, through Austin, to San Antonio in the south. In terms of increased developed land, other leading ecoregions include the East Central Texas Plains Ecoregion (1.3 percent) and the Western Gulf Coastal Plain Ecoregion (1.2 percent). Growth in the Western Gulf Coastal Plain Ecoregion included coastal industrial and amenity-based development. However, sparsely populated ecoregions such as the Northwestern Great Plains, the Northwestern Glaciated Plains, and the Southwestern Tablelands Ecoregions experienced only small increases (less than 0.5 percent of ecoregion area) in developed land, especially those ecoregions that contain extensive rangeland.

Water Land-Cover Class

Climate in the Great Plains ecoregions, which ranges from semiarid to humid, can be highly variable both spatially and temporally, having long periods of drought in some ecoregions and cycles of above-average precipitation in others. Because of climate variability, many ecoregions rely on water storage in reservoirs to irrigate crops, as well as for livestock, for confined-feeding operations, and for household consumption. All of these water uses are related to land change.

Overall, the changes affecting the water land-cover class accounted for an estimated 14,833 km^2 of the total gross land-cover change detected in the 17 Great Plains ecoregions between 1973 and 2000. Total net change, an increase of 0.3 percent, was much less, at an estimated 5,908 km^2.

The top two changes affecting water land cover were both associated with wetland land cover. The wetland-to-water conversion was the leading change (8,494 km^2), and the water-to-wetland conversion was the second-leading change (4,541 km^2), both of which occurred primarily in the Glaciated Plains Ecoregions group. Much of this change was driven by climatic conditions that varied between dry years, which caused lakes and ponds to become seasonal wetlands, and wet years, which caused open water to persist in wetland areas. The wetter-than-normal conditions during the 1990s in the Northern Glaciated Plains Ecoregion and the Northwestern Glaciated Plains Ecoregion (located in the "prairie pothole" region of the northern Great Plains) accounted for most of the wetland-to-water expansion (Garbrecht and Rossel, 2002).

The Northwestern Great Plains Ecoregion, which contains four of the six main-stem reservoirs along the Missouri River, experienced similar water and wetland changes, but for slightly different reasons. Decreases in upstream water availability caused by regional droughts and exacerbated by the resulting decreases in mountain snowpack, as well as changes in reservoir management in response to these conditions, likely contributed to decreased reservoir storage. As water levels dropped, wetland vegetation grew in embayments formed by tributary streams. These changes took place in the late 1980s and early 1990s; however, the reservoirs had mostly recovered by the year 2000 (U.S. Army Corps of Engineers, 2004).

Conversions of grassland/shrubland to water, agriculture to water, and water to grassland/shrubland were the third-, fourth-, and fifth-leading changes, respectively, that affected the water land-cover class in the Great Plains ecoregions. Changes from grassland/shrubland to water across the ecoregions were caused primarily by the construction of new reservoirs and also by flooding from expanding lakebeds. A large number of small reservoirs, commonly called "stock dams" or "stock tanks," were built for livestock water supply, especially in more arid ecoregions such as the Northwestern Great Plains, Central Great Plains, Southern Texas Plains, and Southwestern Tablelands Ecoregions. Larger, multiuse reservoirs also were built. In addition, natural flooding of grassland/shrubland occurred primarily in the Glaciated Plains Ecoregions group, where wetter-than-normal years caused some lakebeds of glacial origin to increase in size. These water bodies may persist as larger surface areas for years before cyclical climatic conditions (for example, periods of drought or below-normal precipitation) reduce their size (Todhunter and Rundquist, 2004; Shapley and others, 2005). Conversions of water to grassland/shrubland resulted when reservoirs, especially small "stock dams," dried up during periods of below-normal precipitation. Overall, water land cover experienced a small net gain of an estimated 440 km^2 from grassland/shrubland land cover between 1973 and 2000.

Wetland Land-Cover Class

Changes in the wetland land-cover class, the fifth-leading gross change in the Great Plains ecoregions, are closely associated with changes in the water land-cover class. As a percentage of land area in the 17 Great Plains ecoregions, wetland land cover decreased by 0.1 percent. As a percentage of the wetland areas in 1973, wetland land cover had decreased by an estimated 7.7 percent (3,081 km^2) by the year 2000. The net decline was caused primarily by wetter climatic conditions, which caused wetland areas to be replaced with persistent open water.

Much of the expansion of wetlands occurred in the Northern Glaciated Plains Ecoregion (part of the "prairie pothole" region) in the mid-1980s and mid- to late 1990s, when wetter-than-normal climatic conditions caused many temporary and seasonal wetlands that were previously farmed to stay persistently wet, keeping them out of crop production. The Western Corn Belt Plains Ecoregion, traditionally included in the "prairie pothole" region before its wetlands were mostly drained or modified to enable cultivation in the late 19th and early 20th centuries, also experienced wetland expansion, but it was only a small fraction when compared to the neighboring Northern Glaciated Plains Ecoregion (an estimated 74 km^2 versus 1,356 km^2).

In the Western Gulf Coastal Plain Ecoregion, conversions of agriculture to wetland had different factors that influenced this type of change. Substantial amounts of ground subsidence in coastal areas may have created wetland conditions on former agricultural land (Davidson and Mace, 2006). Several National Wildlife Refuges also were created in the ecoregion, including the Cameron Prairie National Wildlife Refuge in southwestern Louisiana, where former agricultural land was converted back to wetlands (U.S. Fish and Wildlife Service, 2009).

Other changes affecting the wetland land-cover class were conversions from grassland/shrubland to wetland (an estimated gross change of 450 km^2) and wetland to grassland/shrubland (an estimated gross change of 447 km^2). These conversions took place primarily in the Glaciated Plains Ecoregions group, as well as in several ecoregions in the Southern Plains Ecoregions group, as changes in precipitation patterns contributed to fluctuations in wetland extent. Conversions from forest to wetland also occurred in the Southern Plains Ecoregions group, where reservoirs for metropolitan drinking water were constructed. As these reservoirs filled, upland forest areas were drowned and, thus, were replaced by wetland areas.

The Western Gulf Coastal Plain Ecoregion has a wide variety of wetlands within it, some of which include the western range of bald cypress (*Taxodium distichum*), a commercially valuable wetland tree. This ecoregion experienced the highest amount of conversion from wetland to mechanically disturbed land, a result of forest harvest. The Western Gulf Coastal Plain Ecoregion was also the leading ecoregion for conversion from wetland to developed land, primarily caused by increased urbanization and industrial growth.

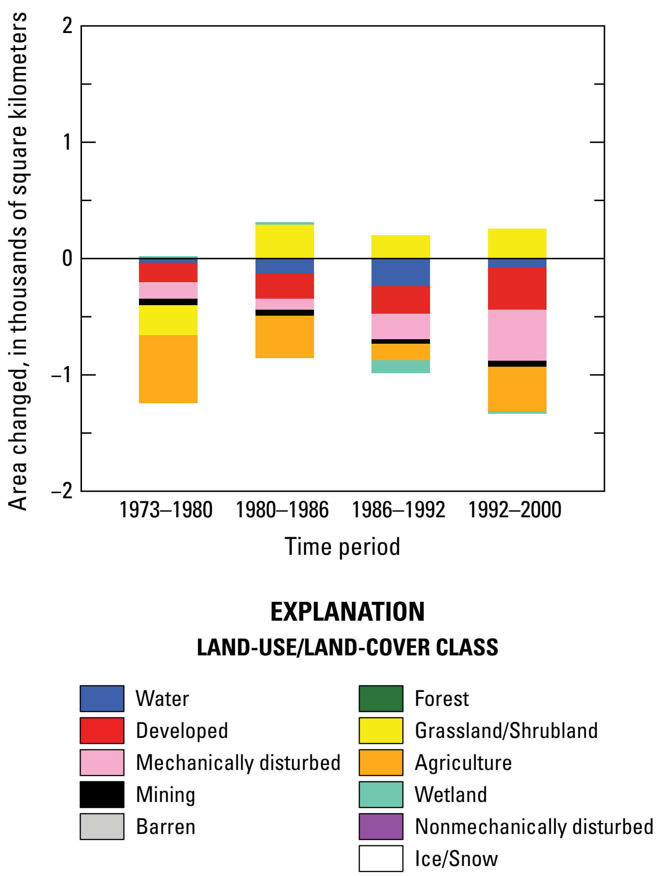


Figure 14. Gross change (area gained from, and lost to, other land-cover classes) in forest land-cover class over entire study period (1973–2000). Colored bars above zero axis indicate land-cover classes that lost area to forest and amounts of area lost, whereas colored bars below zero axis indicate land-cover classes that gained area from forest and amounts of area gained.

Forest Land-Cover Class

A net decline in the forest land-cover class of 0.1 percent (about 3,706 km^2) of the total area of the Great Plains ecoregions occurred during the 27-year study period. However, most forest change was in the Southern Plains Ecoregions group. The largest net decline occurred as agriculture expanded between 1973 and 2000 (about 2,678 km^2). Loss of forest to developed land, clearcutting (mechanically disturbed land), and reservoir construction also made significant contributions to the rates of forest land-cover change (fig. 14).

Mining Land-Cover Class

A net gain in the mining land-cover class of less than 0.1 percent (about 1,407 km^2) of the total area of the Great Plains ecoregions occurred between 1973 and 2000. Although this was a small amount of change, it more than doubled the area of the mining land-cover class. Most of the increase came from the conversion to mining from agriculture and grassland/shrubland. The expansion of quarrying, mineral excavation, and oil and gas extraction provided most of the increase in mining land cover, whereas declines resulted from mine abandonment and the revegetation of reclaimed mine sites. A small amount of mining land cover was abandoned or purposely converted to ponds for recreation or wildlife.

Mechanically Disturbed and Nonmechanically Disturbed Land-Cover Classes

Three main processes resulted in a net expansion in the mechanically disturbed land-cover class and a net decline in the nonmechanically disturbed land-cover class. Expanded forest cutting in the Southern Plains Ecoregions group (1,121 km^2) increased mechanically disturbed land. Large amounts of gross change associated with the cycles of woody-brush clearance and subsequent regrowth resulted in a small net gain of mechanically disturbed land. Changes in nonmechanically disturbed land (about 1,766 km^2 of gross change, and a net-change decline of 1,049 km^2) occurred as grassland/shrubland burned and then reestablished itself following fire disturbance.

Barren Land-Cover Class

A gross change of 2,636 km^2 in the barren land-cover class was associated mostly with fluctuations in the extent of natural water bodies and grassland/shrubland. Transitions to and from barren land caused by changes in precipitation amounts resulted in a small net decline of 33 km^2 of the barren land-cover class.

Summary

The highest amount of land-cover change that took place in the Great Plains ecoregions was due to fluctuations in agriculture, much of it on marginal land, as economic opportunities, sociocultural dynamics, agricultural technologies, and government farm policies changed. Most of the Great Plains ecoregions experienced an overall decline in agricultural land, which was facilitated by the policies and incentives of the Conservation Reserve PrHyperogram. The decline followed an earlier period of agricultural expansion between 1973 and 1980 at the expense of grassland/shrubland.

The drier Western Plains Ecoregions group and the brushy Southern Plains Ecoregions group had relatively high rates of change that reflect substantial fluctuations between agriculture and grassland/shrubland. Ecoregions having biological and physical conditions that were favorable to agriculture tended to have lower rates of change. Variability in precipitation patterns and temperature levels had effects on land-cover change that could be characterized as veiled to obvious. The expansion of surface water area in the Glaciated Plains Ecoregions group was an important story that is tied to both climate and human activity, as reservoirs were constructed throughout the region for flood control, crop irrigation, livestock and residential water supply, and industrial use.

All 17 Great Plains ecoregions saw small but steady increases in the developed land-cover class. Most increases in developed land occurred in the Southern Plains Ecoregions group as urbanization spread onto agricultural land and grassland/shrubland. Cycles of grassland/shrubland clearance in the Southern Plains Ecoregions group also contributed to high rates of gross land-cover change. The trajectories and causes of land-use/land-cover change varied substantially within each ecoregion, giving some indication of the complexity of land-cover-change processes at work across the Great Plains. To aid in the understanding of land-use/land-cover change in greater detail, the remaining chapters in this report contain summaries of change for each of the 17 Great Plains ecoregions; these summaries document the rates, types, and drivers of late 20th century land-use/land-cover change in the Great Plains of the United States.

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Western Plains Ecoregions

Status and Trends of Land Change in the Great Plains of the United States—1973 to 2000
Edited by Janis L. Taylor, William Acevedo, Roger F. Auch, and Mark A. Drummond
U.S. Geological Survey Professional Paper 1794–B, 2015

Chapter 1

Central Great Plains Ecoregion

By Mark A. Drummond

Ecoregion Description

The Central Great Plains Ecoregion is a large, elongated area that covers about 273,189 km^2 (105,479 mi^2) from central Nebraska through Kansas and Oklahoma into north-central Texas (Omernik, 1987; U.S. Environmental Protection Agency, 1997) (fig. 1). The ecoregion is bounded on the west by the Western High Plains and the Southwestern Tablelands Ecoregions; on the north by the Nebraska Sand Hills Ecoregion; on the east by the Western Corn Belt Plains, Flint Hills, and Central Oklahoma/Texas Plains Ecoregions; and on the south by the Edwards Plateau Ecoregion and a small part of the Chihuahuan Deserts Ecoregion (Omernik, 1987).

Agriculture is the primary land use in the Central Great Plains Ecoregion where level topography, water availability, fertile soils, and a long growing season contribute to high productivity among several crops. Overall, about one-half of the ecoregion is in cropland, and much of the other one-half includes confined animal-feeding operations and livestock grazing. Agriculture is aided by warm summer temperatures. With a strong north-south temperature gradient for much of the year, average July temperatures are at or above 27°C for most of the ecoregion. Annual precipitation levels range from about 500 mm (20 in.) per year in the western part of the ecoregion to 800 mm (32 in.) per year in the eastern part (National Atlas of the United States, 2008).

Native grasslands in the ecoregion consist primarily of a mixed-grass prairie that includes little bluestem (*Schizachyrium scoparium*) and grama (*Bouteloua* spp.) grasses, interspersed with mesquite (*Prosopis* spp.) shrublands in the south. Some grasslands and wetlands are managed as protected areas: in particular, the migratory-bird habitat along the Platte River and in the Rainwater Basin Wetland Management District in south-central Nebraska. Millions of water birds migrating along the Central Flyway funnel

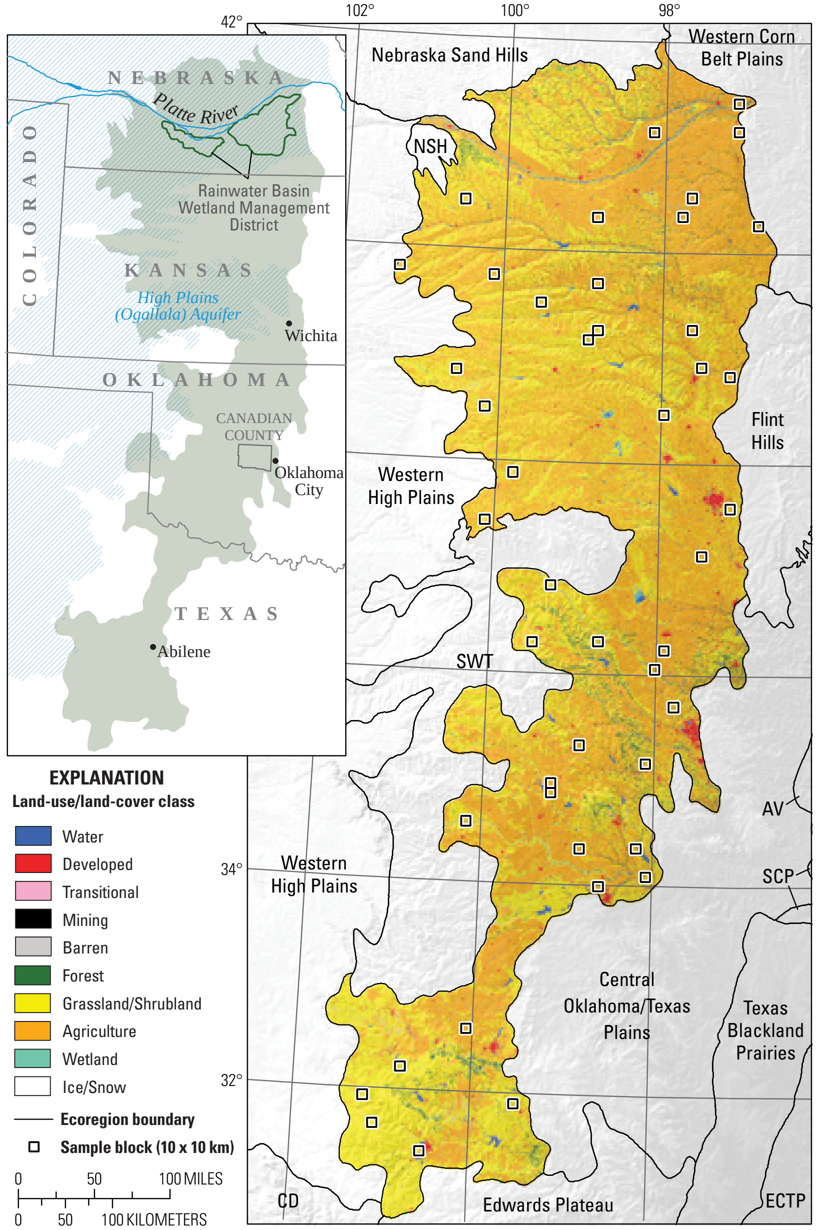

Figure 1. Map of Central Great Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status 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 Great Plains ecoregions are listed in appendix 2. Also shown are parts of one Western United States ecoregion (Chihuahuan Deserts [CD]) and two Midwest–South Central United States ecoregions (Arkansas Valley [AV] and South Central Plains [SCP]). See appendix 3 for definitions of land-use/land-cover classifications.

into this narrow area each spring. Small, shallow playa lakes, which are common throughout the western and central parts of the Great Plains, also provide an ephemeral water source and seasonal-wildlife habitat. Natural and seminatural disturbance regimes that affect vegetation include periodic drought, wildfires that maintain grasslands and prevent encroachment of woody species, and grazing by wildlife and livestock.

The Central Great Plains Ecoregion covers much of the hard winter-wheat area of Kansas and Oklahoma, which is a mainstay of Great Plains agriculture (fig. 2). Wheat crops covered an average of 17.5 percent of the ecoregion during the study period (U.S. Department of Agriculture, 1970–2000 [various years]). In drier areas, wheat fields traditionally have lain fallow every other year, whereas areas of the ecoregion that have adequate moisture grow wheat continuously. Kansas is the top wheat-producing state, and several large grain elevators and flour mills operate in the ecoregion (fig. 3).

Agriculture in the northern part of the ecoregion is heavily irrigated along the Platte River in Nebraska, as well as in areas overlying the eastern extent of the High Plains (Ogallala) aquifer, the largest groundwater complex in the nation, where feed corn is the principal crop (fig. 4). About 30 percent of groundwater used for crop irrigation in the United States is pumped from the High Plains aquifer (Dennehy, 2000), which also underlies the adjacent Western High Plains Ecoregion and the rangelands of the Nebraska Sand Hills Ecoregion.

As with other areas of the Great Plains, water-management issues are central to the Central Great Plains Ecoregion. For example, large-scale confined-feeding operations have expanded in the ecoregion, and they require a readily available source of water, bringing them into competition with other agricultural uses (fig. 5). The area of cropland irrigation also has increased more than 10 times in south-central Kansas, causing declining streamflows and groundwater levels and, thus, affecting water quality (Sophocleous and others, 1999). High evapotranspiration rates and variable amounts of rainfall also increase the need for irrigation. Cotton is an important crop in the southern part of the ecoregion, along with wheat, sorghum, and hay. The Conservation Reserve Program (CRP), which was initiated in 1985 to provide income to farmers for keeping fragile soils and wetlands out of crop production, accounted

Figure 2. Harvesting of winter wheat in Central Great Plains Ecoregion.

Figure 3. Large grain elevator, used to weigh, store, and convey grain, in Central Great Plains Ecoregion.

Figure 4. Furrow irrigation in Central Great Plains Ecoregion.

Figure 5. Confined animal-feeding operation in Central Great Plains Ecoregion.

for 3 percent of the total ecoregion area in 2000 (U.S. Department of Agriculture, 1970–2000 [various years]).

The population of the Central Great Plains Ecoregion was 2.5 million in 2000, a 12 percent increase since 1970; however, 65 percent of the counties lost population (U.S. Census Bureau, 1970–2000 [various years]). Most rural counties that had less than 10,000 people in 1970 lost population by 2000. Although the ecoregion is largely agricultural, modern farming methods often require only a small, seasonal workforce, and many farmers do not live on farms year-round (fig. 6). The consolidation of small family farms into large corporate operations also may account for some of the population shift. The seven largest counties in 1970, having at least 50,000 people, all gained in population by 2000. Canadian County, Oklahoma, gained the most population between 1970 and 2000, from 32,245 to 87,697 people. This 172 percent increase may relate to the proximity of Canadian County to Oklahoma City, Oklahoma, the largest metropolitan area in the ecoregion. Wichita, Kansas, and Abilene, Texas, are other large population centers.

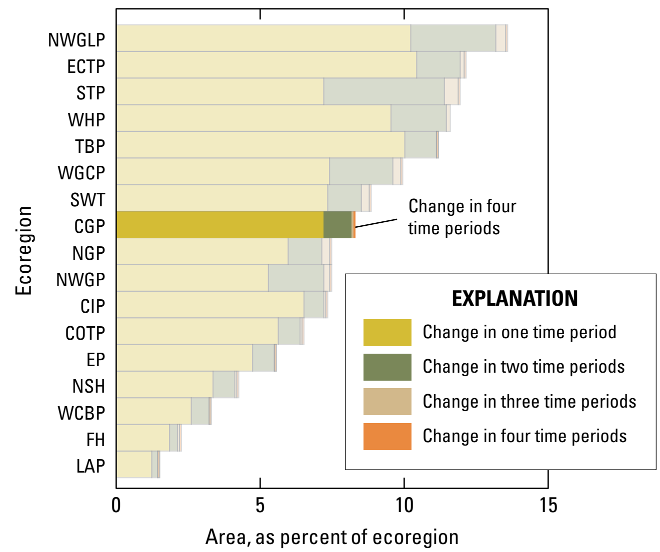

Figure 7. Overall spatial change in Central Great Plains Ecoregion (CGP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Central Great Plains Ecoregion (four time periods) labeled for clarity. See table 4 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 Central Great Plains Ecoregion between 1973 and 2000 is estimated at 8.3 percent (table 1). Compared to other Great Plains ecoregions, change in the Central Great Plains Ecoregion was moderate (fig. 7): most of the area that changed (7.2 percent) did so in only one time period, 0.9 percent changed during two time periods, and 0.1 percent changed during three time periods. Multiple changes were caused mainly by successive conversions between agriculture and grassland/shrubland during two or more time periods but also by natural fluctuations in the surface extent of water and wetland areas. Overall, the estimated annual rates of change during each of the four time periods were relatively consistent (about 0.2–0.3 percent), except between 1986 and 1992 when the annual rate was 0.6 percent of the ecoregion (fig. 8).

Figure 6. Small town in Central Great Plains Ecoregion, many of which are facing dwindling rural populations.

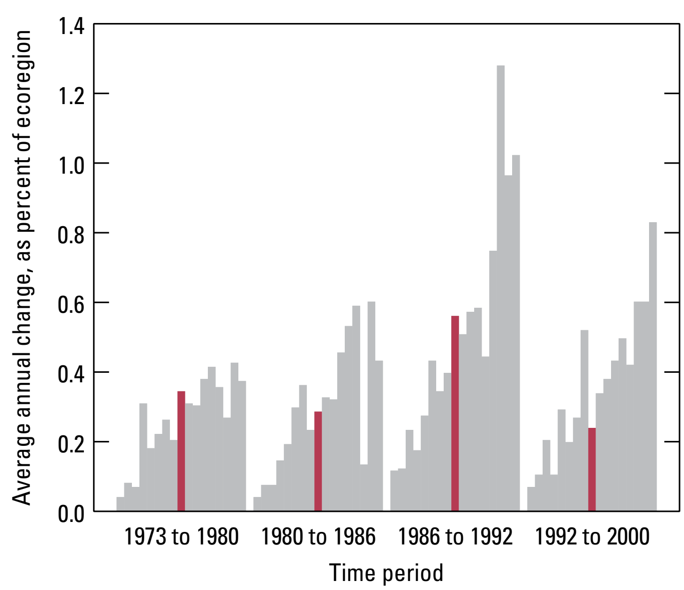

Figure 8. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Central Great Plains Ecoregion are represented by red bars in each time period.

Although most of the land-cover changes were conversions between agriculture and grassland/shrubland, the resulting net changes were relatively small over the entire 27-year study period. The most common land-cover conversion between 1973 and 1980 was grassland/shrubland to agriculture (3,933 km^2) (table 2), a time when export prices for wheat, corn, and soybeans increased substantially. The expansion of economic opportunity contributed to an estimated 1.0 percent decline in grassland/shrubland between 1973 and 1980, from 41.3 percent to 40.3 percent of ecoregion area (table 3). Access to surface water and to High Plains aquifer groundwater, particularly in the northern part of the ecoregion, facilitated an increase in agriculture. Agricultural expansion continued, although at a substantially slower pace (0.1 percent), between 1980 and 1986, a time of financial distress and declining farmland prices. Although the real estate price of farmland during the 1970s had the largest decadal rate of increase on record, farmland values decreased between 1980 and 1986 at the steepest rates on record (nearly 10 percent annually) (Lindert, 1988).

The trend changed significantly between 1986 and 1992, when the CRP was enacted and much agricultural land was converted to grassland/shrubland (6,045 km^2) (table 2). Grassland/shrubland increased by 1.4 percent during this time period (fig. 9); this also was the period that had the highest percentage of total gross change, when 3.4 percent of the ecoregion changed (table 4), caused largely by agricultural land converting to grassland/shrubland through the CRP. Between 1992 and 2000, agriculture had little net change, as some CRP contracts expired and land was returned to crop production while other cropland was newly enrolled in the program.

Over the entire 27-year study period, the dynamics of land-use expansion and decline resulted in a similar amount of conversion from agriculture to grassland/shrubland (10,868 km^2) and from grassland/shrubland to agriculture (10,261 km^2) (table 2). Although the net result was only a small decrease in agriculture, the results suggest that agricultural land-cover class can be quite dynamic, as a substantial amount of marginal land is either in cultivation or abandoned, depending on economic conditions and farm policies.

A loss of 0.6 percent in agricultural land between 1973 and 2000 (fig. 10) was caused by conversion to developed land and by smaller net conversions to grassland/shrubland

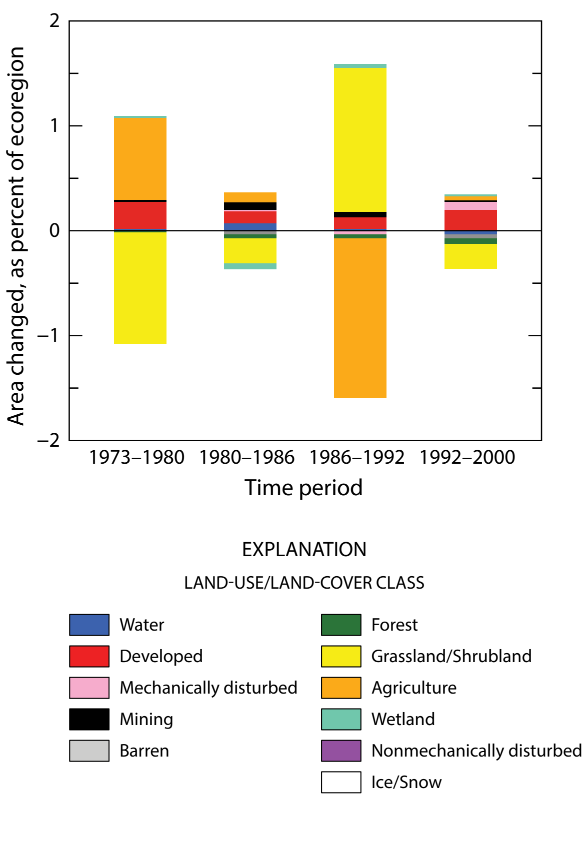

Figure 9. Normalized average net change in Central Great Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

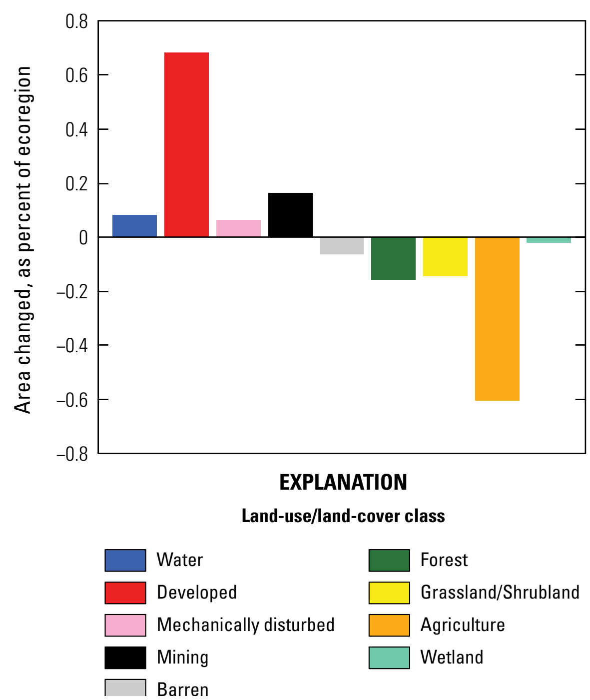

Figure 10. Estimates of net land-cover change in Central Great Plains Ecoregion for each land-cover class between 1973 and 2000. Bars above zero axis represent net gain, whereas bars below zero represent net loss. See appendix 3 for definitions of land-use/land-cover classifications.

and water. The conversion to water primarily was caused by an increase in impounded water. However, agricultural land remained the dominant land-cover class throughout the entire study period (table 3). Grassland/shrubland decreased by 0.1 percent between 1973 and 2000, mostly attributable to the increase in development, mining, and water uses.

Developed land had the highest percentage of net change, with an increase of 0.7 percent (1,869 km^2). Much of the increase in developed land likely is related to urban growth around metropolitan areas, as well as the 12 percent overall increase in the population of the ecoregion. The expansion of developed land generally is a permanent change, whereas spatial changes between agriculture and grassland/shrubland over the long term resulted in much gross change and little net change.

Table 1. Percentage of Central Great Plains 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	7.2	1.1	6.1	8.3	0.8	10.5
2	0.9	0.4	0.6	1.3	0.3	28.2
3	0.1	0.0	0.0	0.1	0.0	35.9
4	0.0	0.0	0.0	0.0	0.0	84.2
Overall spatial change	8.3	1.4	6.8	9.7	1.0	11.8

Table 2. Principal land-cover conversions in Central Great 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	Grassland/Shrubland	Agriculture	3,933	957	654	1.4	59.6
	Agriculture	Grassland/Shrubland	1,514	576	393	0.6	22.9
	Grassland/Shrubland	Developed	396	505	345	0.1	6.0
	Agriculture	Developed	305	378	258	0.1	4.6
	Grassland/Shrubland	Water	50	39	27	0.0	0.8
	Other	Other	401	n/a	n/a	0.1	6.1
		Totals	6,599			2.4	100.0
1980–1986	Grassland/Shrubland	Agriculture	2,026	758	517	0.7	43.1
	Agriculture	Grassland/Shrubland	1,549	381	260	0.6	33.0
	Agriculture	Developed	171	193	132	0.1	3.6
	Wetland	Water	143	202	138	0.1	3.0
	Grassland/Shrubland	Developed	125	166	113	0.0	2.7
	Other	Other	681	n/a	n/a	0.2	14.5
		Totals	4,695			1.7	100.0
1986–1992	Agriculture	Grassland/Shrubland	6,045	2,828	1,930	2.2	65.8
	Grassland/Shrubland	Agriculture	2,125	479	327	0.8	23.1
	Agriculture	Developed	231	276	188	0.1	2.5
	Grassland/Shrubland	Mining	139	100	68	0.1	1.5
	Forest	Agriculture	96	115	79	0.0	1.0
	Other	Other	549	n/a	n/a	0.2	6.0
		Totals	9,185			3.4	100.0
1992–2000	Grassland/Shrubland	Agriculture	2,178	884	604	0.8	41.5
	Agriculture	Grassland/Shrubland	1,761	586	400	0.6	33.5
	Agriculture	Developed	353	269	184	0.1	6.7
	Grassland/Shrubland	Developed	222	245	167	0.1	4.2
	Water	Mechanically disturbed	160	220	150	0.1	3.0
	Other	Other	578	n/a	n/a	0.2	11.0
		Totals	5,251			1.9	100.0
1973–2000	Agriculture	Grassland/Shrubland	10,868	3,662	2,499	4.0	42.2
(overall)	Grassland/Shrubland	Agriculture	10,261	1,925	1,314	3.8	39.9
	Agriculture	Developed	1,061	1,049	716	0.4	4.1
	Grassland/Shrubland	Developed	790	949	648	0.3	3.1
	Forest	Agriculture	338	365	249	0.1	1.3
	Other	Other	2,411	n/a	n/a	0.9	9.4
		Totals	25,730			9.4	100.0

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

	Water		Developed		Mechan-ically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	0.7	0.3	1.0	0.5	0.0	0.0	0.1	0.0	0.7	0.4	2.3	0.5	41.3	5.9	53.4	5.7	0.5	0.5	0.0	0.0
1980	0.7	0.3	1.3	0.7	0.0	0.0	0.1	0.0	0.7	0.4	2.3	0.5	40.3	5.8	54.2	5.7	0.5	0.5	0.0	0.0
1986	0.8	0.3	1.4	0.8	0.0	0.0	0.1	0.1	0.6	0.4	2.2	0.5	40.0	5.8	54.3	5.7	0.4	0.4	0.0	0.0
1992	0.8	0.3	1.5	0.8	0.0	0.0	0.2	0.1	0.6	0.4	2.2	0.5	41.4	5.8	52.8	5.7	0.5	0.4	0.0	0.0
2000	0.8	0.3	1.7	1.0	0.1	0.1	0.2	0.1	0.6	0.4	2.1	0.5	41.2	5.8	52.8	5.7	0.5	0.5	0.0	0.0
Net change	0.1	0.2	0.7	0.5	0.1	0.1	0.2	0.1	–0.1	0.1	–0.2	0.2	-0.1	1.3	–0.6	1.3	0.0	0.0	0.0	0.0
Gross change	0.3	0.2	0.7	0.5	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.2	5.7	1.4	5.8	1.4	0.1	0.1	0.0	0.0
Area, in square kilometers																				
1973	1,878	711	2,788	1,376	0	0	158	73	1,810	1,224	6,245	1,398	112,936	15,984	146,004	15,612	1,371	1,252	0	0
1980	1,940	725	3,492	1,835	10	14	199	95	1,829	1,205	6,185	1,391	110,040	15,808	148,119	15,470	1,377	1,257	0	0
1986	2,151	772	3,790	2,061	74	94	361	193	1,717	1,097	6,094	1,374	109,402	15,853	148,389	15,571	1,212	1,166	0	0
1992	2,205	816	4,079	2,307	1	2	531	311	1,698	1,024	5,978	1,346	113,177	15,913	144,252	15,534	1,269	1,221	0	0
2000	2,099	717	4,657	2,612	179	221	606	346	1,635	980	5,812	1,302	112,540	15,773	144,348	15,447	1,313	1,242	0	0
Net change	221	445	1,869	1,402	179	221	449	311	–175	310	–433	415	–396	3,513	–1,656	3,450	–59	59	0	0
Gross change	855	542	1,869	1,402	327	408	449	311	389	339	468	413	15,491	3,892	15,829	3,854	350	374	0	0

Table 4. Raw estimates of change in Central Great 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	2.4	0.4	2.0	2.8	0.3	12.1	0.3
1980–1986	1.7	0.4	1.4	2.1	0.2	14.4	0.3
1986–1992	3.4	1.0	2.3	4.4	0.7	21.2	0.6
1992–2000	1.9	0.5	1.5	2.4	0.3	16.2	0.2
Estimate of change, in square kilometers							
1973–1980	6,599	1,171	5,429	7,770	799	12.1	943
1980–1986	4,695	989	3,706	5,684	675	14.4	782
1986–1992	9,185	2,858	6,326	12,043	1,951	21.2	1,531
1992–2000	5,251	1,246	4,005	6,497	850	16.2	656

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Status and Trends of Land Change in the Great Plains of the United States—1973 to 2000
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U.S. Geological Survey Professional Paper 1794–B, 2015

Chapter 2

Nebraska Sand Hills Ecoregion

By Janis L. Taylor

Ecoregion Description

The Nebraska Sand Hills Ecoregion covers about 60,541 km^2 (23,375 mi^2), almost entirely within the state of Nebraska (fig. 1). The ecoregion is surrounded by (clockwise, from the north) the Northwestern Great Plains, Northwestern Glaciated Plains, Western Corn Belt Plains, Central Great Plains, and Western High Plains Ecoregions (fig. 1). Nebraska's Sand Hills is an area of grass-stabilized sand dunes considered to be one of the most distinct and homogeneous ecoregions in North America (Omernik, 1987; U.S. Environmental Protection Agency, 1997). According to the Grassland Foundation (2005), Nebraska's Sand Hills is one of the largest and best examples of grasslands left in North America (fig. 2). Topographic relief varies by as much as 60 m, and the sand layers range in thickness from a few meters to more than 122 m (Huntzinger and Ellis, 1993).

Figure 1. Map of Nebraska Sand Hills 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 Great Plains ecoregions are listed in appendix 2. Also shown is part of one Western United States ecoregion, Middle Rockies (MRK). See appendix 3 for definitions of land-use/land-cover classifications.

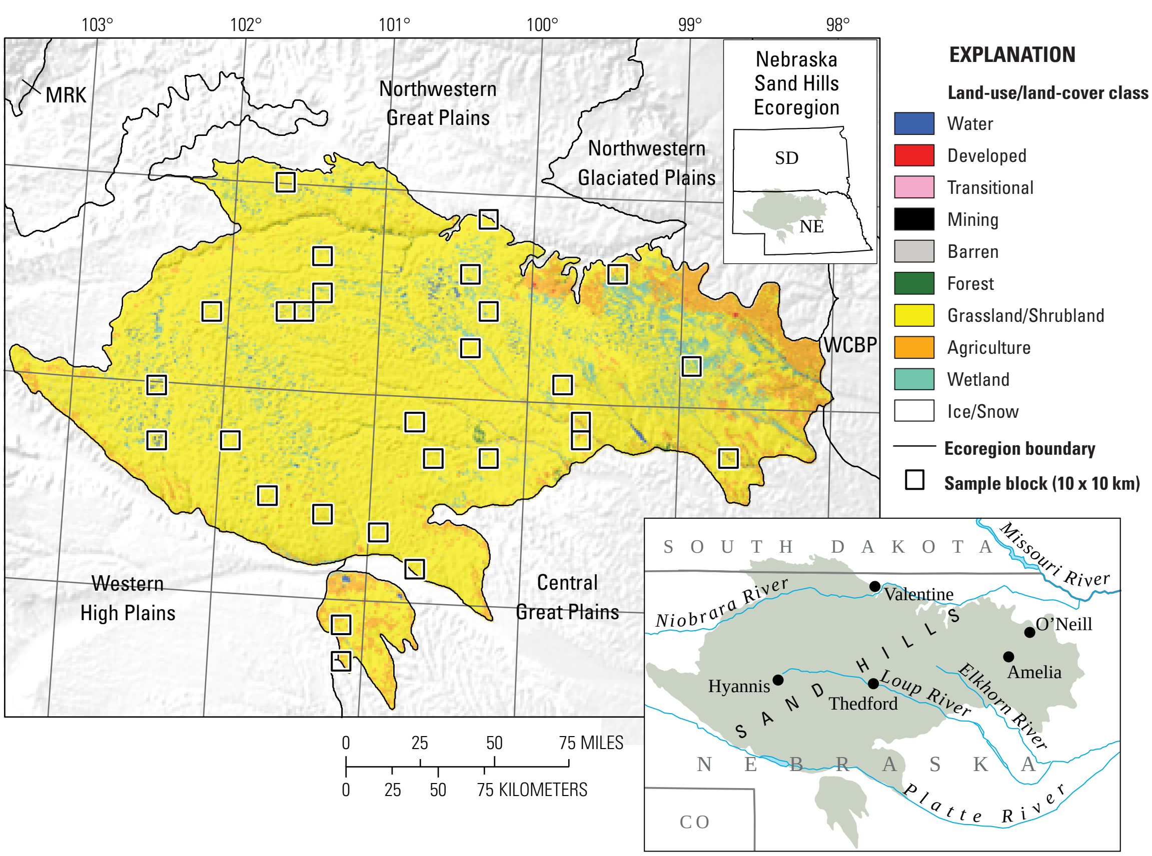

Figure 2. Grasslands extending as far as the eye can see in all directions, in Nebraska Sand Hills Ecoregion. *A*, Long gravel road. *B*, Functional windmill. *C*, Large field of grass.

The climate is considered semiarid, as the Nebraska Sand Hills Ecoregion is in the rain shadow of the Rocky Mountains to the west. The Gulf of Mexico is the principal source of moisture, with most precipitation falling during May and June. Soils in the Nebraska Sand Hills Ecoregion are classified as Aridisols—sandy soils that have a coarse texture and low water-holding capacity—which have high infiltration rates and little runoff after precipitation falls. The water-holding capacity of the soil root zone is less than 100 mm (4 in.). Thus, ranchers and farmers involved in hay and range-livestock production are at high risk during periods of drought (Wilhelm and Wichita, 2002).

Wetlands are scattered throughout the Nebraska Sand Hills Ecoregion, in shallow, wet meadows, in the margins of lakes, and in backwaters associated with spring-fed streams. Wetlands are somewhat common in the valleys between dunes where the water table is at or near the surface (fig. 3). The Loup and Elkhorn Rivers originate in the Nebraska Sand Hills Ecoregion, and the Niobrara River flows across the northern part of the ecoregion. These rivers and their tributaries are sustained by shallow groundwater, and they have a consistent base flow (Bleed and Flowerday, 1998).

Most land within the Nebraska Sand Hills Ecoregion is privately owned, and the primary land uses include rangeland cattle grazing and hay production (fig. 4). Valentine, Hyannis, and Thedford are examples of small ranching communities found within the ecoregion. These rural towns and the counties

Figure 3. Wetlands in Nebraska Sand Hills Ecoregion. *A*, Pond and surrounding wetlands. *B*, Meandering river.

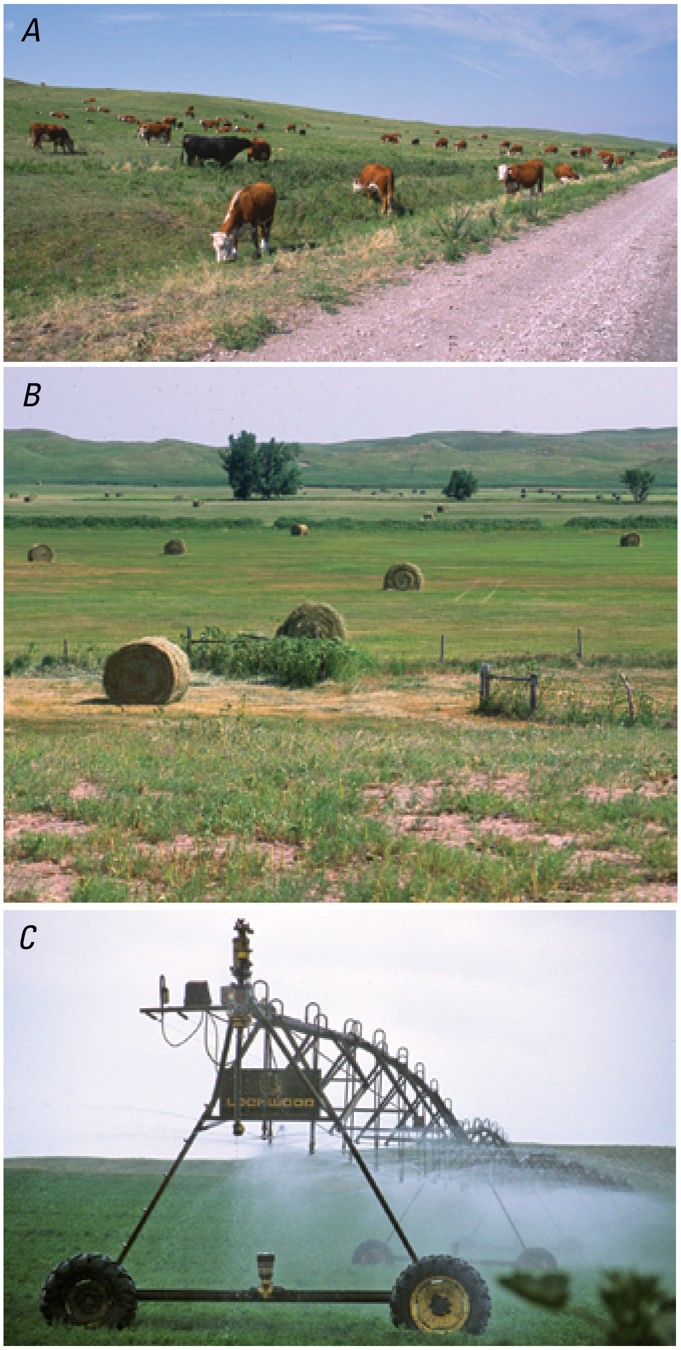

Figure 4. Livestock production and agriculture in Nebraska Sand Hills Ecoregion. *A*, Cattle grazing. *B*, Freshly baled hay. *C*, Center-pivot irrigation.

in which they lie are heavily dependent on agriculture (fig. 5). Between 1970 and 2000, Lincoln County was the only one of the 17 counties in the Nebraska Sand Hills Ecoregion that increased in population (table 1) (U.S. Census Bureau, 1995; Nebraska Department of Economic Development, 2013). In addition to decreasing populations, all 17 counties in the ecoregion have had increases in the median age of their residents (U.S. Census Bureau, 1995; Nebraska Department of Economic Development, 2013).

Figure 5. Rural character of Nebraska Sand Hills Ecoregion. *A*, Grain elevator along railroad tracks. *B*, Cattle ranch. *C*, Downtown O'Neill, Nebraska. *D*, Amelia, Nebraska.

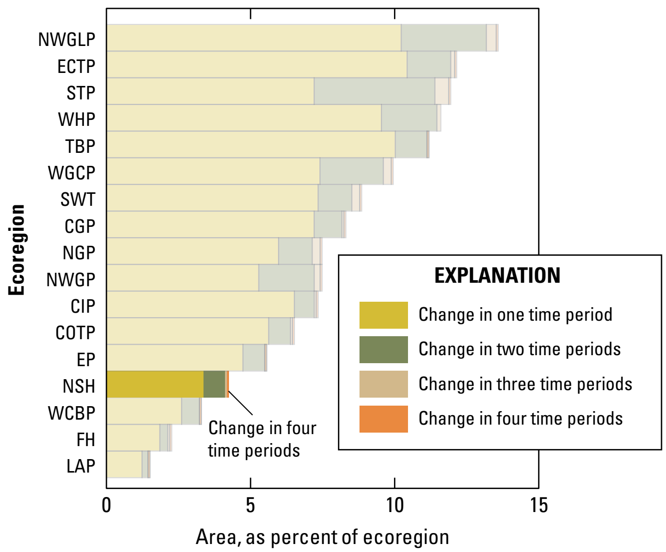

Figure 6. Overall spatial change in Nebraska Sand Hills Ecoregion (NSH; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Nebraska Sand Hills 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.

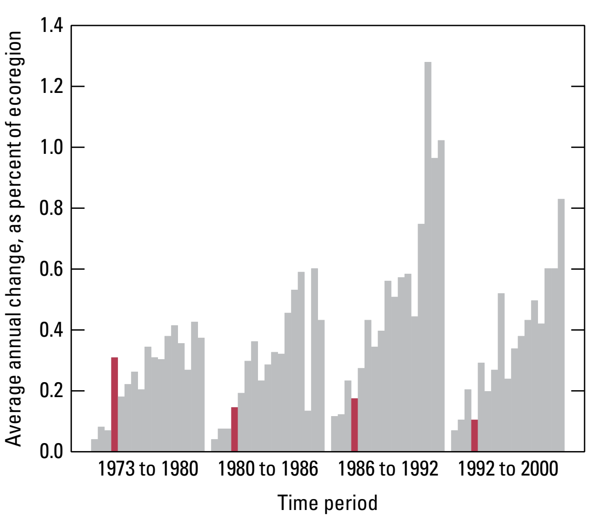

Figure 7. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Nebraska Sand Hills Ecoregion are represented by red bars in each time period.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Nebraska Sand Hills Ecoregion between 1973 and 2000 is 4.0 percent (2,422 km^2) (table 2). Compared to other Great Plains ecoregions, change in the ecoregion was low (fig. 6). Of the 4.0 percent land cover that changed, 3.1 percent changed one time, and 0.9 percent changed more than one time (table 2). Multiple changes during the study period primarily were related to conversions back and forth between grassland/shrubland and agriculture. Total change in each of the four time periods of the study ranged from a low of 0.8 percent between 1992 and 2000 to a high of 2.1 percent between 1973 and 1980 (table 3). After normalizing to an annual rate of change to account for the varying lengths in study periods, the rates ranged from a low of 0.1 percent per year between 1980 and 1986 and between 1992 and 2000 to a high of 0.3 percent per year between 1973 and 1980 (table 4; fig. 7).

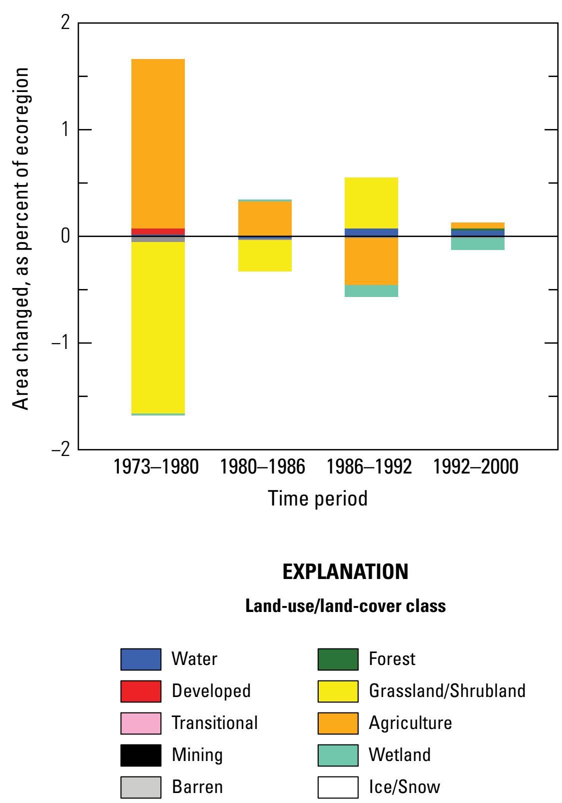

Figure 8. Normalized average net change in Nebraska Sand Hills Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

Grassland/shrubland, agriculture, and wetland constituted about 97 percent of the land cover in the ecoregion during the entire study period. Grassland/shrubland decreased by 1.4 percent (874 km^2), from 87.1 percent of the ecoregion in 1973 to 85.7 percent in 2000 (table 4; fig. 8). Agricultural land increased by 1.5 percent (926 km^2), from 5.5 percent of the ecoregion in 1973 to 7.0 percent in 2000 (table 4; fig. 8). Wetlands decreased by only 0.2 percent (139 km^2) between 1973 and 2000, from 4.6 percent of the ecoregion to 4.4 percent in 2000 (table 4; fig. 8).

Between 1973 and 2000, the two most common land-cover conversions were from grassland/shrubland to agriculture (1,691 km^2) and from agriculture to grassland/shrubland (791 km^2). Overall, these two conversions constituted nearly 84 percent of all changes in the ecoregion during the study period (table 5; fig. 8). Grassland/shrubland to agriculture was the leading conversion in all time periods except between 1986 and 1992. During this time period, the leading conversion was from agriculture to grassland/shrubland, as land was enrolled in the Conservation Reserve Program (CRP) of the U.S. Department of Agriculture's Farm Service Agency. The CRP paid farmers to retire highly erodible cropland or other environmentally sensitive acreage from cultivation.

