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

Professional Paper 1794–D

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

Edited by Kristi L. Sayler, William Acevedo, and Janis L. Taylor

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Cover:
Forest landscape along Blue Ridge Parkway south of Blowing Rock, North Carolina. Photograph by Thomas R. Loveland, 2006.

Inside cover:
Agriculture and forest landscape southeast of Frenchville, Maine. Photograph by Thomas R