The third most common land-cover conversion during the study period was from wetland to water (table 5). During the entire study period, 121 km^2 of wetlands became open water, likely because of climatic fluctuations such as increases in rainfall. The fourth most common conversion was from wetland to agriculture (table 5). This conversion was most common during the last three time periods (1980–1986, 1986–1992, 1992–2000) when wetlands were used for hay production in years when they were dry enough to accommodate machinery.

Overall, the Nebraska Sand Hills Ecoregion had little land-cover change during the study period, in contrast to adjacent ecoregions. The Western High Plains and Central Great Plains Ecoregions to the west and south and the Northwestern Great Plains Ecoregion to the north all changed much more than the Nebraska Sand Hills Ecoregion (12.5, 8.3, and 7.4 percent, respectively) (fig. 6). The deep sandy soils in the Nebraska Sand Hills Ecoregion limit its suitability to land uses other than grazing and hay production, which have been the main land uses for decades.

The changes that occurred (primarily the conversions between grassland/shrubland and agriculture) are due to water availability and fluctuations in agricultural economics. For example, agriculture increased in the ecoregion during the 1970s as center-pivot irrigation became economically and technically viable. However, the topography and deep sandy soils of the Nebraska Sand Hills Ecoregion were not suited to most center-pivot practices, and many newly farmed areas were subsequently abandoned. After 1986, many marginal lands still being farmed were placed in the CRP. However, along the south and west edges of the ecoregion, where sand sheets were thinner, agriculture persisted and continued to expand over the study period. Recent efforts to protect wetlands in order to improve the recharge of the High Plains (Ogalalla) aquifer and to enhance natural areas for wildlife have altered the direction of human-lead change. As agricultural communities struggle economically, more emphasis is placed on enhancing grassland and wetlands for wildlife, thereby expanding opportunities for hunters, anglers, and wildlife enthusiasts in general (Grassland Foundation, 2005).

Table 1. Population levels between 1970 and 2000, as well as median age in year 2000, in counties that intersect Nebraska Sand Hills Ecoregion.

[Data from U.S. Census Bureau (1995) and Nebraska Department of Economic Development (2013). All counties listed are in Nebraska]

County	Population				Median age
	1970	1980	1990	2000	2000
Arthur	606	513	462	444	40.3
Blaine	847	867	675	583	39.8
Brown	4,021	4,377	3,657	3,525	43.1
Cherry	6,846	6,758	6,307	6,148	39.4
Garden	2,929	2,802	2,460	2,292	45.6
Garfield	2,411	2,363	2,141	1,902	45.8
Grant	1,019	877	769	747	39.9
Holt	12,933	13,552	12,599	11,551	40.5
Hooker	939	990	793	783	45
Lincoln	29,538	36,455	32,508	34,632	37.8
Logan	991	983	878	774	41.8
Loup	854	859	683	712	42.9
McPherson	623	593	546	544	40.6
Rock	2,231	2,383	2,019	1,756	44
Sheridan	7,285	7,544	6,750	6,198	42
Thomas	954	973	851	729	44.2
Wheeler	1,054	1,060	948	886	40.4
			Median age, all counties		41.9

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

[Most sample pixels remained unchanged (96.0 percent), whereas 4.0 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	3.1	1.2	1.9	4.4	0.8	26.5
2	0.8	0.5	0.3	1.2	0.3	39.9
3	0.1	0.0	0.0	0.1	0.0	51.0
4	0.0	0.0	0.0	0.0	0.0	64.3
Overall spatial change	4.0	1.5	2.5	5.5	1.0	24.5

Table 3. Raw estimates of change in Nebraska Sand Hills 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	2.1	1.1	1.0	3.3	0.8	35.4	0.3
1980–1986	0.9	0.3	0.6	1.2	0.2	23.0	0.1
1986–1992	1.1	0.4	0.6	1.5	0.3	26.6	0.2
1992–2000	0.8	0.4	0.5	1.2	0.3	30.2	0.1
Estimate of change, in square kilometers							
1973–1980	1,294	679	615	1,973	458	35.4	185
1980–1986	533	181	351	714	122	23.0	89
1986–1992	638	252	387	890	170	26.6	106
1992–2000	502	225	278	727	152	30.2	63

Table 4. Estimated area (and margin of error) of each land-cover class in Nebraska Sand Hills 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	0.7	0.2	0.2	0.0	0.0	0.0	0.0	0.3	0.1	1.0	1.0	87.1	2.3	5.5	2.1	4.6	1.6	0.0	0.0
1980	1.2	0.7	0.2	0.3	0.0	0.0	0.0	0.0	0.3	0.1	1.0	1.0	85.5	2.8	7.1	2.9	4.6	1.6	0.0	0.0
1986	1.2	0.7	0.3	0.3	0.0	0.0	0.0	0.0	0.3	0.1	1.0	1.0	85.2	2.8	7.4	2.9	4.6	1.6	0.0	0.0
1992	1.3	0.8	0.3	0.3	0.0	0.0	0.0	0.0	0.2	0.1	1.0	1.0	85.7	2.8	7.0	2.8	4.5	1.5	0.0	0.0
2000	1.4	0.8	0.3	0.3	0.0	0.0	0.0	0.0	0.2	0.1	1.0	1.0	85.7	2.9	7.0	2.9	4.4	1.5	0.0	0.0
Net change	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	–0.1	0.0	0.0	0.0	–1.4	0.9	1.5	0.9	–0.2	0.2	0.0	0.0
Gross change	0.3	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	3.1	1.5	3.2	1.5	0.5	0.2	0.0	0.0
Area, in square kilometers																				
1973	745	436	121	116	0	0	3	3	187	90	593	590	52,756	1,406	3,329	1,287	2,809	952	0	0
1980	757	451	151	158	0	0	4	4	157	79	592	588	51,779	1,714	4,293	1,764	2,808	952	0	0
1986	746	437	158	166	0	0	5	4	153	77	590	587	51,597	1,721	4,482	1,784	2,811	949	0	0
1992	793	488	161	169	0	0	5	4	147	76	591	587	51,884	1,670	4,219	1,684	2,742	936	0	0
2000	829	514	166	176	0	0	5	4	143	77	593	588	51,881	1,732	4,255	1,728	2,670	918	0	0
Net change	84	94	45	63	0	0	2	2	–44	27	0	5	–874	554	926	551	–139	93	0	0
Gross change	165	118	45	63	0	0	2	2	51	29	8	6	1,877	927	1,929	920	281	119	0	0

Table 5. Principal land-cover conversions in Nebraska Sand Hills 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	Grassland/Shrubland	Agriculture	1,066	645	435	1.8	82.4
	Agriculture	Grassland/Shrubland	91	61	41	0.2	7.0
	Grassland/Shrubland	Developed	24	35	23	0.0	1.8
	Agriculture	Wetland	18	20	14	0.0	1.4
	Barren	Grassland/Shrubland	17	14	9	0.0	1.3
	Other	Other	78	n/a	n/a	0.1	6.0
		Totals	1,294			2.1	100.0
1980–1986	Grassland/Shrubland	Agriculture	312	129	87	0.5	58.5
	Agriculture	Grassland/Shrubland	128	67	45	0.2	24.0
	Wetland	Agriculture	22	19	13	0.0	4.1
	Water	Wetland	21	16	11	0.0	4.0
	Agriculture	Wetland	14	11	7	0.0	2.6
	Other	Other	36	n/a	n/a	0.1	6.8
		Totals	533			0.9	100.0
1986–1992	Agriculture	Grassland/Shrubland	388	233	157	0.6	60.7
	Grassland/Shrubland	Agriculture	120	75	51	0.2	18.9
	Wetland	Water	55	60	40	0.1	8.6
	Wetland	Agriculture	21	26	18	0.0	3.3
	Agriculture	Wetland	14	12	8	0.0	2.1
	Other	Other	41	n/a	n/a	0.1	6.4
		Totals	638			1.1	100.0
1992–2000	Grassland/Shrubland	Agriculture	192	105	71	0.3	38.3
	Agriculture	Grassland/Shrubland	184	159	107	0.3	36.6
	Wetland	Water	41	33	22	0.1	8.2
	Wetland	Agriculture	33	24	16	0.1	6.5
	Wetland	Grassland/Shrubland	12	17	12	0.0	2.4
	Other	Other	40	n/a	n/a	0.1	7.9
		Totals	502			0.8	100.0
1973–2000 (overall)	Grassland/Shrubland	Agriculture	1,691	809	546	2.8	57.0
	Agriculture	Grassland/Shrubland	791	398	269	1.3	26.7
	Wetland	Water	121	100	67	0.2	4.1
	Wetland	Agriculture	83	49	33	0.1	2.8
	Water	Wetland	53	31	21	0.1	1.8
	Other	Other	228	n/a	n/a	0.4	7.7
		Totals	2,967			4.9	100.0

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Chapter 3

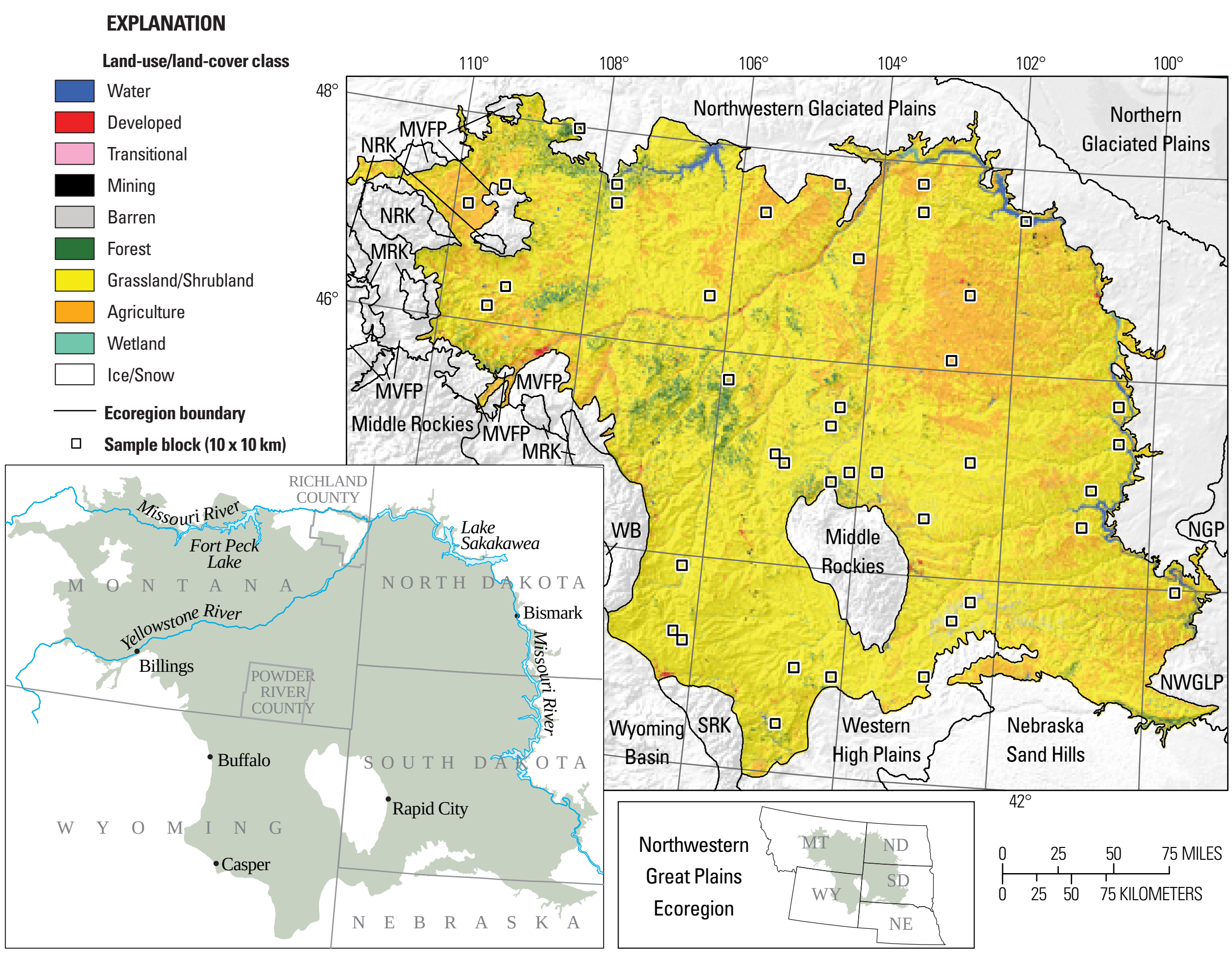
Northwestern Great Plains Ecoregion

By Kristi L. Sayler

Ecoregion Description

The Northwestern Great Plains Ecoregion is a large ecoregion that covers about 346,883 km^2 (133,932 mi^2) of eastern Montana, northeastern Wyoming, western North Dakota, western South Dakota, and northern Nebraska (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The Missouri River and its system of dams and reservoirs (for example, Lake Sakakawea in North Dakota and Fort Peck Lake in Montana) make up the northern border of the ecoregion. The ecoregion is bounded by (clockwise, from the north) the Northwestern Glaciated Plains, Nebraska Sand Hills, Western High Plains, Southern Rockies, Wyoming Basin, Middle Rockies, Northern

Figure 1. Map of Northwestern Great Plains 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 Great Plains ecoregions are listed in appendix 2. Also shown are parts of five Western United States ecoregions: Middle Rockies (MRK), Montana Valley and Foothill Prairies (MVFP), Northern Rockies (NRK), Southern Rockies (SRK), and Wyoming Basin (WB). See appendix 3 for definitions of land-use/land-cover classifications.



Rockies, and Montana Valley and Foothill Prairies Ecoregions (fig. 1). The Northwestern Great Plains Ecoregion contains much tribal, Federal, and State lands, including Indian reservations, national grasslands, Bureau of Land Management lands, national parks, and Montana State Trust Lands.

The Northwestern Great Plains Ecoregion is a semiarid rolling plain of shale- and sandstone-derived soils, punctuated by buttes and badlands (fig. 2). The badlands of North Dakota and South Dakota are unique features of the ecoregion and have been incorporated into national parks. The elevation of the ecoregion ranges from 450 to 1,200 m (McNab and Avers, 1994). This mostly unglaciated plain consists of shallow soils that have clayey textures not conducive to growing crops but are suitable for grazing. The climatic conditions include erratic annual precipitation amounts of 250 to 510 mm (10–20 in.), falling mostly during the summer growing season. Native semiarid grasslands cover most of the ecoregion, including western wheatgrass (*Pascopyrum smithii*), needlegrass (*Achnatherum* spp.), blue grama (*Bouteloua gracilis*), and buffalograss (*Buchloe dactyloides*) (Woods and others, 2002).

Figure 2. Grassland and cropland in Richland County, Montana, in Northwestern Great Plains Ecoregion.

Figure 3. Mosaic of forested hills and grassland in Powder River County, Montana, in Northwestern Great Plains Ecoregion.

The most common land use in the Northwestern Great Plains Ecoregion is livestock grazing of cattle and sheep. Crop agriculture is limited by soil quality, precipitation levels, and the limited access to water for irrigation. The main agricultural areas, which are located in the Missouri Plateau physiographic province in North Dakota, South Dakota, and Montana, are composed mostly of dryland farming (Bryce and others, 1998). Spring wheat is the predominant crop, but smaller areas are planted with barley, oats, sunflowers, and alfalfa and other hay crops. However, drought-resistant, genetically modified crops such as soybeans are becoming increasingly common in the eastern part of the ecoregion (Higgins and others, 2002).

In 2000, the land cover of the ecoregion was an estimated 77.1 percent grassland/shrubland, 15.4 percent agriculture, and 2 to 3 percent each of forest (2.7 percent), barren (2.3 percent), and water (2.1 percent) (table 1). Most forest land is limited to areas of ponderosa pine (*Pinus ponderosa*) in southeastern Montana, as well as small forests along major river valleys of the ecoregion (fig. 3). Mining (including petroleum extraction) also is a minor land use in the ecoregion, as oil, gas, and coal deposits are scattered throughout the Powder River Basin of southeastern Montana and northeastern Wyoming.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Northwestern Great Plains between 1973 and 2000 is 7.4 percent (table 2). Compared to other Great Plains ecoregions, change was moderate (fig. 4). An estimated 5.2 percent of the ecoregion changed only once during the 27-year study period, but other areas changed multiple times during the study period (table 1). Areas that experienced multiple changes included marginal agricultural land that was taken out of production early in the study period, which at first reverted to grassland/shrubland but later was converted back to agricultural land.

The total change per time period varied slightly between 1973 and 2000. The last two time periods (1986–1992, 1992–2000) had greater change than the first two time periods (1973–1980, 1980–1986) (table 3). When normalized to account for the varying lengths in study periods, the period between 1986 and 1992 had the greatest rate of change per year, at 0.5 percent, compared to 0.3 percent per year for the other three time periods (table 3; fig. 5).

Agriculture and grassland/shrubland had the most change during the study period (table 1). Agriculture decreased 1.8 percent, with most of the decrease coming from conversion of agricultural land to grassland/shrubland (table 1; fig. 5). Grassland/shrubland increased 2.2 percent (table 1; fig. 6). In terms of the amount of area changed, the largest conversions during the study period were from agriculture to grassland/shrubland (17,239 km^2) and from grassland/shrubland to agriculture (11,013km^2) (table 4). These two conversions together constituted at least 82 percent of change in all time periods except between 1973 and 1980.

The first two time periods (1973–1980, 1980–1986) saw large conversions of grassland/shrubland to agriculture, which were driven mainly by changes in the agricultural economy, as well as by farm policies such as the Conservation Reserve Program (CRP). The CRP, which the U.S. Congress implemented in 1985 (U.S. Department of Agriculture, 2004), is a voluntary, long-term cropland retirement program that pays participants to retire highly erodible and environmentally sensitive cropland and pastureland from production for a period of 10 to 15 years. Because much of the land in the Northwestern Great Plains Ecoregion is marginal for crop production, it was more economical for landowners to enroll their properties in the CRP rather than to continue using them for agricultural purposes. After 1986, the conversions reversed, as marginal croplands in the ecoregion could be more profitable as grassland/shrubland in the CRP. Nevertheless, about 2,400 km^2 of land in the ecoregion was enrolled in the CRP by the end of 1990 (U.S. Department of Agriculture, 2009).

Another significant change occurred during the first time period (1973–1980), in which a large area (1,390 km^2) of nonmechanically disturbed land converted to grassland/shrubland. This was largely because of a burned area that was mapped as nonmechanically disturbed in one of the sample blocks in 1973 but that had reverted to grassland/shrubland by 1980. Less significant conversions during the study period were noted between the water class and the grassland/shrubland, wetland, and barren classes, which fluctuated because of variations in precipitation over time in the ecoregion.

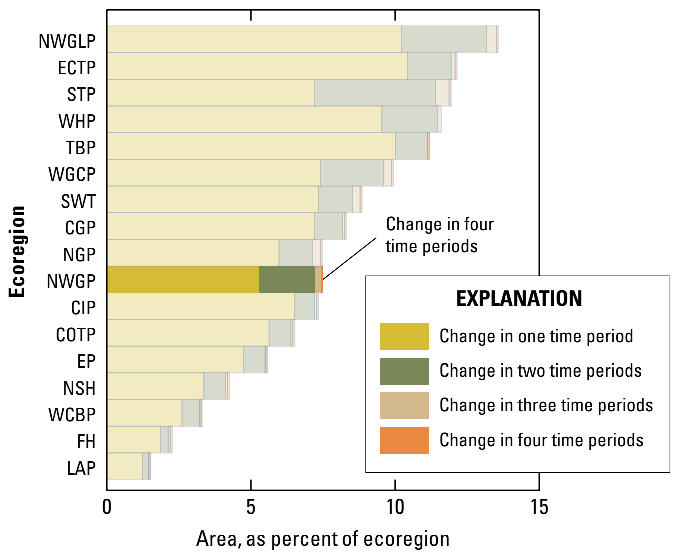


Figure 4. Overall spatial change in Northwestern Great Plains Ecoregion (NWGP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Northwestern Great Plains 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.

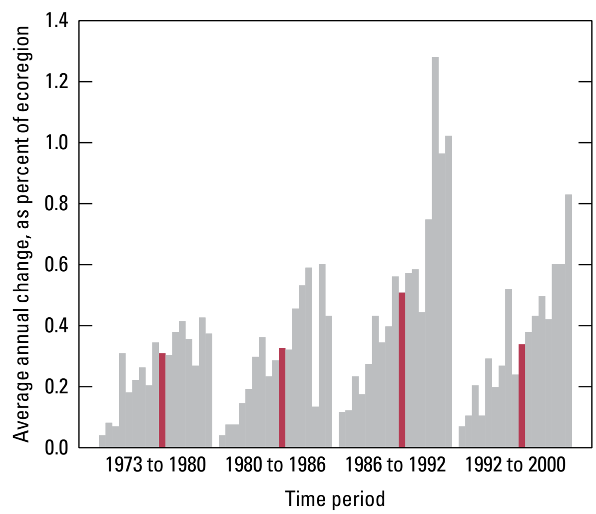


Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Northwestern Great Plains Ecoregion are represented by red bars in each time period.

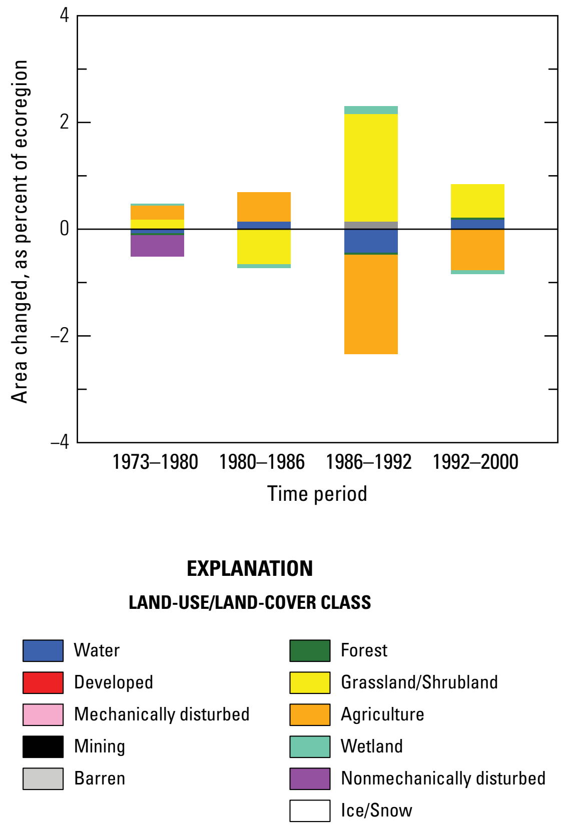


Figure 6. Normalized average net change in Northwestern Great Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

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

	Water		Devel-oped		Mechani-cally disturbed		Mining		Barren		Forest		Grassland/Shru-bland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																						
1973	2.3	2.3	0.2	0.1	0.0	0.0	0.0	0.0	2.2	1.5	2.7	1.1	74.9	5.3	17.2	5.3	0.2	0.1	0.4	0.6
1980	2.2	2.3	0.2	0.1	0.0	0.0	0.0	0.0	2.2	1.5	2.7	1.1	75.0	5.3	17.4	5.3	0.3	0.2	0.0	0.0
1986	2.4	2.3	0.2	0.1	0.0	0.0	0.0	0.0	2.2	1.5	2.7	1.1	74.4	5.2	18.0	5.2	0.2	0.1	0.0	0.0
1992	1.9	2.0	0.2	0.1	0.0	0.0	0.0	0.0	2.3	1.5	2.7	1.1	76.5	4.9	16.1	4.9	0.3	0.2	0.0	0.0
2000	2.1	2.1	0.2	0.1	0.0	0.0	0.0	0.0	2.3	1.5	2.7	1.1	77.1	4.9	15.4	4.8	0.2	0.2	0.0	0.0
Net change	–0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	2.2	1.4	–1.8	1.3	0.1	0.1	–0.4	0.6
Gross change	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	6.4	1.9	5.9	1.9	0.4	0.4	0.4	0.6
Area, in square kilometers																						
1973	7,856	7,883	580	421	0	0	22	26	7,741	5,367	9,315	3,829	259,725	18,436	59,619	18,411	636	410	1,390	2,029
1980	7,673	7,886	580	421	7	10	22	26	7,643	5,359	9,256	3,806	260,330	18,394	60,498	18,364	875	659	0	0
1986	8,182	7,981	580	421	0	0	23	26	7,623	5,355	9,256	3,806	258,123	17,990	62,468	18,133	629	418	0	0
1992	6,625	6,769	591	426	2	2	25	26	8,088	5,353	9,241	3,796	265,213	17,129	55,966	17,045	1,131	758	0	0
2000	7,308	7,296	596	427	20	26	23	26	8,097	5,347	9,264	3,810	267,376	17,075	53,345	16,792	854	619	0	0
Net change	–548	711	17	13	20	26	1	1	355	483	–50	75	7,650	4,863	–6,274	4,447	218	291	–1,390	2,029
Gross change	3,301	2,321	17	13	35	32	6	7	1,046	874	166	116	22,344	6,700	20,564	6,653	1,318	1,294	1,390	2,029

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

[Most sample pixels remained unchanged (92.6 percent), whereas 7.4 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	5.2	1.6	3.7	6.8	1.1	20.4
2	1.9	0.8	1.2	2.7	0.5	26.8
3	0.2	0.1	0.1	0.3	0.1	39.7
4	0.0	0.0	0.0	0.1	0.0	59.0
Overall spatial change	7.4	2.0	5.4	9.4	1.4	18.4

Table 3. Raw estimates of change in Northwestern Great Plains Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at an 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	2.1	0.7	1.4	2.9	0.5	22.7	0.3
1980–1986	2.0	0.7	1.2	2.7	0.5	25.9	0.3
1986–1992	3.0	1.2	1.9	4.2	0.8	26.1	0.5
1992–2000	2.7	0.9	1.8	3.7	0.6	23.9	0.3
Estimate of change, in square kilometers							
1973–1980	7,458	2,487	4,970	9,945	1,694	22.7	1,065
1980–1986	6,820	2,588	4,232	9,409	1,763	25.9	1,137
1986–1992	10,535	4,034	6,501	14,569	2,748	26.1	1,756
1992–2000	9,381	3,291	6,090	12,673	2,242	23.9	1,173

Table 4. Principal land-cover conversions in Northwestern Great 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	Grassland/Shrubland	Agriculture	3,158	840	572	0.9	42.3
	Agriculture	Grassland/Shrubland	2,264	1,044	711	0.7	30.4
	Nonmechanically disturbed	Grassland/Shrubland	1,390	2,029	1,382	0.4	18.6
	Water	Wetland	241	346	236	0.1	3.2
	Barren	Grassland/Shrubland	105	135	92	0.0	1.4
	Other	Other	299	n/a	n/a	0.1	4.0
		Totals	7,458			2.1	100.0
1980–1986	Grassland/Shrubland	Agriculture	4,058	2,413	1,644	1.2	59.5
	Agriculture	Grassland/Shrubland	2,082	755	514	0.6	30.5
	Grassland/Shrubland	Water	275	282	192	0.1	4.0
	Wetland	Water	244	322	220	0.1	3.6
	Barren	Grassland/Shrubland	54	70	47	0.0	0.8
	Other	Other	107	n/a	n/a	0.0	1.6
		Totals	6,820			2.0	100.0
1986–1992	Agriculture	Grassland/Shrubland	7,609	3,448	2,349	2.2	72.2
	Grassland/Shrubland	Agriculture	1,125	620	422	0.3	10.7
	Water	Grassland/Shrubland	677	609	415	0.2	6.4
	Water	Wetland	474	465	317	0.1	4.5
	Water	Barren	431	517	352	0.1	4.1
	Other	Other	219	n/a	n/a	0.1	2.1
		Totals	10,535			3.0	100.0
1992–2000	Agriculture	Grassland/Shrubland	5,284	2,797	1,905	1.5	56.3
	Grassland/Shrubland	Agriculture	2,671	911	620	0.8	28.5
	Grassland/Shrubland	Water	308	198	135	0.1	3.3
	Wetland	Water	241	312	212	0.1	2.6
	Barren	Water	231	261	178	0.1	2.5
	Other	Other	646	n/a	n/a	0.2	6.9
		Totals	9,381			2.7	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	17,239	6,193	4,218	5.0	50.4
	Grassland/Shrubland	Agriculture	11,013	3,342	2,277	3.2	32.2
	Nonmechanically disturbed	Grassland/Shrubland	1,390	2,029	1,382	0.4	4.1
	Water	Grassland/Shrubland	846	610	416	0.2	2.5
	Water	Wetland	722	744	507	0.2	2.1
	Other	Other	2,984	n/a	n/a	0.9	8.7
		Totals	34,195			9.9	100.0

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Status and Trends of Land Change in the Great Plains of the United States—1973 to 2000
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Chapter 4

Southwestern Tablelands Ecoregion

By Carl L. Rich and Mark A. Drummond

Ecoregion Description

The Southwestern Tablelands Ecoregion encompasses about 159,938 km^2 (61,752 mi^2) in Colorado, New Mexico, Texas, Oklahoma, and Kansas (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The ecoregion is bounded on the west by the Southern Rockies and the Arizona/New Mexico Plateau Ecoregions, as well as a small part of the Chihuahuan Deserts Ecoregion; on the north and south by the Western High Plains Ecoregion; and on the east by the Central Great Plains Ecoregion (Omernik, 1987).

The Southwestern Tablelands Ecoregion generally is more rugged than the surrounding ecoregions of the Great Plains, with moderate to considerable local relief. Topographic features include areas of moderately rolling terrain and canyons that dissect the tablelands (fig. 2). Elevation varies from about 400 m in Kansas in the northeastern corner of the ecoregion to about 2,700 m in northeastern New Mexico (National Atlas of the United States, 2008). The highest elevations are at the tops of several old volcanic cones in this part of the Southwestern Tablelands Ecoregion.

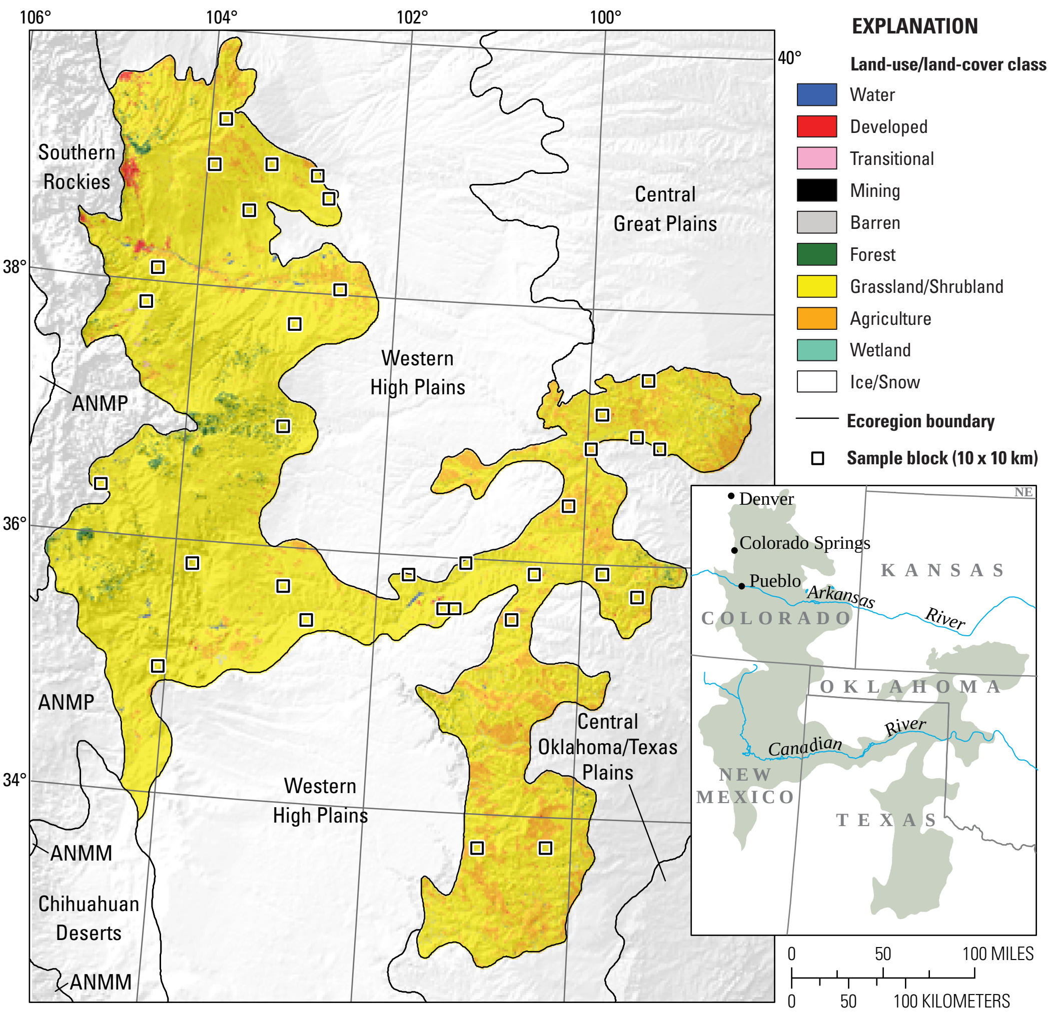

Figure 1. Map of Southwestern Tablelands Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status 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 Great Plains ecoregions are listed in appendix 2. Also shown are parts of four Western United States ecoregions: Arizona/New Mexico Mountains (ANMM), Arizona/New Mexico Plateau (ANMP), Chihuahuan Deserts (CD), and Southern Rockies (SRK). See appendix 3 for definitions of land-use/land-cover classifications.

Precipitation in the Southwestern Tablelands Ecoregion ranges from about 250 mm (10 in.) per year in parts of Colorado and New Mexico to about 630 to 760 mm (25–30 in.) per year in Kansas (National Atlas of the United States, 2008). Grassland/shrubland dominates the land cover on most of the elevated tablelands and vast mesas in the ecoregion; much of it is used for grazing.

The natural vegetation in most of the area is blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*); in the southeastern part of the ecoregion, it is mesquite (*Prosopis* spp.) and buffalo grass. Along the Canadian River in the Southwestern Tablelands Ecoregion is a vegetation community known as shinnery (U.S. Environmental Protection Agency, 2002), a midgrass prairie with open-to-dense broadleaf deciduous shrubs such as Gambel's oak (*Quercus gambelii*) and scrub oak (*Quercus turbinella*), with a few needleleaf evergreen low trees or shrubs (Kuchler, 1964). Although grassland/shrubland dominates the ecoregion, some forest lands also are present on the escarpments of the tablelands.

Land use in the Southwestern Tablelands Ecoregion differs from that of most of the surrounding ecoregions of the Great Plains by its relatively sparse cropland, except along the Arkansas River and in the wetter eastern parts of the ecoregion (figs. 3,4). The most common crop is wheat (*Triticum aestivum*) (U.S. Department of Agriculture, 1970–2000 [various years]). Livestock grazing on grassland/shrubland is the most extensive type of land use (fig. 5).

Minor but important land cover classes include developed and mining. Most of the Southwestern Tablelands Ecoregion is rural, with small towns scattered across the landscape. However, Colorado Springs and Pueblo, Colorado (populations in 2000 of 360,890 and 102,121, respectively), are two of the largest cities within the ecoregion (U.S. Census Bureau, 2000). The Southwestern Tablelands Ecoregion also includes the southern suburbs of Denver. Much of the population growth since 1970 has been in these urban areas of Colorado (U.S. Census Bureau, 1970–2000 [various years]). Petroleum and natural gas production is important in the ecoregion, especially in Texas. Although oil and gas extraction are included in the mining land-cover class in this study, many of the wells and pads are smaller than the minimum mapping unit of 60 m, and so this land-cover class is likely undermapped.

Figure 2. Rangeland, with tablelands in distance, in Southwestern Tablelands Ecoregion.

Figure 3. Sandy soil recently tilled in Southwestern Tablelands Ecoregion.

Figure 4. Field of soybeans in Southwestern Tablelands Ecoregion. No-till farming methods often are used to leave soils and crop residue intact.

Figure 5. Livestock grazing, a common land use in Southwestern Tablelands Ecoregion.

Contemporary Land-Cover Change (1973 to 2000)

The most common types of land-cover change in the Southwestern Tablelands Ecoregion between 1973 and 2000 were from agriculture to grassland/shrubland, and vice versa (table 1). Over the entire study period, these conversions constituted more than 90 percent of all land-cover change. Other leading conversions included a one-time change from grassland/shrubland to nonmechanically disturbed between 1992 and 2000 caused by a fire in the Texas panhandle, and conversions from grassland/shrubland to water caused by water impoundment. However, fluctuations in water levels often caused additional types of land-cover change between the barren and grassland/shrubland classes.

The fact that the dominant changes in the Southwestern Tablelands Ecoregion land cover involved grassland/shrubland and agriculture is not surprising given the overall composition of the land cover within the ecoregion. During all time periods, the ecoregion was composed of 80.0 to 81.9 percent grassland/shrubland and 16.1 to 18.1 percent agricultural land (table 2). Forest constituted an estimated 0.8 percent of the ecoregion, and developed land constituted an estimated 0.4 percent.

The overall spatial change (the percentage of land area that changed at least one time) in the Southwestern Tablelands Ecoregion between 1973 and 2000 is estimated at 8.8 percent (table 3). Most of the changes (7.3 percent of ecoregion area) occurred because of a one-time conversion; multiple changes were caused by switches between grassland/shrubland and agricultural land, as well as fluctuations in water levels of streams and impoundments that may be related to climate variability.

During the first time period (1973–1980), a small net increase occurred in the amount of agriculture land cover, 0.2 percent (table 2). The expansion took place during a period of increased grain exports; thus, it may have resulted, in part, from farm policies that encouraged expansion of cropland. However, unlike several other ecoregions in the Great Plains that experienced substantial agricultural expansion, expansion of cropland in the Southwestern Tablelands Ecoregion was relatively small. After 1980, agriculture land cover decreased.

During the last three time periods (1980–1986, 1986–1992, 1992–2000), a net increase occurred in grassland/shrubland, although the trend was nearly flat between 1980 and 1986 (table 2). The greatest change from one class to another during a single time period was the change from agriculture to grassland/shrubland between 1986 and 1992 (3,870 km^2) (table 1) when grassland/shrubland increased by an estimated 1.6 percent (table 2; fig. 6). This change was caused, in part, by the introduction of the Conservation Reserve Program (CRP). The CRP paid farmers to convert easily erodible or otherwise environmentally sensitive, low-productivity agricultural lands to grasslands (U.S. Department of Agriculture, 2008).

Compared to other Great Plains ecoregions, land-cover change in the Southwestern Tablelands Ecoregion was moderate (fig. 7). Despite a consistently large area of grassland/shrubland, which made up more than 80 percent of the ecoregion's area in all four time periods, fluctuations involving agricultural land use and water were particularly high during the last two time periods (1986–2000). The per-period change estimates ranged from a low of 1.9 percent between 1980 and 1986 to a high of 3.4 percent between 1986 and 1992 when agricultural land began to be enrolled in the CRP (table 4). When the per-period change data are normalized to produce average annual rates of land-cover change, the results range from 0.3 percent between 1973 and 1980 to 0.6 percent between 1986 and 1992 (table 4; fig. 8).

Much of the cropland in the Southwestern Tablelands Ecoregion is considered marginal because of climate and soil conditions. These conditions contributed to fluctuations between grassland/shrubland and agriculture as

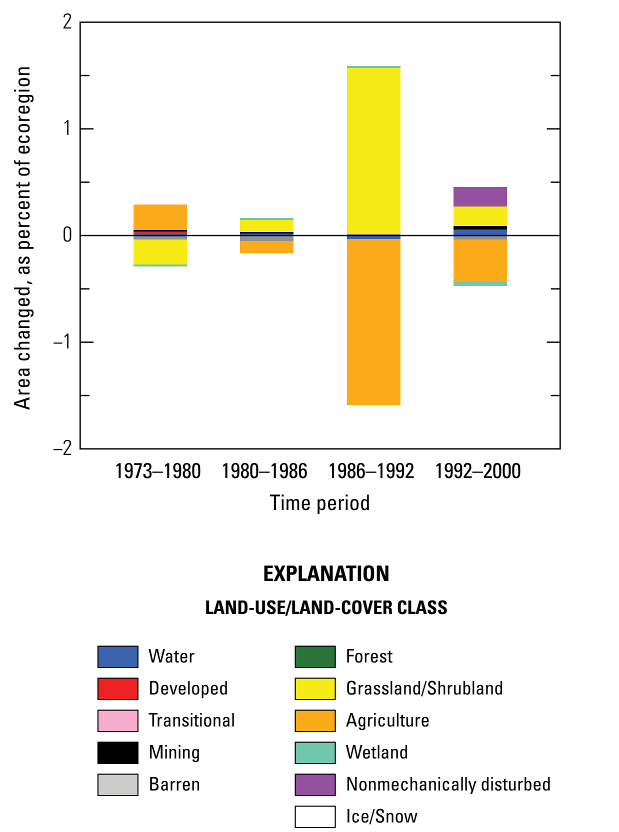

Figure 6. Normalized average net change in Southwestern Tablelands Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

precipitation levels and socioeconomic conditions varied. Because the natural vegetation for most of the ecoregion is grassland/shrubland, it is not surprising that agriculture is continuously reverting back to grassland/shrubland. The rural rangeland character of the ecoregion also contributes to the overall pattern of land-cover change, with developed land concentrated only along its western edge.

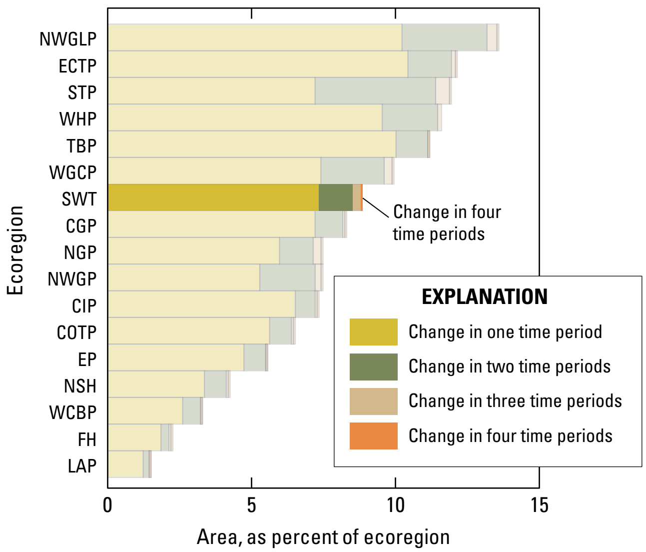

Figure 7. Overall spatial change in Southwestern Tablelands Ecoregion (SWT; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Southwestern Tablelands Ecoregion (four time periods) labeled for clarity. See table 4 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

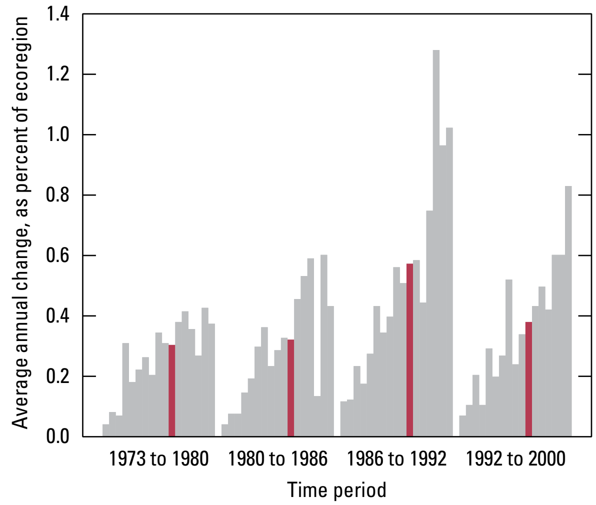

Figure 8. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Southwestern Tablelands Ecoregion are represented by red bars in each time period.

Table 1. Principal land-cover conversions in Southwestern Tablelands 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	Grassland/Shrubland	Agriculture	1,753	823	558	1.1	51.9
	Agriculture	Grassland/Shrubland	1,369	519	352	0.9	40.6
	Barren	Grassland/Shrubland	54	75	50	0.0	1.6
	Grassland/Shrubland	Water	32	25	17	0.0	1.0
	Grassland/Shrubland	Developed	28	33	23	0.0	0.8
	Other	Other	140	n/a	n/a	0.1	4.2
		Totals	3,377			2.1	100.0
1980–1986	Agriculture	Grassland/Shrubland	1,475	782	530	0.9	48.3
	Grassland/Shrubland	Agriculture	1,301	942	638	0.8	42.6
	Barren	Water	52	75	51	0.0	1.7
	Barren	Grassland/Shrubland	42	46	31	0.0	1.4
	Grassland/Shrubland	Water	41	34	23	0.0	1.4
	Other	Other	139	n/a	n/a	0.1	4.6
		Totals	3,051			1.9	100.0
1986–1992	Agriculture	Grassland/Shrubland	3,870	1,533	1,039	2.4	70.4
	Grassland/Shrubland	Agriculture	1,405	731	495	0.9	25.5
	Water	Grassland/Shrubland	65	63	43	0.0	1.2
	Grassland/Shrubland	Water	35	34	23	0.0	0.6
	Water	Barren	23	34	23	0.0	0.4
	Other	Other	103	n/a	n/a	0.1	1.9
		Totals	5,500			3.4	100.0
1992–2000	Agriculture	Grassland/Shrubland	2,454	997	676	1.5	50.9
	Grassland/Shrubland	Agriculture	1,811	976	661	1.1	37.5
	Grassland/Shrubland	Nonmechanically disturbed	316	461	312	0.2	6.5
	Wetland	Water	63	62	42	0.0	1.3
	Grassland/Shrubland	Mining	44	31	21	0.0	0.9
	Other	Other	137	n/a	n/a	0.1	2.8
		Totals	4,825			3.0	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	9,169	3,259	2,208	5.7	54.7
	Grassland/Shrubland	Agriculture	6,270	2,303	1,560	3.9	37.4
	Grassland/Shrubland	Nonmechanically disturbed	316	461	312	0.2	1.9
	Grassland/Shrubland	Water	144	92	63	0.1	0.9
	Barren	Grassland/Shrubland	139	136	92	0.1	0.8
	Other	Other	716	n/a	n/a	0.4	4.3
		Totals	16,754			10.5	100.0

Table 2. Estimated area (and margin of error) of each land-cover class in Southwestern Tablelands 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	0.1	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.3	0.1	0.8	0.4	80.3	5.3	17.9	5.3	0.2	0.1	0.0	0.0
1980	0.1	0.1	0.4	0.2	0.0	0.0	0.1	0.0	0.3	0.1	0.8	0.4	80.0	5.2	18.1	5.3	0.1	0.1	0.0	0.0
1986	0.1	0.1	0.4	0.2	0.0	0.0	0.1	0.0	0.2	0.1	0.8	0.4	80.1	5.0	18.0	5.1	0.2	0.1	0.0	0.0
1992	0.1	0.0	0.4	0.2	0.0	0.0	0.1	0.0	0.2	0.1	0.8	0.4	81.7	4.6	16.5	4.7	0.2	0.1	0.0	0.0
2000	0.2	0.1	0.4	0.2	0.0	0.0	0.1	0.0	0.2	0.1	0.8	0.4	81.9	4.2	16.1	4.3	0.1	0.1	0.2	0.3
Net change	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	–0.1	0.1	0.0	0.0	1.6	2.2	–1.8	2.1	0.0	0.0	0.2	0.3
Gross change	0.3	0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.2	0.0	0.0	6.3	1.8	6.1	1.8	0.1	0.1	0.2	0.3
Area, in square kilometers																				
1973	157	60	627	320	0	1	64	28	470	208	1,335	692	128,432	8,427	28,610	8,556	243	199	0	0
1980	182	80	663	355	3	4	85	38	432	194	1,334	692	128,023	8,386	28,989	8,491	227	196	0	0
1986	219	130	669	356	4	4	95	41	340	136	1,351	694	128,185	8,052	28,813	8,168	264	201	0	0
1992	160	65	673	359	3	3	108	44	364	148	1,348	694	130,666	7,401	26,344	7,492	271	205	0	9
2000	263	120	675	360	2	3	153	69	325	134	1,348	694	130,950	6,741	25,688	6,860	219	164	316	461
Net change	106	81	48	53	2	2	89	47	–146	164	13	19	2,518	3,503	–2,922	3,323	–24	62	316	461
Gross change	444	280	58	54	5	5	93	48	269	264	20	21	10,152	2,920	9,709	2,832	155	101	316	461

Table 3. Percentage of Southwestern Tablelands Ecoregion land cover that changed at least one time during study period (1973–2000) and associated statistical error.

[Most sample pixels remained unchanged (91.2 percent), whereas 8.8 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	7.3	1.8	5.5	9.2	1.2	17.1
2	1.2	0.5	0.7	1.7	0.3	30.1
3	0.2	0.2	0.1	0.4	0.1	50.5
4	0.0	0.0	0.0	0.1	0.0	82.2
Overall spatial change	8.8	2.3	6.5	11.0	1.5	17.4

Table 4. Raw estimates of change in Southwestern Tablelands 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	2.1	0.7	1.4	2.9	0.5	23.9	0.3
1980–1986	1.9	0.9	1.0	2.8	0.6	30.7	0.3
1986–1992	3.4	1.2	2.3	4.6	0.8	22.8	0.6
1992–2000	3.0	1.0	2.0	4.1	0.7	23.5	0.4
Estimate of change, in square kilometers							
1973–1980	3,377	1,192	2,185	4,568	807	23.9	482
1980–1986	3,051	1,383	1,668	4,434	937	30.7	509
1986–1992	5,500	1,854	3,647	7,354	1,256	22.8	917
1992–2000	4,825	1,676	3,150	6,501	1,135	23.5	603

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Chapter 5

Western High Plains Ecoregion

By Mark A. Drummond

Ecoregion Description

The Western High Plains Ecoregion is a high-elevation, semiarid, shortgrass steppe that covers approximately 288,752 km^2 (111,488 mi^2) across parts of eight states (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The Southwestern Tablelands Ecoregion splits the Western High Plains Ecoregion into two large areas: the northern part is surrounded by the Northwestern Great Plains, Nebraska Sand Hills, Central Great Plains, Southwestern Tablelands, and Southern Rockies Ecoregions; the southern part is surrounded by the Southwestern Tablelands, Central Great Plains, and Chihuahuan Deserts Ecoregions.

Surficial geology is the result of uplifted late Tertiary sediments that have been eroded from the uplifting Rocky Mountains, overlain by more recent wind-blown sediments. Agriculture is the dominant land use, with cropland, farmsteads, confined feeding operations, and

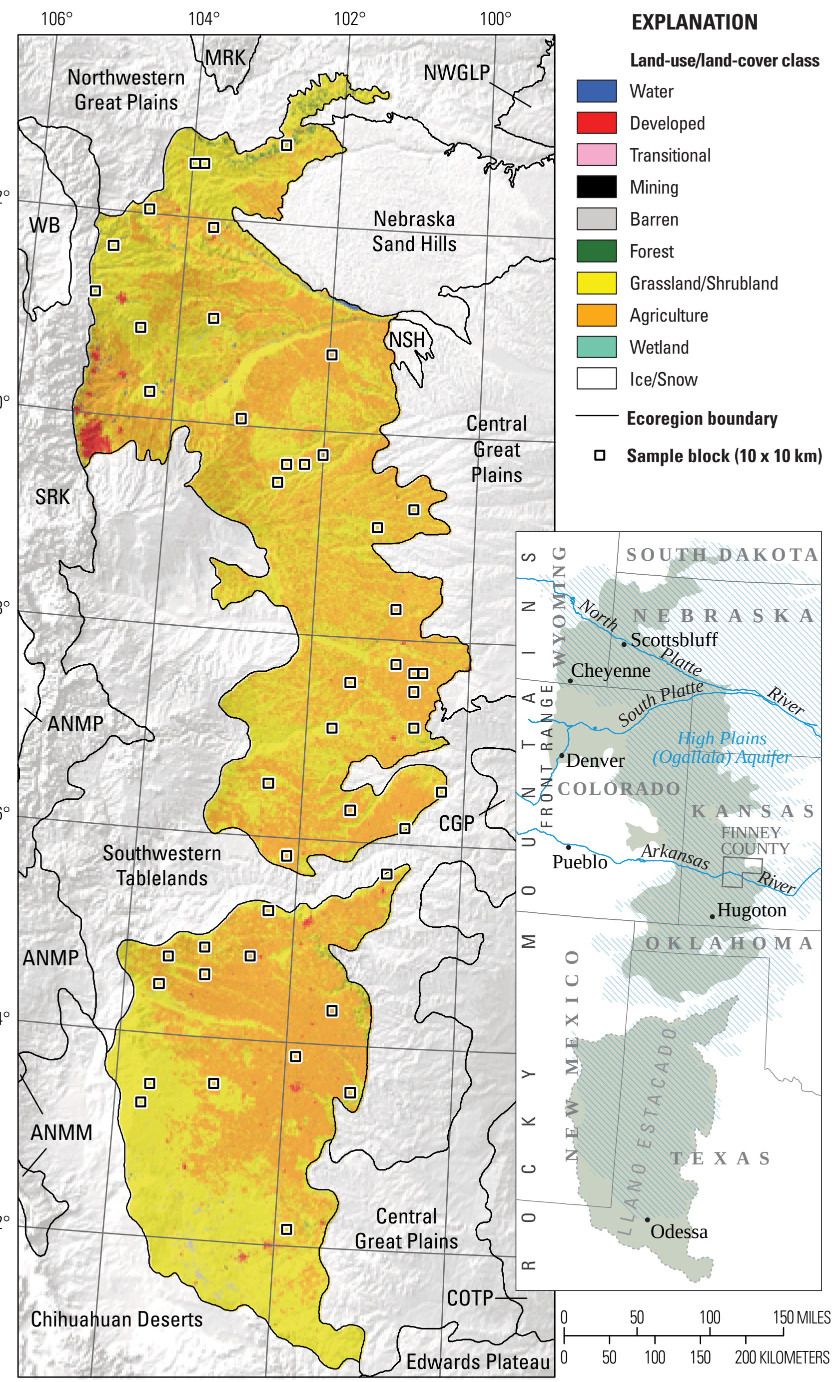

Figure 1. Map of Western High Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status 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 Great Plains ecoregions are listed in appendix 2. Also shown are parts of six Western United States ecoregions: Arizona/New Mexico Mountains (ANMM), Arizona/New Mexico Plateau (ANMP), Chihuahuan Deserts, Middle Rockies (MRK), Southern Rockies (SRK), and Wyoming Basin (WB). See appendix 3 for definitions of land-use/land-cover classifications.

other miscellaneous agricultural uses covering nearly 48 percent of the ecoregion in 2000. Wheat, corn, alfalfa, sorghum, cotton, and specialty crops such as sugar beets have replaced substantial areas of natural land cover within the ecoregion (fig. 2). Livestock grazing is present on much of the remaining grasslands, including large areas of sandy soil that are unsuitable for cultivation (fig. 3). Several National Grasslands lie in the heart of the historic Dust Bowl region in the central part of the ecoregion. Wetland habitat includes a high concentration of small but ecologically important playa lakes, which often are altered by agricultural land use and road construction. Since 1986, the Conservation Reserve Program (CRP), which pays farmers to convert environmentally sensitive land from crops to grassland, has become an important factor in the Western High Plains Ecoregion where many areas are marginal for cultivation. CRP lands covered more than 9 percent of the ecoregion in 2000 (U.S. Department of Agriculture, 1970–2000 [various years]). Oil and natural-gas extraction also is important, and the large Hugoton Field in southwestern Kansas provides fuel for nearby groundwater pumps (fig. 4).

The overall pattern of agricultural land use and the remaining grassland in the Western High Plains Ecoregion is driven largely by climate, soil type, and water availability, as well as by national farm policy, economic opportunity, and other technological and cultural adaptations to the limitations introduced by physical factors. Important physical forces driving the grassland and agricultural ecosystem include highly variable precipitation levels, which range from about 300 mm per year (12 in.) in the western part of the ecoregion to 500 mm per year (under 20 in.) in the eastern part, as well as cycles of intense drought. High rates of evapotranspiration can exceed that of precipitation over long time periods and can contribute to a water deficit for growing crops. Average temperatures during the growing season are high and favor warm-season plants. The natural vegetation of the ecoregion primarily is shortgrass prairie dominated by blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*). Dryland wheat-fallow cropping and no-tillage practices, which improve the retention of soil moisture, are used in areas where water availability is limited but soils are suitable for crops. Streamside irrigation and groundwater pumping are common practices where water is readily available, and these have helped to make the ecoregion important globally for small-grain production and confined-livestock feeding (fig. 5).

The High Plains (Ogallala) aquifer, the largest groundwater complex in the nation, underlies much of the Western High Plains Ecoregion. About 95 percent of the water pumped from the aquifer is used for crop irrigation (Dennehy and others, 2002). Early irrigation was concentrated in areas of the South Platte and North Platte Rivers and in the cotton region of the Llano Estacado in Texas. Turbine pumps used for groundwater irrigation were introduced in the 1930s, permitting modern farming and cattle-ranching practices (Brooks and others, 2001). Substantial pumping began in the 1940s and intensified as cotton production expanded in the southern part of the ecoregion. Technological advances after World War II allowed for more efficient groundwater pumping that expanded the regional pattern of intensive crop production. The increasing use of center-pivot irrigation, beginning in the mid-1960s, allowed more intensive use of fields with uneven topography and sandy soils, where furrow irrigation is unfeasible (Lichtenberg, 1989).

Aquifer declines of greater than 30 m had occurred in some areas by 1980 (Dennehy and others, 2002), causing an increase in the cost of extraction and making water more expensive to use as water levels decline (Terrell and others, 2002). Aquifer recharge in many areas is minimal in relation

Figure 2. Dryland farming, common in Western High Plains Ecoregion.

Figure 3. Rangeland cattle, which often rely on stock ponds of water, in semiarid Western High Plains Ecoregion.

Figure 4. Oil well, many of which dot agricultural landscapes in Western High Plains Ecoregion.

to pumping rates. As a result, the central and southern parts of the ecoregion have experienced groundwater depletion that makes long-term intensive use of the aquifer unsustainable. Other areas have large underground supplies despite declines in aquifer thickness. Recent conservation measures and improved irrigation technology may be slowing the rate of aquifer decline in some areas (McGuire and others, 2003). Streamside irrigation, practiced in areas of the North Platte, South Platte, and Arkansas Rivers, among others, also is vulnerable to low flows associated with regional drought and groundwater withdrawals that reduce streamflow, as well as to competition with urban and industrial uses.

Although urban areas cover less than 1 percent of the ecoregion, they include large areas of the northern part of the "Front Range urban corridor," which extends from Cheyenne, Wyoming, to Pueblo, Colorado, and includes many population centers from Scottsbluff, Nebraska, to Odessa, Texas (fig. 6). Combined population of the 89 counties of the ecoregion was 2.57 million in 2000, a 28 percent increase since 1970 that occurred primarily in urban centers (U.S. Census Bureau, 1970–2000 [various years]). The county with the highest percentage gain was Finney County in southwestern Kansas, which grew by 113 percent (about 19,000 people) from 1970 to 2000. Southwestern Kansas in general and Finney County in particular have a high concentration of irrigated feed-grain production,

Figure 5. Cropland irrigation in Western High Plains Ecoregion, commonly used along streams and in areas where High Plains (Ogallala) aquifer water is readily available.

Figure 6. Small town in Western High Plains Ecoregion, many of which are potentially affected by long-term trends in agriculture.

cattle feedlots, and beef-processing plants that provide employment (Harrington and Lu, 2002) and may be responsible for the population increase. Large cattle-feeding operations moved into the Western High Plains Ecoregion, and out of the Western Corn Belt Ecoregion, as well as out of the Central Corn Belt and Eastern Corn Belt Ecoregions in the Midwest–South Central United States, in part because the dry climate reduces the economic effects of animal disease (Harrington and Lu, 2002).

Contemporary Land-Cover Change (1973 to 2000)

Several trends emerge from analysis of the land-cover data, which indicate an expansion of agriculture prior to 1986 followed by a larger expansion of grassland/shrubland (fig. 7). Between 1973 and 1980, grassland/shrubland was converted to agriculture because overseas markets for wheat increased and also because national farm policies favored expansion (table 1). Intensification of the agricultural industry, including both the concentration of animal-feeding operations and the expansion of irrigated feed-corn production into the ecoregion, also contributed to the land change. Some expansion continued between 1980 and 1986, although an economic downturn in agriculture caused the trend to nearly level out. Agriculture land cover increased by 1.8 percent between 1973 and 1986 (table 2).

Between 1986 and 1992, the trend reversed as 21,606 km^2 of agriculture was converted back to grassland/shrubland, primarily in response to the CRP and other economically driven decisions to abandon crop production. The CRP provided economic incentives to limit crop production on marginal lands. Limited net expansion of grassland/shrubland continued between 1992 and 2000. Agriculture decreased by 7.6 percent between 1986 and 2000 (table 2).

Between 1992 and 2000, the net loss of agriculture land cover was small, at 0.3 percent. However, shifts in the spatial location of grassland/shrubland and agriculture caused a large overall change that affected 4.7 percent of the ecoregion. During this time, CRP leases expired and grassland/shrubland was converted back to agriculture, while other cropland was enrolled in the CRP and planted with grass. Between 1973 and 2000, the total area of agriculture land cover decreased by an estimated 5.8 percent, whereas grassland/shrubland increased by 5.7 percent (fig. 7) (table 2). Grassland/shrubland increased from 44.1 percent of the ecoregion in 1973 to 49.8 percent in 2000. Agricultural land cover decreased from 53.6 percent to 47.8 percent (table 2).

The overall spatial change (the percentage of land area that changed at least one time) in the Western High Plains Ecoregion between 1973 and 2000 is estimated at 12.5 percent (table 3). Compared to other Great Plains ecoregions, change in the Western High Plains Ecoregion was relatively high (fig. 8): most of the area that changed (10.1 percent) did so only once during the study period, 2.3 percent changed twice, and 0.1 percent changed three times. These multiple changes typically were fluctuations between grassland/shrubland and agriculture. Overall, the most common conversion between 1973 and 2000 was from agriculture to grassland/shrubland (29,847 km²), and the second most common conversion was from grassland/shrubland to agriculture (13,188 km²) (table 1).

Expansion of developed land (net change, 0.1 percent) into areas of grassland/shrubland and agricultural land were the next two most common conversions (194 and 171 km², respectively) but represent a relatively small proportion of the overall change. Changes among other land-cover classes affected less than 0.1 percent of the ecoregion. The greatest amount of overall change occurred between 1986 and 1992, when 7.7 percent of the ecoregion changed as agricultural land was converted to grassland/shrubland during the initial phase of the CRP (table 4); during this time period, an estimated 1.3 percent of the ecoregion changed annually (fig. 9; table 4). The period between 1980 and 1986 experienced the least amount of change, at 0.8 percent, when the slow agricultural economy limited the expansion of agriculture.

Land cover changed substantially in the Western High Plains Ecoregion between 1973 and 2000. This change partly resulted from its biological and physical setting (amplified by socioeconomic factors) and an increase in large farming interests, as well as government farm policies and subsidies. More land was used for crop production in good economic times, but marginal farmland was either converted back to grassland/shrubland or abandoned when economic conditions worsened or drought cycles limited crop production. Overall, irrigated agriculture intensified and expanded; however, some areas were affected by declining water availability caused by climate variability, water overuse, or increased costs associated with pumping groundwater. Because of the continuing interaction between environmental and socioeconomic factors, the region is likely to continue to experience land-change fluctuations in the future.

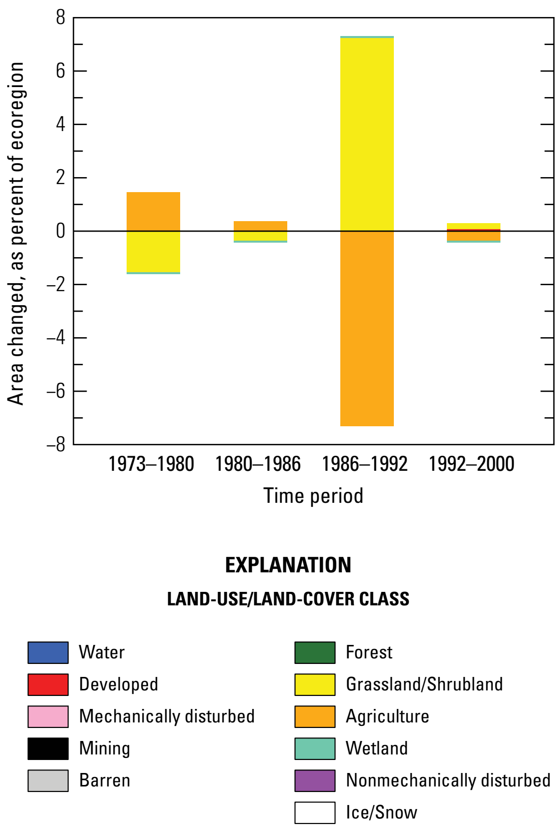

Figure 7. Normalized average net change in Western High Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

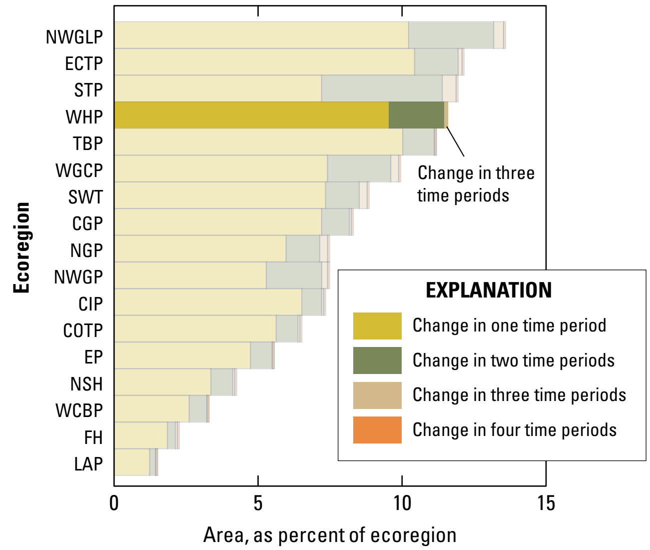

Figure 8. Overall spatial change in Western High Plains Ecoregion (WHP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Western High Plains Ecoregion (three time periods) labeled for clarity. See table 4 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

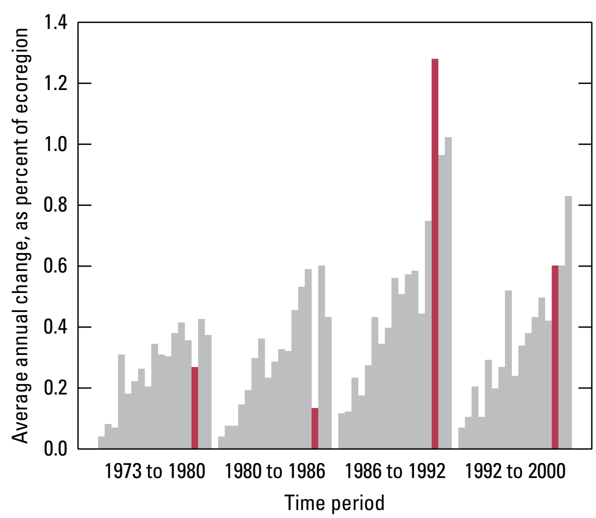

Figure 9. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Western High Plains Ecoregion are represented by red bars in each time period.

Table 1. Principal land-cover conversions in Western High 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	Grassland/Shrubland	Agriculture	4,718	1,667	1,138	1.6	87.9
	Agriculture	Grassland/Shrubland	453	215	147	0.2	8.4
	Agriculture	Developed	103	103	70	0.0	1.9
	Grassland/Shrubland	Developed	22	32	22	0.0	0.4
	Grassland/Shrubland	Mining	21	20	14	0.0	0.4
	Other	Other	49	n/a	n/a	0.0	0.9
		Totals	5,366			1.9	100.0
1980–1986	Grassland/Shrubland	Agriculture	1,613	931	635	0.6	71.9
	Agriculture	Grassland/Shrubland	580	288	196	0.2	25.9
	Grassland/Shrubland	Developed	15	22	15	0.0	0.7
	Agriculture	Developed	14	16	11	0.0	0.6
	Grassland/Shrubland	Mining	8	11	8	0.0	0.3
	Other	Other	12	n/a	n/a	0.0	0.5
		Totals	2,243			0.8	100.0
1986–1992	Agriculture	Grassland/Shrubland	21,606	4,895	3,341	7.5	97.3
	Grassland/Shrubland	Agriculture	539	257	175	0.2	2.4
	Grassland/Shrubland	Developed	16	20	14	0.0	0.1
	Agriculture	Developed	14	14	9	0.0	0.1
	Grassland/Shrubland	Mining	9	8	5	0.0	0.0
	Other	Other	14	n/a	n/a	0.0	0.1
		Totals	22,198			7.7	100.0
1992–2000	Agriculture	Grassland/Shrubland	7,208	2,195	1,498	2.5	52.1
	Grassland/Shrubland	Agriculture	6,318	2,450	1,672	2.2	45.7
	Grassland/Shrubland	Developed	141	146	99	0.0	1.0
	Agriculture	Developed	41	44	30	0.0	0.3
	Wetland	Agriculture	28	37	26	0.0	0.2
	Other	Other	90	n/a	n/a	0.0	0.7
		Totals	13,825			4.8	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	29,847	6,602	4,506	10.3	68.4
	Grassland/Shrubland	Agriculture	13,188	3,530	2,410	4.6	30.2
	Grassland/Shrubland	Developed	194	216	147	0.1	0.4
	Agriculture	Developed	171	164	112	0.1	0.4
	Grassland/Shrubland	Mining	57	43	29	0.0	0.1
	Other	Other	175	n/a	n/a	0.1	0.4
		Totals	43,631			15.1	100.0

Table 2. Estimated area (and margin of error) of each land-cover class in Western High Plains Ecoregion, calculated five times between 1973 and 2000. See appendix 3 for definitions of land-cover classifications.

	Water		Developed		Mechan-ically disturbed		Mining		Barren		Forest		Grassland/Shrubland		Agriculture		Wetland		Non-mechan-ically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	0.2	0.1	0.4	0.3	0.0	0.0	0.1	0.0	0.3	0.2	0.8	1.1	44.1	7.3	53.6	7.5	0.4	0.1	0.0	0.0
1980	0.2	0.1	0.5	0.3	0.0	0.0	0.1	0.0	0.3	0.2	0.8	1.1	42.6	7.2	55.1	7.5	0.4	0.1	0.0	0.0
1986	0.2	0.1	0.5	0.3	0.0	0.0	0.1	0.0	0.3	0.2	0.8	1.1	42.3	7.2	55.4	7.5	0.4	0.1	0.0	0.0
1992	0.2	0.1	0.5	0.3	0.0	0.0	0.1	0.0	0.3	0.2	0.8	1.1	49.6	7.0	48.1	7.2	0.4	0.1	0.0	0.0
2000	0.2	0.1	0.6	0.3	0.0	0.0	0.1	0.0	0.3	0.2	0.8	1.1	49.8	7.2	47.8	7.4	0.4	0.1	0.0	0.0
Net change	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	2.2	–5.8	2.1	0.0	0.0	0.0	0.0
Gross change	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	2.6	12.9	2.6	0.0	0.0	0.0	0.0
Area, in square kilometers																				
1973	630	247	1,273	745	6	7	224	107	769	444	2,436	3,246	127,408	20,965	154,880	21,568	1,126	404	0	0
1980	631	246	1,398	822	1	1	246	123	755	444	2,436	3,246	123,123	20,928	159,057	21,556	1,105	402	0	0
1986	631	246	1,427	837	2	3	257	130	756	444	2,436	3,246	122,065	20,893	160,073	21,539	1,104	403	0	0
1992	634	247	1,457	854	0	0	266	133	754	445	2,436	3,246	143,111	20,247	138,987	20,782	1,106	404	0	0
2000	644	253	1,639	926	4	6	292	140	754	444	2,436	3,246	143,843	20,686	138,070	21,261	1,070	377	0	0
Net change	14	24	366	273	–1	1	69	46	–15	15	0	0	16,435	6,210	–16,811	6,190	–56	55	0	0
Gross change	42	23	366	273	12	15	78	46	21	15	0	0	37,339	7,404	37,258	7,427	95	58	0	0

Table 3. Percentage of Western High Plains 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	10.1	2.0	8.1	12.0	1.3	13.3
2	2.3	0.9	1.5	3.2	0.6	25.3
3	0.1	0.1	0.0	0.2	0.1	58.7
4	0.0	0.0	0.0	0.0	0.0	0.0
Overall spatial change	12.5	2.3	10.2	14.8	1.6	12.7

Table 4. Raw estimates of change in Western High 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	1.9	0.6	1.3	2.5	0.4	22.2	0.3
1980–1986	0.8	0.3	0.4	1.1	0.2	28.8	0.1
1986–1992	7.7	1.7	6.0	9.4	1.2	15.1	1.3
1992–2000	4.8	1.1	3.7	5.9	0.7	15.6	0.6
Estimate of change, in square kilometers							
1973–1980	5,366	1,745	3,621	7,110	1,191	22.2	767
1980–1986	2,243	947	1,296	3,190	646	28.8	374
1986–1992	22,198	4,911	17,287	27,109	3,352	15.1	3,700
1992–2000	13,825	3,168	10,657	16,993	2,162	15.6	1,728

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Glaciated Plains Ecoregions

Status and Trends of Land Change in the Great Plains of the United States—1973 to 2000
Edited by Janis L. Taylor, William Acevedo, Roger F. Auch, and Mark A. Drummond
U.S. Geological Survey Professional Paper 1794–B, 2015

Chapter 6

Lake Agassiz Plain Ecoregion

By Mark S. Brooks

Ecoregion Description

The Lake Agassiz Plain Ecoregion covers 40,636 km² (15,690 mi²) in eastern North Dakota, northwestern Minnesota, and a small part of northeastern South Dakota (fig 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The ecoregion is bounded, on the west and south, by the Northern Glaciated Plains Ecoregion and, on the east, by the Northern Minnesota Wetlands and North Central Hardwood Forests Ecoregions; the Canadian border forms the northern border of the ecoregion (fig. 1).

The modern-day landscape of the Lake Agassiz Plain Ecoregion formed about 10 thousand years ago when the great continental glaciers of North America started to recede. Blocked by large ice sheets, glacial meltwater formed many large glacial lakes. The last proglacial lake to fill the modern-day Red River valley was Glacial Lake Agassiz. What remains today is an extremely flat plain that has an average gradient of about 9 cm per km, as well as a lake-washed till plain and gently rolling uplands along the east and west edges of the Red River valley. Because of its poorly defined floodplains, the Red River valley has experienced numerous floods throughout its young geologic history.

The ecoregion has a continental climate: January average low and high temperatures are about -22°C and 11°C, respectively, and July average low and high temperatures are about 13°C and 28°C, respectively. The average annual number of frost-free days ranges from 95 to 125 days, and the average annual precipitation amount is about 530 mm (21 in.).

During the 19th century, much of the native tallgrass prairie of the Red River valley was replaced with a mostly agricultural land, and agriculture is the principal land-cover class in the ecoregion. The rich, deep, loamy soils, as well as the construction of an extensive drainage system to remove surface

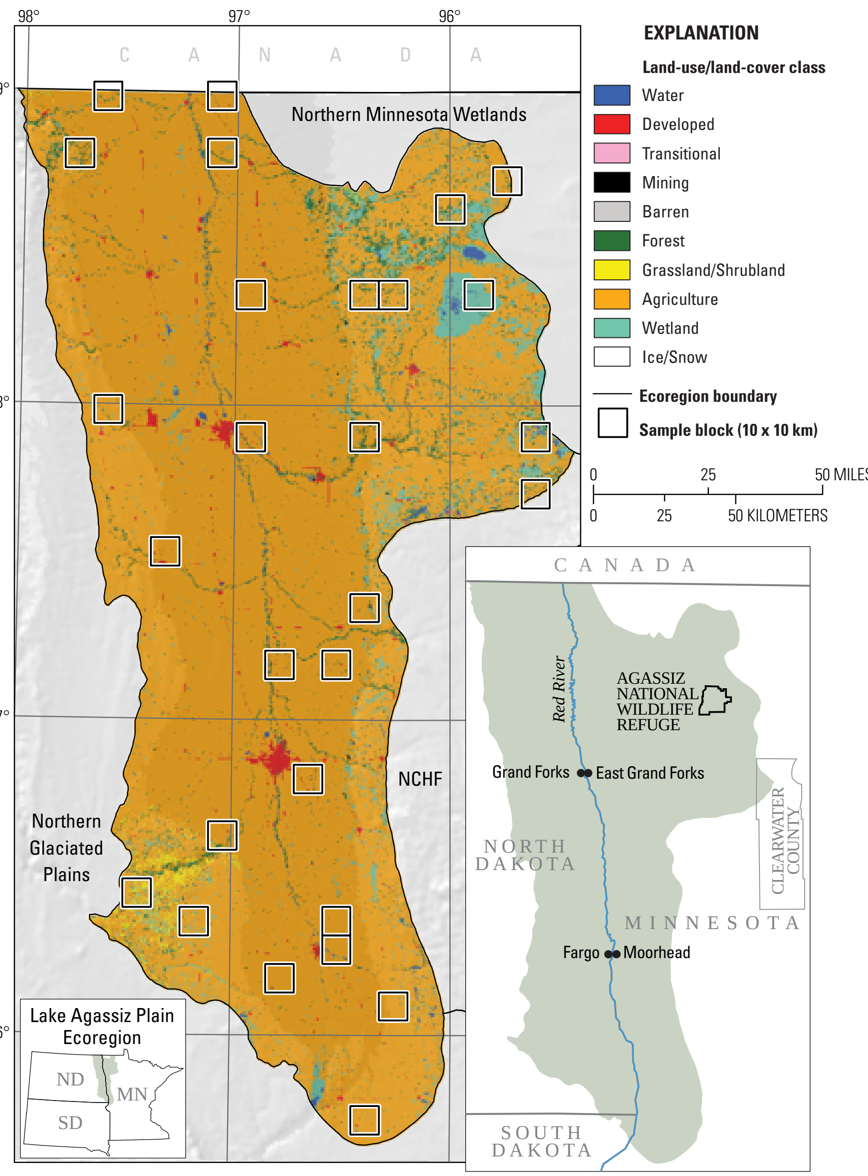

Figure 1. Map of Lake Agassiz Plain Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status 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 Great Plains ecoregions are listed in appendix 2. Also shown are parts of two Midwest–South Central United States ecoregions: North Central Hardwood Forests (NCHF) and Northern Minnesota Wetlands. See appendix 3 for definitions of land-use/land-cover classifications.

water quickly from agricultural lands (fig. 2), have enabled the Red River valley to become one of the most productive agricultural areas in the Great Plains. Major crops produced throughout the Lake Agassiz Plain Ecoregion include potatoes, sugar beets, sunflowers, wheat, barley, corn, and soybeans (figs. 3,4). Pasture and hay production are common in areas of marginal soils (fig. 5).

Secondary land-cover classes include grassland/shrubland, forest, and wetland, which tend to be located away from the high-intensity agriculture found along the Red River valley, with the exception of riparian forest cover (fig. 1). Grassland/shrubland primarily is present in the lake-washed till plains, on the beach ridges and sand deltas around the edge of Glacial Lake Agassiz (Bryce and others, 1998). Wetland and forest more commonly are present in the northeastern upland area of the ecoregion where soils are not as rich. One of the largest remaining wetland lies within this upland area, part of the Agassiz National Wildlife Refuge (U.S. Fish and Wildlife Service, 2009).

Figure 2. Drainage ditch and rolls of tile piping used for field drainage, in Lake Agassiz Plain Ecoregion.

Figure 3. Soybean field ready for harvest, in Lake Agassiz Plain Ecoregion.

Developed land-cover class includes two urban areas situated along the Red River: the Fargo, North Dakota–Moorhead, Minnesota metropolitan statistical area (population, 174,367 in 2000) and the Grand Forks, North Dakota–East Grand Forks, Minnesota metropolitan area (population, 97,478 in 2000) (U.S. Census Bureau, 2003). During the study period, the population in both urban areas remained stable, while the population of rural communities declined as younger residents migrated to larger cities in search of better social and economic opportunities.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Lake Agassiz Plain Ecoregion between 1973 and 2000 is about 1.5 percent (table 1), the lowest amount of change among all 17 Great Plains ecoregions (fig. 6). In addition, the total land-use/land-cover change estimated for each time period was extremely

Figure 4. Sunflower field in Lake Agassiz Plain Ecoregion.

Figure 5. Cattle grazing along County Route 60, in northwestern Clearwater County, Minnesota, Lake Agassiz Plain Ecoregion.

low: the estimated change was 0.2 percent between 1973 and 1980 and between 1980 and 1986, 0.7 percent between 1986 and 1992, and 0.5 percent between 1992 and 2000 (table 2). When normalized to an annual rate of change to adjust for uneven time periods, all time periods had an estimated annual rate of change of 0.1 percent or less (table 2; fig. 7).

The composition of land-use/land-cover classes in the Lake Agassiz Plain Ecoregion changed very little during the study period. In 2000, agriculture was the predominant land-cover class in the ecoregion (about 80.9 percent), followed by grassland/shrubland (about 7.3 percent), forest (about 5.5 percent), and wetland (about 4.7 percent). The remaining land-cover classes combined constituted about 1.6 percent of the ecoregion (table 3).

The largest overall net change during the study period was a 0.6 percent decrease (about 247 km²) in agriculture, the greatest amount of change occurring between 1986 and 1992. In contrast, grassland/shrubland increased by 0.5 percent (196 km²) over the study period (table 3; fig. 8). The large amount of change between agriculture and grassland/shrubland between 1986 and 1992 was associated with the enrollment of cropland in the Conservation Reserve Program (CRP). The CRP is a Federal program implemented in the mid-1980s to reduce soil erosion and improve water quality and wildlife habitat by paying farmers to remove marginal and erodible cropland from production and to restore it to native grasslands and other natural landscapes.

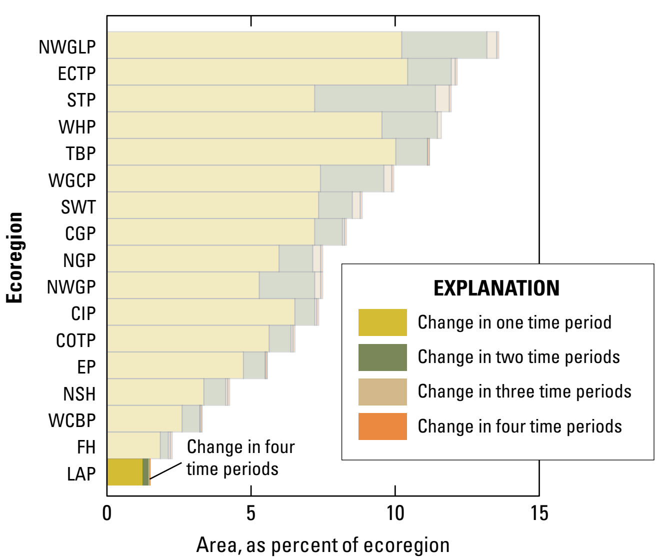

Figure 6. Overall spatial change in Lake Agassiz Plain Ecoregion (LAP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Lake Agassiz 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.

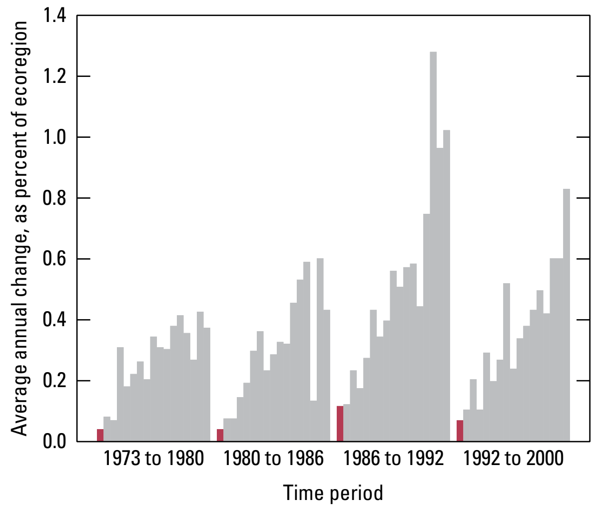

Figure 7. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Lake Agassiz Plain Ecoregion are represented by red bars in each time period.

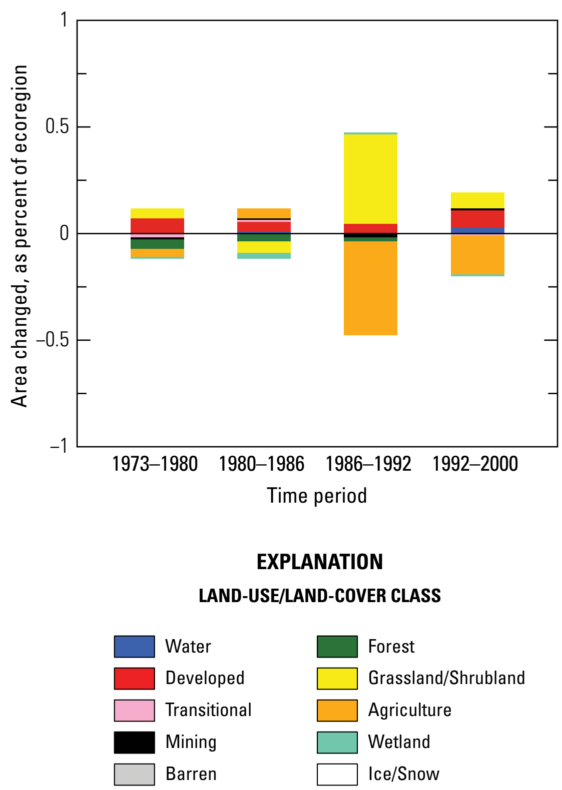

Figure 8. Normalized average net change in Lake Agassiz Plain Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3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

The most common land-cover conversions during the 27-year study period highlight the strong influence that agriculture had on the ecoregion. Agriculture was part of each of the top five conversions, which included both losses to and gains from other land-cover classes (table 4). The leading changes were the conversions of an estimated 297 km² of agricultural land to grassland/shrubland and an estimated 104 km² of grassland/shrubland to agricultural land; these two conversions constituted nearly 60 percent of all change in the ecoregion. Other changes involving agriculture included the conversions of an estimated 80 km² of agriculture to developed, 44 km² of forest to agriculture, and 28 km² of wetland to agriculture (table 4).

The fact that the Lake Agassiz Plain Ecoregion had the lowest amount land-cover change among the 17 Great Plains ecoregions was mainly because of the dominance and stability of agriculture. Although the ecoregion was relatively stable, conversions between agriculture and other land-use/land-cover classes were observed in each time period. The CRP had a moderate influence on land-cover change in the ecoregion; the National Agricultural Statistics Service reported a 6 percent increase in cropland enrollment in the CRP between 1987 and 1997 (Blann and others, 2009), which explains the large amount of agricultural land that converted to grassland/shrubland between 1986 and 1992. Other government programs have been implemented to mitigate the effects of re-engineered natural waterways and intensive agricultural production that have increased the severity of flooding and soil erosion, reduced water quality, and fragmented wildlife habitat within the Red River valley.

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

[Most sample pixels remained unchanged (98.5 percent), whereas 1.5 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	1.3	0.4	0.9	1.7	0.2	18.8
2	0.1	0.1	0.0	0.3	0.1	44.3
3	0.0	0.0	0.0	0.1	0.0	63.1
4	0.0	0.0	0.0	0.0	0.0	70.9
Overall spatial change	1.5	0.4	1.1	1.9	0.3	19.1

Table 2. Raw estimates of change in Lake Agassiz 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 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	0.2	0.1	0.2	0.3	0.1	24.9	0.0
1980–1986	0.2	0.1	0.1	0.3	0.1	26.6	0.0
1986–1992	0.7	0.3	0.4	1.0	0.2	29.3	0.1
1992–2000	0.5	0.2	0.4	0.7	0.1	21.5	0.1
			Estimate of change, in square kilometers				
1973–1980	101	37	64	138	25	24.9	14
1980–1986	98	39	59	137	26	26.6	16
1986–1992	278	121	157	398	81	29.3	46
1992–2000	212	68	144	279	46	21.5	26

Table 3. Estimated area (and margin of error) of each land-cover class in Lake Agassiz 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		Nonmechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
										Area, in percent stratum										
1973	0.4	0.2	0.7	0.3	0.0	0.0	0.1	0.1	0.0	0.0	5.6	1.6	6.8	4.3	81.5	5.8	4.8	1.7	0.0	0.0
1980	0.4	0.2	0.8	0.3	0.0	0.0	0.1	0.1	0.0	0.0	5.6	1.6	6.9	4.3	81.5	5.8	4.7	1.7	0.0	0.0
1986	0.4	0.2	0.8	0.3	0.0	0.0	0.1	0.1	0.0	0.0	5.5	1.6	6.8	4.3	81.5	5.8	4.7	1.7	0.0	0.0
1992	0.4	0.2	0.9	0.3	0.0	0.0	0.1	0.1	0.0	0.0	5.5	1.6	7.3	4.3	81.1	5.8	4.7	1.7	0.0	0.0
2000	0.5	0.2	1.0	0.4	0.0	0.0	0.1	0.1	0.0	0.0	5.5	1.6	7.3	4.3	80.9	5.7	4.7	1.7	0.0	0.0
Net change	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	–0.1	0.1	0.5	0.2	–0.6	0.3	0.0	0.0	0.0	0.0
Gross change	0.1	0.0	0.3	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.8	0.3	1.1	0.3	0.1	0.1	0.0	0.0
										Area, in square kilometers										
1973	169	86	288	115	8	12	45	37	0	0	2,288	653	2,782	1,756	33,121	2,345	1,935	691	0	0
1980	170	87	318	122	0	0	44	37	0	0	2,268	648	2,799	1,762	33,108	2,344	1,929	692	0	0
1986	174	86	339	135	2	3	47	37	0	0	2,253	644	2,777	1,756	33,126	2,338	1,918	683	0	0
1992	174	85	358	138	2	2	40	28	0	0	2,246	643	2,948	1,756	32,948	2,341	1,921	680	0	0
2000	186	85	390	158	0	0	43	28	0	0	2,245	644	2,978	1,767	32,874	2,335	1,919	682	0	0
Net change	17	11	102	52	–8	12	–2	13	0	0	–43	30	196	101	–247	109	–15	18	0	0
Gross change	29	15	102	52	15	13	23	13	0	0	55	29	340	133	455	135	54	29	0	0

Table 4. Principal land-cover conversions in Lake Agassiz 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" 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	22	15	10	0.1	21.5
	Forest	Agriculture	20	12	8	0.0	19.4
	Agriculture	Grassland/Shrubland	19	17	12	0.0	19.1
	Grassland/Shrubland	Agriculture	11	11	7	0.0	11.3
	Mechanically disturbed	Developed	8	12	8	0.0	8.1
	Other	Other	21	n/a	n/a	0.1	20.6
		Totals	101			0.2	100.0
1980–1986	Grassland/Shrubland	Agriculture	30	21	14	0.1	30.2
	Agriculture	Developed	17	13	9	0.0	17.0
	Forest	Agriculture	12	11	7	0.0	12.1
	Agriculture	Grassland/Shrubland	10	8	5	0.0	9.8
	Wetland	Agriculture	9	10	6	0.0	9.3
	Other	Other	21	n/a	n/a	0.1	21.5
		Totals	98			0.2	100.0
1986–1992	Agriculture	Grassland/Shrubland	188	99	67	0.5	67.7
	Grassland/Shrubland	Agriculture	18	12	8	0.0	6.3
	Agriculture	Wetland	13	13	9	0.0	4.8
	Wetland	Agriculture	11	15	10	0.0	4.0
	Agriculture	Developed	10	7	5	0.0	3.7
	Other	Other	37	n/a	n/a	0.1	13.5
		Totals	278			0.7	100.0
1992–2000	Agriculture	Grassland/Shrubland	80	37	25	0.2	37.6
	Grassland/Shrubland	Agriculture	46	39	26	0.1	21.5
	Agriculture	Developed	32	24	16	0.1	15.0
	Wetland	Water	11	9	6	0.0	5.1
	Agriculture	Wetland	7	7	5	0.0	3.4
	Other	Other	37	n/a	n/a	0.1	17.4
		Totals	212			0.5	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	297	134	90	0.7	43.1
	Grassland/Shrubland	Agriculture	104	56	38	0.3	15.1
	Agriculture	Developed	80	45	31	0.2	11.7
	Forest	Agriculture	44	28	19	0.1	6.3
	Wetland	Agriculture	28	33	22	0.1	4.1
	Other	Other	136	n/a	n/a	0.3	19.7
		Totals	689			1.7	100.0

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Chapter 7

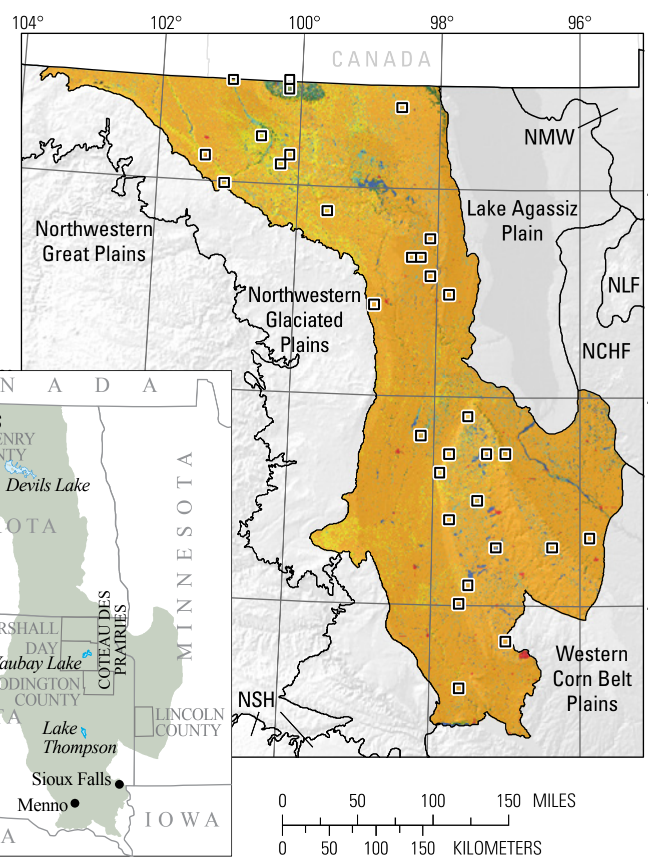
Northern Glaciated Plains Ecoregion

By Roger F. Auch

Ecoregion Description

The Northern Glaciated Plains Ecoregion, which covers about 141,340 km^2 (54,572 mi^2), runs north-south across eastern North Dakota and South Dakota, widening to the east into western Minnesota (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The ecoregion is surrounded by (clockwise, from the east) the Lake Agassiz Plain, North Central Hardwood Forests, Western Corn Belt Plains, and Northwestern Glaciated Plains Ecoregions; the Canadian border forms its northern border (fig. 1).

The climate of the Northern Glaciated Plains Ecoregion is considered to be continental (hot or warm summers and cold winters). Average annual precipitation amounts range from about 510 to 610 mm (20 to 24 in.) for most of the ecoregion, but they decrease to the northwest and increase to the southeast (Kottek and others, 2006; PRISM Climate Group, 2006). This subhumid climate makes the ecoregion a “transitional grassland,” meaning that it contains both tallgrass- and shortgrass-prairie communities. Although the ecoregion historically has been dominated by grasslands, Euro-American settlers converted most of it to farmland. The recent (less than 25,000 years ago) glaciation of most of the Northern Glaciated Plains Ecoregion (Johnson and Higgins, 1997) left many glacial landforms, contributing greatly to the land-use/land-cover classes seen today [2013]. Drift plains, large glacial-lake basins, and shallow river valleys that have level-to-undulating surfaces and deep soils provide the substrate for crop agriculture. Grasslands remain where glaciers left behind large deposits of rock, gravel, and sand, and they generally are used for grazing livestock. This geological history also has resulted in an immature



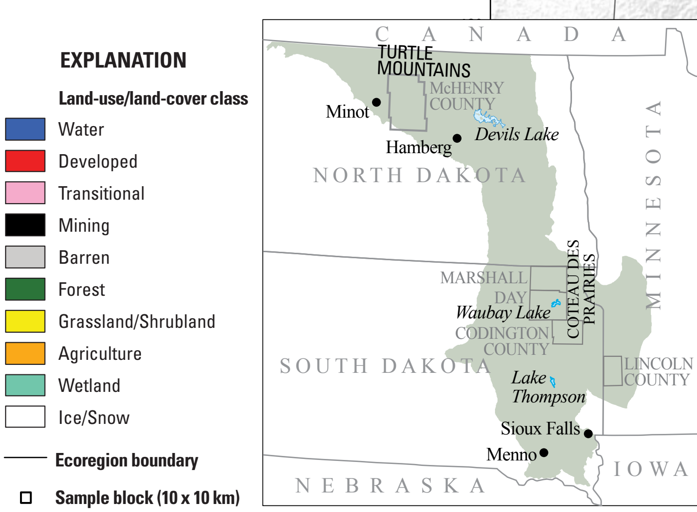


Figure 1. Map of Northern Glaciated Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “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 Great Plains ecoregions are listed in appendix 2. Also shown are parts of three Midwest–South Central United States ecoregions: North Central Hardwood Forests (NCHF), Northern Lakes and Forests (NLF), and Northern Minnesota Wetlands (NMW). See appendix 3 for definitions of land-use/land-cover classifications.

drainage system, and the ecoregion is dotted with wetland depressions that vary widely in size and permanence, as well as subregional concentrations of glacially formed permanent lakes. Agricultural land, grasslands, wetlands, and water form the general mosaic of land cover in the ecoregion.

Agriculture is the most common land-cover class in the ecoregion, and grain and cattle production are the dominant land uses. Although most agricultural land cover is cropland, farming is limited by certain soil, topographic, and wetland conditions, and latitudinal and longitudinal differences influence the combinations of crops that can be grown. The main crops grown in the ecoregion are corn and soybeans in the southern part; soybeans and wheat in the central part; and wheat, other small grains, and canola (rapeseed) in the northern part (fig. 2). Hay production, especially from alfalfa, also is a common use of cropland. Small, intensively used pastures also are included in the agriculture land-cover class.

Livestock grazing on large expanses of grasslands typically is considered a localized and low-intensity land use (fig. 3). Rocky soils and steep slopes are the main reasons grasslands persist in these areas, and, to a lesser extent, in the ecoregion in general. Grassland/shrubland land-cover class also is present on wildlife habitat areas such as federally owned and state-owned wildlife refuges and waterfowl production areas, as well as other public lands.

Figure 2. Field of canola (rapeseed) in flower, surrounding wetland in extreme north-central North Dakota, Northern Glaciated Plains Ecoregion.

Figure 3. Cattle grazing on distant grassy hillside, in Marshall County, South Dakota, Northern Glaciated Plains Ecoregion.

Wetland and water are common land-cover classes in the Northern Glaciated Plains Ecoregion, but their concentration varies (both in number and in size) locally. Water is present mostly in permanent lakes, in semipermanent "wetland" lakes that may be open water in some years and wetland vegetation in others, and in a few reservoirs (fig. 4).

Minor land-cover classes include forest, developed, and mining. Forested land, which is limited and tends to be subregionally concentrated, is present in the Turtle Mountains, in the Coteau des Prairies, and in the northern parts of the ecoregion (Bryce and others, 1998) (fig. 5). Larger riparian areas and farm shelterbelts also may have forest cover but may not have been wide enough (that is, discernable using a 60-m-wide mapping unit) to map continuously, although exceptions are common. Developed land, which was present within cities and towns, constitutes a small part of the ecoregion. Most small towns in the Northern Glaciated Plains Ecoregion grew little in area during the study period, and many of them are declining in population and economic diversity (fig. 6). Aggregate mining also occurs in the ecoregion, owing to its glacial geology, but it tends to be limited in size.

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 Glaciated Plains Ecoregion between 1973 and 2000 is 7.4 percent (table 1). Compared to other Great Plains ecoregions, change in the ecoregion was moderate (fig. 7). The Northern Glaciated Plains Ecoregion changed less than the Northwestern Glaciated Plains Ecoregion to the west but more than either the Lake Agassiz Plain Ecoregion to the east-northeast or the Western Corn Belt Plains Ecoregion to the south (fig. 7). Most of the change (6.0 percent) occurred only one time during the study period, but some areas (1.4 percent) experienced multiple changes (table 1). The multiple changes typically involved either the back-and-forth conversions between wetlands and open, persistent water owing to changes in climatic cycles or the conversions of grassland to crop production early in the study period and then back to grassland upon enrollment in the Conservation Reserve Program (CRP) after 1985. The last two time periods (1986–1992, 1992–2000) had more change than the first two time periods (1973–1980, 1980–1986) (table 2). When normalized to an annual rate to account for the varying lengths in study periods, the periods between 1973 and 1980 and between 1980 and 1986 had the lowest rate of change (0.2 percent) (table 2). The rate of change continued to increase after 1986, and the period between 1992 and 2000 had the highest rate of change (0.5 percent) (table 2; fig. 8).

The agriculture and water land-cover classes had the most net change during the study period, followed by wetland and grassland/shrubland (table 3; fig. 9). Agriculture had a net loss of 2.0 percent, changing primarily to grassland/shrubland, wetland, water, developed, and mining. With the exception of the conversions to developed, all of this agriculture land-use/land-cover change could be temporary. The most common conversion over the study period was from agriculture to grassland/shrubland. An estimated 3,386 km^2 of agriculture changed to grassland/shrubland (table 4), most of it during the last two time periods (1986–1992, 1992–2000) when the CRP was in effect. The CRP paid farmers to retire marginal cropland to native grasslands through contracts, usually 10 years in duration. Although some land in the ecoregion may have been under a second CRP contract by the year 2000, this did not assure a permanent change from agriculture to grassland/shrubland (Leathers and Harrington, 2000). A more ephemeral change was the conversion of agriculture to wetland, as wetter than normal climatic conditions kept many temporary and seasonal wetlands out of crop production (Kirby and others, 2002). A series of wet years in the mid-1980s and mid- to late 1990s contributed to most of the agriculture-to-wetland change.

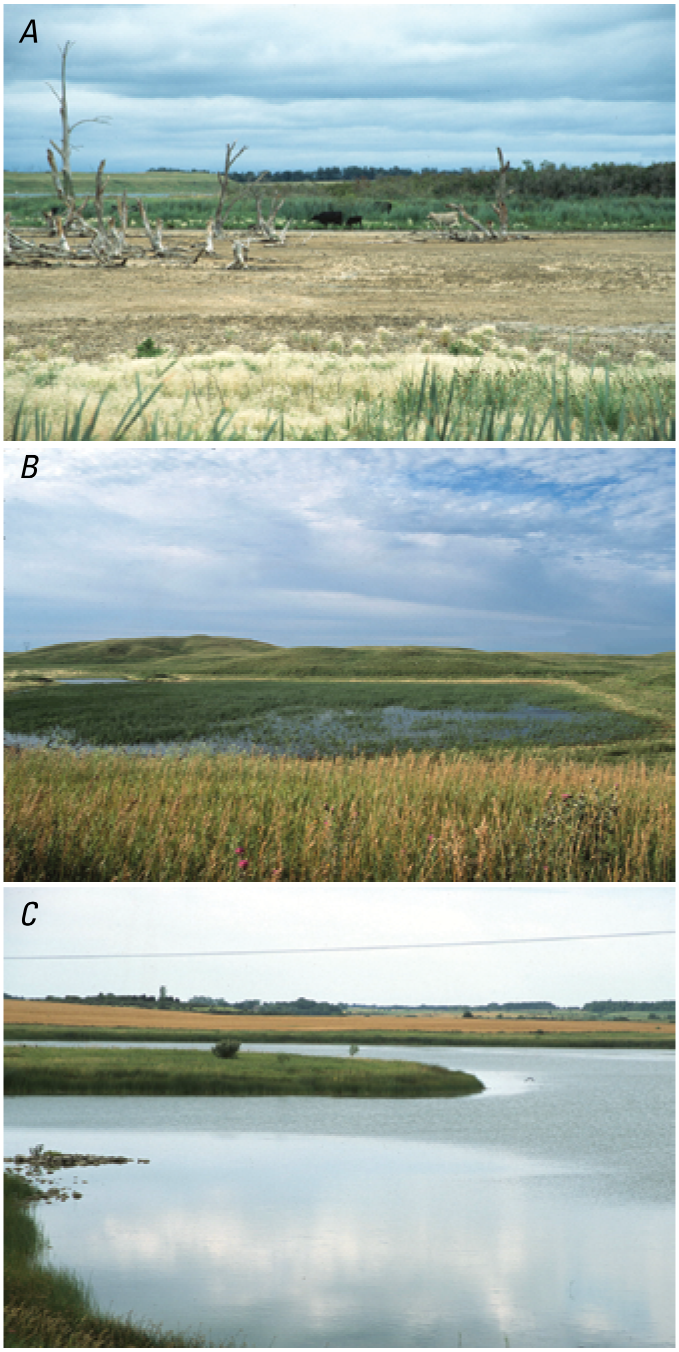


Figure 4. Wetland and water areas in Northern Glaciated Plains Ecoregion. *A*, Cattle grazing in dried-up wetland, in Codington County, South Dakota. *B*, Common scene of grass and wetlands, in Day County, South Dakota. *C*, More permanent natural lake, in Lincoln County, Minnesota.

Water land cover increased by a net 2.0 percent during the study period (table 3). Water gained mostly from wetland, agriculture, and grassland/shrubland. The second most common conversion during the study period was wetland to water. An estimated 3,244 km^2 of wetland changed to water (table 4), most of it during the last time period (1992–2000). Although gains in water from wetland may be more of an ephemeral event owing to wetter climatic conditions (table 4), gains in water from agriculture and grassland/shrubland could represent a longer term but still cyclic change in which many larger glacial lake basins flooded during the study period. Water bodies such as Lake Thompson and Waubay Lake in South Dakota, Devils Lake in North Dakota, and many more minor lakes expanded in size from the mid-1980s onwards. These water bodies may persist as large surface areas for years (Todhunter and Rundquist, 2004; Shapley and others, 2005; South Dakota Game, Fish and Parks, 2006).

Wetland land cover decreased by a net 0.9 percent between 1973 and 2000 (table 3), much of it a change to

Figure 5. Patch of natural forest surrounded by grasslands, in McHenry County, North Dakota, Northern Glaciated Plains Ecoregion. Cattle ranching is dominant land use in this part of ecoregion.

Figure 6. Developed areas in Northern Glaciated Plains Ecoregion. *A*, New developed land on outskirts of Minot, North Dakota. New development was limited almost exclusively to periphery of ecoregion's cities. *B*, Farming community of Menno, South Dakota. Although many small towns in ecoregion experienced little physical growth, they appeared to be economically stable. *C*, Former post office in small central North Dakota town of Hamberg. As communities decline, some developed areas are abandoned.

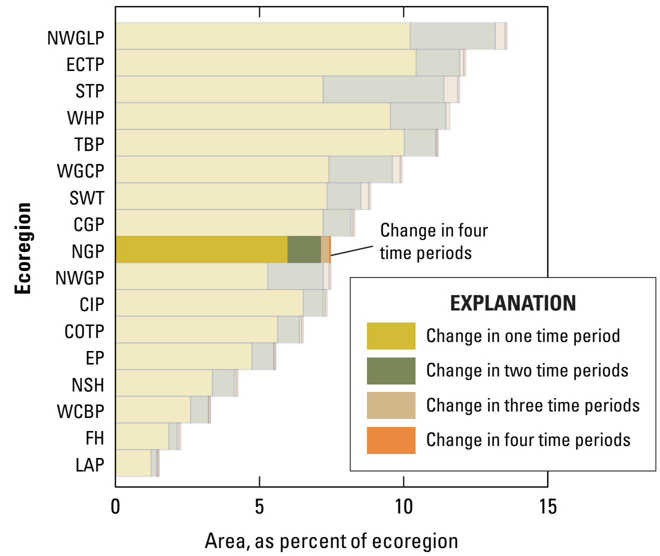


Figure 7. Overall spatial change in Northern Glaciated Plains Ecoregion (NGP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Northern Glaciated 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.

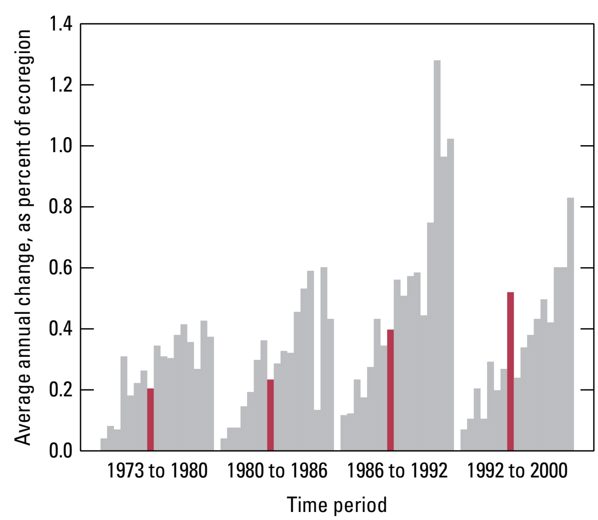


Figure 8. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Northern Glaciated Plains Ecoregion are represented by red bars in each time period.

open-water conditions. Although this change may reverse itself during drier climatic cycles, the trend from the 1980s onwards was that of wetlands converting to open water, especially during the period between 1992 and 2000.

Although grassland/shrubland land cover increased by a net 0.7 percent during the study period (table 3), the change was variable across the ecoregion. It also is possible that multiple conversions affecting grassland/shrubland negated stronger directional trends. Gross change in grassland/shrubland was much higher, at 2.7 percent (table 3). One of the major factors affecting grassland/shrubland was the dynamic relation between grassland/shrubland and agriculture. When the estimated changes from agriculture to grassland/shrubland and from grassland/shrubland to agriculture are the only changes considered (table 4), they show that grassland/shrubland lost to agriculture during the first two time periods (1973–1980, 1980–1986), a time of agricultural economic expansion, but that the trend reversed itself during the last two time periods (1986–1992, 1992–2000), mostly owing to the CRP. The grassland/shrubland net gain decreased between 1992 and 2000, as some of the first CRP contracts expired and were not renewed (Leistritz and others, 2002) and as formerly unbroken grassland/shrubland areas were converted to cropland for the first time (Higgins and others, 2002).

The major factors that affected land-change dynamics in the Northern Glaciated Plains Ecoregion during the study period were (1) shifts in the agricultural economy and in Federal farm policies, causing conversions between grassland/shrubland and agriculture, and (2) cyclic climatic conditions, resulting in conversions between wetland and water and between agriculture and wetland. All these were temporal pulses of change: more grassland/shrubland was converted to agriculture during the first two time periods (1973–1980, 1980–1986), whereas the reverse occurred in the last two time periods (1986–1992, 1992–2000), after implementation of the CRP. Wetland-to-water and agriculture-to-wetland conversions were much more dominant in the second half of the study period than in the first half, owing to a series of wet years. For the most part, such conversions were temporary in nature. In some cases, however, the conversion of grassland/shrubland and wetland back to agriculture may be permanent because restoration efforts can be cost prohibitive, and, furthermore, they usually do not produce results as ecologically complex as native grassland/shrubland and wetlands.

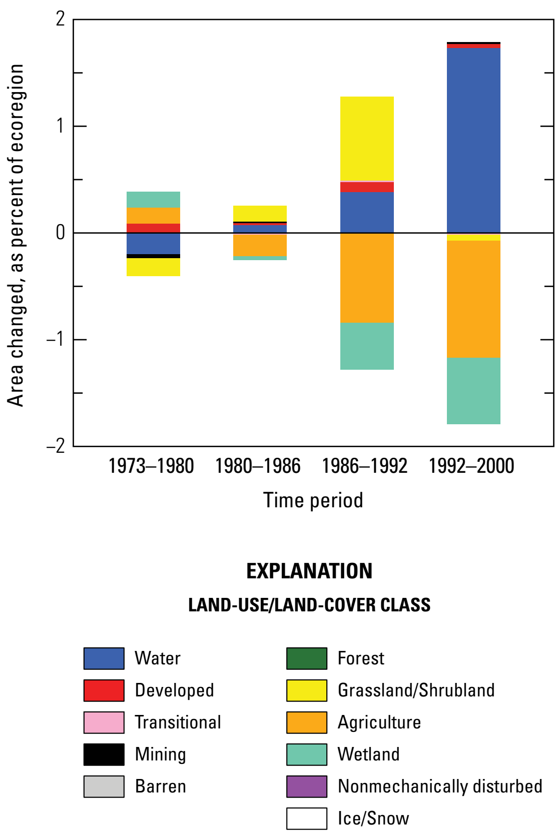


Figure 9. Normalized average net change in Northern Glaciated Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

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

[Most sample pixels remained unchanged (92.6 percent), whereas 7.4 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	6.0	1.1	4.9	7.1	0.8	12.7
2	1.1	0.3	0.8	1.5	0.2	19.2
3	0.3	0.1	0.2	0.4	0.1	20.0
4	0.0	0.0	0.0	0.1	0.0	19.8
Overall spatial change	7.4	1.4	6.1	8.8	0.9	12.5

Table 2. Raw estimates of change in Northern Glaciated 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	1.4	0.3	1.1	1.7	0.2	13.0	0.2
1980–1986	1.4	0.3	1.1	1.7	0.2	14.4	0.2
1986–1992	2.4	0.5	1.8	2.9	0.4	15.2	0.4
1992–2000	4.1	1.0	3.1	5.2	0.7	16.8	0.5
			Estimate of change, in square kilometers				
1973–1980	2,008	386	1,622	2,393	261	13.0	287
1980–1986	1,960	418	1,542	2,378	282	14.4	327
1986–1992	3,333	749	2,584	4,082	507	15.2	556
1992–2000	5,860	1,458	4,402	7,318	986	16.8	733

Table 3. Estimated area (and margin of error) of each land-cover class in Northern Glaciated 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	3.5	2.1	1.4	1.6	0.0	0.0	0.1	0.1	0.0	0.0	3.0	2.6	17.7	4.4	68.5	5.7	5.9	1.0	0.0	0.0
1980	3.3	2.1	1.5	1.6	0.0	0.0	0.1	0.0	0.0	0.0	3.0	2.5	17.5	4.4	68.6	5.7	6.0	1.0	0.0	0.0
1986	3.4	2.1	1.5	1.6	0.0	0.0	0.1	0.1	0.0	0.0	3.0	2.5	17.7	4.5	68.4	5.7	6.0	1.0	0.0	0.0
1992	3.7	2.1	1.6	1.8	0.0	0.0	0.1	0.1	0.0	0.0	3.0	2.5	18.5	4.7	67.5	5.8	5.6	1.0	0.0	0.0
2000	5.5	2.3	1.6	1.8	0.0	0.0	0.1	0.1	0.0	0.0	3.0	2.5	18.4	4.7	66.4	5.8	4.9	1.0	0.0	0.0
Net change	2.0	0.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	–2.0	0.9	–0.9	0.6	0.0	0.0
Gross change	2.9	0.8	0.2	0.2	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.9	0.5	0.3	0.3	2.3	0.6	0.0	0.0
									Area, in square kilometers											
1973	4,938	2,946	1,949	2,211	12	18	116	110	0	0	4,266	3,605	25,009	6,266	96,762	8,070	8,289	1,382	0	0
1980	4,651	2,930	2,080	2,271	8	12	82	66	0	0	4,256	3,591	24,787	6,283	96,970	8,060	8,506	1,419	0	0
1986	4,747	2,952	2,116	2,307	0	0	101	86	0	0	4,258	3,591	24,995	6,377	96,661	8,121	8,462	1,422	0	0
1992	5,294	3,017	2,248	2,475	15	14	107	87	0	0	4,251	3,585	26,104	6,642	95,473	8,241	7,849	1,350	0	0
2000	7,769	3,240	2,283	2,491	5	7	140	103	0	0	4,238	3,574	26,034	6,698	93,916	8,135	6,956	1,477	0	0
Net change	2,830	932	334	297	–7	20	24	30	0	0	–27	34	1,026	959	–2,846	1,245	–1,333	854	0	0
Gross change	4,094	1,125	334	297	54	43	127	92	0	0	66	33	3,790	902	4,817	1,181	3,316	892	0	0

Table 4. Principal land-cover conversions in Northern Glaciated 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	Grassland/Shrubland	Agriculture	496	204	138	0.4	24.7
	Water	Wetland	478	220	149	0.3	23.8
	Agriculture	Grassland/Shrubland	296	186	126	0.2	14.7
	Wetland	Agriculture	198	78	52	0.1	9.8
	Wetland	Water	193	64	43	0.1	9.6
	Other	Other	347	n/a	n/a	0.2	17.3
		Totals	2,008			1.4	100.0
1980–1986	Agriculture	Grassland/Shrubland	564	278	188	0.4	28.8
	Wetland	Water	344	122	83	0.2	17.6
	Grassland/Shrubland	Agriculture	339	204	138	0.2	17.3
	Water	Wetland	255	72	48	0.2	13.0
	Agriculture	Wetland	186	72	49	0.1	9.5
	Other	Other	272	n/a	n/a	0.2	13.9
		Totals	1,960			1.4	100.0
1986–1992	Agriculture	Grassland/Shrubland	1414	558	378	1.0	42.4
	Wetland	Water	791	312	211	0.6	23.7
	Water	Wetland	247	94	63	0.2	7.4
	Grassland/Shrubland	Agriculture	226	130	88	0.2	6.8
	Wetland	Agriculture	211	73	49	0.1	6.3
	Other	Other	444	n/a	n/a	0.3	13.3
		Totals	3,333			2.4	100.0
1992–2000	Wetland	Water	1,916	496	335	1.4	32.7
	Agriculture	Grassland/Shrubland	1,113	486	328	0.8	19.0
	Agriculture	Wetland	895	620	419	0.6	15.3
	Grassland/Shrubland	Agriculture	855	344	232	0.6	14.6
	Agriculture	Water	428	296	200	0.3	7.3
	Other	Other	654	n/a	n/a	0.5	11.2
		Totals	5,860			4.1	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	3,386	1,180	798	2.4	25.7
	Wetland	Water	3,244	814	550	2.3	24.6
	Grassland/Shrubland	Agriculture	1,915	602	407	1.4	14.6
	Agriculture	Wetland	1,356	758	513	1.0	10.3
	Water	Wetland	1,107	325	220	0.8	8.4
	Other	Other	2,152	n/a	n/a	1.5	16.4
		Totals	13,161			9.3	100.0

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Chapter 8

Northwestern Glaciated Plains Ecoregion

By Janis L. Taylor

Ecoregion Description

The Northwestern Glaciated Plains Ecoregion stretches from the Rocky Mountains across northern Montana, through northwestern and central North Dakota and central South Dakota, into northern Nebraska, covering about 160,684 km^2 (62,040 mi^2). The Canadian border forms the northern limit of the ecoregion, and the Missouri River makes up much of its southern and western border (fig. 1), although the large reservoirs along the Missouri River created by dams on the river (for example, Lake Sakakawea in North Dakota and Fort Peck Lake in Montana) are not part of the ecoregion. This ecoregion is located between the more level and moister Northern Glaciated Plains Ecoregion to the east and the more topographically irregular and drier Northwestern Great Plains Ecoregion to the south (Omernik, 1987; U.S. Environmental Protection Agency, 1997; Woods and others, 1999). Other ecoregions that abut the Northwestern Glaciated Plains

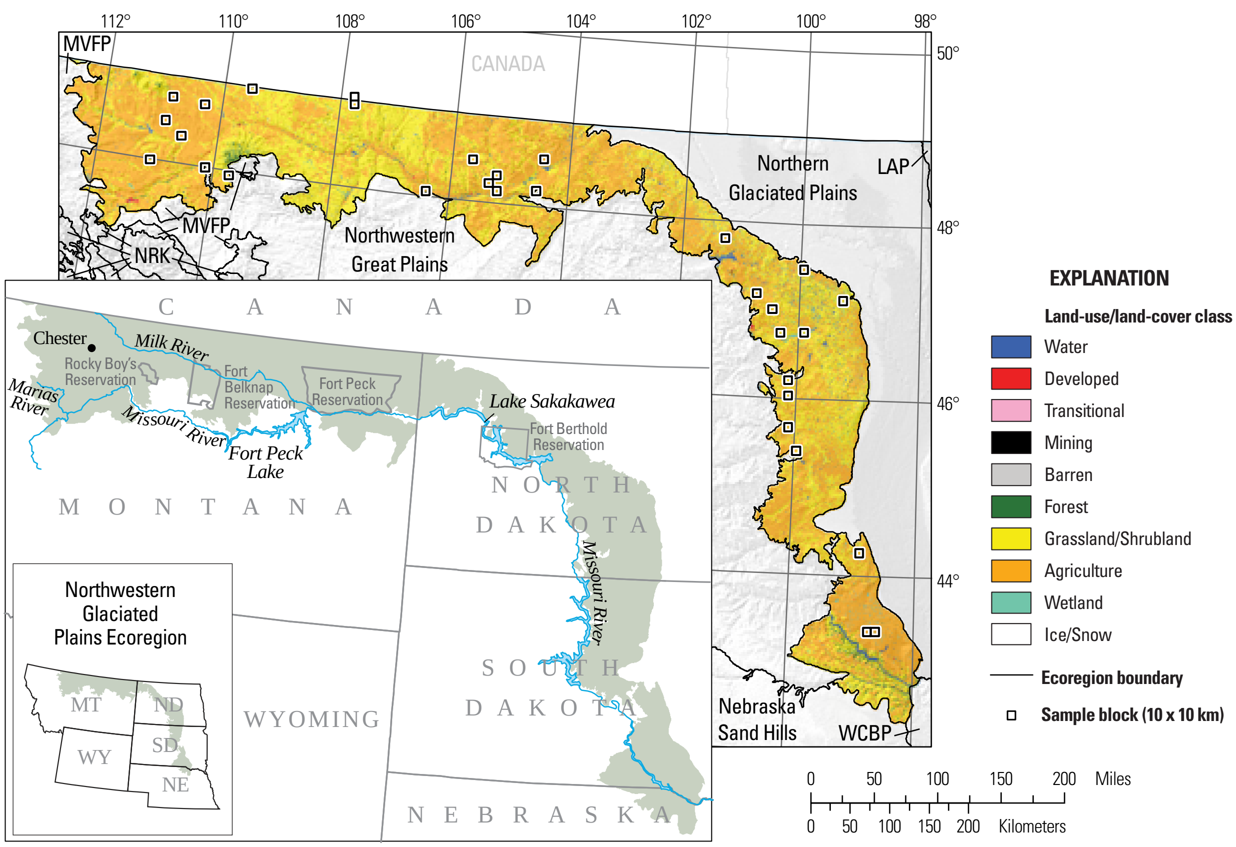

Figure 1. Map of Northwestern Glaciated Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "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 Great Plains ecoregions are listed in appendix 2. Also shown are parts of two Western United States ecoregions: Montana Valley and Foothill Prairies (MVFP) and Northern Rockies (NRK). See appendix 3 for definitions of land-use/land-cover classifications.

Ecoregion are the Western Corn Belt Plains and the Nebraska Sand Hills Ecoregions to the south and the Montana Valley and Foothill Prairies and the Northern Rockies Ecoregions to the west (fig. 1).

Continental glaciers deposited the gravelly outwash material that marks the western and southwestern border of the ecoregion. Brown clay loam soils and gravelly areas derived from glacial tills are common. Groundwater is shallow and plentiful, and the area is dotted with numerous semipermanent and seasonal wetlands, locally referred to as “prairie potholes” (fig. 2). These wetlands and larger, shallow lakes are rich in wildlife. Rivers that flow through the Northwestern Glaciated Plains Ecoregion include the Marias, Milk, and Missouri Rivers.

The ecoregion, which is in the rain shadow of the Rocky Mountains, has a semiarid climate characterized by cold winters, hot summers, low humidity, light rainfall, and plentiful sunshine. Land uses such as dryland farming and grazing have been shaped by the semiarid climate and strong, drying winds. In the west, rangeland and wheat fields are widespread (fig. 3), with agriculture on the undissected gravel benches and in the alluvial river valleys. Further east, extensive grain farms of wheat, soybeans, sunflowers (fig. 4*A*), and corn are common, as are hay and oilseed crops (fig. 4*B*). The native vegetation is a mixed-grass prairie consisting primarily of blue grama (*Bouteloua gracilis*), needlegrass (*Stipa* spp.), and wheatgrass (*Pascopyrum* spp.). Oil and gas production also occurs throughout the ecoregion, primarily in the western part.

Most of the land within the Northwestern Glaciated Plains Ecoregion is privately owned. Towns are small and there is little developed land. The four Indian reservations in the ecoregion are the Fort Berthold Reservation in North Dakota and the Rocky Boy’s, Fort Belknap, and Fort Peck Reservations in Montana. The rural counties and small towns (fig. 5) that constitute this ecoregion mostly are dependent on agricultural and are isolated from larger metropolitan areas. From 1970 to 2000, only 5 of the 38 counties that are entirely or partly within the ecoregion increased in population (table 1) (U.S. Census Bureau, 1970–2000 [various years]).

Figure 2. Typical prairie pothole, in Northwestern Glaciated Plains Ecoregion.

Figure 3. Wheat fields in distance and grassland in foreground, in Northwestern Glaciated Plains Ecoregion.

Figure 4. Agricultural land uses in Northwestern Glaciated Plains Ecoregion. *A*, Field of sunflowers. *B,* Safflower in bloom.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Northwestern Glaciated Plains Ecoregion between 1973 and 2000 is 14.1 percent (table 2). Of that total, 10.7 percent changed one time, and 3.4 percent changed two or more times (table 2). This ecoregion had the highest overall spatial change among all 17 Great Plains ecoregions (fig. 6).

Total change during the study period ranged from a low of 2.6 percent of the ecoregion between 1973 and 1980 and between 1980 and 1986 to a high of 6.6 percent between 1992 and 2000 (table 3). After normalizing to an annual rate of change to adjust for uneven time periods (fig. 7), the rates ranged from a low of 0.4 percent per year between 1973 and 1980 and between 1980 and 1986 to a high of 1.0 percent per year between 1986 and 1992 (table 3; fig. 7). The period between 1992 and 2000 had an annual rate of change of 0.8 percent per year (table 3; fig. 7).

Agriculture, grassland/shrubland, and wetland constituted 97.9 percent (157,130 km^2) of the ecoregion in 1973 (table 4). Agriculture decreased from 60.8 percent of the ecoregion in 1973 to 57.1 percent in 2000 (table 4). Grassland/shrubland increased from 33.9 percent in 1973 to 37.3 percent in 2000 (table 4). Grassland/shrubland and agriculture both had a gross change (the total area converting into and out of a class) of about 9.9 percent of ecoregion area during the entire study period, whereas wetland decreased 1.2 percent and water increased 1.3 percent during that same period (table 4; fig. 8).

Between 1973 and 2000, the most common land-cover conversion was from agriculture to grassland/shrubland (14,688 km^2), which constituted 50.9 percent of all changes (table 5). The second most common conversion was grassland/shrubland to agriculture (9,027 km^2), 31.3 percent of all changes (table 5). Conversion from grassland/shrubland to agriculture was the leading conversion in the first two time periods (table 5). After 1986, the leading conversion was from agriculture to grassland/shrubland. Between 1986 and 1992, more than three times the area that was converted to agriculture in the two previous time periods was converted to grassland/shrubland (fig. 8). Other notable conversions included wetland to water and water to wetland. Between 1992 and 2000, the area of water more than doubled, most of it coming from the wetland land-cover class.

Figure 5. Washington Avenue, a main street in Chester, Montana, in Northwestern Glaciated Plains Ecoregion.

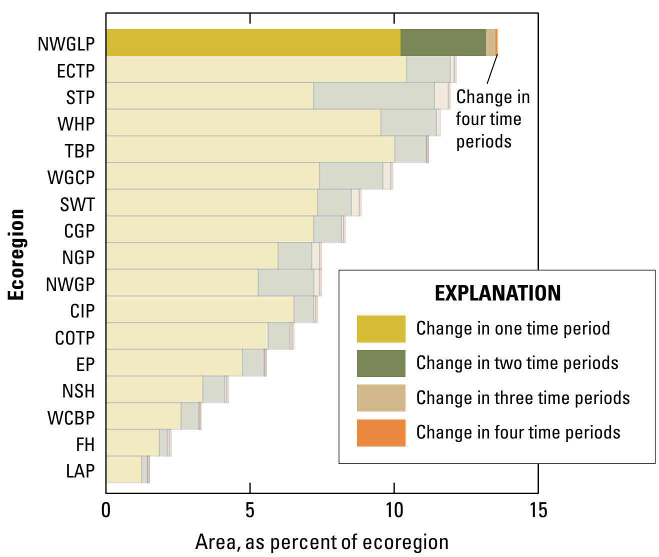

Figure 6. Overall spatial change in Northwestern Glaciated Plains Ecoregion (NWGLP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Northwestern Glaciated Plains 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.

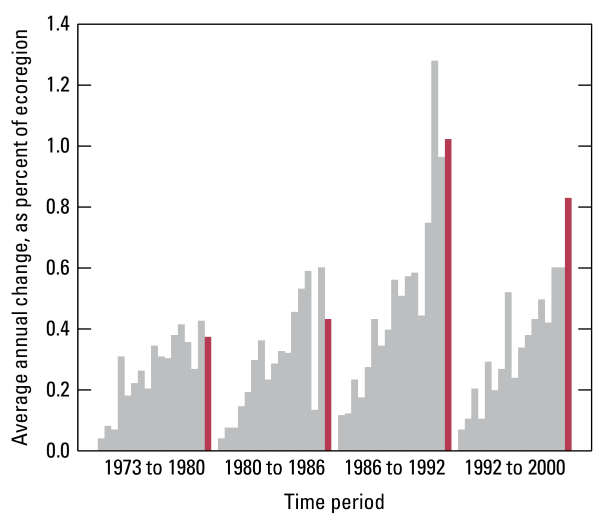

Figure 7. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Northwestern Glaciated Plains Ecoregion are represented by red bars in each time period.

Most of the change that occurred in the Northwestern Glaciated Plains Ecoregion between 1973 and 2000 can be attributed to anthropogenic drivers, specifically the gains and losses of grassland/shrubland and agriculture. In the 1970s, soaring wheat prices driven by foreign grain purchases, government incentives, and high land values resulted in the conversion of large areas of grazing land or native grassland to agriculture (Watts and others, 1983; Garrett-Davis, 2004). The practice of fallowing in alternating summers allowed for successful small-grain farming, even in areas having marginal soils (Bryce and others, 1998; Woods and others, 1999). However, in the 1980s, foreign exports of grain declined sharply and farm land prices plummeted. In 1985, the U.S. Department of Agriculture established the Conservation Reserve Program (CRP) to remove highly erodible land from agricultural production (Ribaurdo and others, 1990). By the year 2000, more land in Montana was enrolled in CRP than in either North Dakota or South Dakota (table 6) (U.S. Department of Agriculture, 2008). Conversion from agriculture to grassland/shrubland peaked between 1986 and 1992, and this trend continued throughout the 1990s, although at a slower rate.

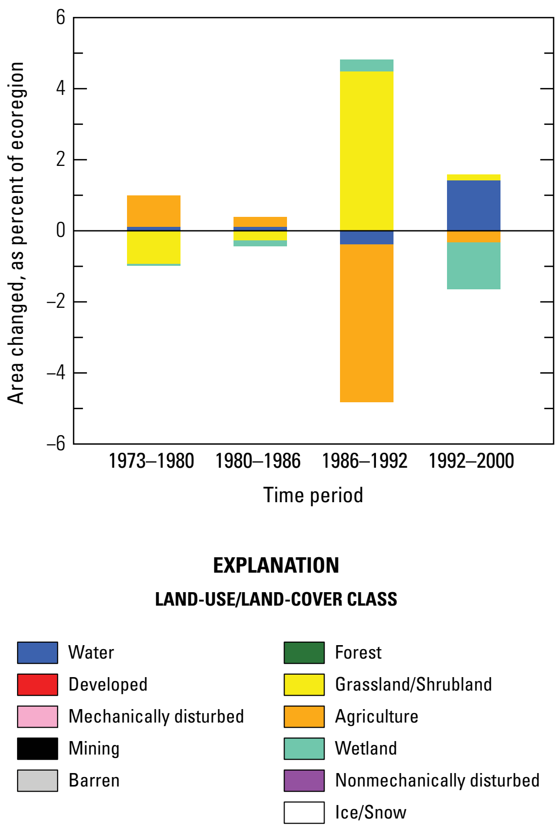

Figure 8. Normalized average net change in Northwestern Glaciated Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See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

Also in the 1990s, soybeans and other genetically modified crops were planted in areas once considered too dry to support them, especially in North Dakota and South Dakota. These new crops, along with crop insurance, decreased the risk of farming in drier areas that had poorer soil quality (Higgins and others, 2002). Agriculture and livestock grazing will remain as the major land uses in the ecoregion as new crops and farming methods will continue to create changes. The trend towards biofuel production also will generate change in the coming years, perhaps increasing incentives for producing certain crops.

Changes to water and wetland primarily were driven by wet-and-dry weather cycles, the 1990s being a much wetter decade than previous decades (Garbrecht and Rossel, 2002). However, some wetland change resulted from the expansion of arable land. In drier years, farmers have access to wetland areas to harvest wild grass hay. In some cases, wetlands are drained and the land is incorporated in adjacent cropland (Leitch and Danielson, 1979).

Protection of grasslands and wetlands for wildlife habitat is being promoted by conservationists, the tourism industry, and outfitters. Some consider grasslands to be the most threatened ecosystem in the United States (Johnson, 2000). The tourism industry sees improvements in wildlife habitat as a means of attracting more visitors to small towns to view wildlife; outfitters see it as a means to attract more hunters and fishermen into the ecoregion. Collectively, increased visitation improves economic vitality of these small towns, as people work hard to make a living in the Northwestern Glaciated Plains Ecoregion. Other changes to the rural communities across the ecoregion will be stimulated as economic opportunities expand.

Table 1. Population levels and total amounts of population change between 1970 and 2000, as well as future population estimates, of counties that intersect Northwestern Glaciated Plains Ecoregion (U.S. Census Bureau, 1970–2000 [various years]).

[n/a, not available]

State	County	Population				Population change, 1970–2000	Estimated population, 2007
		1970	1980	1990	2000		
Montana	Blaine	6,727	6,999	6,728	7,009	282	6,550
	Chouteau	6,473	6,092	5,452	5,970	–503	5,254
	Daniels	3,083	2,835	2,266	2,017	–1,066	1,650
	Hill	17,358	17,985	17,654	16,673	–685	16,568
	Liberty	2,359	2,329	2,295	2,158	–201	1,796
	Phillips	5,386	5,367	5,163	4,601	–785	3,948
	Richland	9,837	12,243	10,716	9,667	–170	9,182
	Roosevelt	10,365	10,467	10,999	10,620	255	10,148
	Sheridan	5,779	5,414	4,732	4,105	–1,674	3,373
	Valley	11,471	10,250	8,239	7,675	–3,796	6,899
	Toole	5,839	5,559	5,046	5,267	–572	5,144
							Estimated population, 2006
North Dakota	Burleigh	40,714	54,811	60,131	69,416	28,702	75,384
	Divide	4,564	3,494	2,899	2,283	–2,281	2,092
	Emmons	7,200	5,877	4,830	4,331	–2,869	3,645
	Kidder	4,362	3,833	3,332	2,753	–1,609	2,453
	Logan	4,245	3,493	2,847	2,308	–1,937	1,999
	McIntosh	5,545	4,800	4,021	3,390	–2,155	2,956
	McLean	11,251	12,383	10,457	9,311	–1,940	8,543
	Mountrail	8,437	7,679	7,021	6,631	–1,806	6,442
	Sheridan	3,232	2,819	2,148	1,710	–1,522	1,408
	Stutsman	23,550	24,154	22,241	21,908	–1,642	20,761
	Wells	7,847	6,979	5,864	5,102	–2,745	4,432
	Williams	19,301	22,237	21,129	19,761	460	19,456
							Estimated population, 2006
South Dakota	Aurora	4,183	3,628	3,135	3,058	–1,125	n/a
	Brule	5,870	5,245	5,485	5,364	–506	5,167
	Campbell	2,866	2,243	1,965	1,782	–1,084	1,494
	Charles Mix	9,994	9,680	9,131	9,350	–644	9,224
	Douglas	4,569	4,181	3,746	3,458	–1,111	3,168
	Edmunds	5,548	5,159	4,356	4,367	–1,181	4,062
	Faulk	3,893	3,327	2,744	2,640	–1,253	2,339
	Gregory	6,710	6,015	5,359	4,792	–1,918	4,268
	Hand	5,883	4,948	4,272	3,741	–2,142	3,323
	Hughes	11,632	14,220	14,817	16,481	4,849	16,946
	Jerauld	3,310	2,929	2,425	2,295	–1,015	2,071
	McPherson	5,022	4,027	3,228	2,904	–2,118	2,565
	Potter	4,449	3,674	3,190	2,693	–1,756	2,321
	Sully	2,362	1,990	1,589	1,556	–806	1,435
	Walworth	7,842	7,011	6,087	5,974	–1,868	5,425

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

[Most sample pixels remained unchanged (85.9 percent), whereas 14.1 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	10.7	1.8	8.9	12.5	1.2	11.4
2	3.0	0.8	2.2	3.8	0.5	18.2
3	0.3	0.2	0.1	0.5	0.1	40.1
4	0.1	0.0	0.0	0.1	0.0	44.9
Overall spatial change	14.1	2.2	11.9	16.4	1.5	10.7

Table 3. Raw estimates of change in Northwestern Glaciated 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	2.6	0.6	2.0	3.2	0.4	15.6	0.4
1980–1986	2.6	0.7	1.9	3.3	0.5	18.5	0.4
1986–1992	6.1	1.3	4.8	7.4	0.9	14.3	1.0
1992–2000	6.6	1.5	5.1	8.1	1.0	15.0	0.8
Estimate of change, in square kilometers							
1973–1980	4,210	973	3,237	5,183	658	15.6	601
1980–1986	4,158	1,136	3,022	5,294	768	18.5	693
1986–1992	9,838	2,081	7,757	11,919	1,407	14.3	1,640
1992–2000	10,628	2,356	8,271	12,984	1,593	15.0	1,328

Table 4. Estimated area (and margin of error) of each land-cover class in Northwestern Glaciated 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	1.3	0.5	0.3	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.3	33.9	5.9	60.8	5.9	3.2	1.1	0.0	0.0
1980	1.4	0.6	0.3	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.3	32.9	5.7	61.6	5.8	3.1	1.1	0.0	0.0
1986	1.5	0.6	0.3	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.3	32.7	5.6	61.9	5.6	3.0	1.0	0.0	0.0
1992	1.2	0.5	0.4	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.3	37.1	5.8	57.4	5.9	3.3	1.1	0.0	0.0
2000	2.6	1.0	0.4	0.2	0.0	0.0	0.0	0.0	0.1	0.1	0.5	0.3	37.3	5.8	57.1	5.9	2.0	0.6	0.0	0.0
Net change	1.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	1.7	–3.6	1.7	–1.2	0.6	0.0	0.0
Gross change	2.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	2.0	9.9	2.0	2.3	1.0	0.0	0.0
Area, in square kilometers																				
1973	2,109	831	499	278	0	0	8	6	116	103	822	480	54,410	9,457	97,635	9,478	5,085	1,798	0	0
1980	2,265	889	520	294	6	8	9	8	112	103	827	476	52,939	9,214	99,012	9,295	4,993	1,717	0	0
1986	2,467	913	528	300	0	0	10	7	116	103	832	476	52,486	8,972	99,457	9,039	4,788	1,656	0	0
1992	1,911	842	569	326	1	1	17	15	118	103	835	477	59,669	9,382	92,260	9,416	5,305	1,846	0	0
2000	4,248	1,554	578	332	0	1	19	13	113	103	833	477	59,942	9,248	91,774	9,484	3,175	999	0	0
Net change	2,139	1,072	80	66	0	1	11	9	–3	4	11	19	5,532	2,772	–5,860	2,775	–1,910	1,002	0	0
Gross change	4,062	1,673	80	66	14	17	24	20	15	22	24	18	15,970	3,212	15,952	3,234	3,692	1,572	0	0

Table 5. Principal land-cover conversions in Northwestern Glaciated 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 (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Grassland/Shrubland	Agriculture	2,438	840	568	1.5	57.9
	Agriculture	Grassland/Shrubland	1,000	317	214	0.6	23.8
	Wetland	Water	376	240	162	0.2	8.9
	Water	Wetland	254	157	106	0.2	6.0
	Agriculture	Wetland	33	28	19	0.0	0.8
	Other	Other	109	n/a	n/a	0.1	2.6
		Totals	4,210			2.6	100.0
1980–1986	Grassland/Shrubland	Agriculture	1,976	739	500	1.2	47.5
	Agriculture	Grassland/Shrubland	1,529	669	452	1.0	36.8
	Wetland	Water	383	227	154	0.2	9.2
	Water	Wetland	173	100	67	0.1	4.2
	Agriculture	Wetland	19	13	9	0.0	0.5
	Other	Other	78	n/a	n/a	0.0	1.9
		Totals	4,158			2.6	100.0
1986–1992	Agriculture	Grassland/Shrubland	7,997	1,968	1,331	5.0	81.3
	Grassland/Shrubland	Agriculture	833	337	228	0.5	8.5
	Water	Wetland	674	370	250	0.4	6.8
	Wetland	Water	139	89	60	0.1	1.4
	Wetland	Agriculture	37	19	13	0.0	0.4
	Other	Other	159	n/a	n/a	0.1	1.6
		Totals	9,838			6.1	100.0
1992–2000	Agriculture	Grassland/Shrubland	4,162	1,508	1,020	2.6	39.2
	Grassland/Shrubland	Agriculture	3,780	1,209	817	2.4	35.6
	Wetland	Water	2,276	1,089	736	1.4	21.4
	Grassland/Shrubland	Water	120	100	68	0.1	1.1
	Water	Wetland	112	103	70	0.1	1.1
	Other	Other	179	n/a	n/a	0.1	1.7
		Totals	10,628			6.6	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	14,688	3,103	2,098	9.1	50.9
	Grassland/Shrubland	Agriculture	9,027	1,947	1,316	5.6	31.3
	Wetland	Water	3,172	1,388	939	2.0	11.0
	Water	Wetland	1,212	514	347	0.8	4.2
	Grassland/Shrubland	Water	159	110	74	0.1	0.6
	Other	Other	574	n/a	n/a	0.4	2.0
		Totals	28,834			17.9	100.0

Table 6. Areas (in square kilometers) of cumulative enrollment in Conservation Reserve Program by year of counties that intersect Northwestern Glaciated Plains Ecoregion (U.S. Department of Agriculture, 2008).

State	County	Area (km²)		
		1986	1992	2000
Montana	Blaine	0	469	651
	Chouteau	4	613	950
	Daniels	13	592	594
	Hill	0	675	1,078
	Liberty	0	331	486
	Phillips	16	515	682
	Richland	8	296	453
	Roosevelt	13	571	694
	Sheridan	14	697	596
	Valley	0	821	824
	Totals	68	5,579	6,357
North Dakota	Burleigh	3	409	382
	Divide	4	396	269
	Emmons	2	250	285
	Kidder	29	438	446
	Logan	0	238	232
	McIntosh	2	183	237
	McLean	1	401	292
	Mountrail	0	383	204
	Sheridan	0	261	240
	Stutsman	3	675	711
	Wells	1	268	271
	Williams	0	219	217
	Totals	45	4,121	3,786
South Dakota	Aurora	4	42	55
	Brule	0	27	19
	Campbell	0	125	161
	Charles Mix	0	33	28
	Douglas	0	6	16
	Edmunds	0	289	99
	Faulk	0	93	41
	Gregory	0	20	10
	Hand	0	70	131
	Hughes	0	48	41
	Jerauld	0	87	47
	McPherson	2	256	185
	Potter	0	160	112
	Sully	0	84	79
	Walworth	0	124	63
	Totals	6	1,464	1,087

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Chapter 9

Western Corn Belt Plains Ecoregion

By Roger F. Auch

Ecoregion Description

The Western Corn Belt Plains Ecoregion is centered in Iowa, with parts extending into southern Minnesota, eastern Nebraska, northeastern Kansas, northwestern Missouri, and small areas of western Wisconsin and southeastern South Dakota (fig. 1), covering about 216,363 km^2 (83,538 mi^2). The ecoregion is surrounded by (clockwise, from its northernmost point) the North Central Hardwood Forests, Driftless Area, Central Corn Belt Plains, Interior River Lowlands, Central Irregular Plains, Flint Hills, Central Great Plains, Nebraska Sand Hills, Northwestern Glaciated Plains, and Northern Glaciated Plains Ecoregions (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997).

The climate of the Western Corn Belt Plains Ecoregion is considered to be continental (hot summers and cold winters). Average annual precipitation amounts range from 610 to 915 mm (24–36 in.), slightly less in the northwestern part of the ecoregion (Kottek and others, 2006; PRISM Climate Group, 2006). The topography is level-to-rolling plains underlain by glaciated till, with hilly loess-covered plains in the western part (Omernik, 1987; U.S. Environmental Protection Agency, 2002) (fig. 2).

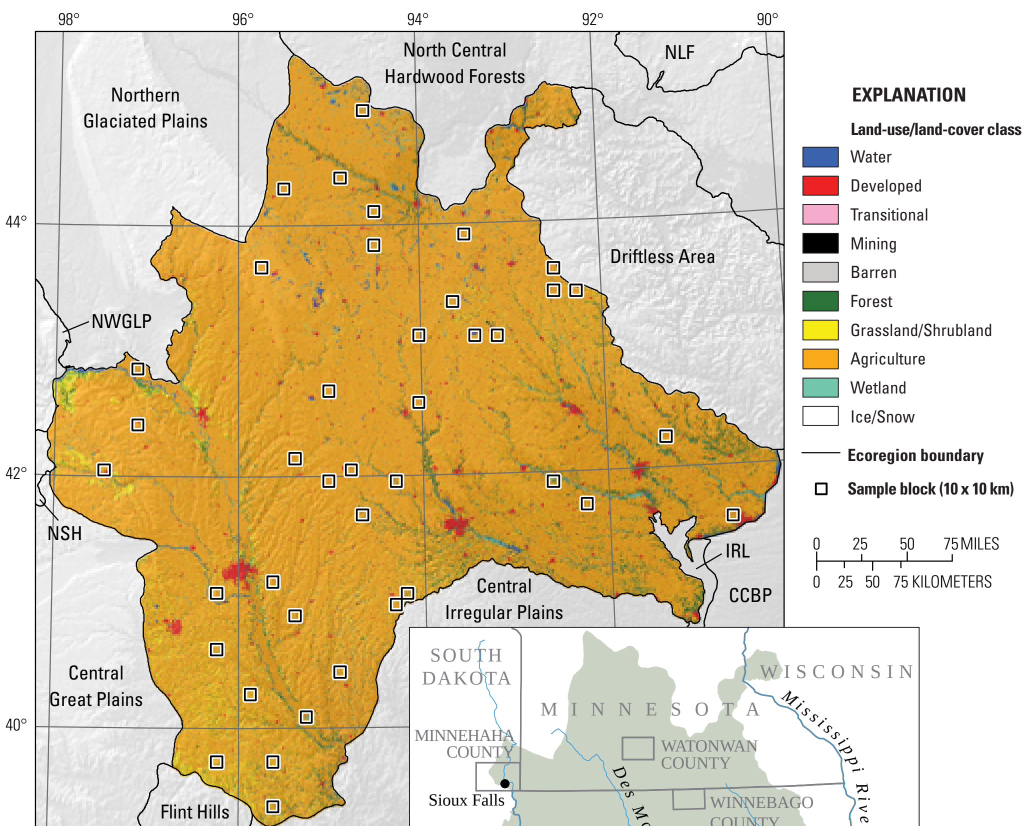

Figure 1. Map of Western Corn Belt Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status 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 Great Plains ecoregions are listed in appendix 2. Also shown are five Midwest–South Central United States ecoregions: Central Corn Belt Plains (CCBP), Driftless Area, Interior River Lowland (IRL), North Central Hardwood Forests, and Northern Lakes and Forests (NLF). See appendix 3 for definitions of land-use/land-cover classifications.

The Western Corn Belt Plains Ecoregion in the first half of the 19th century was predominantly tallgrass prairie, forest (both riparian and oak-prairie savanna), and wetlands (both herbaceous marshes and wooded floodplains) (Dinsmore, 1994; Karnitz and Asbjornsen, 2006). The combination of climate, topography, and soils in the ecoregion enabled Euro-American settlers during the second half of the 19th century to convert most of the existing land to farmland (primarily cropland). Draining of herbaceous wetlands to create more farmland peaked in the first decades of the 20th century (Vileisis, 1997; Timmerman, 2001).

Agriculture continued to dominate the ecoregion during the study period (1973–2000). The Western Corn Belt Plains Ecoregion is a world leader in corn and soybean production (U.S. Environmental Protection Agency, 2002) (figs. 3*A*,*B*), although other crops such as alfalfa hay and wheat also are grown there. The agriculture land-use/land-cover class also includes pastureland used for livestock production such as hogs and beef cattle (figs. 3*C*,*D*).

Other land-use/land-cover classes present in smaller areas of the ecoregion include forest, grassland/shrubland, developed, wetland, water, and mining. Forests grew

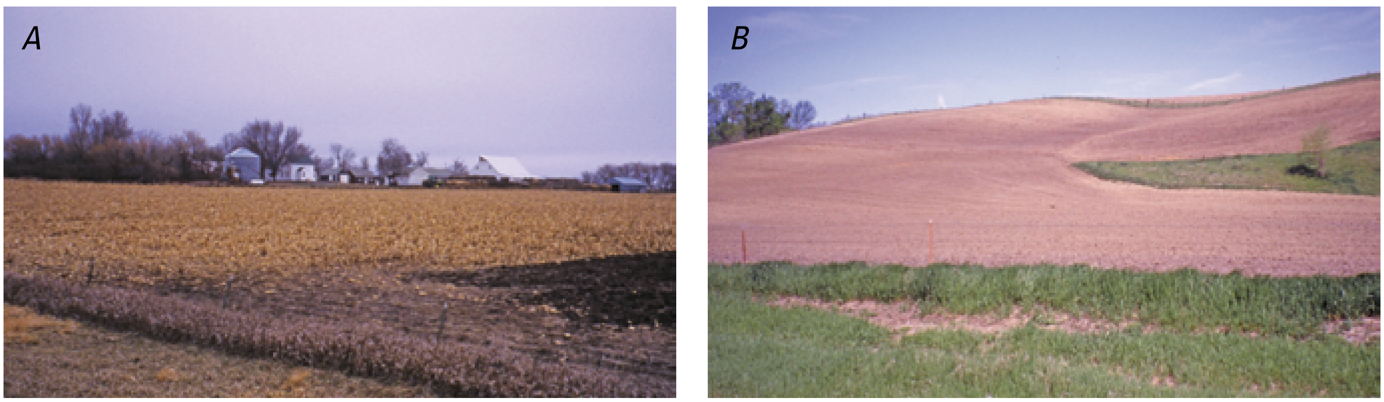

Figure 2. Landforms in Western Corn Belt Plains Ecoregion. *A*, Nearly level plains of glacial till in southwestern Minnesota. *B*, Hilly cropland in northeastern Nebraska.

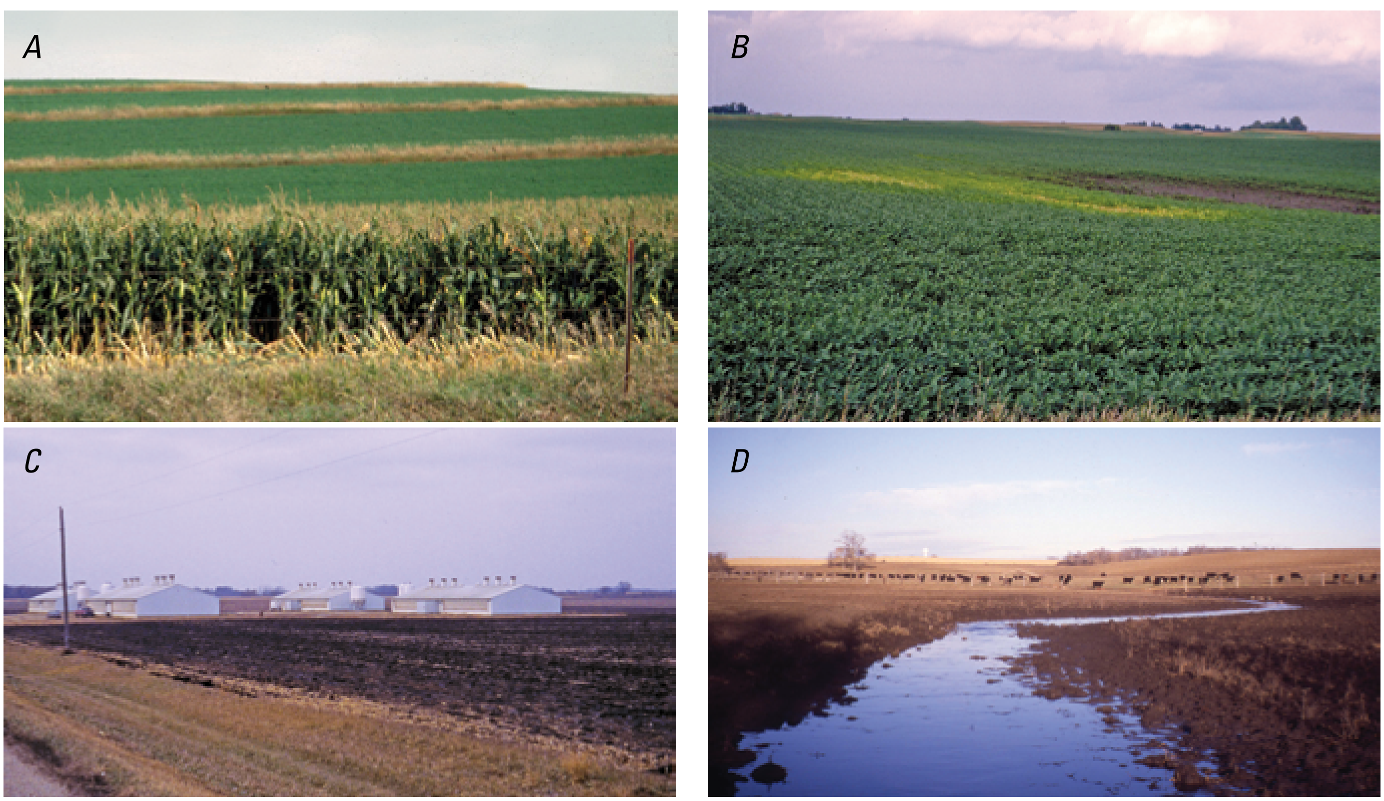

Figure 3. Crops and livestock production in Western Corn Belt Plains Ecoregion. *A*, Field of alfalfa hay and corn near Manning, Iowa. *B*, Soybean field in north-central Iowa. *C*, Hog confinement buildings in Watonwan County, Minnesota. *D*, Cattle feedlot in Minnehaha County, eastern South Dakota.

primarily in the larger river valleys and in areas along the eastern and southern margins of the ecoregion (fig. 1). Other forested land may have been present in farm shelterbelts but may not have been wide enough (that is, discernable using a 60 m × 60 m mapping unit) to map continuously. Grassland/shrubland consisted of less intensively used grazing areas (usually in more topographically varied areas) and wildlife-habitat areas, as well as, in the latter parts of the study period, idled Conservation Reserve Program (CRP) farmland (fig. 4). Developed land was present in major cities such as Omaha, Nebraska, and Des Moines, Iowa, as well as in many small farm towns across the ecoregion (fig. 5). Little exurban development occurred except on the fringes of the cities. Wetland was a minor land-use/land-cover class in the ecoregion, present primarily in bottomland riparian areas and herbaceous marshes.

Figure 4. Areas of grassland/shrubland in Western Corn Belt Plains Ecoregion. *A*, Grassy field on sloped land in Iowa County, Iowa. *B*, Prairie grasses, in wildlife habitat maintained by state and private conservation organizations, in southwestern Minnesota. *C*, Conservation Reserve Program field in northwestern Missouri.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Western Corn Belt Plains Ecoregion between 1973 and 2000 is 3.2 percent (table 1). Compared to other Great Plains ecoregions, change in the ecoregion was low (fig. 6). The Western Corn Belt Plains Ecoregion changed less than the Northern Glaciated Plains and Northwestern Glaciated Plains Ecoregions to the

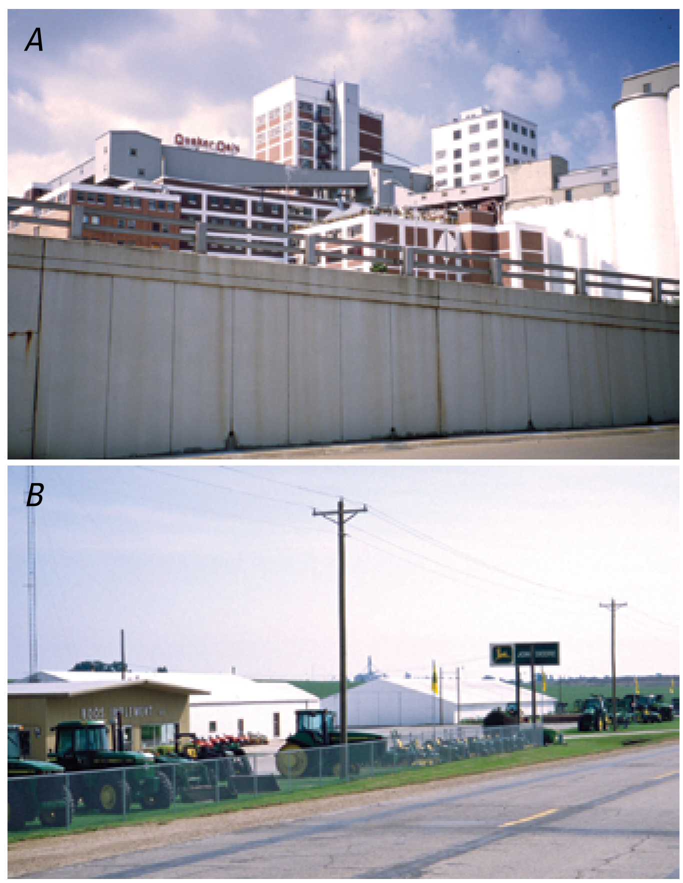

Figure 5. Developed areas in Western Corn Belt Plains Ecoregion. *A*, Food-processing plant and other buildings in Cedar Rapids, Iowa. *B*, Farm equipment business, a common sight in many small towns in ecoregion.

northwest, the Nebraska Sand Hills and Central Great Plains Ecoregions to the southwest, and the Central Irregular Plains Ecoregion to the south, but it experienced more overall change than the Flint Hills Ecoregion to the south-southwest (fig. 6). Most of the change (2.6 percent) occurred only one time during the study period, but some areas (0.6 percent) experienced multiple changes (table 1). Typical examples of land that experienced multiple changes in the ecoregion were agricultural land taken out of production and converted to grassland/shrubland, as well as areas that shifted back and forth between wetland and water, owing to changing climatic cycles. The last two time periods (1986–1992, 1992–2000) had more change than the first two time periods (1973–1980, 1980–1986) (table 2). When the uneven time periods were normalized to an annual rate of change, the periods between 1986 and 1992 and between 1992 and 2000 had the highest rate of change (0.2 percent), and the periods between 1973 and 1980 and between 1980 and 1986 had the lowest rate of change (0.1 percent) (fig. 7).

Land cover and land use within the Western Corn Belt Plains Ecoregion was fairly stable during the study period (1973–2000). Agriculture and grassland/shrubland had the most net change during the study period, followed by developed (table 3). Agriculture constituted 90 percent of the ecoregion in 1973, declining to 87.9 percent by 2000 (table 3) primarily through conversion to grassland/shrubland, developed, and, to lesser extent, water and wetland (table 4). Related to this loss was a net gain of 1.4 percent in grassland/shrubland (table 3). Most of the change from agriculture to grassland/shrubland occurred during the last two time periods (1986–1992, 1992–2000) when the CRP was in effect (table 4). The CRP paid farmers to retire marginal cropland to native grasslands through contracts, usually 10 years in duration. The initial implementation of the CRP had the greatest effect between 1986 and 1992, when conversions from agriculture to grassland/shrubland increased substantially (table 4; fig. 8). Although some land in the ecoregion may have been under a second CRP contract by the year 2000, much grassland/shrubland reverted to agriculture between 1992 and 2000, probably owing to CRP land being placed back into production (table 4; fig. 8) (Leathers and Harrington, 2000). The conversion of agriculture to water, mostly in the form of new reservoirs of various sizes, was a small but noteworthy factor in the loss of agriculture land cover. Agricultural land also was lost through grassland- and wetland-restoration efforts within the ecoregion, especially during the second half of the study period (Fletcher and Koford, 2003; Schilling and Spooner, 2006); however, on a ecoregional scale, such efforts affected only small areas of farmland. Grassland- and wetland-restoration efforts can result in more permanent conversions of agricultural land, whereas conversions of agricultural land enrolled in the CRP can be temporary (fig. 9).

An increase in developed land was the third largest net change (0.5 percent) in the ecoregion between 1973 and 2000 (table 3). The conversion of agriculture to developed was the most permanent change in the ecoregion. The Western

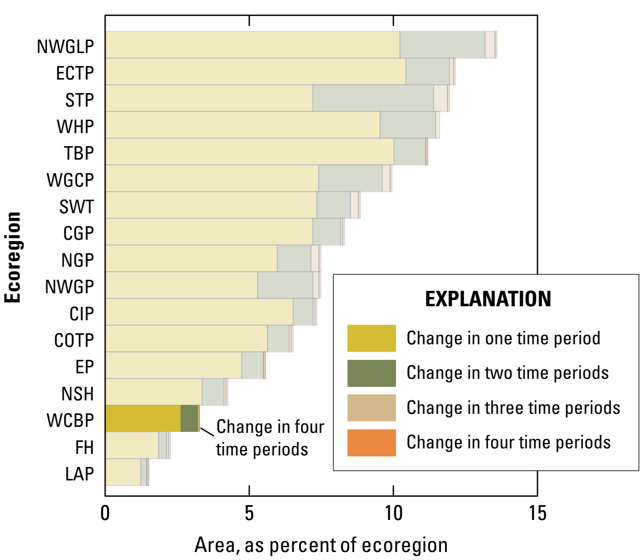

Figure 6. Overall spatial change in Western Corn Belt Plains Ecoregion (WCBP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Western 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.

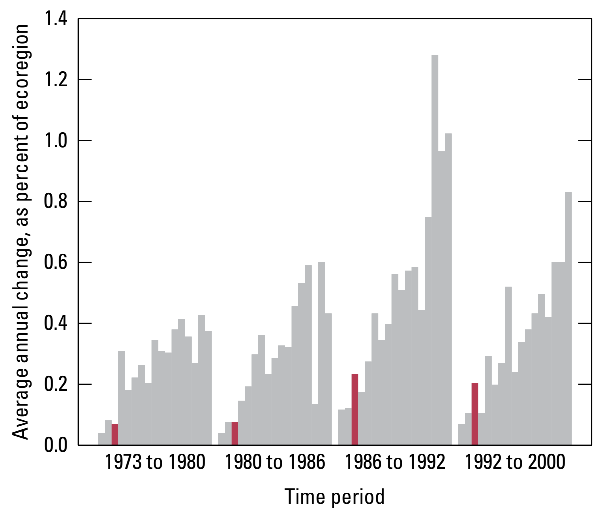

Figure 7. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Western Corn Belt Plains Ecoregion are represented by red bars in each time period.

Corn Belt Plains Ecoregion gained an estimated 1,102 km^2 of developed land (table 3), 1,033 km^2 of which was from agricultural land (table 4). The number of people needed to farm and support agricultural land continued to decrease during the study period, and many rural counties continued to decline in population (Waisanen, 2003). However, small- and medium-sized urban areas in the ecoregion attracted people, especially as service-based employment became a larger part of urban economies. Manufacturing remained as an important part of the economy of the ecoregion, and smaller cities benefited by physically growing by adding new, small-scale manufacturing plants (Waisanen, 2003) (fig. 10).

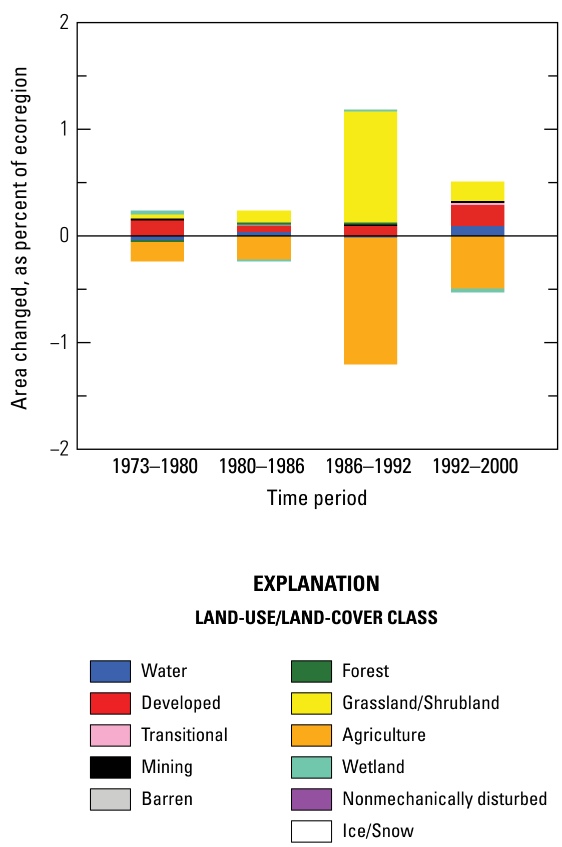

Figure 8. Normalized average net change in Western Corn Belt Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

Figure 9. Restoration efforts in Western Corn Belt Plains Ecoregion. *A*, Tallgrass prairie conservation and restoration in northern Iowa. *B*, Wetlands restoration, in Winnebago County, Iowa, a cooperative effort by multiple parties. *C*, Federal- and state-funded wetlands restoration project in Winnebago County, Iowa.

Figure 10. Developed areas in Western Corn Belt Plains Ecoregion. *A*, Abandoned businesses in small east-central Iowa town, one of many farm towns in decline in ecoregion. *B*, New housing in Walford, Iowa, just southwest of Cedar Rapids. Most newly developed land was on edge of cities or in nearby small towns. *C*, New manufacturing plant that makes new steel products from scrap metal, in Norfolk, Nebraska, one of several small cities attracting new industries.

Table 1. Percentage of Western 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 (96.8 percent), whereas 3.2 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	2.6	0.7	1.9	3.3	0.5	17.5
2	0.6	0.2	0.4	0.7	0.1	20.0
3	0.0	0.0	0.0	0.1	0.0	35.1
4	0.0	0.0	0.0	0.0	0.0	44.6
Overall spatial change	3.2	0.8	2.5	4.0	0.5	16.1

Table 2. Raw estimates of change in Western 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	0.5	0.2	0.3	0.7	0.1	28.6	0.1
1980–1986	0.5	0.2	0.3	0.6	0.1	23.0	0.1
1986–1992	1.4	0.4	1.0	1.7	0.2	17.7	0.2
1992–2000	1.6	0.4	1.2	2.0	0.3	17.3	0.2
			Estimate of change, in square kilometers				
1973–1980	1,002	421	581	1,422	286	28.6	143
1980–1986	991	334	657	1,326	228	23.0	165
1986–1992	2,972	771	2,201	3,744	525	17.7	495
1992–2000	3,496	886	2,609	4,382	604	17.3	437

Table 3. Estimated area (and margin of error) of each land-cover class in Western 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	0.8	0.5	1.7	0.7	0.0	0.0	0.1	0.0	0.0	0.0	3.3	0.9	2.5	0.7	90.0	2.0	1.6	0.9	0.0	0.0
1980	0.8	0.5	1.8	0.8	0.0	0.0	0.1	0.0	0.0	0.0	3.2	0.9	2.5	0.7	89.8	2.1	1.7	1.0	0.0	0.0
1986	0.8	0.5	1.9	0.8	0.0	0.0	0.1	0.0	0.0	0.0	3.3	0.9	2.6	0.7	89.6	2.1	1.7	1.0	0.0	0.0
1992	0.8	0.5	2.0	0.9	0.0	0.0	0.1	0.0	0.0	0.0	3.3	0.9	3.7	0.9	88.4	2.3	1.7	1.0	0.0	0.0
2000	0.9	0.5	2.2	1.0	0.0	0.0	0.1	0.1	0.0	0.0	3.3	0.9	3.9	1.0	87.9	2.4	1.7	1.0	0.0	0.0
Net change	0.1	0.2	0.5	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	1.4	0.4	–2.1	0.6	0.0	0.1	0.0	0.0
Gross change	0.4	0.2	0.5	0.3	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.1	2.0	0.5	2.7	0.7	0.3	0.1	0.0	0.0
Area, in square kilometers																				
1973	1,745	1,121	3,670	1,479	9	13	131	59	9	13	7,061	1,924	5,452	1,460	194,763	4,378	3,523	2,040	0	0
1980	1,683	1,098	3,984	1,691	15	15	172	79	3	4	7,003	1,913	5,517	1,472	194,370	4,520	3,615	2,179	0	0
1986	1,776	1,123	4,109	1,775	9	10	178	81	9	12	7,073	1,934	5,731	1,504	193,890	4,613	3,588	2,166	0	0
1992	1,741	1,114	4,321	1,944	2	2	217	104	8	9	7,093	1,956	7,987	2,010	191,340	4,998	3,655	2,205	0	0
2000	1,952	1,159	4,772	2,143	17	16	245	122	11	14	7,088	1,943	8,406	2,066	190,276	5,267	3,597	2,216	0	0
Net change	207	356	1,102	717	8	5	114	81	2	2	26	91	2,955	882	–4,487	1,331	74	210	0	0
Gross change	774	391	1,102	717	50	37	218	114	20	27	341	111	4,414	1,151	5,794	1,443	560	258	0	0

Table 4. Principal land-cover conversions in Western 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" 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	Agriculture	Developed	301	236	161	0.1	30.1
	Water	Wetland	159	153	104	0.1	15.9
	Agriculture	Grassland/Shrubland	155	80	54	0.1	15.4
	Grassland/Shrubland	Agriculture	89	74	51	0.0	8.9
	Wetland	Water	65	55	37	0.0	6.4
	Other	Other	233	n/a	n/a	0.1	23.3
		Totals	1,002			0.5	100.0
1980–1986	Agriculture	Grassland/Shrubland	303	120	81	0.1	30.6
	Agriculture	Developed	114	95	65	0.1	11.5
	Wetland	Water	106	83	56	0.0	10.7
	Water	Wetland	69	52	35	0.0	7.0
	Grassland/Shrubland	Forest	55	38	26	0.0	5.5
	Other	Other	344	n/a	n/a	0.2	34.7
		Totals	991			0.5	100.0
1986–1992	Agriculture	Grassland/Shrubland	2,311	702	478	1.1	77.8
	Agriculture	Developed	198	192	131	0.1	6.7
	Water	Wetland	89	83	57	0.0	3.0
	Agriculture	Wetland	46	46	31	0.0	1.6
	Grassland/Shrubland	Forest	42	27	19	0.0	1.4
	Other	Other	285	n/a	n/a	0.1	9.6
		Totals	2,972			1.4	100.0
1992–2000	Agriculture	Grassland/Shrubland	1,514	606	413	0.7	43.3
	Grassland/Shrubland	Agriculture	1,014	403	274	0.5	29.0
	Agriculture	Developed	419	226	154	0.2	12.0
	Agriculture	Water	98	103	70	0.0	2.8
	Wetland	Water	59	50	34	0.0	1.7
	Other	Other	391	n/a	n/a	0.2	11.2
		Totals	3,496			1.6	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	4,283	1,137	774	2.0	50.6
	Grassland/Shrubland	Agriculture	1,175	461	314	0.5	13.9
	Agriculture	Developed	1,033	691	471	0.5	12.2
	Water	Wetland	334	203	138	0.2	4.0
	Wetland	Water	264	127	87	0.1	3.1
	Other	Other	1,372	n/a	n/a	0.6	16.2
		Totals	8,461			3.9	100.0

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East-Central Plains Ecoregions

Chapter 10

Central Irregular Plains Ecoregion

By Krista A. Karstensen

Ecoregion Description

The Central Irregular Plains Ecoregion encompasses 122,589 km^2 (47,332 mi^2) of southern Iowa, northern and central Missouri, eastern Kansas, and northeastern Oklahoma (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The ecoregion is surrounded by (clockwise, from the north) the Western Corn Belt Plains, Interior River Lowland, Ozark Highlands, Boston Mountains, Arkansas Valley, Central Oklahoma/Texas Plains, and Flint Hills Ecoregions (fig. 1). The most populous cities in the ecoregion are Kansas City, Missouri, and Tulsa, Oklahoma, with populations of 441,545 and 393,049, respectively, in the year 2000 (U.S. Census Bureau, 2010).

The topography of the Central Irregular Plains Ecoregion is more variable than that of the Western Corn Belt Plains Ecoregion to the north but less irregular and less forested than that of the ecoregions to the south and east (Chapman and others, 2002). The northern part of the ecoregion (in northern Missouri and southern Iowa) ranges from flat to moderately hilly, and it includes natural wetlands along the Grand River.

The natural vegetation in the ecoregion is a grassland–oak woodland mosaic. The prairie grassland primarily is composed of little bluestem (*Schizachyrium scoparium*) and sideoats grama (*Bouteloua curtipendula*) grasses (Chapman and others, 2002), both native grasses that have agricultural uses: little bluestem is a forage species that is readily grazed by livestock and also is suitable for hay, and sideoats grama is one of the most important range grasses as it can lengthen the grazing season and, therefore, increase the forage production (U.S. Department of Agriculture, 2002a,b).

In addition to the Grand River, the Central Irregular Plains Ecoregion includes stretches of the Missouri, Chariton, Des Moines, Kansas, Arkansas, and Thompson Rivers and their tributaries. The ecoregion, which is in a mesic temperature regime, receives a mean annual precipitation of 800–1,000 mm

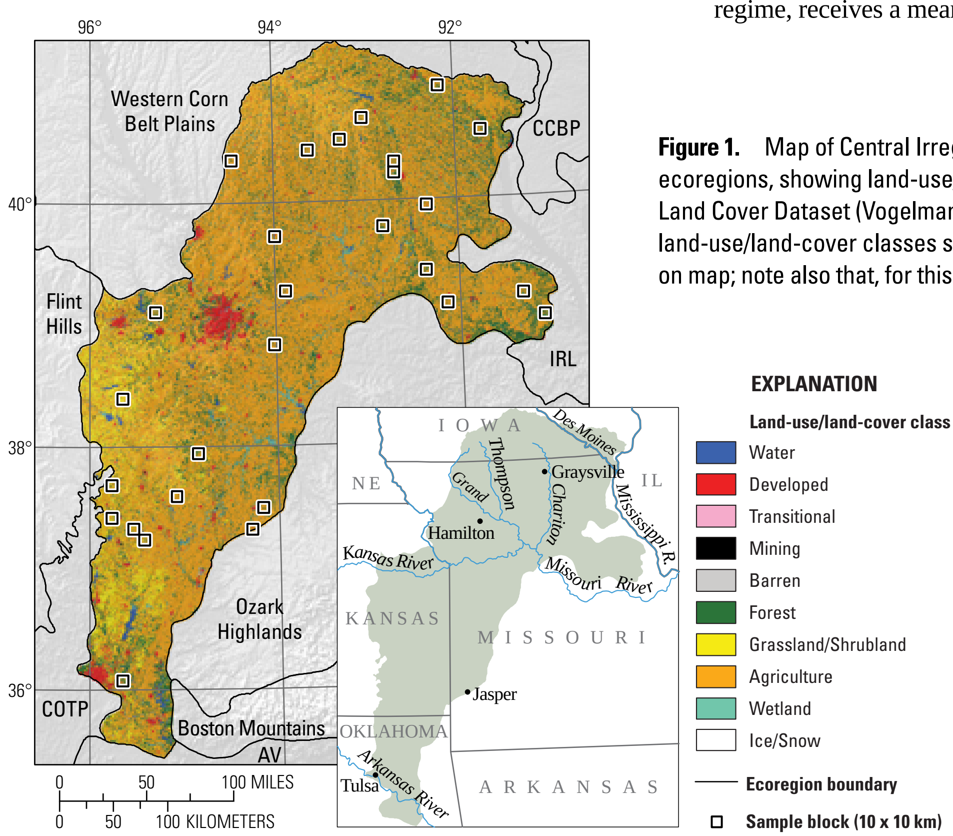


Figure 1. Map of Central Irregular Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status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

(32–40 in.) (Chapman and others, 2002). In 1993, the Mississippi River system flood (known informally as the "Great Flood of 1993;" Johnson and others, 2004) inundated a large part of the ecoregion's agricultural areas in northern Missouri and southern Iowa. Although patterns of flooding in this ecoregion depend on basin size and topography, the high incidence of large floods in the central Midwest and upper Mississippi River valley (for example, the 1993 flood) also is due to the mesoscale convective complexes—large, multiple-celled, persistent thunderstorm systems largely fed by moisture from the Gulf of Mexico—that frequently strike the ecoregion (O'Connor and Costa, 2003).

Glacial tills form the parent material for most of the soil in Iowa and the northern part of Missouri, whereas the southern part of the ecoregion was not glaciated (Chapman and others, 2002). Loess deposits generally increase near the Missouri River (Chapman and others, 2002). The southwestern part of the ecoregion (west-central Missouri, western Kansas, and northern Oklahoma) has claypan soils and a smoother topography (Chapman, and others, 2002).

Although the Central Irregular Plains Ecoregion has a variety of land uses, agriculture dominates much of the landscape. The gently rolling topography and generally fertile soils are conducive to various agricultural practices such as contour farming, which is common in Iowa and northern Missouri (Chapman and others, 2002). Crops common to the ecoregion include corn, soybeans, wheat (fig. 2), and sorghum (U.S. Department of Agriculture, 2009b,c,d,e). Cattle production also is an important land use (U.S. Department of Agriculture, 2009b,c,d,e). Most Iowa counties in this ecoregion have 50 percent or more of their land in agricultural production (U.S. Department of Agriculture, 2009b). The Conservation Reserve Program (CRP) is a Federal program created in 1985 to provide financial assistance to eligible farmers to help manage natural resource concerns on their land, particularly through the conversion of marginal agricultural land to grassland/shrubland.

Figure 2. Wheat field near Jasper, Missouri, in Central Irregular Plains Ecoregion.

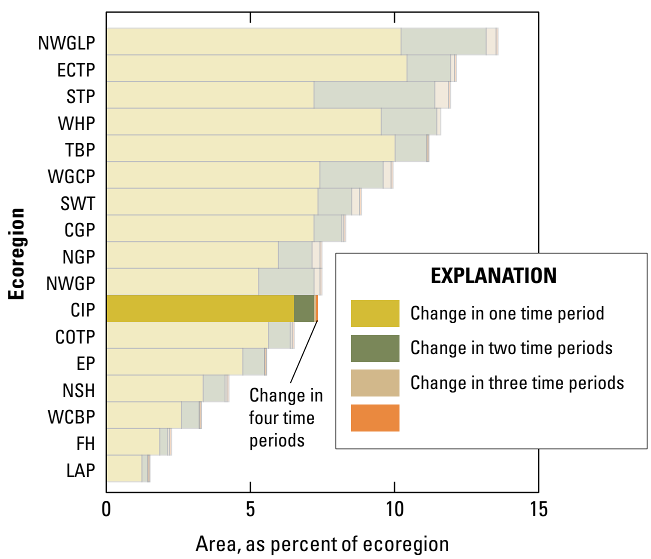


Figure 3. Overall spatial change in Central Irregular Plains Ecoregion (CIP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Central Irregular 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 Central Irregular Plains Ecoregion between 1973 and 2000 is 7.3 percent (table 1). Compared to other Great Plains ecoregions, change in the ecoregion was moderate, but it was greater than in two neighboring ecoregions: the Flint Hills Ecoregion, mostly rangeland, and the intensively cropped Western Corn Belt Plains Ecoregion (fig. 3). An estimated 6.5 percent of the ecoregion changed one time during the 27-year study period, while 0.7 percent changed two times and 0.1 percent changed three times.

Change percentages varied only slightly from 1973 to 2000, with the total change (percent of the ecoregion affected) ranging from a low of 1.8 percent to a high of 2.2 percent (table 2). The average annual rate of change was highest between 1980 and 1986, at 0.4 percent (444 km^2) per year (table 2; fig. 4).

In 2000, agriculture was the largest land-cover class in the ecoregion, estimated at 59.9 percent (73,466 km^2), with a net decrease of 3.0 percent over the study period (table 3; fig. 5). Large areas of agricultural land were converted to grassland/shrubland and developed land. Forest was the second largest land-cover class, encompassing 20.4 percent (24,956 km^2) of the ecoregion in 1973 and 20.0 percent (24,539 km^2) in 2000 (table 3). Grassland/shrubland, the third most extensive land-cover class, increased from 13.5 percent (16,572 km^2) of the ecoregion in 1973 to 15.9 percent (19,462 km^2) in 2000 (table 3).

Overall, the most common land-cover conversion in every study period was the conversion from agriculture to grassland/shrubland. Between 1973 and 2000, 5,366 km^2 were converted from agriculture to grassland/shrubland (table 4). However, this conversion did not result in a large net increase in grassland/shrubland because, during the same time period, the second most common conversion was from grassland/shrubland to agricultural land (2,128 km^2). The inception of the Conservation Reserve Program (CRP) and the economic crisis of the 1980s may explain much of this conversion. Forested land also declined in the ecoregion, which can be attributed primarily to clearing for agricultural expansion.

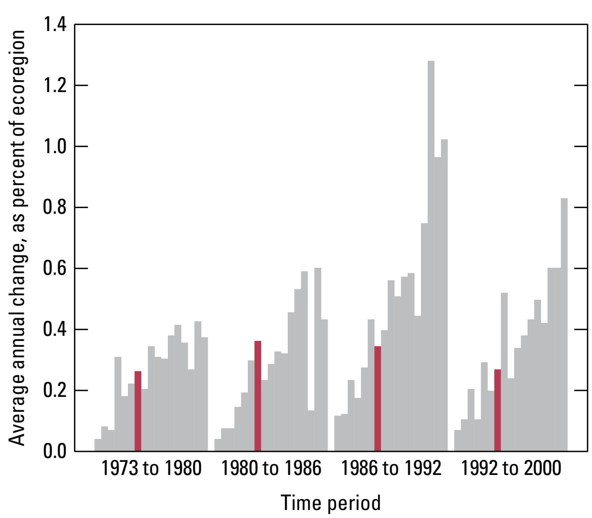
Economics play an important role in the land-use story of the Central Irregular Plains Ecoregion. Major factors influencing conversion of agricultural land to grassland/shrubland during the study period include the economic crisis of the 1980s, the socioeconomic repercussions of the "Great Flood of 1993" (Johnson and others, 2004), and the CRP.

The economic climate of the 1970s encouraged farmers to expand production to benefit from improved export opportunities, strong commodity prices, increased farm income, and higher farmland values. Abundant credit financed the expansion as high rates of inflation and low real interest rates encouraged investment in farmland, and many farmers took on heavy debt loads, becoming vulnerable to sudden shifts in economic forces (Stam and Dixon, 2004; Cofer and others, 2009).

The economic crisis of the early 1980s greatly changed these conditions as export markets contracted and input prices and interest rates rose. The financial stress became more severe when declines in farm commodity prices, income, and land values (the asset used to secure debt) made it difficult for some farmers to service their debts (Stam and Dixon, 2004; Cofer and others, 2009). The crisis may have had an influence in the amount of agricultural land that was converted to grassland/shrubland in the 1980s. The associated banking crisis of the early 1980s imposed particular economic hardship on small, family-operated farms as many farm banks failed, and many farms faced foreclosure. Many of these farms may have been converted from agricultural land to grassland/shrubland.

The "Great Flood of 1993" devastated cropland, also influencing land-use changes in the Central Irregular Plains Ecoregion. From April 1 to August 31, 1993, precipitation amounts approached 1,219 mm (48 in.) in east-central Iowa, surpassing the normal annual precipitation average of 762 to 914 mm (30–36 in.) in that area (Johnson and others, 2004). The extent of the damage caused by the flood to agricultural resources shows how climatic influences may affect land-cover change by decreasing agricultural production.

The inception of the CRP in 1985 contributed significantly to the conversion from agriculture to grassland/



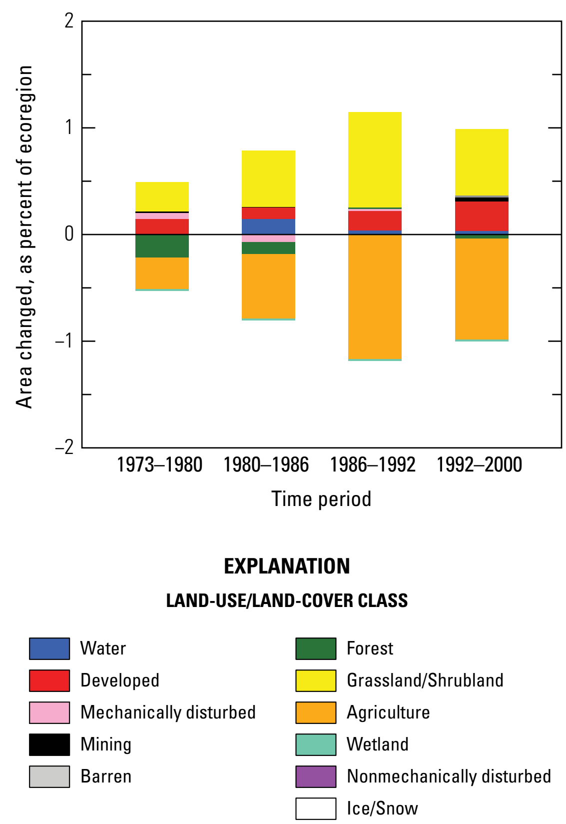


Figure 4. Normalized average net change in Central Irregular Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

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

shrubland (fig. 6). The CRP annual cumulative enrollment statistics show that the acreage enrolled in CRP greatly increased between 1986 and 1992, from 321 km² (79,400 acres) to 5,058 km² (1,250,000 acres), respectively, before declining in 2000 by about 647 km² (160,000 acres) (U.S. Department of Agriculture, 2009a).

No-till conservation tillage was encouraged in many parts of the ecoregion in the 1980s, and it continues to be widely practiced. Conservation tillage provides a more economical way to manage cropland, and it likely contributed to grassland/shrubland being converted back to agriculture (fig. 7) (U.S. Department of Agriculture, 1997). Between 1990 and 2010, the population and settlements of the Amish—a distinctly rural people who live on and cultivate small but diversified farms—increased throughout the ecoregion (Elizabethtown College, 2010), possibly adding to the increase in agriculture.

Figure 6. Land enrolled in Conservation Reserve Program, near Graysville, Missouri, in Central Irregular Plains Ecoregion.

Figure 7. Conservation tillage on farm near Hamilton, Missouri, in Central Irregular Plains Ecoregion.

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

[Most sample pixels remained unchanged (92.7 percent), whereas 7.3 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	6.5	1.7	4.8	8.2	1.1	17.5
2	0.7	0.4	0.4	1.0	0.2	32.1
3	0.1	0.1	0.0	0.1	0.0	64.1
4	0.0	0.0	0.0	0.0	0.0	98.8
Overall spatial change	7.3	2.0	5.4	9.3	1.3	18.1

Table 2. Raw estimates of change in Central Irregular 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	1.8	0.6	1.2	2.4	0.4	22.3	0.3
1980–1986	2.2	0.8	1.3	3.0	0.6	25.6	0.4
1986–1992	2.0	0.6	1.4	2.7	0.4	20.8	0.3
1992–2000	2.2	0.8	1.3	3.0	0.6	25.9	0.3
Estimate of change, in square kilometers							
1973–1980	2,218	734	1,484	2,951	495	22.3	317
1980–1986	2,663	1,012	1,652	3,675	683	25.6	444
1986–1992	2,511	774	1,737	3,285	522	20.8	418
1992–2000	2,644	1,017	1,628	3,661	686	25.9	331

Table 3. Estimated area (and margin of error) of each land-cover class in Central Irregular 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	0.7	0.2	1.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	20.4	3.1	13.5	3.3	62.9	4.4	1.0	0.4	0.0	0.0
1980	0.7	0.2	1.5	0.5	0.1	0.1	0.0	0.0	0.0	0.0	20.1	3.1	13.8	3.4	62.7	4.4	1.0	0.4	0.0	0.0
1986	0.8	0.2	1.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	20.0	3.1	14.3	3.5	62.1	4.5	1.0	0.4	0.0	0.0
1992	0.9	0.2	1.8	0.7	0.0	0.0	0.1	0.0	0.0	0.0	20.0	3.1	15.2	3.7	60.9	4.6	1.0	0.4	0.0	0.0
2000	0.9	0.2	2.1	0.8	0.0	0.0	0.1	0.0	0.0	0.0	20.0	3.1	15.9	3.8	59.9	4.8	1.0	0.4	0.0	0.0
Net change	0.2	0.1	0.7	0.4	0.0	0.0	0.1	0.0	0.0	0.0	–0.3	0.2	2.4	1.5	–3.0	1.6	0.0	0.0	0.0	0.0
Gross change	0.3	0.1	0.7	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.7	0.2	4.2	1.3	4.8	1.4	0.0	0.0	0.0	0.0
Area, in square kilometers																				
1973	821	218	1,722	540	29	35	28	24	28	37	24,956	3,782	16,572	4,055	77,166	5,344	1,266	517	0	0
1980	831	213	1,894	596	88	88	54	30	35	38	24,697	3,751	16,912	4,202	76,813	5,399	1,265	517	0	0
1986	1,011	246	2,022	660	0	0	58	31	30	37	24,564	3,755	17,575	4,321	76,072	5,518	1,257	512	0	0
1992	1,059	247	2,259	798	5	8	73	36	29	37	24,570	3,766	18,694	4,533	74,648	5,694	1,253	510	0	0
2000	1,100	247	2,611	975	8	7	110	57	42	39	24,539	3,741	19,462	4,692	73,466	5,920	1,251	509	0	0
Net change	279	127	889	537	–21	36	82	52	14	13	–418	290	2,890	1,888	–3,700	2,009	–16	20	0	0
Gross change	389	147	892	536	219	177	84	52	29	33	873	254	5,116	1,643	5,907	1,734	40	24	0	0

Table 4. Principal land-cover conversions in Central Irregular 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	Grassland/Shrubland	905	381	257	0.7	40.8
	Grassland/Shrubland	Agriculture	585	480	324	0.5	26.4
	Forest	Grassland/Shrubland	146	108	73	0.1	6.6
	Forest	Agriculture	144	65	44	0.1	6.5
	Agriculture	Developed	106	116	78	0.1	4.8
	Other	Other	331	n/a	n/a	0.3	14.9
		Totals	2,218			1.8	100.0
1980–1986	Agriculture	Grassland/Shrubland	1,342	606	409	1.1	50.4
	Grassland/Shrubland	Agriculture	648	450	304	0.5	24.3
	Forest	Grassland/Shrubland	106	96	65	0.1	4.0
	Grassland/Shrubland	Forest	95	65	44	0.1	3.6
	Forest	Agriculture	85	44	30	0.1	3.2
	Other	Other	388	n/a	n/a	0.3	14.6
		Totals	2,663			2.2	100.0
1986–1992	Agriculture	Grassland/Shrubland	1,663	594	401	1.4	66.2
	Grassland/Shrubland	Agriculture	391	289	195	0.3	15.6
	Agriculture	Developed	136	85	57	0.1	5.4
	Grassland/Shrubland	Forest	73	39	26	0.1	2.9
	Grassland/Shrubland	Developed	70	83	56	0.1	2.8
	Other	Other	178	n/a	n/a	0.1	7.1
		Totals	2,511			2.0	100.0
1992–2000	Agriculture	Grassland/Shrubland	1,456	878	592	1.2	55.0
	Grassland/Shrubland	Agriculture	505	312	211	0.4	19.1
	Agriculture	Developed	206	139	94	0.2	7.8
	Grassland/Shrubland	Developed	105	107	72	0.1	4.0
	Grassland/Shrubland	Forest	89	54	36	0.1	3.4
	Other	Other	284	n/a	n/a	0.2	10.7
		Totals	2,644			2.2	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	5,366	2,005	1,353	4.4	53.5
	Grassland/Shrubland	Agriculture	2,128	1,243	839	1.7	21.2
	Agriculture	Developed	503	253	171	0.4	5.0
	Forest	Agriculture	323	125	84	0.3	3.2
	Grassland/Shrubland	Forest	304	124	84	0.2	3.0
	Other	Other	1,412	n/a	n/a	1.2	14.1
		Totals	10,036			8.2	100.0

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Chapter 11

Flint Hills Ecoregion

By Steven Kambly

Ecoregion Description

The Flint Hills Ecoregion, which extends about 350 km north-south from Marshall County, Kansas, to Osage County, Oklahoma, includes the Flint Hills in eastern Kansas and the Osage Hills in north-central Oklahoma. The ecoregion covers an area of about 27,911 km^2 (10,777 mi^2) and is about 100 km wide at its widest point, between Lyon and Marion Counties, Kansas (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The ecoregion is bounded on the west by the Central Great Plains Ecoregion, on the north by the Western Corn Belt Plains Ecoregion, and on the east by the Central Irregular Plains and Central Oklahoma/Texas Plains Ecoregions.

A subhumid continental climate accounts for large daily and seasonal temperature fluctuations in the Flint Hills Ecoregion. Summer high temperatures may reach 38°C, whereas winter temperatures may fall as low as -12°C. The ecoregion receives about 760 to 960 mm (30–38 in.) of annual precipitation, the high end of the range occurring in the southern part of the ecoregion. Most precipitation falls during the growing season, from April to September.

Expansive areas of grazed uplands and cultivated lowlands characterize the Flint Hills Ecoregion. Upland topography includes rolling hills that have moderately steep to steep slopes and areas of relatively flat terrain. Soils are derived from underlying limestones, shales, and sandstones (Malin, 1942). Many upland areas have thin soils underlain by limestone that contains bands of erosion-resistant chert, or flint, thus giving the ecoregion its name. Chert stones and rock outcroppings are scattered throughout the upland areas, making it difficult to plow for crop production. Some upland soils support farming, but cost efficiency and other

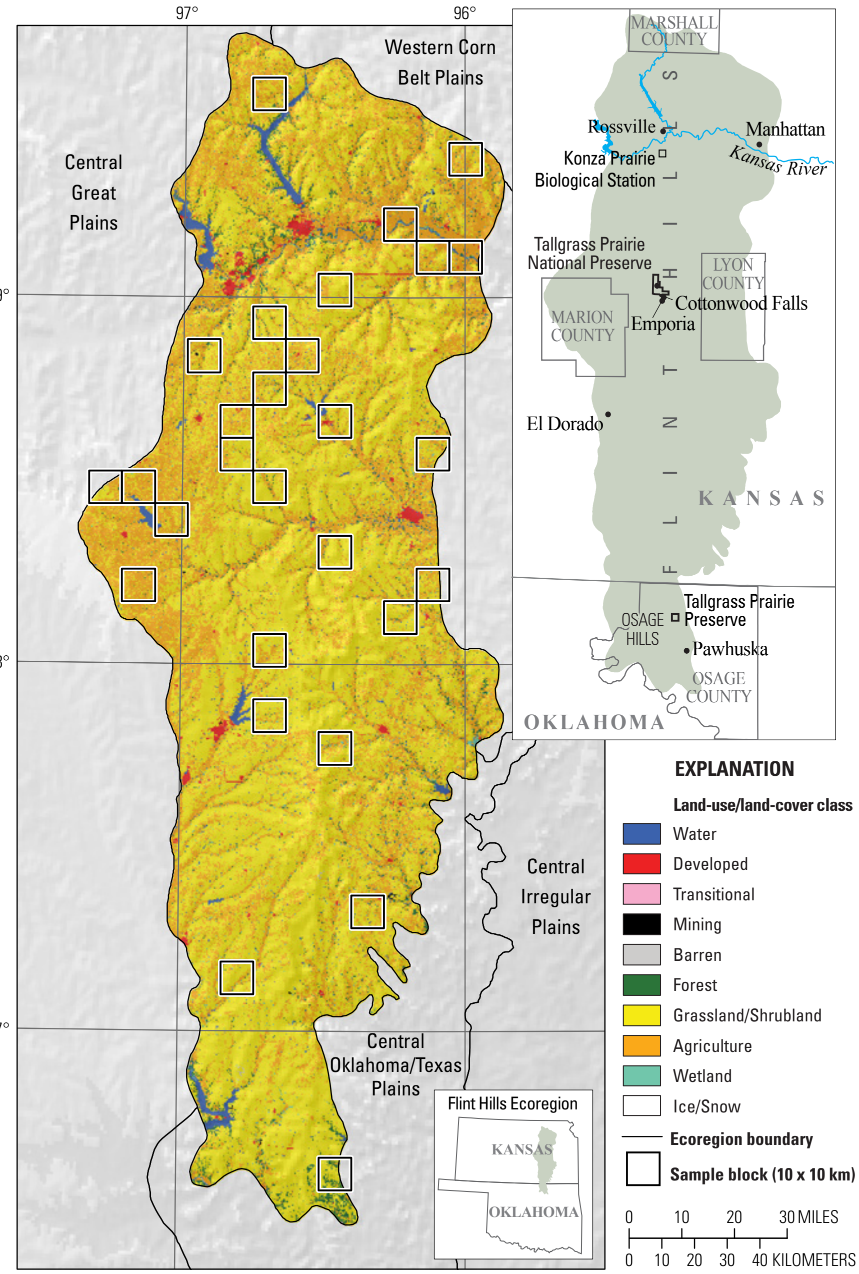

Figure 1. Map of Flint Hills Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends 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 Great Plains ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

factors (including historical and sociological circumstances) contribute to the lack of upland crop production (Kollmorgen and Simonett, 1965). The lowland and lower slope soils, which include deep and permeable silt loams and silty clay loams (Bragg and Hulbert, 1976), support various crops such as wheat, corn, sorghum, soybeans, alfalfa, and oats (figs. 2, 3). Lowland fields tend to be medium to small in size, whereas upland rangelands typically are much larger.

The ecoregion's leading land-cover class is grassland/shrubland, dominated by warm-season grasses, particularly big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and Indiangrass (*Sorghastrum nutans*) (Briggs and others, 2002). Since the 1880s, the grasses have served as forage for cattle transported from Texas and other parts of the southwestern plains. The grazing season usually begins in early spring and continues during the summer, after which the cattle are shipped to slaughterhouses or feedlots. The grasses are maintained through spring burning of the lands to eliminate shrubs and small trees. With their growing tip near the surface, grasses withstand the burns and reemerge each year (Klinkenborg, 2007). Before Euro-American settlement, Native Americans maintained grazing areas for bison using a similar management regime.

The Flint Hills Ecoregion is dotted with small towns (figs. 4,5), most of which have lost much population in the last several decades, a pattern typical of rural communities in the Great Plains (Licht, 1997). Some larger Kansas towns

Figure 2. Wheat field adjacent to Kansas River, which traverses northern part of Flint Hills Ecoregion.

Figure 3. Corn field in Kansas River valley, in Flint Hills Ecoregion.

Figure 4. Small town of Rossville, Kansas (population 1,014 in 2000), in Flint Hills Ecoregion.

Figure 5. Chase County Courthouse, Cottonwood Falls, Kansas (population 966 in 2000), in Flint Hills Ecoregion. Completed in 1873, courthouse was built using limestone that is available in abundance in Flint Hills and that has been used as building material since beginning of Euro-American settlement.

such as Emporia and El Dorado, which are not exclusively linked to the rural economy, grew by less than 5 percent between 1970 and 2000. Manhattan, Kansas, a college town, increased by 62 percent during this same time. Despite these population increases, the amount of developed lands in the ecoregion remained less than 1 percent during the entire 27-year study period.

Although widespread agricultural production in the Great Plains has resulted in the near-total loss of once-extensive native prairie lands, the Flint Hills Ecoregion includes the largest remnant of tallgrass prairie in North America (Knapp and Seastedt, 1998). In 1996, Congress passed legislation to create the Tallgrass Prairie National Preserve, near the geographic center of the ecoregion, to protect 44 km^2 of tallgrass-prairie ecosystem. Additional preserves have been established in the Flint Hills Ecoregion, including the 35 km^2 Konza Prairie Biological Station near Manhattan, Kansas, and the 166 km^2 Tallgrass Prairie Preserve near Pawhuska, Oklahoma. Both preserves, which are owned partly by The Nature Conservancy, are research oriented and work jointly with local universities.

Potential changes to the Flint Hills Ecoregion include those resulting from certain grazing management practices that may affect the diversity and composition of tallgrass-prairie plant communities (Hickman and others, 2004). In addition, grazing and burning practices have disturbed bird nesting habitats, particularly the habitat of the endangered Greater Prairie Chicken (*Tympanuchus cupido*) (Robbins and others, 2002). Moreover, invasion of eastern redcedar (*Juniperus virginiana*) populations (fig. 6) in the northern part of the Flint Hills Ecoregion has resulted in conversions of grasslands to forest; drivers include an increase in human settlement and overgrazing, which have led to fire suppression practices and low fire intensity, respectively (Briggs and others, 2002). Grasslands also are threatened by the spread of *Sericea lespedeza*, an Asian legume that diminishes the diversity of native grasses (Middendorf and others, 2008).

Figure 6. Eastern redcedar (*Juniperus virginiana*) trees invading prairie lands in eastern part of Flint Hills 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 Flint Hills Ecoregion between 1973 and 2000 is estimated at 2.2 percent (table 1). Compared to other Great Plains ecoregions, change in the Flint Hills Ecoregion was small (fig. 7). An estimated 1.9 percent of the ecoregion was converted from one land-cover class to another, and 0.3 percent underwent two changes (table 1). The small extent of change shows the overall stability of the ecoregion. Change occurred more frequently in lowland areas owing to conversions between grassland/shrubland and agriculture. Estimated change per time period ranged from a low of 0.4 percent between 1980 and 1986 to a high of 0.8 percent between 1992 and 2000 (table 2). The other two time periods (1973–1980, 1986–1992) had changes of 0.6 percent and 0.7 percent, respectively. When change per time period is normalized by year, all four had a low change rate of 0.1 percent per year (table 2; fig. 8). The low change rates primarily reflect the stability of the ecoregion, although these rates can mask fluctuations in the extent of grassland/shrubland and agricultural lands.

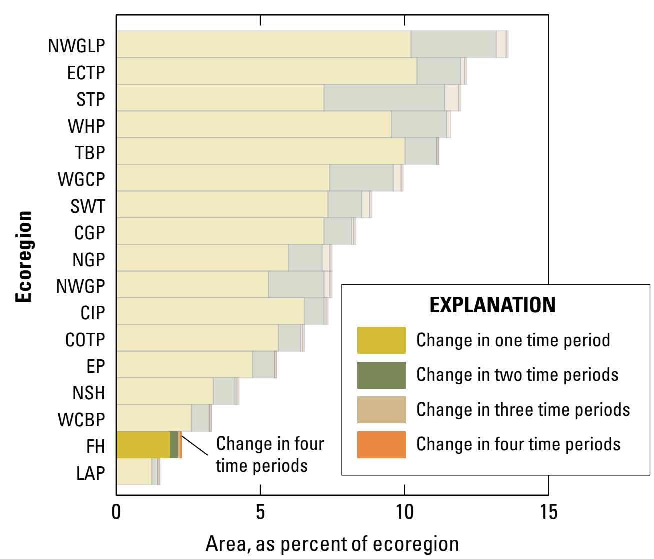

Figure 7. Overall spatial change in Flint Hills Ecoregion (FH; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Flint Hills 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.

Grassland/shrubland and agriculture, which are the predominant land-cover classes, extending over an estimated 90 percent of the ecoregion, showed the greatest change per time period. Changes in these two were often complementary: as grassland/shrubland increased in area, agricultural land decreased in area (fig. 9). During the study period (1973–2000), grassland/shrubland increased overall, as well as in three of the four time periods (table 3), and agriculture decreased by amounts that are similar to the increases in grassland/shrubland: grassland/shrubland increased by 0.6 percent, while agricultural lands decreased by 0.7 percent (table 3; fig 9). The remaining land-cover classes showed small amounts of change as forested lands decreased consistently in each time period while developed lands increased. However, these changes, when added to changes within other land-cover classes, constituted less than 0.1 percent of the ecoregion's land area.

The most common land-cover conversion between 1973 and 2000 (and the most common in each time period) was the conversion of an estimated 344 km^2 of agricultural land to grassland/shrubland (table 4). The second most common was the conversion of about 148 km^2 of grassland/shrubland to agriculture. These two leading conversions account for nearly 70 percent of the land-cover conversions during the study period, possibly reflecting the activities of small farm operations as they convert grassland/shrubland to and from pasture or cropland (agriculture land-cover class).

Other than the conversions between these two major land-cover types (agriculture and grassland/shrubland), land cover changed only infrequently in the ecoregion during the study period. The lack of change is partly due to steep slopes and thin, rocky soils on the uplands, which make it poorly suited to farming. In addition, the ongoing practices of burning and grazing have been essential to the maintenance of the tallgrass ecosystem (Middendorf and others, 2008). In areas where fire is suppressed, prairie grasses may be overtaken by forest (Briggs and others, 2002).

The small change that occurred was mostly in the lowlands where grassland/shrubland and agriculture are frequently situated next to each other. Many conversions from agriculture to grassland/shrubland after 1985 are likely due to participation in the Conservation Reserve Program (CRP), which was created by the U.S. Congress in 1985 and became a key factor in agriculture-to-grassland/shrubland conversions. In Kansas, the CRP

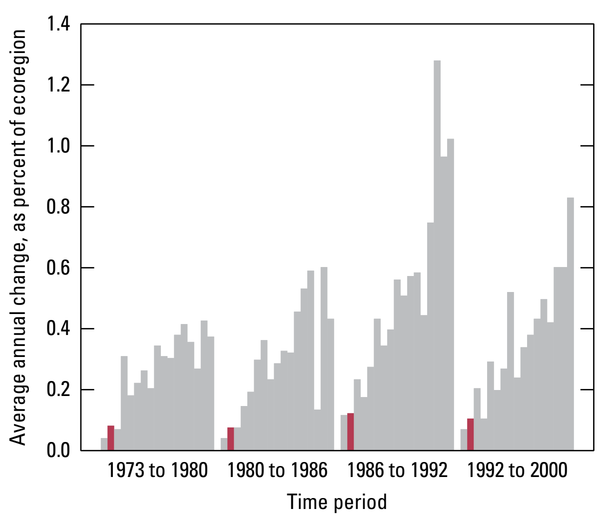

Figure 8. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Flint Hills Ecoregion are represented by red bars in each time period.

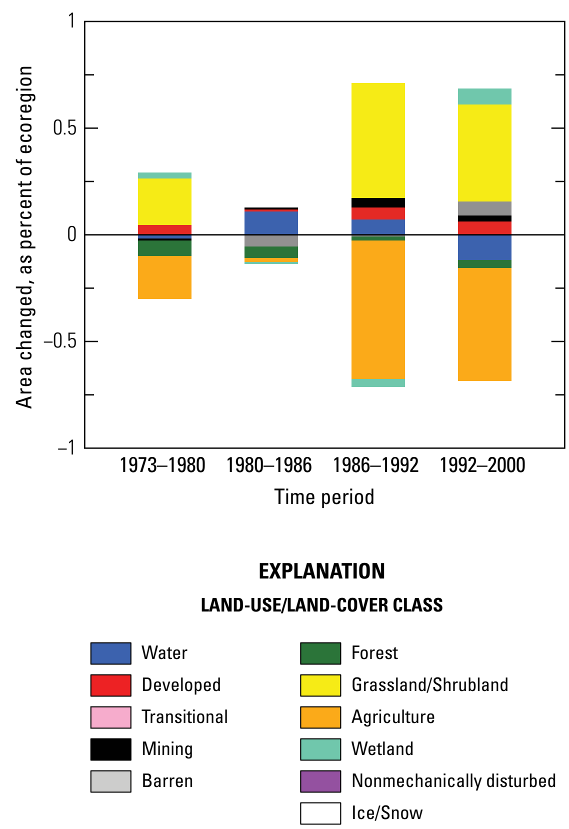

Figure 9. Normalized average net change in Flint Hills Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions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

has been responsible for about 11,700 km^2 of conversions from agriculture to grassland/shrubland (Egbert and others, 2001). Although large areas of agriculture were being converted to grassland/shrubland, a smaller amount of land was being converted from grassland/shrubland to agriculture. The reasons for the loss of grassland/shrubland to agriculture are unclear, although some may be due to a process called “slippage,” in which farmers place additional agricultural lands into production to compensate for lands enrolled in the CRP (Peterson and others, 2004).

Future land-cover conversions would likely include an increase of residential home construction (developed land-cover class) on grassland/shrubland or agricultural lands. The Flint Hills and their environs have become increasingly known for their scenic value, and development pressures have begun to influence land-management decisions on the part of conservation organizations, landowners, and government.

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

[Most sample pixels remained unchanged (97.8 percent), whereas 2.2 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	1.9	0.4	1.5	2.3	0.3	15.4
2	0.3	0.1	0.2	0.4	0.1	28.4
3	0.0	0.0	0.0	0.1	0.0	51.7
4	0.0	0.0	0.0	0.0	0.0	65.8
Overall spatial change	2.2	0.5	1.7	2.7	0.3	15.4

Table 2. Raw estimates of change in Flint Hills 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	0.2	0.4	0.8	0.1	21.7	0.1
1980–1986	0.4	0.1	0.3	0.6	0.1	19.8	0.1
1986–1992	0.7	0.2	0.6	0.9	0.1	15.0	0.1
1992–2000	0.8	0.3	0.5	1.1	0.2	22.3	0.1
Estimate of change, in square kilometers							
1973–1980	160	51	109	211	35	21.7	23
1980–1986	124	36	88	161	25	19.8	21
1986–1992	198	44	154	241	30	15.0	33
1992–2000	228	75	152	303	51	22.3	28

Table 3. Estimated area (and margin of error) of each land-cover class in Flint Hills 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	1.2	0.4	0.9	0.3	0.0	0.0	0.0	0.0	0.1	0.1	6.2	1.1	50.9	6.5	40.4	6.7	0.4	0.2	0.0	0.0
1980	1.2	0.4	0.9	0.3	0.0	0.0	0.0	0.0	0.1	0.1	6.1	1.1	51.0	6.5	40.3	6.7	0.5	0.2	0.0	0.0
1986	1.2	0.4	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	6.1	1.1	51.0	6.5	40.3	6.7	0.5	0.2	0.0	0.0
1992	1.3	0.4	0.9	0.3	0.0	0.0	0.1	0.0	0.0	0.0	6.1	1.2	51.3	6.5	39.9	6.7	0.4	0.2	0.0	0.0
2000	1.2	0.4	0.9	0.4	0.0	0.0	0.1	0.1	0.1	0.1	6.1	1.2	51.5	6.5	39.7	6.7	0.5	0.2	0.0	0.0
Net change	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	–0.1	0.1	0.6	0.3	–0.7	0.4	0.0	0.0	0.0	0.0
Gross change	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.1	1.3	0.4	1.4	0.3	0.1	0.1	0.0	0.0
Area, in square kilometers																				
1973	326	104	239	91	0	0	9	6	19	19	1,725	316	14,200	1,818	11,270	1,872	123	62	0	0
1980	323	104	245	94	0	0	8	6	18	18	1,715	317	14,231	1,818	11,243	1,871	128	63	0	0
1986	339	106	247	95	0	0	9	8	10	13	1,709	318	14,230	1,817	11,241	1,873	126	64	0	0
1992	350	109	254	97	0	0	16	13	9	10	1,706	324	14,305	1,820	11,150	1,877	121	63	0	9
2000	334	103	263	99	0	0	20	14	19	19	1,701	323	14,369	1,818	11,075	1,870	130	62	0	0
Net change	8	14	24	12	0	0	11	12	0	7	–24	28	169	91	–195	100	7	7	0	0
Gross change	58	27	24	12	0	0	19	14	27	27	49	27	368	99	390	98	28	17	0	0

Table 4. Principal land-cover conversions in Flint Hills 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	Agriculture	Grassland/Shrubland	71	33	22	0.3	44.2
	Grassland/Shrubland	Agriculture	42	27	18	0.1	26.1
	Water	Barren	8	8	6	0.0	5.2
	Barren	Water	8	7	5	0.0	4.7
	Forest	Agriculture	7	6	4	0.0	4.3
	Other	Other	25	n/a	n/a	0.1	15.5
		Totals	160			0.6	100.0
1980–1986	Agriculture	Grassland/Shrubland	42	22	15	0.2	33.8
	Grassland/Shrubland	Agriculture	34	20	13	0.1	27.2
	Barren	Water	11	13	9	0.0	9.0
	Forest	Agriculture	8	7	5	0.0	6.1
	Grassland/Shrubland	Water	5	5	3	0.0	4.4
	Other	Other	24	n/a	n/a	0.1	19.6
		Totals	124			0.4	100.0
1986–1992	Agriculture	Grassland/Shrubland	111	39	27	0.4	56.2
	Grassland/Shrubland	Agriculture	24	11	8	0.1	12.3
	Grassland/Shrubland	Forest	8	8	6	0.0	3.9
	Forest	Agriculture	7	6	4	0.0	3.7
	Barren	Water	6	8	5	0.0	2.9
	Other	Other	42	n/a	n/a	0.1	21.0
		Totals	198			0.7	100.0
1992–2000	Agriculture	Grassland/Shrubland	120	62	42	0.4	52.7
	Grassland/Shrubland	Agriculture	48	25	17	0.2	21.0
	Water	Wetland	11	9	6	0.0	4.8
	Water	Barren	11	10	7	0.0	4.6
	Grassland/Shrubland	Developed	6	6	4	0.0	2.6
	Other	Other	32	n/a	n/a	0.1	14.2
		Totals	228			0.8	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	344	120	81	1.2	48.4
	Grassland/Shrubland	Agriculture	148	55	37	0.5	20.8
	Water	Barren	28	27	18	0.1	3.9
	Forest	Agriculture	26	19	13	0.1	3.6
	Barren	Water	26	25	17	0.1	3.6
	Other	Other	139	n/a	n/a	0.5	19.6
		Totals	709			2.5	100.0

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Southern Plains Ecoregions

Chapter 12

Central Oklahoma/Texas Plains Ecoregion

By Michael P. Stier

Ecoregion Description

The Central Oklahoma/Texas Plains Ecoregion covers more than 103,412 km^2 (39,928 mi^2) of southeastern Kansas, central Oklahoma, and north-central Texas (fig. 1). The ecoregion is bounded on the west by the Central Great Plains Ecoregion; on the north by the Flint Hills Ecoregion; on the east by the Central Irregular Plains, Arkansas Valley, Ouachita Mountains, South Central Plains, and Texas Blackland Prairies Ecoregions; and on the south by the Edwards Plateau Ecoregion (Omernik, 1987; U.S. Environmental Protection Agency, 1997).

The Central Oklahoma/Texas Plains Ecoregion, also referred to as “Cross Timbers,” is characterized by a complex mosaic of upland deciduous forest, savanna, and prairie communities (fig. 2) that make up the broad ecotone between the forested low mountains of eastern Oklahoma and the grasslands to the west. Two large forest zones, which run northeast to southwest from central Oklahoma to north-central Texas, are dominated by blackjack oak (*Quercus marilandica*), post oak (*Quercus stellata*), and eastern redcedar (*Juniperus virginiana*). Four-hundred-year-old post oaks live in the “Cross Timbers” region. These forests, which are among the least disturbed forests east of the Rocky Mountains, have survived because they were not ideal for lumber production, and their steep terrain is unsuitable for farming (fig. 3) (University of Arkansas Tree-Ring Laboratory, 2007; see also, Stahle and others,

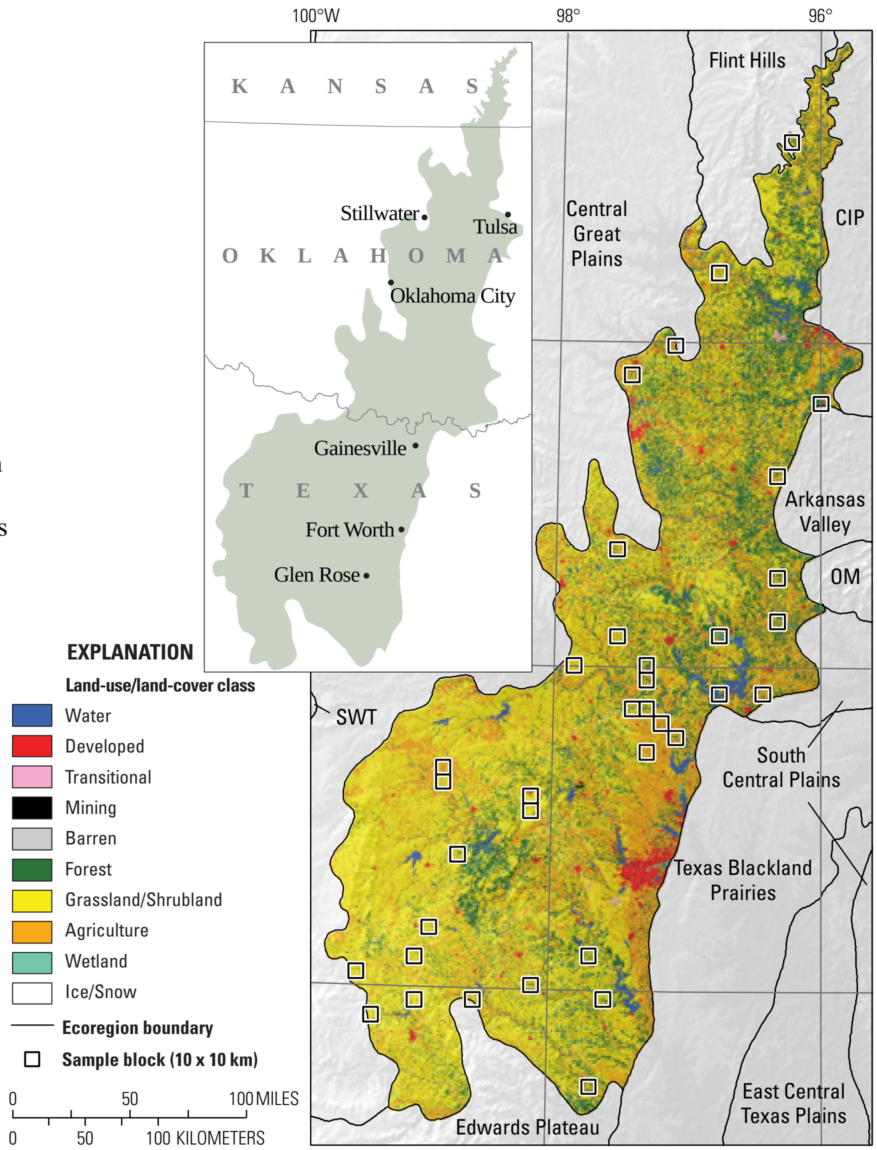

Figure 1. Map of Central Oklahoma /Texas Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for 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 Great Plains ecoregions are listed in appendix 2. Also shown are parts of three Midwest–South Central United States ecoregions: Arkansas Valley, Ouachita Mountains (OM), and South Central Plains. See appendix 3 for definitions of land-use/land-cover classifications.

2003). The large, gently sloping prairie that separates these forests consists of thin soils over hard layers of resistant limestone. Other areas of the ecoregion include patches of mixed-grass prairie habitat embedded within the oak woodlands.

The topography of the Central Oklahoma/Texas Plains Ecoregion is rolling to hilly uplands separated by narrow stream valleys that have steep gradients. Elevations range from 100 to 400 m (McNab and Avers, 1996). The climate is considered subhumid, with average annual precipitation levels that vary from 525 mm (20 in.) in the southwestern part of the ecoregion to 900 mm (35 in.) in the northeastern part. Most precipitation falls in spring, and winter is the driest season.

The most common land use is livestock ranching of cattle, sheep, and goats. Crops grown in the deeper and more fertile soils include small grains, sorghum, cotton, and alfalfa. Peanuts, tree fruits, and vegetables are grown in the south (U.S. Department of Agriculture, 1981). Overall, nearly 75 percent of the natural vegetation has been cleared for ranching and cultivation (McNab and Avers, 1996). Grassland/shrubland is the most extensive land-cover class, followed by agricultural land.

Figure 2. Savanna landscape with grasses and scattered trees surrounding pasture in Central Oklahoma/Texas Plains Ecoregion.

Lease hunting is common on large ranches, providing an additional source of income to private landowners. Big-game species commonly hunted, especially in the Texas part of the ecoregion, include white-tailed deer (*Odocoileus virginianus*), pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), wild turkey (*Meleagris gallopavo*), and javelina (*Pecari tajacu*).

Other land uses include urban and exurban development and oil and gas extraction (fig. 4). Much of the increase in the ecoregion's population is supported by the growing oil industry, which attracts numerous jobs to the area. Nearly all the counties in the ecoregion increased in population from 1980 to 2005 (U.S. Census Bureau, 2005). As the population grew, urban centers benefitting from the oil and gas industry expanded, causing new development along the ecoregion's periphery near Tulsa, Oklahoma, and Fort Worth, Texas.

A growing concern in this ecoregion is the loss and fragmentation of wildlife habitat owing to land-use/land-cover change. The clearing of brush and forests for pasture, cropland, or development affects wildlife resources. Threatened or endangered species observed in this area include the black-capped vireo (*Vireo atricapilla*), the golden-cheeked warbler (*Dendroica chrysoparia*), the Texas kangaroo rat (*Dipodomys elator*), and the Texas horned lizard (*Phrynosoma cornutum*). Long-term declines in big-game species such as the pronghorn or white-tailed deer are attributed primarily to habitat loss, competition with livestock for food and forage, and losses to predators (Texas Parks and Wildlife, 2007).

Figure 3. Post oak forest in Central Oklahoma/Texas Plains Ecoregion.

Figure 4. Oil pump next to irrigated pasture in Central Oklahoma/Texas 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 Oklahoma/Texas Plains Ecoregion between 1973 and 2000 is estimated at 6.5 percent (table 1). Compared to other Great Plains ecoregions, change in the Central Oklahoma/Texas Plains Ecoregion was moderate (fig. 5). Of the land that changed, 5.6 percent changed one time, 0.8 percent changed two times, and 0.1 percent changed three times (table 1). For those few land areas that changed two or more times, the change generally was back and forth between two land-cover classes: for example, between agriculture and grassland/shrubland. Although the total change per time period was less than 2 percent in three of the four time periods (table 2), the period between 1986 and 1992 had a slightly higher percentage of land-cover change, at 2.6 percent. Much of this increase was a result of conversion of agricultural land to grassland/shrubland (table 3). When normalized to account for varying time-period lengths, the estimated annual rates of change increased gradually in the first three time periods (1973–1980, 1980–1986, 1986–1992), from 0.2 to 0.4 percent of the ecoregion per year, before dropping to 0.2 percent between 1992 and 2000 (table 2; fig. 6).

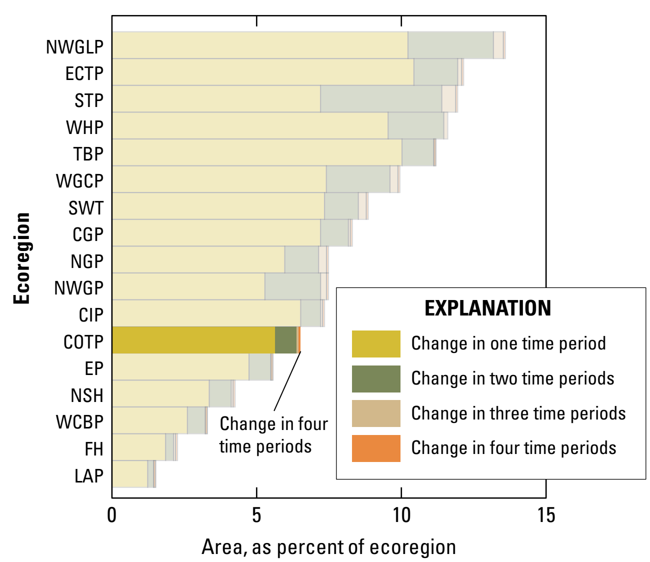

Figure 5. Overall spatial change in Central Oklahoma/Texas Plains Ecoregion (COTP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Central Oklahoma/Texas 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.

Grassland/shrubland, agriculture, and forest areas constitute an estimated 93 percent of the land cover in this ecoregion. Grassland/shrubland, the dominant land-cover class, remained relatively stable between 1973 and 2000, ranging from 46.5 to 46.9 percent of the ecoregion (table 4). Between 1973 and 2000, forest decreased by 0.4 percent, from 19.6 to 19.2 percent of the ecoregion (table 4). In the early part of the study period, forest was cleared for agriculture and grassland/shrubland. Much of the cleared forest land was used to support the growing livestock industry. As part of the forest-clearing process, aerial applications of broadleaf herbicides were used to kill oaks and to release understory grasses for grazing. The resulting dead trees were gathered in piles and burned. In some cases, large areas of ancient post oaks, red cedar, and blackjack oaks were removed and replaced by rangeland (Francaviglia, 2003).

The largest net changes over the entire study period (1973–2000) were a 0.7 percent increase in developed land and a 0.7 decrease in agricultural land. Developed land steadily increased throughout the study period, with an estimated net increase of 677 km^2 (table 4). About 50 percent of the new developed land was formerly grassland/shrubland (table 3). A steady increase in population likely contributed to the increase in developed land throughout the ecoregion. Overall, the decline in agriculture resulted from new development and also participation in the Conservation Reserve Program (CRP). The CRP provided economic incentives to farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover,

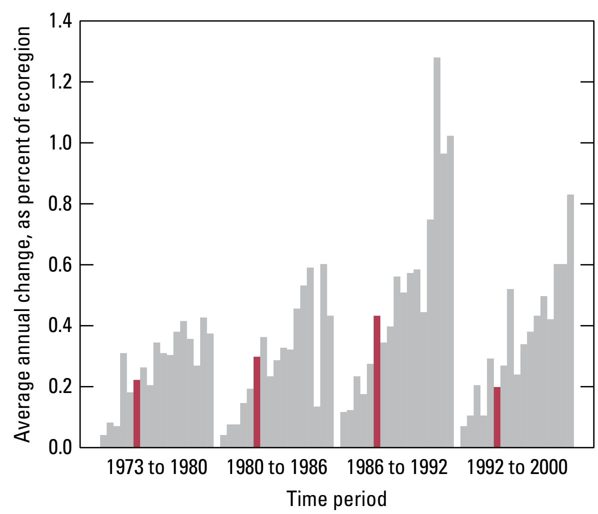

Figure 6. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Central Oklahoma/Texas Plains Ecoregion are represented by red bars in each time period.

such as grasses and forbes, specific wildlife plantings, trees, filter strips (vegetated surfaces designed to treat surface runoff), or riparian buffers (U.S. Department of Agriculture, 2008).

Between 1973 and 2000, the most significant land-cover conversions in the Central Oklahoma/Texas Plains Ecoregion were fluctuations between grassland/shrubland and agriculture that were influenced by government policies and the global economic climate. Conversions to and from grassland/shrubland and agriculture were nearly equal between 1973 and 1980 and between 1992 and 2000 (table 3). In the other two time periods, however, this was not the case. Between 1980 and 1986, agriculture decreased, likely owing to the global recession in the early 1980s that caused a reduced grain demand and a decrease in farm land values. Between 1986 and 1992, the rapid increase in the conversion of agriculture back to grassland/shrubland likely was related to the initiation of the CRP (U.S. Department of Agriculture, 2009). Between 1992 and 2000, the conversion of grassland/shrubland to agriculture was significantly less, probably owing to CRP land going back into crop production.

Another notable change in the ecoregion was the steady increase in development, especially exurban development (fig. 7). Population growth in Oklahoma City, Tulsa, and Stillwater, Oklahoma, as well as in Gainesville, Glen Rose, and Fort Worth, Texas, contributed to the expansion of developed land. In addition, new developed land near or along reservoirs and lakes increased as people built homes near outdoor recreational sites.

Rangeland expanded at times during the study period as forest areas were converted to grassland/shrubland for livestock grazing (fig. 8). Tall brush, which includes mesquite (*Prosopis* spp.) and live oak (*Quercus virginiana)* was cleared for raising cattle and, to a lesser degree, along with some forest areas, for growing hay and expanding pastures.

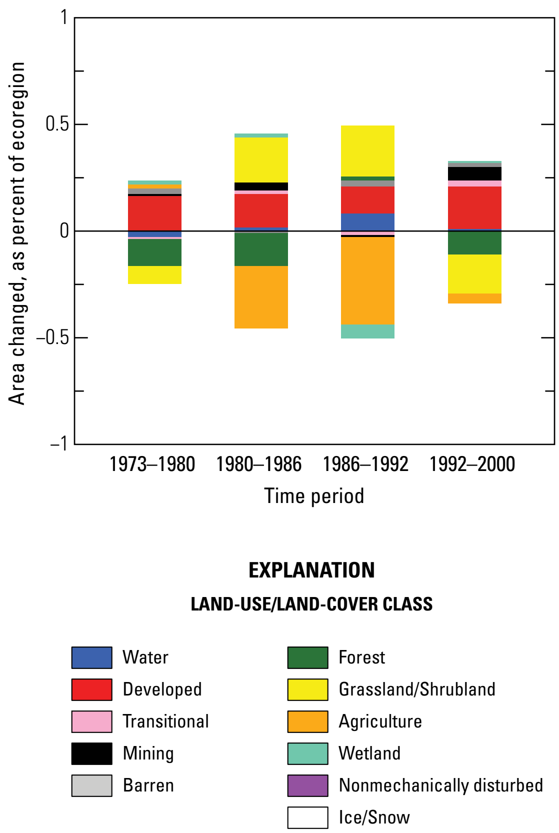

Figure 7. Normalized average net change in Central Oklahoma/Texas Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See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

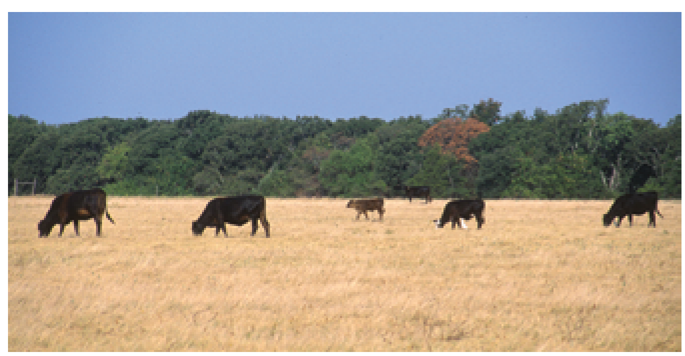

Figure 8. Cattle grazing in open pasture in Central Oklahoma/Texas Plains Ecoregion.

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

[Most sample pixels remained unchanged (93.5 percent), whereas 6.5 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	5.6	1.0	4.6	6.6	0.7	12.6
2	0.8	0.3	0.5	1.1	0.2	28.2
3	0.1	0.0	0.0	0.1	0.0	34.1
4	0.0	0.0	0.0	0.0	0.0	67.0
Overall spatial change	6.5	1.2	5.2	7.7	0.8	13.0

Table 2. Raw estimates of change in Central Oklahoma/Texas 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	1.5	0.4	1.1	2.0	0.3	19.2	0.2
1980–1986	1.8	0.5	1.3	2.2	0.3	17.9	0.3
1986–1992	2.6	0.8	1.8	3.4	0.6	21.7	0.4
1992–2000	1.6	0.3	1.3	1.9	0.2	13.4	0.2
			Estimate of change, in square kilometers				
1973–1980	1,595	452	1,144	2,047	307	19.2	228
1980–1986	1,842	485	1,357	2,326	329	17.9	307
1986–1992	2,664	852	1,812	3,516	579	21.7	444
1992–2000	1,616	319	1,296	1,935	217	13.4	202

Table 3. Principal land-cover conversions in Central Oklahoma/Texas 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	Grassland/Shrubland	Agriculture	474	286	194	0.5	29.7
	Agriculture	Grassland/Shrubland	458	214	145	0.4	28.7
	Forest	Grassland/Shrubland	128	75	51	0.1	8.0
	Grassland/Shrubland	Developed	106	83	56	0.1	6.6
	Grassland/Shrubland	Forest	81	58	39	0.1	5.1
	Other	Other	349	n/a	n/a	0.3	21.9
		Totals	1,595			1.5	100.0
1980–1986	Agriculture	Grassland/Shrubland	678	331	225	0.7	36.8
	Grassland/Shrubland	Agriculture	404	198	135	0.4	21.9
	Forest	Grassland/Shrubland	115	75	51	0.1	6.2
	Forest	Agriculture	113	98	66	0.1	6.1
	Grassland/Shrubland	Forest	94	45	30	0.1	5.1
	Other	Other	439	n/a	n/a	0.4	23.8
		Totals	1,842			1.8	100.0
1986–1992	Agriculture	Grassland/Shrubland	1,160	451	306	1.1	43.6
	Grassland/Shrubland	Agriculture	796	626	425	0.8	29.9
	Grassland/Shrubland	Forest	109	58	40	0.1	4.1
	Wetland	Water	69	97	66	0.1	2.6
	Forest	Grassland/Shrubland	56	33	22	0.1	2.1
	Other	Other	474	n/a	n/a	0.5	17.8
		Totals	2,664			2.6	100.0
1992–2000	Grassland/Shrubland	Agriculture	447	149	101	0.4	27.7
	Agriculture	Grassland/Shrubland	442	139	94	0.4	27.3
	Grassland/Shrubland	Forest	107	90	61	0.1	6.6
	Grassland/Shrubland	Developed	104	49	34	0.1	6.4
	Forest	Grassland/Shrubland	102	41	28	0.1	6.3
	Other	Other	414	n/a	n/a	0.4	25.6
		Totals	1,616			1.6	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	2,738	861	585	2.6	35.5
	Grassland/Shrubland	Agriculture	2,120	809	550	2.1	27.5
	Forest	Grassland/Shrubland	401	173	118	0.4	5.2
	Grassland/Shrubland	Forest	391	171	116	0.4	5.1
	Grassland/Shrubland	Developed	328	139	94	0.3	4.2
	Other	Other	1,739	n/a	n/a	1.7	22.5
		Totals	7,717			7.5	100.0

Table 4. Estimated area (and margin of error) of each land-cover class in Central Oklahoma/Texas 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	2.3	1.8	2.9	1.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	19.6	3.0	46.5	6.0	4.4	1.0	0.7	0.0	0.0
1980	2.3	1.8	3.0	1.2	0.0	0.0	0.1	0.0	0.0	0.1	0.1	19.5	3.0	46.5	5.9	4.4	1.0	0.7	0.0	0.0
1986	2.3	1.8	3.2	1.3	0.0	0.0	0.2	0.1	0.1	0.1	0.1	19.3	3.0	46.7	5.8	4.3	1.0	0.8	0.0	0.0
1992	2.4	1.8	3.3	1.3	0.0	0.0	0.1	0.1	0.1	0.1	0.1	19.3	3.0	46.9	5.9	4.3	0.9	0.7	0.0	0.0
2000	2.4	1.8	3.5	1.4	0.0	0.0	0.2	0.1	0.1	0.1	0.1	19.2	3.0	46.7	5.9	4.3	1.0	0.7	0.0	0.0
Net change	0.1	0.0	0.7	0.2	0.0	0.0	0.1	0.1	0.1	0.1	0.1	–0.4	0.2	0.2	0.9	1.0	0.0	0.0	0.0	0.0
Gross change	0.2	0.1	0.7	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.9	0.2	3.3	0.8	0.9	0.1	0.1	0.0	0.0
Area, in square kilometers																				
1973	2,409	1,848	2,963	1,229	12	10	110	47	36	24	20,257	3,150	48,136	6,208	28,473	4,577	1,016	720	0	0
1980	2,378	1,847	3,135	1,249	7	7	118	47	71	70	20,122	3,102	48,058	6,141	28,489	4,502	1,034	745	0	0
1986	2,401	1,852	3,291	1,293	29	23	157	64	65	59	19,963	3,059	48,279	5,982	28,184	4,398	1,044	776	0	0
1992	2,484	1,856	3,424	1,334	13	9	148	56	94	100	19,988	3,062	48,526	6,127	27,756	4,479	981	712	6	9
2000	2,489	1,854	3,640	1,406	40	26	211	88	112	121	19,876	3,056	48,333	6,124	27,714	4,444	994	725	0	0
Net change	80	49	677	258	28	25	101	90	76	101	–381	234	197	914	–759	1,008	–22	35	0	0
Gross change	211	151	677	258	93	58	240	113	91	124	962	255	3,413	876	3,449	949	133	142	0	0

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Status and Trends of Land Change in the Great Plains of the United States—1973 to 2000
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Chapter 13

East Central Texas Plains Ecoregion

By Krista A. Karstensen

Ecoregion Description

The East Central Texas Plains Ecoregion, which encompasses 44,076 km^2 (17,018 mi^2) in east Texas (Omernik, 1987; U.S. Environmental Protection Agency, 1997) (fig. 1), extends north from just south of the San Antonio River to an area near the Oklahoma border. The ecoregion is bounded by (clockwise, from its east end) the South Central Plains, Western Gulf Coastal Plain, and Southern Texas Plains Ecoregions, as well as the northern section of the Texas Blackland Prairies Ecoregion; in addition, it almost completely surrounds the separate, smaller, southern section of the Texas Blackland Prairies Ecoregion (fig. 1).

The East Central Texas Plains Ecoregion includes the San Antonio, North Sulphur, South Sulphur, Trinity, Navasota, Brazos, Colorado, and Guadalupe Rivers; Lake

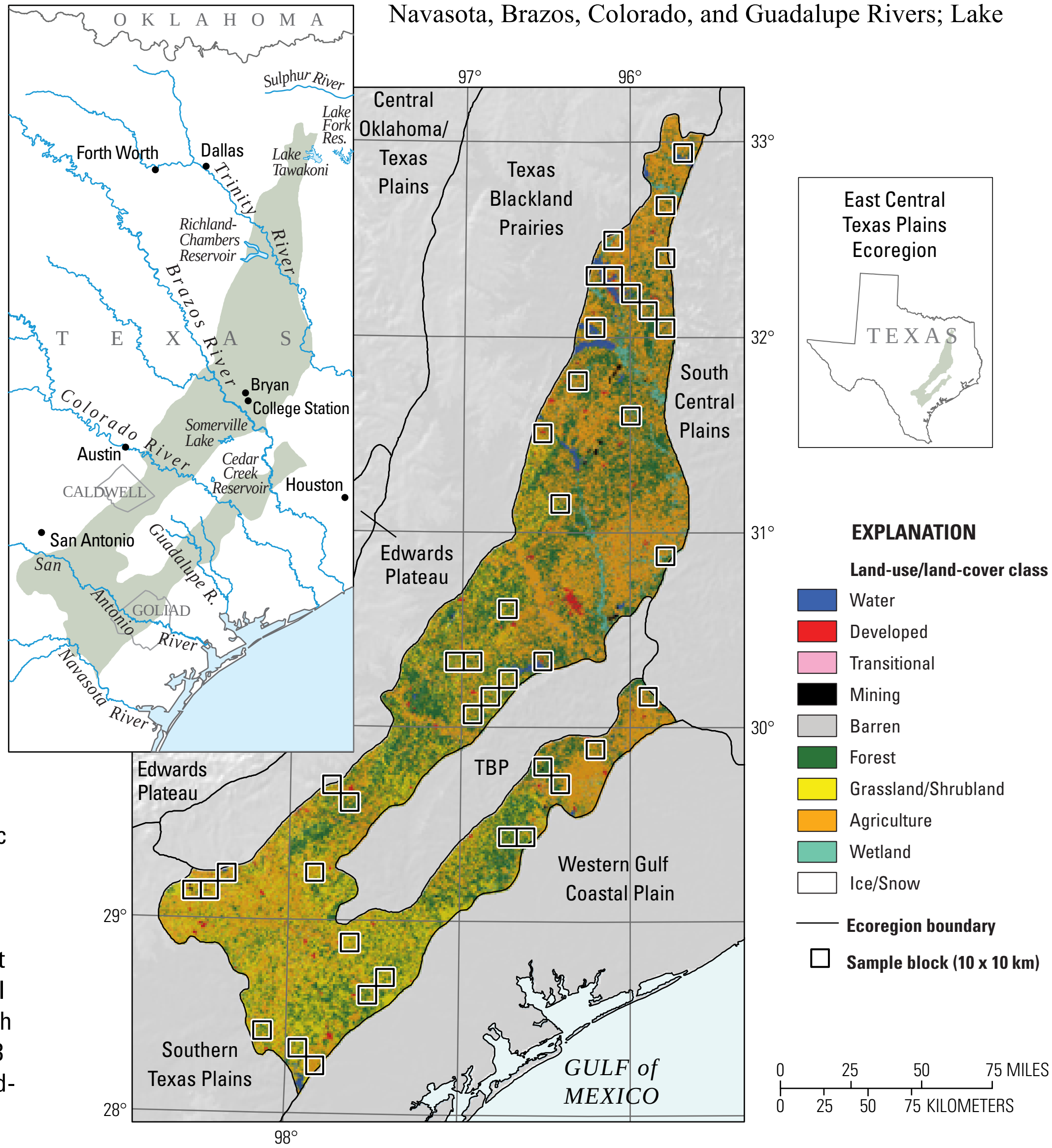

Figure 1. Map of East Central Texas Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land-Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “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 Great Plains ecoregions are listed in appendix 2. Also shown is part of one Midwest–South Central United States ecoregion, South Central Plains. See appendix 3 for definitions of land-use/land-cover classifications.

Tawakoni and Somerville Lake; and Lake Fork, Richland-Chambers, and Cedar Creek Reservoirs. Two neighboring cities in the ecoregion, Bryan and College Station, Texas, had a combined population of 152,415 in April 2000, an increase of 9.7 percent since 1990 (U.S. Census Bureau, 2001).

Elevations in the ecoregion increase gradually from southeast to northwest. The topography is characterized by irregular plains that have acidic soils along the parallel ridges and valleys, sandy and sandy loam soils on the uplands, and clay and clay loams in the low-lying areas (Griffith and others, 2004). Additionally, much of the ecoregion is underlain by claypan, which affects the movement and availability of water for plant growth (Griffith and others, 2004). Annual precipitation amounts range from 1,000 to 1,200 mm (40–48 in.) north of Cedar Creek Reservoir and from 700 to 1,000 mm (28–40 in.) south of the Trinity River.

Historically, fire has played an essential role in maintaining grassy clearings. In the absence of fire, woody invasions have taken place (Griffith and others, 2004). The clearing of woody vegetation has permitted the regrowth of mixed native or introduced grasses and forbs on grassland sites or mixed herbaceous communities (Texas Parks and Wildlife, 2008). The deciduous forest in the East Central Texas Plains Ecoregion mostly is composed of post oak (*Quercus stellata*) and blackjack oak (*Quercus marilandica*). Post oak forests are prevalent on sandy soils in the ecoregion, particularly in the area north of College Station (Yantis, 1984; Amy Hays, Texas A&M University, oral commun., 2009). The south-central part of the ecoregion, along the Colorado River, has the westernmost tract of longleaf pine (*Pinus palustris)* in the United States (Griffith and others, 2004; Amy Hays, Texas A&M University, oral commun., 2009).

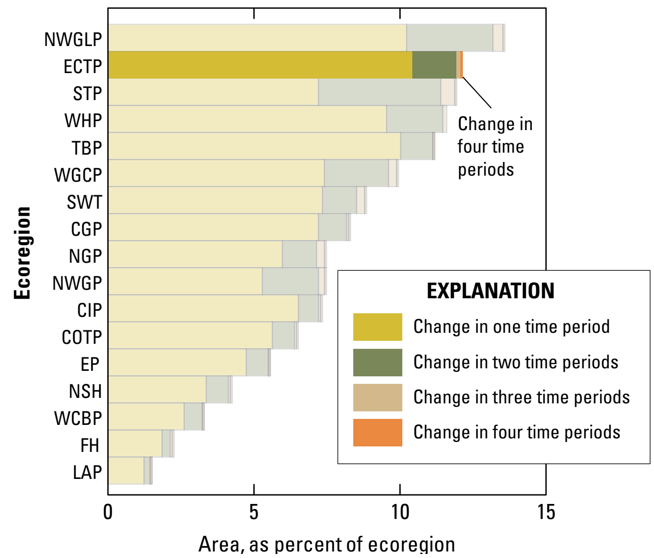

Figure 2. Overall spatial change in East Central Texas Plains Ecoregion (ECTP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in East Central Texas 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 East Central Texas Plains Ecoregion between 1973 and 2000 is estimated at 12.1 percent (table 1). Compared to the other Great Plains ecoregions, change in the East Central Texas Plains Ecoregion was the second highest (fig. 2). An estimated 10.5 percent of the ecoregion changed only one time, whereas 1.5 percent and 0.1 percent changed two and three times, respectively, during the entire 27-year study period (table 1). When normalized to account for varying lengths of study periods, annual rates of change ranged from a low of 0.4 percent per year, between 1973 and 1980 and between 1992 and 2000, to a high of 0.7 percent per year, between 1986 and 1992 (table 2; fig. 3).

Agriculture covered 46.3 percent of the ecoregion in 2000, despite an overall net decrease of 2.7 percent by the end of the study period (table 3). Forest was the second leading land-cover class, at 30.5 percent of the ecoregion in 2000, despite an overall net decrease of 1.8 percent since 1973 (table 3). Grassland/shrubland constituted 14.4 percent of the ecoregion in 2000.

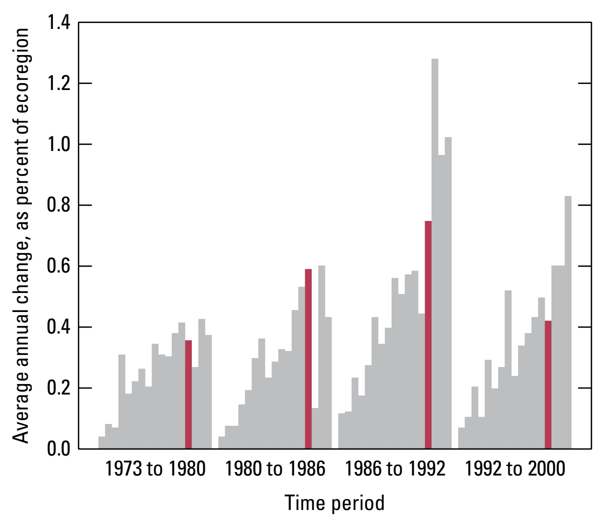

Figure 3. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for East Central Texas Plains Ecoregion are represented by red bars in each time period.

Of all the land-cover classes in the East Central Texas Plains Ecoregion, grassland/shrubland, developed, and water had the largest overall net increases, at 1.3 percent (table 3; fig. 4).

Between 1973 and 2000, the five most common land-cover conversions were (1) agriculture to grassland/shrubland, (2) forest to agriculture, (3) grassland/shrubland to forest, (4) grassland/shrubland to agriculture, and (5) agriculture to forest (table 4). Although conversions to developed were not among the top five leading land-cover conversions during the study period, the net increase of 1.3 percent (581 km^2) in developed land was significant.

The East Central Texas Plains Ecoregion is a mosaic of improved pastureland, rangeland, and cropland (Griffith and others, 2004). Although agricultural lands declined overall during the study period, it still constitutes the largest land-cover class in the ecoregion. Between 1970 and 2000, about 1,000 new farms and ranches were established in Texas each year, even though the total area in farms and ranches has declined by almost 3 million acres during the same time period, a statewide trend that is apparent in the East Central Texas Plains Ecoregion (U.S. Department of Agriculture, 2009).

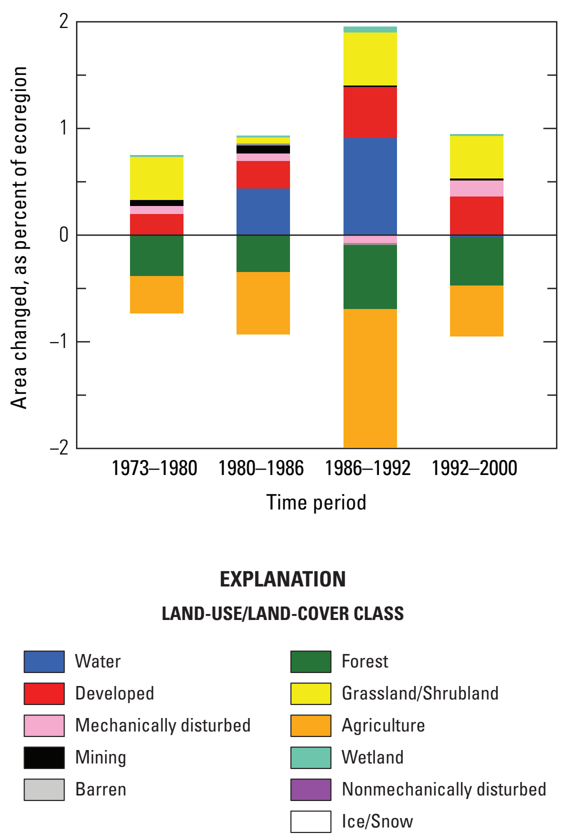

Figure 4. Normalized average net change in East Central Texas Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

The East Central Texas Plains Ecoregion historically has been a mix of post oak and blackjack oak forest and savanna on sandy soils, interspersed with midgrass and tallgrass prairie on areas of heavier soil (Chuck Kowaleski, Texas Parks and Wildlife, written commun., 2009). Although much of this land originally was farmed, the sandier sites quickly lost their fertility (Chuck Kowaleski, Texas Parks and Wildlife, written commun., 2009). The average land-ownership size increased as old farms were consolidated into ranches (Yantis, 1984). In 1974, the central part of the ecoregion had about 18 people, 104 cattle, and 11 hogs per square mile (Yantis, 1984). Starting in the 1980s, Texas A&M AgriLife Extension Service promoted the idea of converting native grasses to coastal Bermudagrass (*Cynodon dactylon*) tame pastures, which, when limed and fertilized, allowed much higher stocking rates (1 cow per acre) than can be achieved on native ranges (Chuck Kowaleski, Texas Parks and Wildlife, written commun., 2009) (fig. 5). Although the land use in the 1980s was similar to that of the 1970s, the continued increase in human population was bringing more “weekend ranchers” to the area, and the average size of landholdings was decreasing (Yantis, 1984).

The impact of population on land use in the later part of the study period is correlated with changes in ownership and size of tracts (Wilkins and others, 2003). Between 1992 and 2001, the most notable land-use trend was the conversion of native rangelands and croplands to nonnative “improved pastures” (Wilkins and others, 2003). Unlike the consolidation that occurred in the early 1970s, fragmentation of rural acreage became dominant in the 1990s as large properties were divided into smaller parcels (Wilkins and others, 2003). This may help to describe the principal land-cover change in this ecoregion, namely agriculture to grassland/shrubland. As the land becomes fragmented, the tracts become too small for traditional farming and ranching (Wilkins and others, 2003) (fig. 6).

Land in the ecoregion also has become increasingly valuable with the expanding population of the nearby metropolitan areas. In about 1994, a trend began in which land use shifted from high intensity (crop production) to low intensity (rangeland). Such lands are not considered abandoned agriculture; rather,

Figure 5. Cattle in pasture in Caldwell County, Texas, in East Central Texas Plains Ecoregion.

the owners simply find more economic value in holding these lands than in growing crops on them (Amy Hays, Texas A&M University, oral commun., 2009). Additionally, the shift from high intensity to low intensity, or tame pasture, has allowed many of the former savanna areas to become heavily overgrown with a yaupon (*Ilex vomitoria*) understory (Chuck Kowaleski, Texas Parks and Wildlife, written commun., 2009).

Figure 6. Ranchland in Goliad County, Texas, in East Central Texas Plains Ecoregion.

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

[Most sample pixels remained unchanged (87.9 percent), whereas 12.1 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	10.5	1.5	8.9	12.0	1.0	10.1
2	1.5	0.3	1.2	1.8	0.2	15.2
3	0.1	0.0	0.1	0.2	0.0	24.0
4	0.0	0.0	0.0	0.0	0.0	39.5
Overall spatial change	12.1	1.8	10.3	13.9	1.2	10.2

Table 2. Raw estimates of change in East Central Texas 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	2.5	0.5	2.0	2.9	0.3	12.4	0.4
1980–1986	3.5	0.8	2.8	4.3	0.5	14.8	0.6
1986–1992	4.5	1.4	3.1	5.9	1.0	21.2	0.7
1992–2000	3.4	0.5	2.9	3.9	0.3	10.1	0.4
Estimate of change, in square kilometers							
1973–1980	1,100	200	900	1,300	136	12.4	157
1980–1986	1,558	338	1,219	1,896	231	14.8	260
1986–1992	1,977	615	1,362	2,592	419	21.2	329
1992–2000	1,487	219	1,267	1,706	149	10.1	186

Table 3. Estimated area (and margin of error) of each land-cover class in East Central Texas 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	2.6	1.3	1.8	0.5	0.0	0.0	0.2	0.1	0.1	0.1	32.3	4.0	13.0	3.0	49.0	4.5	1.0	0.3	0.0	0.0
1980	2.6	1.3	2.0	0.6	0.1	0.0	0.3	0.2	0.1	0.1	31.9	3.9	13.4	3.0	48.6	4.4	1.0	0.3	0.0	0.0
1986	3.1	1.4	2.3	0.7	0.1	0.1	0.4	0.2	0.1	0.1	31.6	3.8	13.5	2.9	48.0	4.3	1.0	0.3	0.0	0.0
1992	4.0	1.7	2.8	0.8	0.1	0.0	0.4	0.2	0.1	0.1	30.9	3.8	14.0	2.9	46.8	4.3	1.1	0.3	0.0	0.0
2000	4.0	1.7	3.2	0.9	0.2	0.2	0.4	0.2	0.1	0.1	30.5	3.7	14.4	3.0	46.3	4.3	1.1	0.3	0.0	0.0
Net change	1.3	1.3	1.3	0.5	0.2	0.2	0.2	0.1	0.0	0.0	–1.8	1.0	1.3	0.8	–2.7	1.4	0.1	0.1	0.0	0.0
Gross change	1.6	1.3	1.3	0.5	0.6	0.3	0.3	0.2	0.0	0.0	3.6	0.8	3.7	0.6	5.5	1.0	0.2	0.1	0.0	0.0
Area, in square kilometers																				
1973	1,154	560	812	240	3	4	92	56	29	30	14,225	1,769	5,735	1,331	21,590	1,972	434	147	0	0
1980	1,156	559	903	270	33	21	118	79	30	30	14,059	1,700	5,907	1,324	21,434	1,929	436	147	0	0
1986	1,350	600	1,020	303	62	47	155	106	32	30	13,910	1,662	5,934	1,294	21,174	1,909	437	144	0	0
1992	1,756	758	1,232	370	28	19	159	108	31	30	13,640	1,671	6,150	1,291	20,613	1,907	465	145	0	0
2000	1,747	751	1,393	418	98	72	161	101	31	30	13,444	1,632	6,330	1,310	20,403	1,898	470	146	0	0
Net change	593	564	581	230	94	72	69	48	1	2	–782	432	595	357	–1,187	604	36	30	0	0
Gross change	685	563	581	230	268	119	119	73	6	5	1,603	341	1,642	279	2,406	461	69	42	0	0

Table 4. Principal land-cover conversions in East Central Texas 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	Grassland/Shrubland	334	98	67	0.8	30.3
	Forest	Agriculture	208	85	58	0.5	18.9
	Grassland/Shrubland	Forest	102	48	32	0.2	9.3
	Grassland/Shrubland	Agriculture	91	37	25	0.2	8.3
	Agriculture	Forest	74	37	25	0.2	6.7
	Other	Other	291	n/a	n/a	0.7	26.5
		Totals	1,100			2.5	100.0
1980–1986	Agriculture	Grassland/Shrubland	369	116	79	0.8	23.7
	Forest	Agriculture	197	48	33	0.4	12.7
	Grassland/Shrubland	Forest	189	69	47	0.4	12.1
	Grassland/Shrubland	Agriculture	139	55	38	0.3	9.0
	Agriculture	Forest	114	54	36	0.3	7.3
	Other	Other	549	n/a	n/a	1.2	35.3
		Totals	1,558			3.5	100.0
1986–1992	Agriculture	Grassland/Shrubland	563	154	105	1.3	28.5
	Forest	Water	200	202	138	0.5	10.1
	Grassland/Shrubland	Agriculture	175	81	55	0.4	8.9
	Agriculture	Water	149	199	135	0.3	7.5
	Grassland/Shrubland	Forest	149	51	35	0.3	7.5
	Other	Other	741	n/a	n/a	1.7	37.5
		Totals	1,977			4.5	100.0
1992–2000	Agriculture	Grassland/Shrubland	430	153	104	1.0	28.9
	Forest	Agriculture	197	73	50	0.4	13.3
	Grassland/Shrubland	Forest	147	38	26	0.3	9.9
	Grassland/Shrubland	Agriculture	139	52	35	0.3	9.4
	Forest	Grassland/Shrubland	78	37	25	0.2	5.3
	Other	Other	496	n/a	n/a	1.1	33.3
		Totals	1,487			3.4	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	1,695	338	230	3.8	27.7
	Forest	Agriculture	746	179	122	1.7	12.2
	Grassland/Shrubland	Forest	587	163	111	1.3	9.6
	Grassland/Shrubland	Agriculture	545	177	121	1.2	8.9
	Agriculture	Forest	326	123	84	0.7	5.3
	Other	Other	2,222	n/a	n/a	5.0	36.3
		Totals	6,121			13.9	100.0

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Chapter 14

Edwards Plateau Ecoregion

By Michael P. Stier and Beverly A. Friesen

Ecoregion Description

The Edwards Plateau Ecoregion covers about 58,634 km^2 (22,639 mi^2) in south-central Texas (fig. 1). It is mainly an eroded and uplifted limestone plateau commonly referred to as the “hill country” (fig. 2). In the south and east, the ecoregion is characterized by hilly topography, and it is separated from neighboring ecoregions further south and east by a geologic feature known as the “Balcones Escarpment,” a fault zone containing numerous cliffs and springs. The ecoregion is surrounded by (clockwise, from its southwest end) the Chihuahuan Deserts, Central Great Plains, Central Oklahoma/Texas Plains, Texas Blackland Prairies, and Southern Texas Plains Ecoregions (Omernik, 1987; U.S. Environmental Protection Agency, 1997).

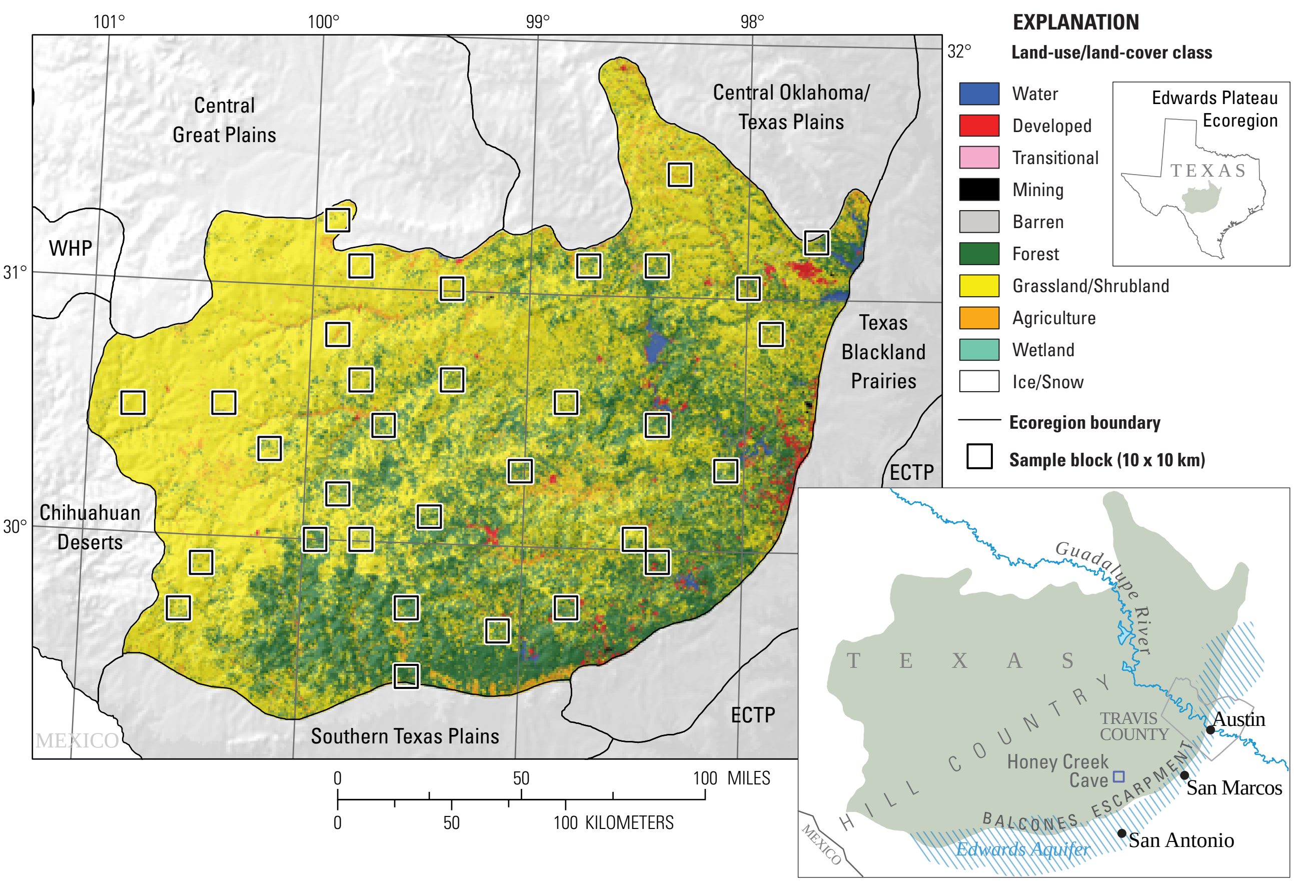

Figure 1. Map of Edwards Plateau Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status and 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 Great Plains ecoregions are listed in appendix 2. Also shown is part of one Western United States ecoregion, Chihuahuan Deserts. See appendix 3 for definitions of land-use/land-cover classifications.

Elevations in the Edwards Plateau Ecoregion range from about 100 m to more than 1,000 m. Average annual rainfall amounts are 380 to 840 mm (15–33 in.), increasing from west to east and peaking in May, June, and September. The Edwards Plateau Ecoregion is one of the largest areas of continuous karst topography in the United States. Karst terrain, formed by the erosion of limestone bedrock, is characterized by sinkholes and caves that allow water to flow in underground drainage systems. Cave and karst aquifers, such as the large Edwards aquifer, are important economic and scientific resources (fig. 3). Honey Creek Cave, a tributary of the Guadalupe River, is the longest cave in Texas (32 km long) and is still being explored (Texas State Historical Association, 2007).

Vegetation primarily consists of small trees, shrubs, and grasses in juniper (*Juniperus* spp.) and oak (*Quercus* spp.) associations, mesquite (*Prosopis* spp.) and oak savannas, and scrub oak (*Quercus turbinella*) forests (fig. 4). The major land use is livestock grazing of beef cattle, sheep, and goats (fig. 5). In addition to livestock production, many ranches offer commercial hunting of exotic and native species to provide an additional source of income. In more populated areas throughout the ecoregion, the diverse economy is driven by tourism, pharmaceutical and high-tech companies, military installations, and numerous universities and colleges (for example, University of Texas at Austin, as well as Texas State University, in San Marcos).

The two largest urban centers in the Edwards Plateau Ecoregion are San Antonio and Austin, which lie near its southeastern edge. Nearly all municipal, industrial, and irrigation water used in the San Antonio area comes from the Edwards aquifer (Blome and others, 2006). Although the ecoregion historically has been a semiarid, sparsely populated rangeland, development in this rugged area has expanded. As urban areas and economic activities continue to flourish, the population of the ecoregion is expected to grow considerably. Travis County (which includes Austin) is the most populous county in the ecoregion, and its population is expected to nearly double between 2000 and 2050 (El-Hage and Moulton, 1999). Expected population growth and the increasing demand for water raise concerns for the sustainability of the Edwards aquifer and the future availability of water resources in the ecoregion.

Figure 2. “Hill country” in Edwards Plateau Ecoregion.

Figure 4. Prairie oak savanna with post oak (*Quercus stellata*) and live oak (*Quercus virginiana*) mixed with Indiangrass (*Sorghastrum nutans*) and little bluestem (*Schizachyrium scoparium*) grasses, in Edwards Plateau Ecoregion.

Figure 3. Source water for Edwards aquifer flowing through limestone, in Edwards Plateau Ecoregion.

Figure 5. Cattle and goats grazing in open pasture in Edwards Plateau 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 Edwards Plateau Ecoregion between 1973 and 2000 is estimated at 5.5 percent (table 1). Compared to other Great Plains ecoregions, change in the Edwards Plateau Ecoregion was moderate (fig. 6). Of the land that changed, 4.7 percent changed one time, and 0.7 percent changed two times (table 1). Two or more changes occurred when forest and grassland/shrubland areas were cleared for pasture (agriculture land-cover class) or to enhance rangeland for grazing (mechanically disturbed land-cover class). Over time, however, some of these cleared areas reverted back to their original forested state if they were not continually managed.

Land-use/land-cover change per time period was relatively small for the first three time periods (1973–1980, 1980–1986, 1986–1992), ranging from about 1.2 to 1.6 percent (table 2). Between 1992 and 2000, change across the ecoregion increased by a modest 2.3 percent. Comparing normalized annual rates of land-cover change (table 2; fig. 7), the period between 1986 and 1992 experienced nearly the same normalized annual rate of change as the period between 1992 and 2000, but they experienced different types of land-cover conversions (table 3).

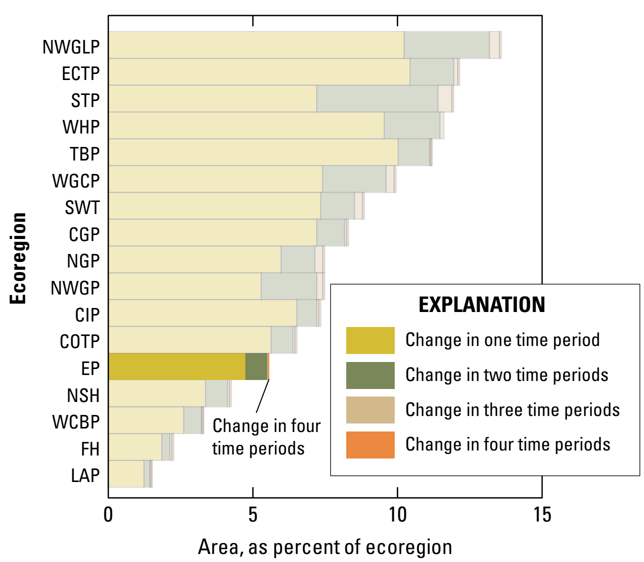

Figure 6. Overall spatial change in Edwards Plateau Ecoregion (EP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Edwards Plateau 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.

Grassland/shrubland and forest constitute nearly 83 percent of the ecoregion's area (table 4). The dominant land cover is grassland/shrubland; throughout the study period (1973–2000), the amount of grassland/shrubland remained stable at about 56 percent of the ecoregion. Forest and agriculture were not as stable as grassland/shrubland during the study period: forest declined from 28.5 to 27.0 percent of the ecoregion, while agriculture increased from 13.7 to 14.3 percent of the ecoregion (table 4; figure 8).

The dominant land-cover conversions between 1986 and 1992 were in the grassland/shrubland class. During this time period, however, grassland/shrubland increased rather than decreased in coverage at the expense of forest and agricultural land (table 3). Contributing to these land-cover conversions were extensive brush management to improve livestock pasture, as well as the enactment of the Conservation Reserve Program (CRP) in 1985, which provided incentives to convert highly erodible cropland to permanent vegetative cover.

Over the entire study period (1973–2000), the dominant factor influencing land-use/land-cover change in the Edwards Plateau Ecoregion was the clearing of forest to expand rangeland for livestock grazing and to create open range for lease hunting on ranchlands (table 3). Trees and shrubs were removed to increase the diversity needed to support a range of wildlife. Lease hunting offered by ranchers was an important recreational and economic activity in the ecoregion.

Additionally, ranchers clear mesquite and other brush to improve conditions for white-tailed deer (*Odocoileus virginianus*), quail (*Colinus virginianus* and *Callipepla squamata*), wild turkey (*Meleagris gallopavo*), javelina (*Pecari tajacu*), and blackbuck (*Antilope cervicapra*), as well as endangered wildlife species such as the black-capped vireo

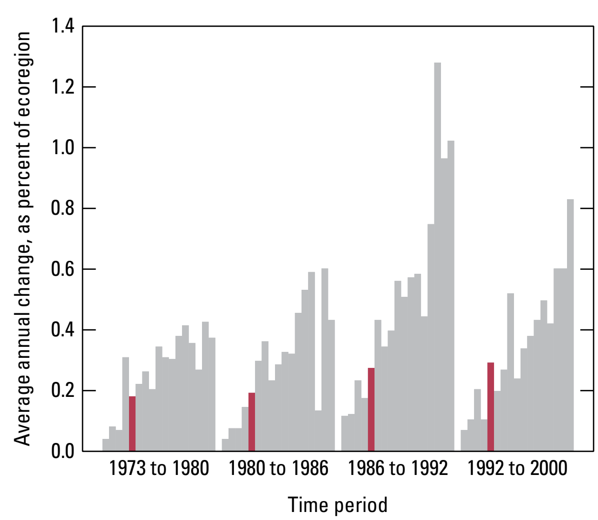

Figure 7. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Edwards Plateau Ecoregion are represented by red bars in each time period.

(*Vireo atricapilla*) (Texas Parks and Wildlife, 2007). Ranchers use mechanical methods such as root plowing to thin out or remove unwanted brush, and they also use herbicides and biological methods to keep brush from returning (Bovey, 2001).

Agricultural land increased slightly between 1973 and 2000 as grassland/shrubland was converted to pasture for enhanced livestock grazing (table 3). Developed lands also increased throughout the study period, resulting in a net gain of more than 0.5 percent (314 km^2) between 1973 and 2000 (table 4; fig. 8). Population gains in the urbanizing areas surrounding the Austin and San Antonio metropolitan regions contributed most of this increase (U.S. Census Bureau, 1970–2000 [various years]). After 1986, most development occurred on forest or grassland/shrubland (fig. 8).

The Edwards Plateau Ecoregion is changing from a characteristically rural region to an urban one. Since 1940, the population growth rate of the Edwards Plateau Ecoregion has surpassed that of the United States as a whole, with most of the population increases occurring in the ecoregion's urban areas. As population grows and land development expands, one of the main challenges within the ecoregion will be to maintain an adequate supply of clean water from the Edwards aquifer. Declining groundwater levels of the Edwards aquifer are making the water susceptible to contamination. As groundwater levels decline, salt-water intrusion from the Texas Gulf Coast into the aquifer is possible (McCormick and others, unpub. data, 2004). Additionally, expanding land development is causing groundwater to become more susceptible to urban-pollutant runoff. To address these issues, communities within the Edwards Plateau Ecoregion are working with scientists and urban and regional planners to ensure that the water resources of the Edwards aquifer will be adequate for future generations.

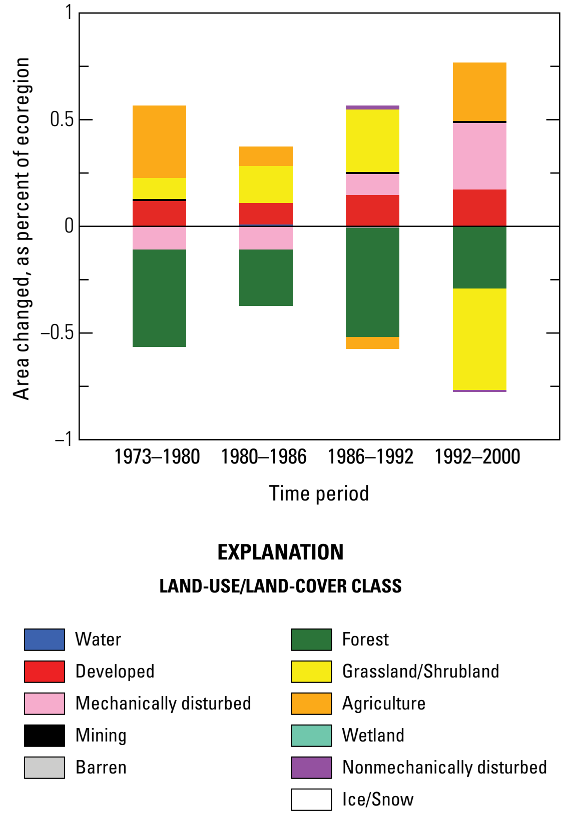

Figure 8. Normalized average net change in Edwards Plateau Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for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

Table 1. Percentage of Edwards Plateau 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	4.7	1.0	3.7	5.7	0.8	14.5
2	0.8	0.4	0.4	1.1	0.2	34.6
3	0.0	0.0	0.0	0.0	0.0	49.8
4	0.0	0.0	0.0	0.0	0.0	97.2
Overall spatial change	5.5	1.2	4.3	6.7	0.8	14.5

Table 2. Raw estimates of change in Edwards Plateau 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 eco-region)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	1.2	0.6	0.7	1.8	0.4	30.1	0.2
1980–1986	1.2	0.4	0.7	1.6	0.3	24.6	0.2
1986–1992	1.6	0.4	1.2	2.0	0.3	17.2	0.3
1992–2000	2.3	0.5	1.8	2.8	0.4	15.6	0.3
Estimate of change, in square kilometers							
1973–1980	729	324	405	1,053	220	30.1	104
1980–1986	676	245	431	921	166	24.6	113
1986–1992	950	242	709	1,192	164	17.2	158
1992–2000	1,352	311	1,041	1,663	211	15.6	169

Table 3. Principal land-cover conversions in Edwards Plateau 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.

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	Grassland/Shrubland	145	91	61	0.2	19.8
	Mechanically disturbed	Grassland/Shrubland	143	203	138	0.2	19.6
	Forest	Agriculture	114	136	92	0.2	15.7
	Grassland/Shrubland	Mechanically disturbed	108	136	92	0.2	14.8
	Grassland/Shrubland	Agriculture	96	72	49	0.2	13.1
	Other	Other	124	n/a	n/a	0.2	17.0
		Totals	729			1.2	100.0
1980–1986	Forest	Grassland/Shrubland	180	129	87	0.3	26.7
	Mechanically disturbed	Grassland/Shrubland	100	136	92	0.2	14.8
	Grassland/Shrubland	Agriculture	97	46	31	0.2	14.4
	Grassland/Shrubland	Forest	91	104	71	0.2	13.4
	Agriculture	Grassland/Shrubland	67	67	46	0.1	10.0
	Other	Other	140	n/a	n/a	0.2	20.7
		Totals	676			1.2	100.0
1986–1992	Forest	Grassland/Shrubland	315	180	122	0.5	33.1
	Agriculture	Grassland/Shrubland	148	67	46	0.3	15.6
	Grassland/Shrubland	Agriculture	100	53	36	0.2	10.5
	Grassland/Shrubland	Forest	92	57	39	0.2	9.6
	Grassland/Shrubland	Mechanically disturbed	91	65	44	0.2	9.6
	Other	Other	204	n/a	n/a	0.3	21.5
		Totals	950			1.6	100.0
1992–2000	Grassland/Shrubland	Agriculture	291	146	99	0.5	21.5
	Grassland/Shrubland	Mechanically disturbed	232	163	110	0.4	17.2
	Agriculture	Grassland/Shrubland	200	137	93	0.3	14.8
	Forest	Grassland/Shrubland	168	77	52	0.3	12.4
	Grassland/Shrubland	Forest	134	74	50	0.2	9.9
	Other	Other	328	n/a	n/a	0.6	24.3
		Totals	1,352			2.3	100.0
1973–2000 (overall)	Forest	Grassland/Shrubland	807	369	250	1.4	21.8
	Grassland/Shrubland	Agriculture	584	210	142	1.0	15.7
	Grassland/Shrubland	Mechanically disturbed	472	277	187	0.8	12.7
	Agriculture	Grassland/Shrubland	436	209	141	0.7	11.8
	Grassland/Shrubland	Forest	322	153	104	0.5	8.7
	Other	Other	1,087	n/a	n/a	1.9	29.3
		Totals	3,708			6.3	100.0

Table 4. Estimated area (and margin of error) of each land-cover class in Edwards Plateau 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	0.3	0.1	1.2	0.6	0.3	0.4	0.1	0.0	0.2	0.1	28.5	6.0	55.7	6.5	13.7	4.3	0.0	0.0	0.0	0.0
1980	0.3	0.1	1.4	0.7	0.2	0.2	0.1	0.0	0.2	0.1	28.0	5.9	55.8	6.5	14.0	4.3	0.0	0.0	0.0	0.0
1986	0.3	0.1	1.5	0.7	0.1	0.1	0.1	0.0	0.2	0.1	27.8	5.8	55.9	6.5	14.1	4.3	0.0	0.0	0.0	0.0
1992	0.3	0.1	1.6	0.8	0.2	0.1	0.1	0.0	0.2	0.1	27.3	5.6	56.2	6.4	14.1	4.3	0.0	0.0	0.0	0.0
2000	0.3	0.1	1.8	0.9	0.5	0.3	0.1	0.0	0.2	0.1	27.0	5.5	55.8	6.2	14.3	4.2	0.0	0.0	0.0	0.0
Net change	0.0	0.0	0.6	0.3	0.2	0.2	0.0	0.0	0.0	0.0	–1.5	0.8	0.1	0.9	0.6	0.5	0.0	0.0	0.0	0.0
Gross change	0.0	0.0	0.5	0.3	1.3	0.8	0.0	0.0	0.0	0.0	2.0	0.7	3.8	0.9	1.6	0.5	0.0	0.0	0.1	0.1
Area, in square kilometers																				
1973	174	51	725	381	179	217	31	12	136	72	16,705	3,525	32,642	3,823	8,032	2,529	8	7	0	0
1980	174	51	797	398	115	136	36	14	137	72	16,439	3,466	32,701	3,838	8,227	2,514	8	7	0	0
1986	181	52	853	433	53	47	38	15	135	72	16,283	3,385	32,805	3,786	8,278	2,510	8	7	0	0
1992	180	52	938	489	114	66	45	18	134	72	15,983	3,297	32,974	3,737	8,244	2,508	8	7	13	19
2000	181	52	1,040	543	297	167	49	20	134	72	15,811	3,233	32,697	3,650	8,410	2,469	8	6	7	11
Net change	7	11	314	183	117	141	18	14	–2	6	–894	444	55	518	377	317	0	0	7	11
Gross change	21	9	314	183	755	452	23	13	9	7	1,196	429	2,218	547	963	289	0	0	34	39

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Chapter 15

Southern Texas Plains Ecoregion

By Michael P. Stier

Ecoregion Description

The Southern Texas Plains Ecoregion covers an area of about 54,744 km^2 (21,137 mi^2) that stretches from just southwest of San Antonio, Texas, south to the Mexican border (fig.1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The Balcones Escarpment, which extends eastward from the Rio Grande, near the city of Del Rio, Texas, to San Antonio, is the northern boundary of the ecoregion. The ecoregion is surrounded by, from northwest to southeast, the Chihuahuan Deserts, Edwards Plateau, Texas Blackland Prairies, East Central Texas Plains, and Western Gulf Coastal Plain Ecoregions.

The terrain in the Southern Texas Plains Ecoregion is relatively flat, with areas of rolling hills that range in elevation from 30 to 300 m (fig. 2). The ecoregion consists of three major subdivisions: (1) the Interior Lowland Belt, which is characterized by black soils; (2) the Coastal Belt, which is blanketed by a thick cover of sand; and (3) the Central Dissected Belt, which consists of mostly calcareous clays and some areas of deep sand (Texas State Historical Association, 2007). Average annual rainfall amounts range from 510 to 760 mm (20–30 in.), increasing from west to east across the ecoregion (Conservation History Association of Texas, 2008).

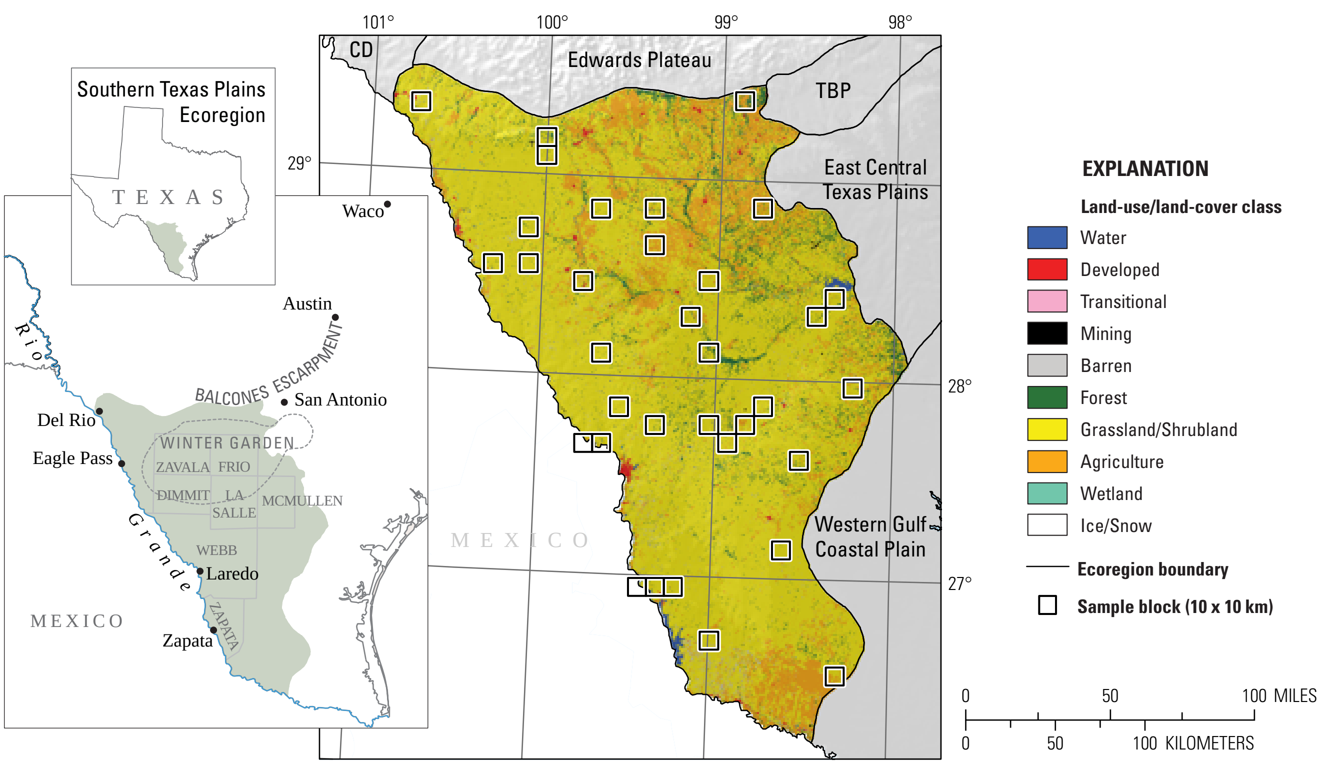

Figure 1. Map of Southern Texas Plains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status 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 Great Plains ecoregions are listed in appendix 2. Also shown is part of one Western United States ecoregion, Chihuahuan Deserts (CD). See appendix 3 for definitions of land-use/land-cover classifications.

This ecoregion is characterized by savannas, plains, and shrublands that are dominated by drought-tolerant, and often thorn-laden, small trees and shrubs (Omernik, 1987). Mesquite (*Prosopis* spp.), which often is the dominant woody species, is found as scattered individuals or in grouped stands in grasslands. Historically, grasses were a major component of the ecoregion prior to settlement. As grasses were grazed by livestock, the fragile soil structure eroded away, leaving mostly rocky, dry soils that mainly support woody species (Texas A&M Forest Service, 2008). Today (2014), as a result of overgrazing and the suppression of natural wildfires, mesquite, pricklypear (*Opuntia* spp.) cactus, eastern redcedar (*Juniperus virginiana*), Ashe's juniper (*Juniperus ashei*), and abundant blackbrush (*Coleogyne ramosissima*) are encroaching into the grasslands (Harker, 1999). Because of woody encroachment into grassland areas, brush management is often necessary to improve range for livestock grazing.

Although the predominant land cover is grassland/shrubland, agriculture is present in subregional concentrations. Major crops grown include hay, wheat, oats, cotton, sorghum, and sunflowers. Bermuda onions, cabbage, spinach, beets, and other vegetables are grown in the "Winter Garden" region (fig. 3), located in the northeast corner of the Southern Texas Plains Ecoregion, north of Laredo, Texas, and centered around Dimmit, Zavala, Frio, and La Salle Counties. This irrigated area also produces melons and nuts. Most land outside the irrigated areas is rangeland devoted to livestock production. Other major rural industries include petroleum and natural-gas extraction and lease hunting.

Figure 2. Shrub-dominated grassland/shrubland in Southern Texas Plains Ecoregion.

Figure 3. Field of irrigated cabbage in "Winter Garden" agricultural area, located in south Texas, north of Laredo and southwest of San Antonio, in Southern Texas Plains Ecoregion.

Border cities such as Laredo and Eagle Pass, Texas, play an increasingly important role in the economy of the ecoregion through cross-border trade with Mexico, including trucking and health services (Patrick, 2000; Gilmer and others, 2001). The population within the ecoregion grew considerably during the study period (1973–2000). Webb County, which includes Laredo, the largest city in the ecoregion, grew from 99,258 in 1980 to 193,117 in 2000 (U.S. Census Bureau, 1970–2000 [various years]). Only the already sparsely populated McMullen County decreased in population, from 879 in 1980 to 851 in 2000 (U.S. Census Bureau, 1970–2000 [various years]).

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 Texas Plains Ecoregion between 1973 and 2000 is estimated at 12 percent (table 1). Compared to other Great Plains ecoregions, change in the Southern Texas Plains Ecoregion was moderately high (fig. 4). Of the land that changed, 7.2 percent changed one time, 4.2 percent change two times, and 0.5 percent changed three times (table 1). In many instances, grassland/shrubland was converted to agriculture or mechanically disturbed in one time period, only to revert to grassland/shrubland in a subsequent time period.

Change per time period was moderate between 1973 and 1980 (3.0 percent) and between 1980 and 1986 (3.6 percent) (table 2). During the last two time periods (1986–1992, 1992–2000), land-use/land-cover change was significantly higher (5.8 percent and 4.8 percent, respectively). Much of this change can be attributed to brush-management activities to improve livestock grazing and wildlife habitat. Principal land-cover conversions during these last two time periods involved grassland/shrubland and mechanically disturbed land (table 3). When normalized to account for varying lengths in study periods, annual rates of change increased gradually between 1973 and 1992, from 0.4 percent to 1.0 percent, and then decreased to 0.6 percent between 1992 and 2000 (table 2; fig. 5).

Grassland/shrubland and agriculture make up almost 92 percent of the ecoregion. The largest net change that occurred between 1973 and 2000 was a 1.0 percent (544 km^2) increase in agricultural land and a 0.9 percent (517 km^2) decrease in grassland/shrubland (table 4).

Between 1973 and 2000, mechanically disturbed land had little net increase but experienced a gross change equivalent

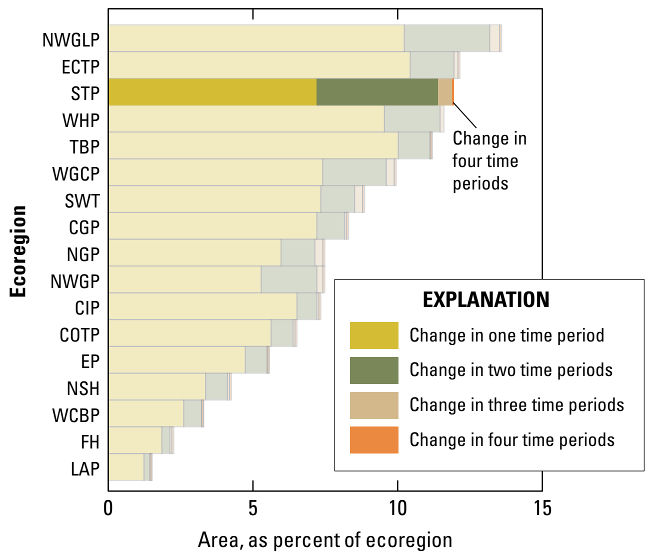

Figure 4. Overall spatial change in Southern Texas Plains Ecoregion (STP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Southern Texas 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.

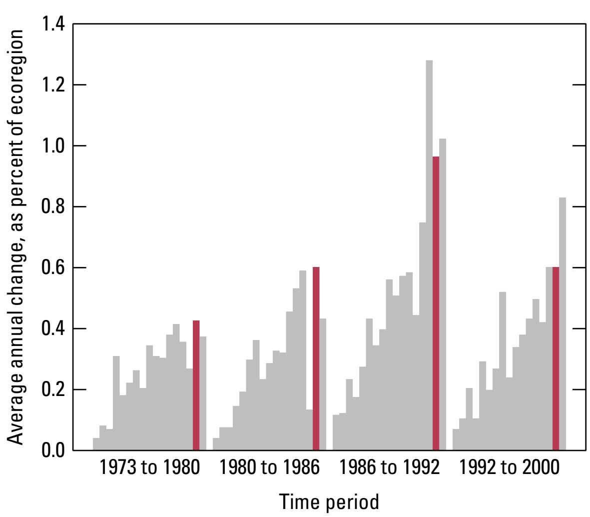

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Southern Texas Plains Ecoregion are represented by red bars in each time period.

to 4.2 percent of the ecoregion (2,279 km²). A large amount of grassland/shrubland was converted to mechanically disturbed land between 1986 and 1992 (table 3). By 2000, most of the mechanically disturbed land was converted back to grassland/shrubland, and, as a result, the amount of mechanically disturbed land showed very little net change between 1973 and 2000. This also was true for grassland/shrubland, which had large amounts of gross change (8.4 percent) and much less net change (–0.9 percent) (table 4).

Other net changes generally were minor in terms of total area affected. Surface-water area decreased by 283 km² (table 4). Wetland expanded by 129 km² as surface water retreated from small lakes, reservoirs, and ponds likely because of annual or seasonal variation in precipitation levels (table 4). A slight increase in mining land of 115 km² was caused by the expansion of gas- and oil-drilling activities (table 4).

Developed land steadily increased throughout the study period: in 1973, it covered 0.5 percent of the ecoregion (296 km²), and by 2000, it covered 0.8 percent of the ecoregion (454 km²) (table 4; fig. 6). Population gains in the urbanizing areas of Laredo, Del Rio, and Zapata, Texas, contributed to the expansion of developed land (U.S. Census Bureau, 1970–2000 [various years]). Most development expanded

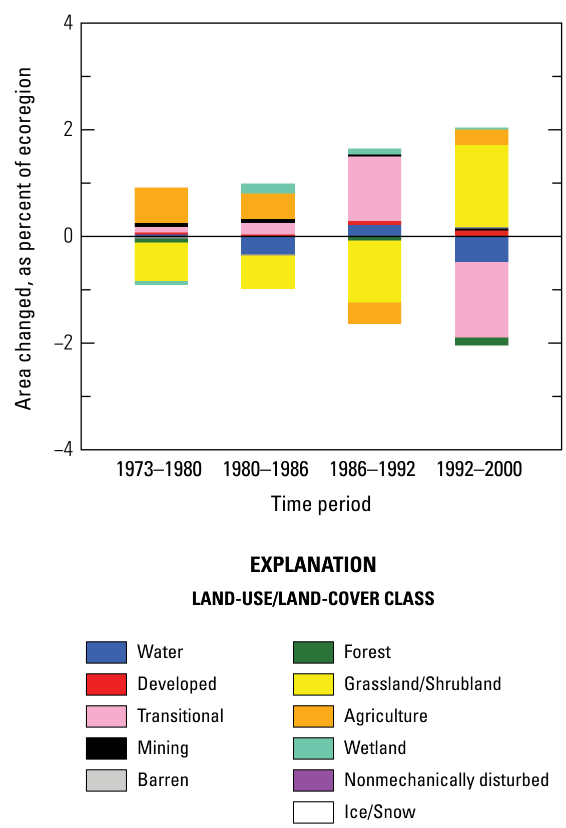

Figure 6. Normalized average net change in Southern Texas Plains Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

onto grassland/shrubland and agricultural land, especially during the last two time periods (1986–1992, 1992–2000).

The four most common land-cover conversions were grassland/shrubland to agriculture, agriculture to grassland/shrubland, grassland/shrubland to mechanically disturbed, and mechanically disturbed to grassland/shrubland (table 3). Agricultural land increased over the entire study period, at the expense of grassland/shrubland. Demand for livestock and agricultural products such as wheat, vegetables, and cotton led to the expansion of agriculture, specifically in the irrigated "Winter Garden" region. Not all of the grassland/shrubland-to-agriculture conversions were successful, however, especially when crops were grown on poor soils with limited water supplies. The failure of farmers and ranchers to raise crops in these areas caused some of the agricultural land to revert to grassland/shrubland.

Another major factor that influenced land-use/land-cover change in the Southern Texas Plains Ecoregion was brush clearing to improve wildlife habitat and grazing conditions for livestock, which caused a temporary increase in the amount of mechanically disturbed land between 1986 and 1992 (most of the cleared land had reverted to grassland/shrubland by 2000). Ranchers used mechanical means such as root plowing and front-end stacking, as well as fire, herbicides, and biological means, to thin out mesquite and other woody brush (Bovey, 2001). In many areas of the ecoregion, "checkerboard," or "patchwork style" brush-clearing patterns were created by the ranchers (Archer and others, 2011) to provide the diversity of cover needed to support a range of wildlife species, including white-tailed deer (*Odocoileus virginianus*), quail (*Cyrtonyx montezumae, Callipepla squamata,* and *Colinus virginianus*), the endangered black-capped vireo (*Vireo atricapilla*), mourning dove (*Zenaida macroura*), white-winged dove (*Zenaida asiatica*), javelina (*Pecari tajacu*), and blackbuck (*Antilope cervicapra*) (Texas Parks and Wildlife, 2007) (fig. 7). The rows of brush that were left unplowed provided cover for many birds, whereas the brush-cleared rows that were reseeded with grass improved grazing for both livestock and wildlife, including game wildlife, and so the lease hunting offered by ranchers flourished in the ecoregion. As these brush-management techniques increased, so, too, did the amount of land-cover change during the study period.

Figure 7. White-tailed deer in brush-cleared lane on ranch in Southern Texas Plains Ecoregion.

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

[Most sample pixels remained unchanged (88.0 percent), whereas 12.0 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	7.2	1.2	6.0	8.4	0.8	11.4
2	4.2	2.1	2.1	6.3	1.4	33.7
3	0.5	0.5	0.0	0.9	0.3	62.2
4	0.0	0.0	0.0	0.0	0.0	66.1
Overall spatial change	12.0	2.5	9.4	14.5	1.7	14.4

Table 2. Raw estimates of change in Southern Texas 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	3.0	0.7	2.2	3.7	0.5	16.8	0.4
1980–1986	3.6	1.0	2.7	4.6	0.6	17.9	0.6
1986–1992	5.8	2.3	3.5	8.1	1.6	26.8	1.0
1992–2000	4.8	1.9	3.0	6.7	1.3	26.2	0.6
Estimate of change, in square kilometers							
1973–1980	1,625	402	1,223	2,027	272	16.8	232
1980–1986	1,979	522	1,456	2,501	354	17.9	330
1986–1992	3,172	1,255	1,917	4,426	850	26.8	529
1992–2000	2,639	1,021	1,619	3,660	692	26.2	330

Table 3. Principal land-cover conversions in Southern Texas 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	Grassland/Shrubland	Agriculture	689	267	181	1.3	42.4
	Agriculture	Grassland/Shrubland	338	161	109	0.6	20.8
	Grassland/Shrubland	Mechanically disturbed	168	107	72	0.3	10.3
	Mechanically disturbed	Grassland/Shrubland	136	99	67	0.2	8.4
	Grassland/Shrubland	Mining	61	82	55	0.1	3.7
	Other	Other	233	n/a	n/a	0.4	14.4
		Totals	1,625			3.0	100.0
1980–1986	Grassland/Shrubland	Agriculture	640	269	182	1.2	32.4
	Agriculture	Grassland/Shrubland	413	156	105	0.8	20.8
	Grassland/Shrubland	Mechanically disturbed	296	328	222	0.5	14.9
	Mechanically disturbed	Grassland/Shrubland	125	85	58	0.2	6.3
	Water	Grassland/Shrubland	124	165	112	0.2	6.3
	Other	Other	381	n/a	n/a	0.7	19.3
		Totals	1,979			3.6	100.0
1986–1992	Grassland/Shrubland	Mechanically disturbed	976	982	666	1.8	30.8
	Agriculture	Grassland/Shrubland	755	259	176	1.4	23.8
	Grassland/Shrubland	Agriculture	395	153	104	0.7	12.5
	Mechanically disturbed	Grassland/Shrubland	230	222	151	0.4	7.3
	Grassland/Shrubland	Water	116	115	78	0.2	3.7
	Other	Other	699	n/a	n/a	1.3	22.0
		Totals	3,172			5.8	100.0
1992–2000	Mechanically disturbed	Grassland/Shrubland	834	961	651	1.5	31.6
	Grassland/Shrubland	Agriculture	377	165	111	0.7	14.3
	Agriculture	Grassland/Shrubland	360	133	90	0.7	13.6
	Grassland/Shrubland	Mechanically disturbed	178	129	88	0.3	6.7
	Water	Wetland	147	135	91	0.3	5.6
	Other	Other	744	n/a	n/a	1.4	28.2
		Totals	2,639			4.8	100.0
1973–2000 (overall)	Grassland/Shrubland	Agriculture	2,101	591	400	3.8	22.3
	Agriculture	Grassland/Shrubland	1,865	546	370	3.4	19.8
	Grassland/Shrubland	Mechanically disturbed	1,618	1,155	783	3.0	17.2
	Mechanically disturbed	Grassland/Shrubland	1,326	1,046	709	2.4	14.1
	Water	Wetland	311	223	151	0.6	3.3
	Other	Other	2,194	n/a	n/a	4.0	23.3
		Totals	9,414			17.2	100.0

Table 4. Estimated area (and margin of error) of each land-cover class in Southern Texas 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	0.8	0.7	0.5	0.4	0.6	0.4	0.2	0.1	0.1	0.1	5.5	2.3	79.1	4.7	12.5	3.4	0.8	0.3	0.0	0.0
1980	0.9	0.6	0.6	0.4	0.6	0.4	0.2	0.2	0.1	0.1	5.4	2.3	78.4	4.8	13.1	3.6	0.7	0.3	0.0	0.0
1986	0.5	0.2	0.6	0.4	0.9	0.8	0.3	0.2	0.1	0.1	5.4	2.3	77.7	4.9	13.6	3.7	0.9	0.3	0.0	0.0
1992	0.8	0.5	0.7	0.4	2.1	1.9	0.3	0.2	0.1	0.1	5.3	2.3	76.6	5.0	13.2	3.7	1.0	0.4	0.0	0.0
2000	0.3	0.1	0.8	0.5	0.6	0.4	0.4	0.2	0.1	0.1	5.1	2.2	78.1	5.0	13.5	3.8	1.0	0.4	0.0	0.0
Net change	–0.5	0.6	0.3	0.2	0.1	0.3	0.2	0.1	0.0	0.0	–0.3	0.2	–0.9	1.2	1.0	1.1	0.2	0.2	0.0	0.0
Gross change	1.5	1.2	0.3	0.2	4.2	3.6	0.4	0.2	0.1	0.1	0.5	0.2	8.4	3.3	4.7	1.0	0.6	0.4	0.0	0.0
Area, in square kilometers																				
1973	448	357	296	200	306	220	83	62	61	72	2,998	1,243	43,294	2,573	6,831	1,887	426	165	0	0
1980	477	354	320	205	353	229	124	115	55	63	2,941	1,239	42,896	2,640	7,195	1,973	383	159	0	0
1986	291	129	354	212	468	417	155	124	43	46	2,933	1,249	42,562	2,689	7,459	2,007	479	187	0	0
1992	423	288	393	221	1,129	1,015	167	113	39	41	2,904	1,246	41,924	2,738	7,226	2,004	538	212	0	0
2000	165	74	454	246	350	217	198	95	50	55	2,819	1,227	42,777	2,756	7,376	2,061	555	206	0	0
Net change	–283	346	158	96	44	187	115	66	–12	17	–179	87	–517	630	544	628	129	108	0	0
Gross change	839	641	159	96	2,279	1,990	206	134	33	47	256	111	4,606	1,830	2,588	537	351	196	0	0

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Status and Trends of Land Change in the Great Plains of the United States—1973 to 2000
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Chapter 16

Texas Blackland Prairies Ecoregion

By Roger F. Auch

Ecoregion Description

The Texas Blackland Prairies Ecoregion, located in central Texas, consists of two disjunct sections (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). The larger, northern section runs roughly north-south, from San Antonio, Texas, to the Oklahoma border north-northeast of Dallas, Texas; it is bounded by (clockwise, from its southwest end) the Southern Texas Plains, Edwards Plateau, Central Oklahoma/Texas Plains, South Central Plains, and East Central Texas Plains Ecoregions. The smaller, southern section, which is located about 88 km southeast of San Antonio and is oriented northeast-southwest, is commonly called the “Fayette Prairie” (Griffith and others, 2004). The southern section is almost entirely surrounded by the East Central Texas Plains Ecoregion; a small part of the South Central Plains Ecoregion abuts its east end. The entire Texas Blackland Prairies Ecoregion covers about 50,501 km^2 (19,498 mi^2).

The climate is classified as warm temperate (hot summers and cool winters), with precipitation levels that range from 710 to 1,015 mm (28–40 in.) in an average year. Precipitation is less in the western part of the ecoregion and more in the eastern part (Kottek and others, 2006; PRISM Climate Group, 2006). The landforms are level-to-rolling plains, and soils typically are fine textured, clayey, and high in shrink-and-swell potential (Omernik, 1987; U.S. Environmental Protection Agency, 2002; U.S. Department of Agriculture, 2008b) (fig. 2).

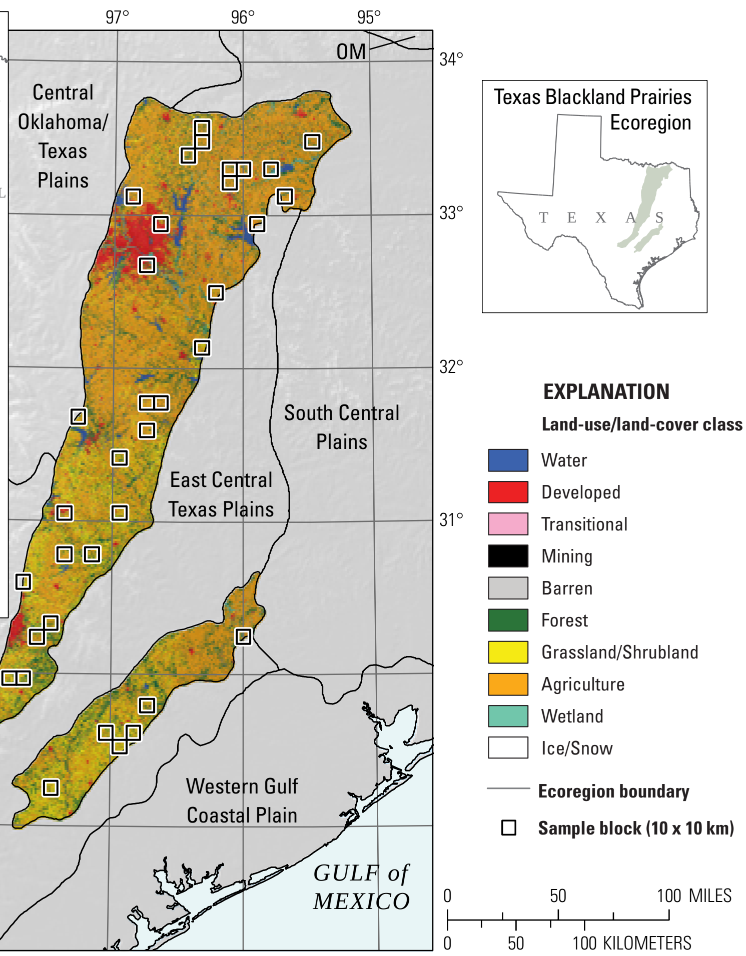

Figure 1. Map of Texas Blackland Prairies Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this “Status 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 Great Plains ecoregions are listed in appendix 2. Also shown are parts of two Midwest–South Central United States ecoregions: Ouachita Mountains (OM) and South Central Plains. See appendix 3 for definitions of land-use/land-cover classifications.

The Texas Blackland Prairies Ecoregion at the beginning of the 19th century was predominantly tallgrass prairie, with forest along stream courses and in upland areas (White, 2006). By the end of the 1800s, most of the ecoregion had been converted to farmland (primarily cropland), although much of this cropland had been converted to well-maintained tame grass pastureland by 1973, the start of the study period (White, 2006) (fig. 3). This pastureland is classified with cropland as agriculture land-cover class.

Agriculture remained the predominant land-cover class in the ecoregion during the entire 27-year study period. The major crops grown in the Texas Blackland Prairies Ecoregion in 2002 were hay, corn, wheat, sorghum, cotton, pecans, and soybeans. Types of livestock production were primarily beef cattle and some goats and horses, as well as poultry in localized areas (U.S. Department of Agriculture, 2008c) (fig. 4).

Other principal land-cover classes of the ecoregion during the study period included forest, grassland/shrubland, and developed. Minor land-cover classes included wetland, water, and mining. Forest was found primarily in stream drainages throughout the ecoregion and, in particular, where mesquite (*Prosopis* spp.) and juniper (*Juniperus* spp.) shrubland was allowed to grow into tree-height woodlands (fig. 5). Forested wetlands in riparian bottomlands were another minor natural land-cover class (Texas Parks and Wildlife, 1997). Grassland/shrubland was found in less intensely used grazing land, which typically had more varied topography, and on land where woody vegetation, such as shrub-sized mesquite and juniper, was allowed to grow on pastureland. Later in the study period, other areas of grassland/shrubland may have been farmland that was idled as part of the Conservation Reserve Program (CRP), although this program was much less important in the Texas Blackland Prairies Ecoregion than in ecoregions of the northern and central Great Plains (U.S. Department of Agriculture, 2008a) (fig. 6).

Development occurred in a variety of places, from small farming communities to booming metropolitan areas such as the greater Dallas, Austin, and San Antonio, Texas, areas. Exurban residential development, although widespread throughout the ecoregion, was more prevalent in areas within commuting distances of the major urban centers (fig. 7). Water land-cover class was present primarily as reservoirs and stock ponds, some of which were constructed during the study period. Aggregate production was the dominant mining land use.

Figure 2. Harvested field in Hunt County, Texas, in northern part of Texas Blackland Prairies Ecoregion, showing soils that helped give ecoregion its name.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Texas Blackland Prairies Ecoregion between 1973 and 2000 is estimated at 11.1 percent (table 1). Compared to other Great Plains ecoregions, change in the Texas Blackland Prairies Ecoregion was relatively high (fig. 8). The amount of change was similar to that of the East Central Texas Plains and Southern Texas Plains Ecoregions but greater than that of the Central Oklahoma/Texas Plains and Edwards Plateau Ecoregions (fig. 8). Most of the land (10.0 percent) changed only once during the study period, but some areas (1.1 percent) changed multiple times (table 1). The multiple changes typically involved change between agriculture

Figure 3. Well-maintained pastures in Texas Blackland Prairies Ecoregion. *A*, Level pasture with scattered oak trees in "Fayette Prairie" (southern section of Texas Blackland Prairies Ecoregion), east of Saint Hedwig, Texas. *B*, Cattle and cattle egrets (*Bubulcus ibis*), in pasture north of Lockhart, Texas.

(marginal farmland) and grassland/shrubland, as well as some conversion of agriculture to grassland/shrubland or forest. When change per time period is normalized to account for varying lengths in study periods, the annual rate of change was highest between 1986 and 1992, at 0.6 percent (296 km^2) (table 2; fig. 9).

The agriculture land-cover class had the most net change during the study period (table 3). Agriculture had a net loss of 5.6 percent (2,814 km^2) (table 3), primarily through conversion to grassland/shrubland and developed land (table 4) and, to a lesser extent, to forest and mining. The conversion of agriculture to grassland/shrubland occurred mostly because of less intense management of pastureland and abandonment of

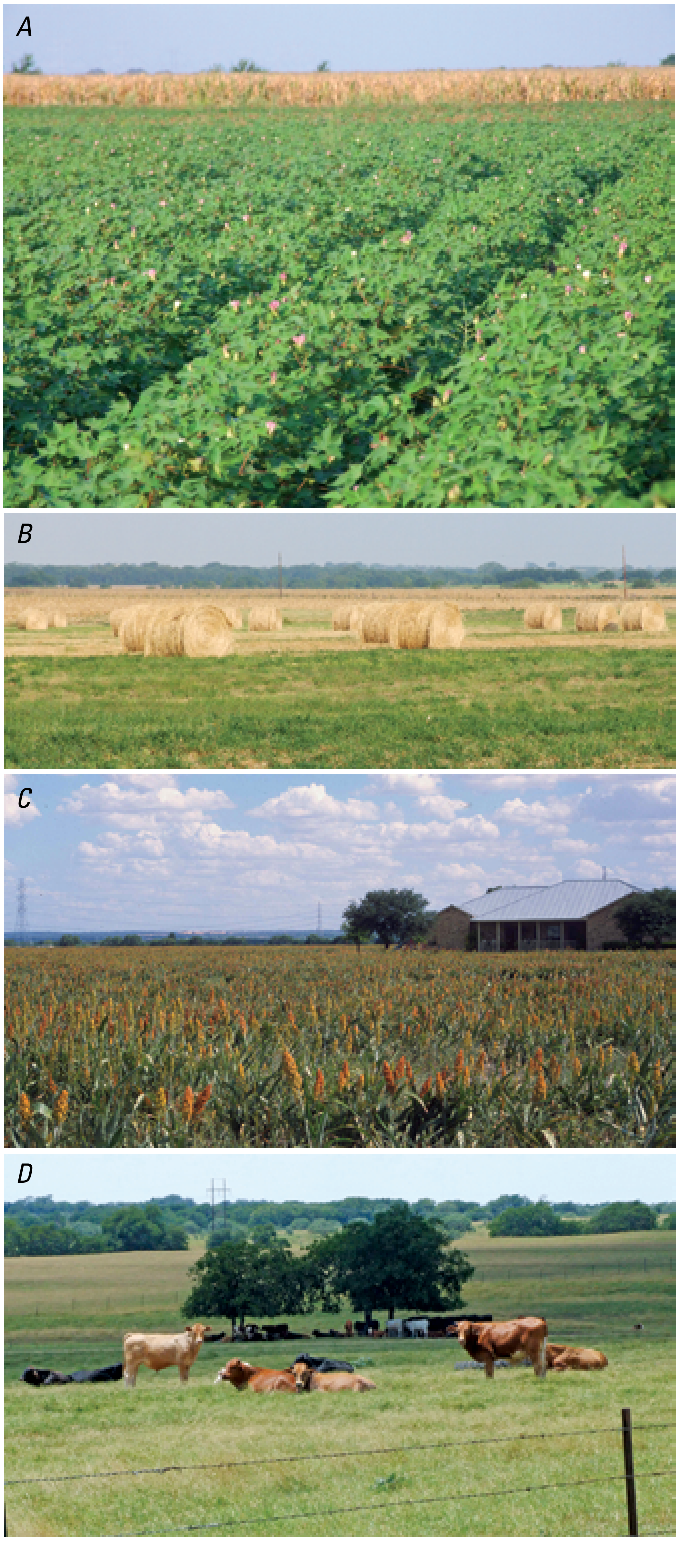

Figure 4. Crops and livestock found in Texas Blackland Prairies Ecoregion. *A*, Cotton and corn fields in northern Caldwell County, Texas. *B*, Hay bales in field east of Rosebud, Texas. *C*, Sorghum field south of San Antonio, Texas, near southwest border of ecoregion. *D*, Cattle grazing and getting shade on pasture east of Georgetown, Texas.

Figure 5. Forested land in Texas Blackland Prairies Ecoregion. Patch of forest (*A*) that follows stream drainage behind cropland, in western Milam County, Texas; mesquite (*B*) and juniper (*C*) woodlands, which are becoming more common in ecoregion, from area east of Brazos River southeast of Waco, Texas (heights of trees are 5–7 m).

agricultural land. The permanent conversion of agriculture to developed was caused mainly by the increasing population and the subsequent economic growth. Changes from agriculture to grassland/shrubland or to forest can be temporary because this land is easily returned to agricultural use.

Between 1973 and 2000, the developed land-cover class had the second largest net change, an increase of 3.8 percent (table 3). The Texas Blackland Prairies Ecoregion gained an estimated 1,933 km^2 of developed land (table 3), from multiple sources: the increase in developed land came predominantly from agriculture (1,172 km^2) and grassland/shrubland (590 km^2) (table 4), as well as from forest (158 km^2) (fig. 10). Most new development was along the Interstate 35 corridor that follows the west side of the ecoregion from San Antonio to Dallas. Economic growth in metropolitan

Figure 6. Grassland/shrubland in Texas Blackland Prairies Ecoregion. (*A*) Less intensely used grazing land in eastern Fayette County, Texas. (*B*) Overgrown pasture with mesquite encroachment of shrub-sized woody vegetation, in pasture north of Coolidge, Texas. (*C*) Idled farmland, possibly from participation in Conservation Reserve Program, in northern Caldwell County, Texas.

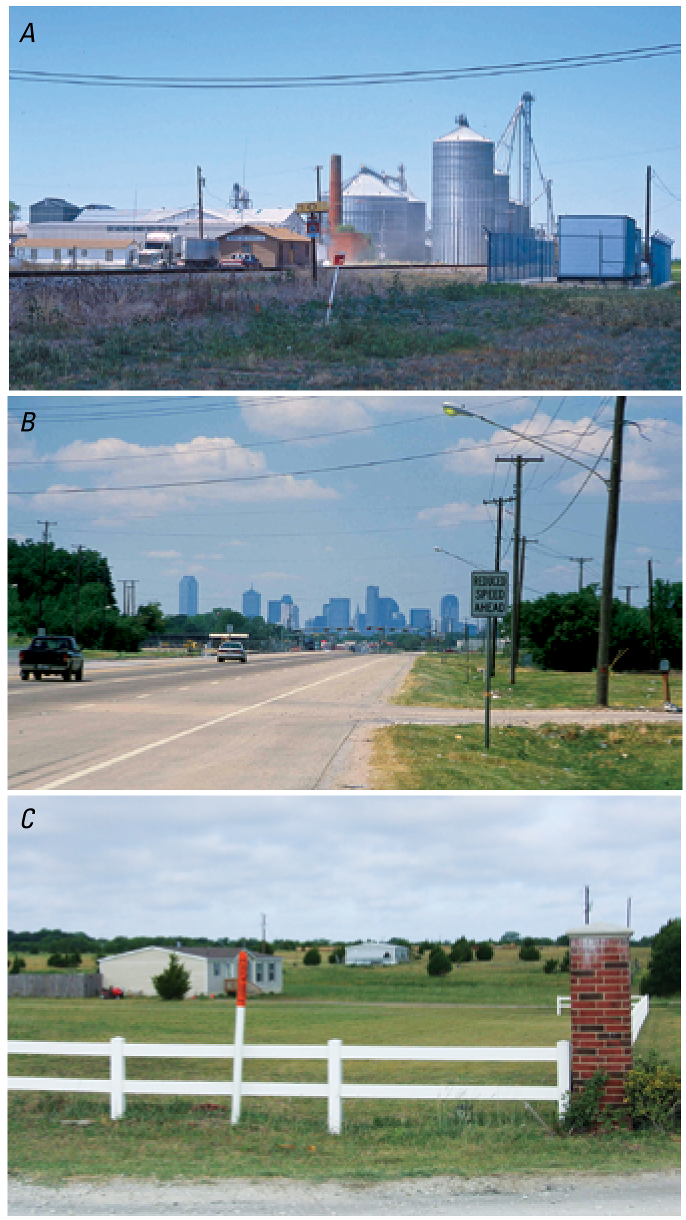

Figure 7. Developed land in Texas Blackland Prairies Ecoregion. *A*, Agricultural infrastructure businesses in farming community of Granger, Texas. *B*, View of downtown Dallas skyline taken from south side of city. *C*, Exurban housing (common in ecoregion, usually on larger lots), in Fannin County, Texas, northeast of Dallas metropolitan area.

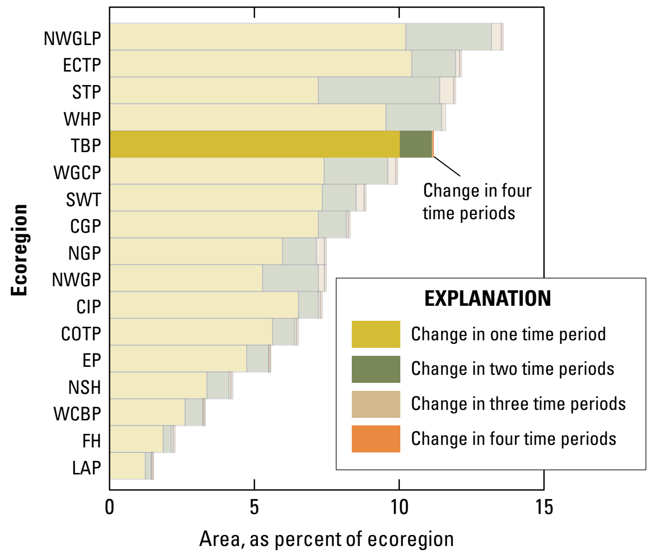

Figure 8. Overall spatial change in Texas Blackland Prairies Ecoregion (TBP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Texas Blackland Prairies 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.

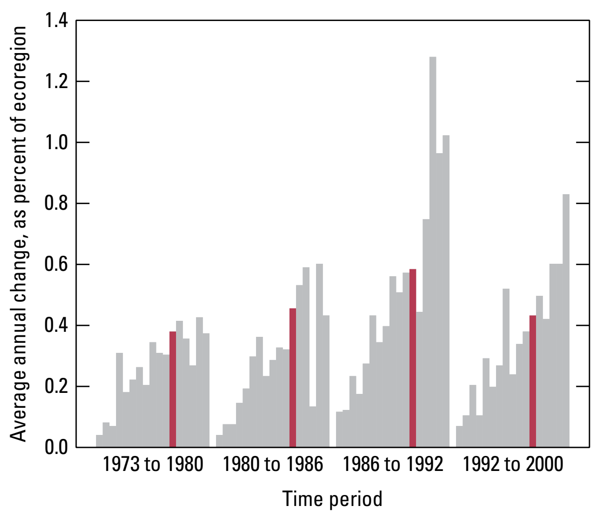

Figure 9. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Texas Blackland Prairies Ecoregion are represented by red bars in each time period.

San Antonio, Austin, and Dallas, as well as in smaller cities such as Temple and Waco, Texas, fueled much of the increased development in the ecoregion (Scarbrough, 2005; Erlichman, 2006).

Grassland/shrubland had the third largest net change during the study period, increasing by 0.9 percent (436 km^2) (table 3), almost exclusively from agriculture. At the same time, grassland/shrubland was lost to developed, agriculture, and forest (fig. 11). This high rate of conversion into and out of grassland/shrubland gave that class a large gross change of

Figure 10. New developed land in Texas Blackland Prairies Ecoregion. *A*, New construction in subdivision of larger lots associated with golf course, in Georgetown, Texas, north of Austin. *B*, Retail shopping center, in Garland, Texas. *C*, Newer housing on edge of Westminster, Texas, in northeast Collin County.

3.9 percent (1,952 km^2) that was much larger than the overall net change of 0.9 percent (table 3). Land held in speculation for future development on the periphery of metropolitan areas may have increased the amount of grassland/shrubland in the ecoregion. Other changes include the conversion from grassland/shrubland "brush" to forest-height woodlands as woody vegetation was allowed to mature.

The main stories of change in the Texas Blackland Prairies Ecoregion between 1973 and 2000 were the deintensification of agriculture to both grassland/shrubland and forest, as well as the continued growth of the major metropolitan areas within the ecoregion. The deintensification of agriculture (usually converting to grassland/shrubland) occurred primarily because of less intense management of pastureland, outright agricultural abandonment, and extensive land speculation at the periphery of metropolitan areas. The conversion of agriculture to grassland/shrubland and even forest may have been the result of changing patterns of landownership, in which the emphasis by new owners was not on production of livestock but, instead, on wildlife habitat, aesthetic values, and other environmentally conscious land uses (Hamilton and Ueckert, 2004).

The conversions of agriculture, grassland/shrubland, and forest to developed accounted for about 31.0 percent of the estimated total area that changed during the study period. Conversions of agriculture and grassland/shrubland to developed were among the top land-use/land-cover changes during all four time periods (table 4). Altogether, developed land gained an estimated 1,933 km^2 between 1973 and 2000 (table 3), and more increases in developed land are expected, as three counties on the outskirts of Dallas (Collin, Rockwall, and Kaufman Counties), as well as two counties that flank Austin to the north and southwest (Williamson and Hays Counties), ranked in the top 100 fastest growing counties in the United States between 2000 and 2006 (Advertising Age, 2008) (fig. 12).

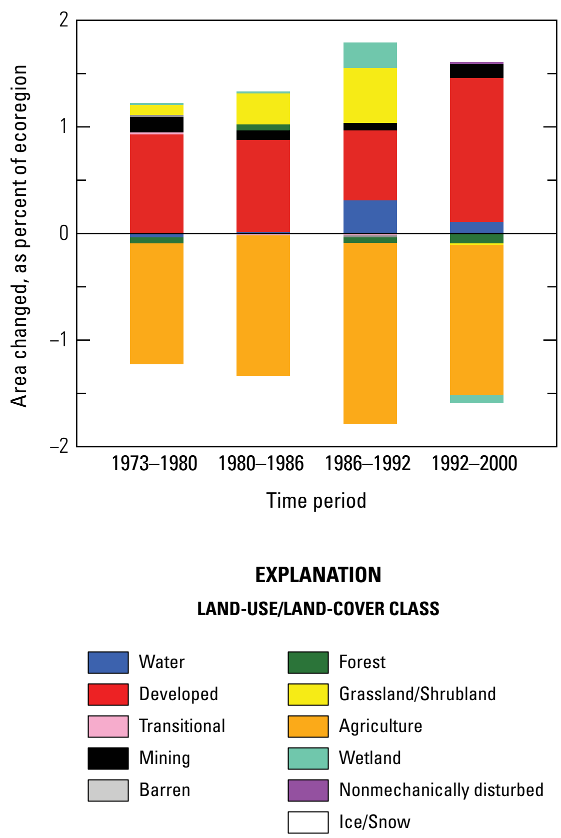

Figure 11. Normalized average net change in Texas Blackland Prairies Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use/land-cover classifications.

Figure 12. More developed land in Texas Blackland Prairies Ecoregion post-2000. *A*, Rooftops of new residential housing advancing in Frisco, Texas, on north side of Dallas urbanized area. *B*, Earth-moving equipment poised to work on Texas State Highway 130 toll road east of Austin, a divided highway that arcs around Austin urbanized area to relieve congestion on Interstate 35.

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

[Most sample pixels remained unchanged (88.9 percent), whereas 11.1 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	10.0	2.3	7.7	12.3	1.5	15.5
2	1.1	0.4	0.7	1.5	0.3	23.2
3	0.0	0.0	0.0	0.0	0.0	25.6
4	0.0	0.0	0.0	0.0	0.0	76.1
Overall spatial change	11.1	2.6	8.5	13.7	1.8	16.0

Table 2. Raw estimates of change in Texas Blackland Prairies 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	2.6	0.9	1.8	3.5	0.6	22.3	0.4
1980–1986	2.7	0.6	2.1	3.3	0.4	14.2	0.5
1986–1992	3.5	1.3	2.2	4.8	0.9	25.6	0.6
1992–2000	3.5	1.0	2.4	4.5	0.7	19.9	0.4
Estimate of change, in square kilometers							
1973–1980	1,332	436	896	1,769	297	22.3	190
1980–1986	1,369	285	1,084	1,655	194	14.2	228
1986–1992	1,774	668	1,106	2,442	455	25.6	296
1992–2000	1,742	508	1,234	2,251	346	19.9	218

Table 3. Estimated area (and margin of error) of each land-cover class in Texas Blackland Prairies 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	0.8	0.2	8.9	4.7	0.0	0.0	0.2	0.1	0.0	0.0	14.0	1.7	11.8	2.9	63.4	4.9	0.9	0.3	0.0	0.0
1980	0.8	0.2	9.8	4.8	0.0	0.0	0.3	0.2	0.0	0.0	13.9	1.7	11.9	2.9	62.3	5.0	0.9	0.3	0.0	0.0
1986	0.8	0.2	10.7	5.0	0.0	0.0	0.4	0.3	0.0	0.0	14.0	1.7	12.2	2.8	60.9	5.1	0.9	0.3	0.0	0.0
1992	1.1	0.4	11.3	5.1	0.0	0.0	0.5	0.4	0.0	0.0	13.9	1.7	12.7	2.9	59.2	5.3	1.2	0.6	0.0	0.0
2000	1.2	0.5	12.7	5.4	0.0	0.0	0.6	0.4	0.0	0.0	13.9	1.7	12.7	2.8	57.8	5.5	1.1	0.5	0.0	0.0
Net change	0.4	0.5	3.8	1.9	0.0	0.0	0.4	0.3	0.0	0.0	–0.2	0.4	0.9	1.1	–5.6	2.1	0.2	0.3	0.0	0.0
Gross change	0.6	0.5	3.8	1.9	0.1	0.1	0.5	0.3	0.0	0.0	1.5	0.4	3.9	0.9	6.6	2.0	0.5	0.5	0.0	0.0
Area, in square kilometers																				
1973	407	102	4,490	2,362	5	5	81	55	17	14	7,074	875	5,965	1,471	32,011	2,468	452	138	0	0
1980	395	91	4,961	2,447	20	18	155	105	25	19	7,042	865	6,008	1,443	31,440	2,512	455	136	0	0
1986	406	91	5,396	2,531	16	16	206	154	18	15	7,062	868	6,159	1,434	30,776	2,582	463	137	0	0
1992	564	184	5,731	2,594	5	7	247	184	16	12	7,034	864	6,410	1,452	29,913	2,658	582	286	0	0
2000	617	243	6,423	2,713	6	4	304	213	14	10	6,995	850	6,401	1,416	29,196	2,755	544	238	1	1
Net change	210	235	1,933	949	1	5	223	172	–3	8	–79	210	436	567	–2,814	1,069	92	133	1	1
Gross change	315	234	1,933	949	67	44	263	173	21	16	760	196	1,952	461	3,345	1,018	245	239	1	1

Table 4. Principal land-cover conversions in Texas Blackland Prairies 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	Grassland/Shrubland	351	161	109	0.7	26.3
	Agriculture	Developed	331	300	204	0.7	24.8
	Grassland/Shrubland	Agriculture	150	99	67	0.3	11.2
	Grassland/Shrubland	Developed	109	89	60	0.2	8.2
	Forest	Agriculture	71	37	25	0.1	5.3
	Other	Other	321	n/a	n/a	0.6	24.1
		Totals	1,332			2.6	100.0
1980–1986	Agriculture	Grassland/Shrubland	444	137	94	0.9	32.4
	Agriculture	Developed	263	142	97	0.5	19.2
	Grassland/Shrubland	Forest	109	64	44	0.2	8.0
	Grassland/Shrubland	Developed	109	56	38	0.2	8.0
	Grassland/Shrubland	Agriculture	76	34	23	0.2	5.6
	Other	Other	369	n/a	n/a	0.7	26.9
		Totals	1,369			2.7	100.0
1986–1992	Agriculture	Grassland/Shrubland	592	230	157	1.2	33.4
	Agriculture	Developed	204	98	67	0.4	11.5
	Grassland/Shrubland	Forest	115	53	36	0.2	6.5
	Grassland/Shrubland	Agriculture	108	40	27	0.2	6.1
	Grassland/Shrubland	Developed	105	57	39	0.2	5.9
	Other	Other	651	n/a	n/a	1.3	36.7
		Totals	1,774			3.5	100.0
1992–2000	Agriculture	Grassland/Shrubland	453	146	99	0.9	26.0
	Agriculture	Developed	375	239	163	0.7	21.5
	Grassland/Shrubland	Developed	267	139	95	0.5	15.3
	Grassland/Shrubland	Agriculture	123	51	35	0.2	7.1
	Grassland/Shrubland	Forest	97	38	26	0.2	5.5
	Other	Other	429	n/a	n/a	0.8	24.6
		Totals	1,742			3.5	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	1,839	537	366	3.6	29.6
	Agriculture	Developed	1,172	698	476	2.3	18.8
	Grassland/Shrubland	Developed	590	298	203	1.2	9.5
	Grassland/Shrubland	Agriculture	456	144	98	0.9	7.3
	Grassland/Shrubland	Forest	376	148	101	0.7	6.1
	Other	Other	1,785	n/a	n/a	3.5	28.7
		Totals	6,218			12.3	100.0

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Chapter 17

Western Gulf Coastal Plain Ecoregion

By Mark A. Drummond

Ecoregion Description

The Western Gulf Coastal Plain Ecoregion is an elongated, low-elevation area that covers 80,965 km^2 (31,261 mi^2). The ecoregion extends from west of the Mississippi River delta in southwestern Louisiana into Texas, running along the entire Gulf Coast of Texas to the Mexican border (fig. 1) (Omernik, 1987; U.S. Environmental Protection Agency, 1997). It is surrounded by, from southwest to northeast, the Southern Texas Plains, East Central Texas Plains, South Central Plains, and Mississippi Alluvial Plain Ecoregions (fig. 1).

The Western Gulf Coastal Plain Ecoregion is a level plain composed mostly of sedimentary strata deposited by repeated cycles of sea-level fluctuations, overlain by fine-textured clays and sand. Several major waterways (including

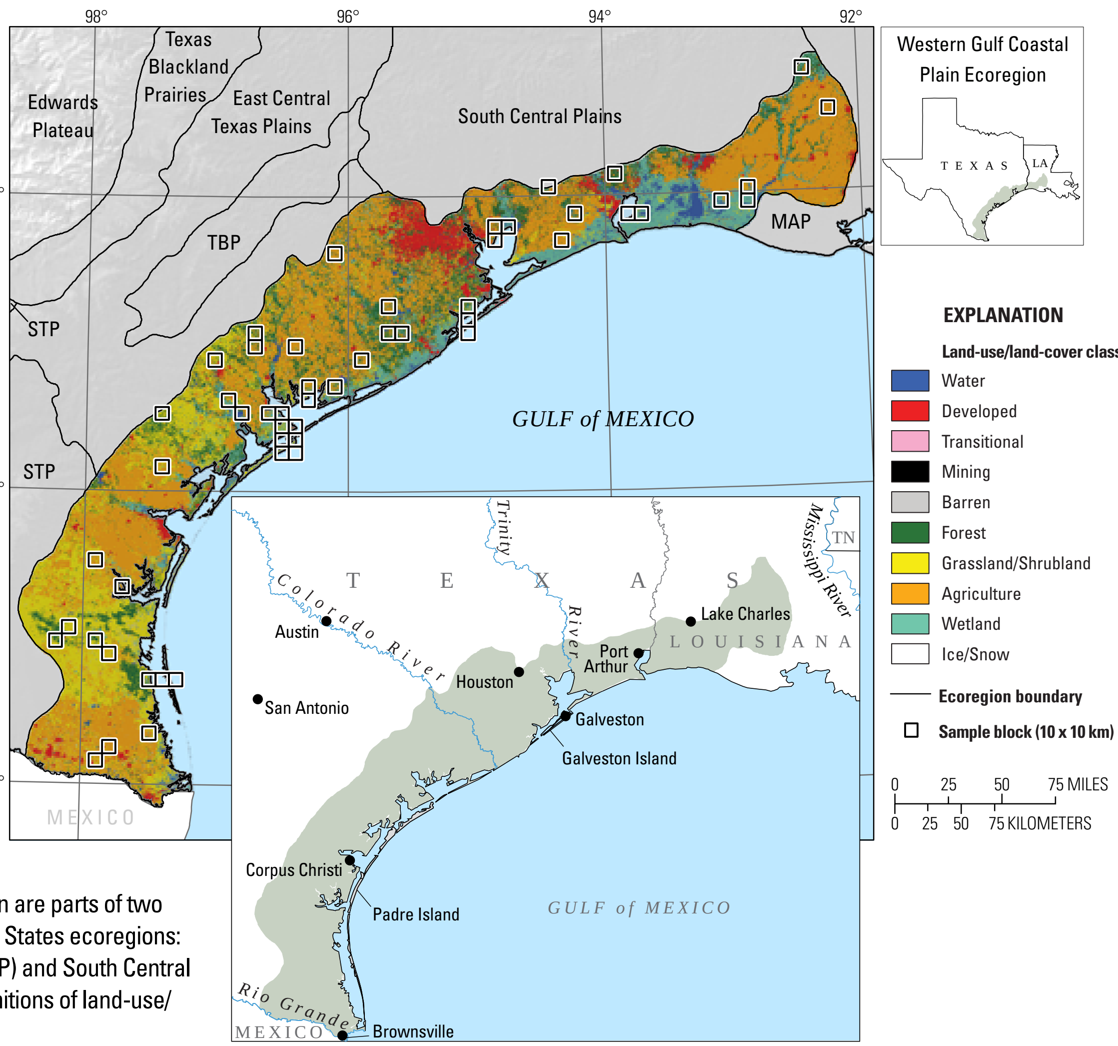

Figure 1. Map of Western Gulf Coastal Plain Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land-cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "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 Great Plains ecoregions are listed in appendix 2. Also shown are parts of two Midwest–South Central United States ecoregions: Mississippi Alluvial Plains (MAP) and South Central Plains. See appendix 3 for definitions of land-use/land-cover classifications.

the Trinity River, the Colorado River, and the Rio Grande) dissect the coastal plain, emptying into the Gulf of Mexico. The Coastal Lowlands aquifer, which underlies much of the ecoregion, is the main source of groundwater. However, aquifer pumping rates are a concern, especially in the greater Houston–Galveston, Texas, area where groundwater levels have declined by as much as 100 m, causing saltwater intrusion and land subsidence (Davidson and Mace, 2006).

The Western Gulf Coastal Plain Ecoregion primarily is a flat grassland prairie, dominated by little bluestem (*Schizachyrium scoparium*) and other grasses. Woody vegetation has encroached on areas of intensive livestock grazing and also of fire suppression (Archer, 1990) (fig. 2). Loblolly pine (*Pinus taeda*), grown for both lumber and paper production, and hardwoods grow along the higher elevation margins of the ecoregion. In the southern part of the ecoregion, clusters of live oak (*Quercus virginiana*) grow on sandy ridges, known as oak mottes. Hardwoods also grow along numerous wooded bottomland floodplains throughout the ecoregion, although many of these forests have been cleared for cropland, pastureland, and urbanization. Coastal marshes and estuaries are extensive along the Gulf of Mexico, from the southern Louisiana parishes into eastern Texas (fig. 3). About 85 percent of wetlands are freshwater environments, and 15 percent are saltwater environments (Moulton and others, 1997). Long barrier islands and adjoining lagoons are more prevalent along the southern Texas coast, including the area from Galveston Island in the north to Padre Island in the south. Several large bays line the Texas coastline, including six deep-water harbors; the port of Houston is the largest of these harbors.

Sand plains and dunes, which are found in a limited area north of the lower Rio Grande valley, support little cropland compared to the rest of the ecoregion, much of which is intensively cropped and irrigated. Honey mesquite (*Prosopis glandulosa*) and granjeno (*Celtis pallida*) shrubs have invaded much of the valley. Natural habitat in the southern tip of Texas and elsewhere in the ecoregion supports various subtropical and marine bird communities, as well as Central Flyway species, making it an area of high species diversity.

Figure 2. Brush clearance of livestock pasture, in Western Gulf Coastal Plain Ecoregion.

Figure 3. Freshwater marsh in southwestern Louisiana, Western Gulf Coastal Plain Ecoregion.

Figure 4. Cotton field in Western Gulf Coastal Plain Ecoregion.

Figure 5. Catfish farm in Western Gulf Coastal Plain Ecoregion.

Large areas in the Western Gulf Coastal Plain Ecoregion are used to grow crops and to graze livestock (fig. 4), and smaller areas are used for inland fish production (fig. 5). Agriculture is aided by a subtropical climate of mild winters and hot summers influenced by the Gulf of Mexico. Precipitation amounts in the ecoregion range from about 650 mm (25 in.) in the southwest to 1,500 mm (60 in.) in the northeast. The southernmost part of the ecoregion has a long growing season, having frost-free periods of more than 320 days, which allows cotton, corn, sorghum, sugarcane, citrus, melons, and vegetables to be grown along the Rio Grande floodplain (Griffith and others, 2004). About one-half of freshwater wetlands also are used for growing rice (often referred to as agricultural wetlands), particularly in the middle part of the ecoregion (Moulton and others, 1997).

Ecological goods and services from coastal wetlands and water bodies are important to the economy of the ecoregion; activities include commercial and recreational fishing, oyster harvesting and shrimp nurseries, waterfowl hunting, and birdwatching (Moulton and others, 1997). Overall, about 70 percent of Texas industry and commerce happens within 160 km of the coast, and more than one-half of petroleum production in the United States is located in the region (fig. 6) (Texas General Land Office, 1995; Moulton and others, 1997). Various human land uses (including canal dredging and channelization, aquifer drawdown, urbanization, and agriculture) contribute to wetland loss in southwestern Louisiana and Texas.

The largest population center in the ecoregion is Houston, Texas, where population nearly doubled during the study period. Between 1970 and 2000, the population of the ecoregion increased by 85 percent, and more than one-half of the increase was concentrated in the Houston area (U.S. Bureau of Census, 1970–2000 [various years]); only four counties lost population. The southern coastal cities of Texas have populations that are increasingly seasonal, as tourism increases and retirees and others temporarily move south for the mild climate during the winter months.

Figure 6. Petroleum processing plant in Western Gulf Coastal Plain Ecoregion. Petroleum-related industries are important to ecoregion's economic base.

Contemporary Land-Cover Change (1973 to 2000)

Land cover is diverse in the Western Gulf Coastal Plain Ecoregion, with agriculture, grassland/shrubland, wetland, forest, and water each constituting more than 10 percent of the total area during all time periods (table 1). The overall spatial change (the percentage of land area that changed at least one time) in the ecoregion between 1973 and 2000 is 9.9 percent (table 2; fig. 7). Compared to other Great Plains ecoregions, change in the ecoregion was higher than average (fig. 7). About 2.5 percent of the overall change was caused by multiple conversions (table 2), representing large land areas shifting between grassland/shrubland and agriculture. The large gross changes between grassland/shrubland and agriculture were the two most common conversions between 1973 and 2000 (table 3).

Although agriculture covered the most total area in the ecoregion, it declined from 31.6 percent in 1973 to 30.6 percent in 2000 (table 1). The estimated 1.0 percent decline was the largest loss of land cover during the study period (fig. 8). Although substantial gross fluctuations between agriculture and grassland/shrubland occurred during the study period, most of the net loss of agriculture occurred because of conversion to wetland and developed land,

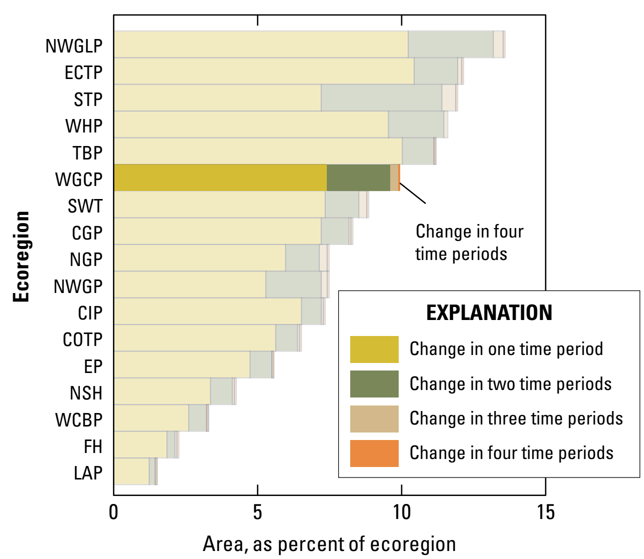

Figure 7. Overall spatial change in Western Gulf Coastal Plain Ecoregion (WGCP; darker bars) compared with that of all 17 Great Plains ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that experienced change during one, two, three, or four time periods; highest level of spatial change in Western Gulf Coastal Plain Ecoregion (four time periods) labeled for clarity. See table 4 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

as well as to grassland/shrubland and forest. The loss of agricultural land to wetlands may have been caused by land subsidence where coastal aquifer groundwater levels have declined or by wetland engineering.

The largest single net gain among all land-cover classes in the ecoregion was an estimated 1.2 percent increase in developed land, increasing from 2.4 percent in 1973 to 3.6 percent in 2000 (table 1). Most developed land was converted from agricultural land, particularly around large metropolitan areas such as Houston, Texas, but also in many smaller population centers across the ecoregion. Expansion of developed land was relatively steady across all time periods.

Between 1973 and 1980, the largest net changes in land cover across the ecoregion were a decrease in grassland/shrubland (0.5 percent) and an increase in developed (0.3 percent) (fig. 9). Agriculture expanded at the expense of grassland/shrubland in response to favorable farm policies, as well as to economic opportunities such as increased grain exports, and developed land mainly expanded onto agricultural land. Between 1980 and 1986, agriculture decreased by 320 km^2, and grassland/shrubland increased by 194 km^2 (table 1); both trends likely are related to unfavorable economic conditions such as inflation and the steep decline in farmland value (Lindert, 1988). The decrease also was a result of continued increase in development, mainly on former agricultural land.

Between 1986 and 1992, agriculture continued to decline by 301 km^2 as it was converted to wetland, forest, developed, and grassland/shrubland (table 1). However, small gains in grassland/shrubland caused by agricultural abandonment were offset by conversions to forest elsewhere in the ecoregion. Conversion of forest to mechanically disturbed (primarily by forest clearcutting, but also by timber harvesting on loblolly pine plantations) also was a common type of land-cover conversion.

Between 1992 and 2000, developed land had the most net change, increasing by 342 km^2 (table 1), with conversions dispersed among grassland/shrubland, agriculture, and forest. The leading land-cover conversions during this time period also were related to timber harvest and regrowth. While some forest was converted to mechanically disturbed, other clearcut areas revegetated to grassland/shrubland, often an intermediate stage between mechanically disturbed and forest.

Other important land-cover changes during the study period included conversions from grassland/shrubland to

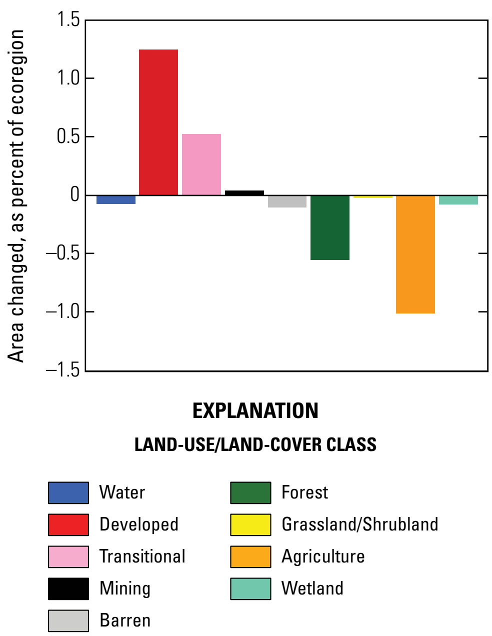

Figure 8. Estimates of net land-cover change in Western Gulf Coastal Plain Ecoregion for each land-cover class between 1973 and 2000. Bars above zero axis represent net gain, whereas bars below zero represent net loss. See appendix 3 for definitions of land-use/land-cover classifications.

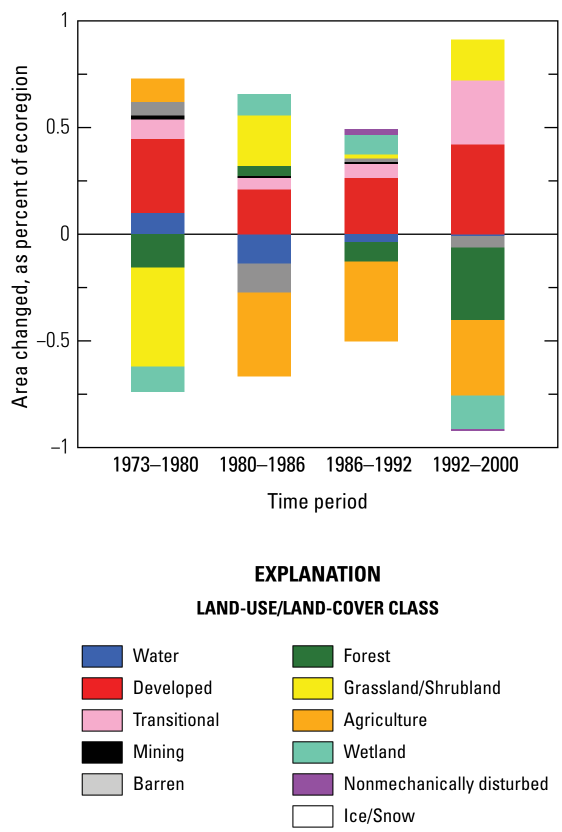

Figure 9. Normalized average net change in Western Gulf Coastal Plain Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix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

mechanically disturbed and then back to grassland/shrubland. These changes are related to the removal of invading woody vegetation through mechanical means, prescribed burns, and herbicide treatments (Archer, 1990).

Overall, the estimated annual rates of change during each of the four time periods were relatively consistent, ranging from about 0.4 percent to 0.5 percent (table 4; fig. 10). The greatest rates of change were between 1980 and 1986, when agriculture had a large decline that likely was caused by the economic downturn, and between 1992 and 2000, when conversions involving developed land and forest were prominent.

During the entire study period, much of the change occurred between agriculture and grassland/shrubland (table 3), driven by agricultural expansion during economic booms followed by agricultural decline caused by cropland abandonment during economic downturns and also by conversions to developed land. However, much land-cover change also was caused by forest harvesting and regrowth. The largest net change between 1973 and 2000 was an expansion of developed land (table 1), caused by urban growth and population increase.

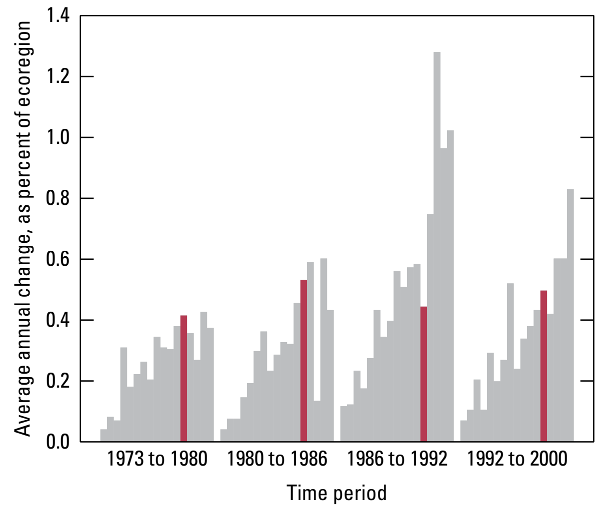

Figure 10. Estimates of land-cover change per time period, normalized to annual rates of change for all 17 Great Plains ecoregions (gray bars). Estimates of change for Western Gulf Coastal Plain Ecoregion are represented by red bars in each time period.

Table 1. Estimated area (and margin of error) of each land-cover class in Western Gulf Coastal 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	17.5	7.8	2.4	0.7	0.1	0.1	0.0	0.0	2.1	2.4	12.1	3.5	20.4	5.9	31.6	6.0	13.8	4.4	0.0	0.0
1980	17.6	7.7	2.7	0.8	0.2	0.1	0.1	0.0	2.2	2.4	11.9	3.5	19.9	5.7	31.7	5.9	13.6	4.5	0.0	0.0
1986	17.5	7.8	2.9	0.8	0.2	0.1	0.1	0.0	2.1	2.2	11.9	3.5	20.2	5.7	31.3	5.9	13.7	4.4	0.0	0.0
1992	17.5	7.7	3.2	0.9	0.3	0.2	0.1	0.1	2.1	2.3	11.8	3.4	20.2	5.7	30.9	5.8	13.8	4.5	0.0	0.0
2000	17.5	7.7	3.6	1.1	0.6	0.4	0.1	0.1	2.0	2.2	11.5	3.3	20.4	5.7	30.6	5.7	13.7	4.4	0.0	0.0
Net change	–0.1	0.2	1.2	0.5	0.5	0.4	0.0	0.0	–0.1	0.2	–0.6	0.4	0.0	0.9	–1.0	0.9	–0.1	0.2	0.0	0.0
Gross change	1.2	0.4	1.2	0.5	1.3	0.6	0.0	0.0	0.4	0.3	1.6	0.6	3.9	1.2	4.0	1.3	1.5	0.6	0.1	0.1
Area, in square kilometers																				
1973	14,192	6,280	1,918	571	75	44	34	32	1,739	1,936	9,758	2,862	16,526	4,749	25,581	4,853	11,141	3,598	0	0
1980	14,274	6,238	2,202	628	150	81	48	35	1,792	1,945	9,636	2,831	16,148	4,625	25,669	4,775	11,046	3,647	0	0
1986	14,166	6,277	2,373	688	200	118	55	37	1,680	1,816	9,672	2,840	16,342	4,640	25,349	4,740	11,128	3,584	0	0
1992	14,142	6,268	2,587	765	255	183	63	43	1,696	1,861	9,592	2,769	16,357	4,624	25,048	4,678	11,203	3,640	23	32
2000	14,133	6,251	2,929	928	499	307	67	43	1,656	1,802	9,311	2,639	16,509	4,588	24,764	4,595	11,079	3,600	17	21
Net change	–59	150	1,011	435	424	293	33	26	–83	138	–447	317	–17	733	–818	757	–62	140	17	21
Gross change	979	315	1,012	435	1,038	449	38	26	292	256	1,312	472	3,167	1,011	3,266	1,014	1,226	459	58	65

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

[Most sample pixels remained unchanged (90.1 percent), whereas 9.9 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	7.4	1.7	5.7	9.1	1.1	15.4
2	2.2	0.5	1.7	2.8	0.4	16.6
3	0.3	0.1	0.1	0.4	0.1	28.5
4	0.0	0.0	0.0	0.0	0.0	38.7
Overall spatial change	9.9	2.2	7.7	12.1	1.5	15.0

Table 3. Principal land-cover conversions in Western Gulf Coastal 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" 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	Grassland/Shrubland	Agriculture	635	373	254	0.8	27.0
	Agriculture	Grassland/Shrubland	349	169	115	0.4	14.8
	Wetland	Water	165	104	71	0.2	7.0
	Agriculture	Wetland	163	169	115	0.2	6.9
	Agriculture	Developed	146	132	90	0.2	6.2
	Other	Other	893	n/a	n/a	1.1	38.0
		Totals	2,351			2.9	100.0
1980–1986	Agriculture	Grassland/Shrubland	478	268	183	0.6	18.5
	Water	Wetland	265	137	93	0.3	10.3
	Wetland	Agriculture	193	252	171	0.2	7.5
	Wetland	Water	167	137	93	0.2	6.5
	Grassland/Shrubland	Forest	160	114	78	0.2	6.2
	Other	Other	1,314	n/a	n/a	1.6	51.0
		Totals	2,577			3.2	100.0
1986–1992	Agriculture	Grassland/Shrubland	331	144	98	0.4	15.4
	Grassland/Shrubland	Agriculture	243	125	85	0.3	11.3
	Forest	Mechanically disturbed	232	181	123	0.3	10.8
	Agriculture	Wetland	119	168	114	0.1	5.5
	Grassland/Shrubland	Forest	115	64	43	0.1	5.3
	Other	Other	1,105	n/a	n/a	1.4	51.5
		Totals	2,145			2.6	100.0
1992–2000	Agriculture	Grassland/Shrubland	594	489	333	0.7	18.6
	Grassland/Shrubland	Agriculture	427	289	197	0.5	13.4
	Forest	Mechanically disturbed	381	264	180	0.5	11.9
	Grassland/Shrubland	Forest	167	76	52	0.2	5.2
	Mechanically disturbed	Grassland/Shrubland	151	121	82	0.2	4.7
	Other	Other	1,476	n/a	n/a	1.8	46.2
		Totals	3,196			3.9	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	1,751	817	557	2.2	17.1
	Grassland/Shrubland	Agriculture	1,458	737	502	1.8	14.2
	Forest	Mechanically disturbed	779	510	348	1.0	7.6
	Water	Wetland	549	208	141	0.7	5.3
	Grassland/Shrubland	Forest	528	243	166	0.7	5.1
	Other	Other	5,204	n/a	n/a	6.4	50.7
		Totals	10,269			12.7	100.0

Table 4. Raw estimates of change in Western Gulf Coastal Plain Ecoregion land cover, computed for each of four time periods between 1973 and 2000, and associated error at an 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	2.9	0.7	2.2	3.6	0.5	16.0	0.4
1980–1986	3.2	0.8	2.4	4.0	0.6	17.5	0.5
1986–1992	2.6	0.6	2.0	3.3	0.4	15.7	0.4
1992–2000	3.9	1.2	2.7	5.1	0.8	20.7	0.5
Estimate of change, in square kilometers							
1973–1980	2,351	553	1,798	2,904	377	16.0	336
1980–1986	2,577	663	1,914	3,241	452	17.5	430
1986–1992	2,145	495	1,650	2,640	337	15.7	357
1992–2000	3,196	973	2,223	4,169	663	20.7	399

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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–B, which covers 17 ecoregions in the Great Plains of the United States—provides an assessment of the rates and causes of land-use and land-cover change in the Great Plains of the United States region between 1973 and 2000. The other three volumes of this Professional Paper (1794–A, 1794–C, and 1794–D) provide similar analyses for the Western United States, the Midwest–South Central 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 and others (1987) and later modified by the U.S. Environmental Protection Agency (1999), 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°
70°
30°
90°
80°
CANADA
ATLANTIC OCEAN
Gulf of Mexico
MIDWEST–SOUTH CENTRAL UNITED STATES
EASTERN UNITED STATES
LAINS
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
Western Allegheny Plateau
Central Irregular Plains
Interior River Lowland
Great
Flint Hills
Interior Plateau
Central Appalachians
Ozark Highlands
Boston Mountains
Arkansas Valley
Quachita Mountains
Mississippi Alluvial Plain
Ridge and Valley
Blue Ridge Mountains
Southwestern Appalachians
Piedmont
South Central Plains
TBP
MVLP
Southeastern Plains
East Central Texas Plains
Western Gulf Coastal Plain
Southern Coastal Plain
SFCP
Middle Atlantic Coastal Plain
Northern Piedmont
ACPB
MACP
NCA
NAPU
NEH
EGLHL
NECZ
Northeastern Highlands
LPH
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 Great Plains of the United States

CGP	Central Great Plains Ecoregion
CIP	Central Irregular Plains Ecoregion
COTP	Central Oklahoma/Texas Plains Ecoregion
ECTP	East Central Texas Plains Ecoregion
EP	Edwards Plateau Ecoregion
FH	Flint Hills Ecoregion
LAP	Lake Agassiz Plain Ecoregion
NGP	Northern Glaciated Plains Ecoregion
NSH	Nebraska Sand Hills Ecoregion
NWGLP	Northwestern Glaciated Plains Ecoregion
NWGP	Northwestern Great Plains Ecoregion
STP	Southern Texas Plains Ecoregion
SWT	Southwestern Tablelands Ecoregion
TBP	Texas Blackland Prairies Ecoregion
WCBP	Western Corn Belt Plains Ecoregion
WGCP	Western Gulf Coastal Plain Ecoregion
WHP	Western High 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 the present; and Landsat ETM+ data are available from 1999 to the present. 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.

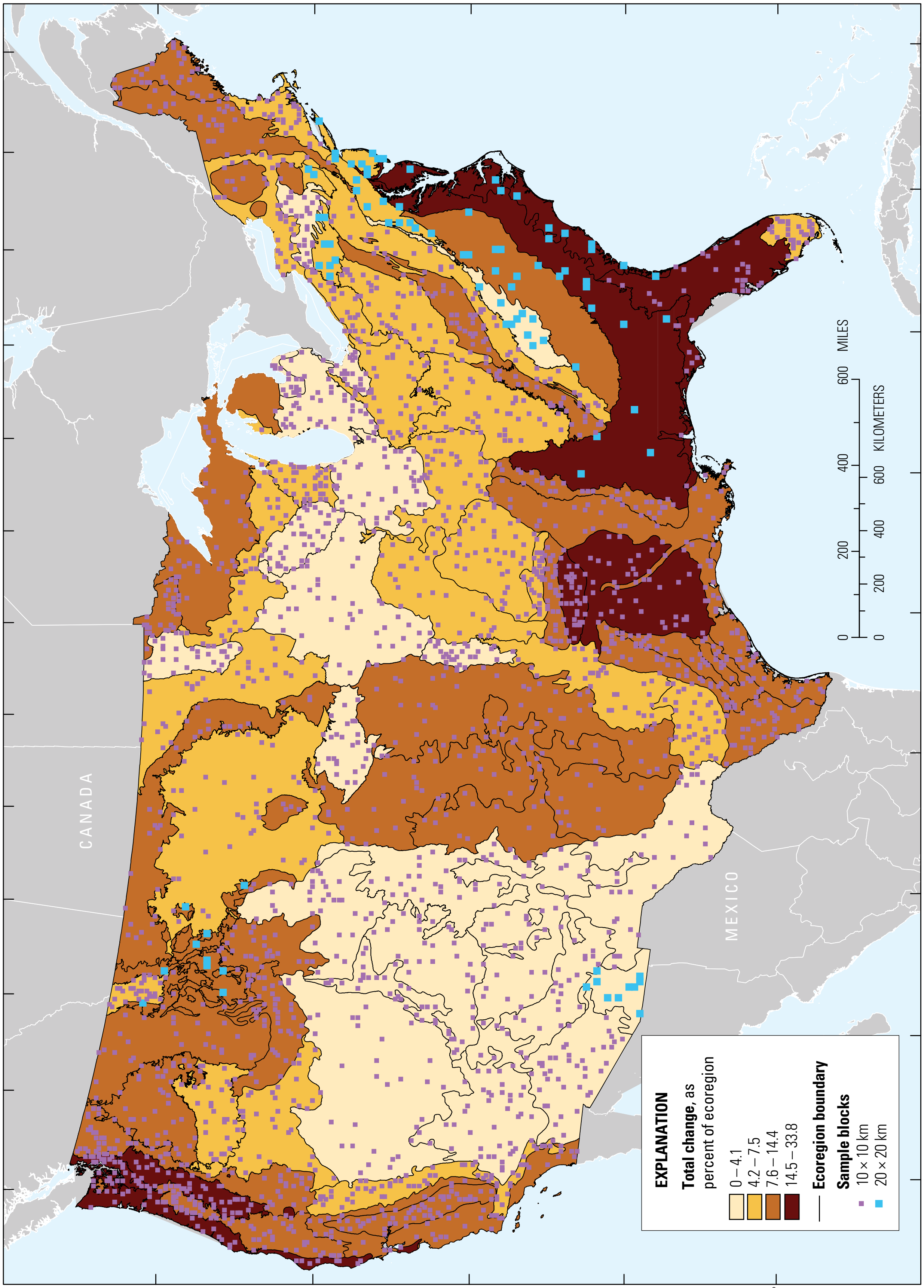

Figure 4.1. Map of ecoregions in conterminous United States, showing locations of 2,688 sample blocks that were used in “Status and Trends of Land Change” study (purple and blue squares indicate locations of 10 × 10 km and 20 × 20 km sample blocks, respectively). Also shown are amounts of total change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

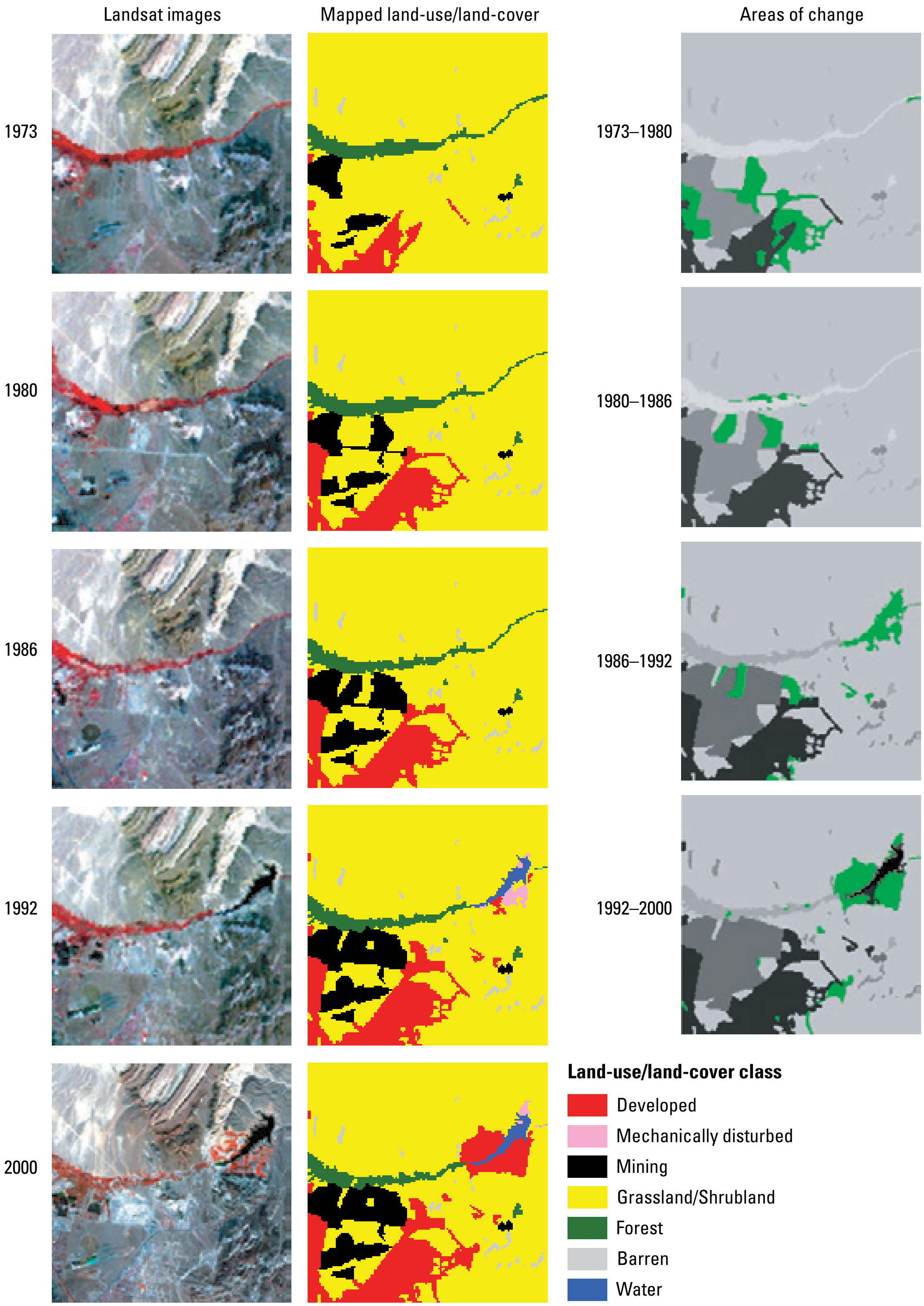

Figure 4.2. Example of data compiled for each sample block, showing sample block 14-0555 (located near Henderson, Nevada, in Mojave Basin and Range Ecoregion, one of Western United States ecoregions). Left column is satellite imagery collected for each of five years analyzed in study (imagery sources 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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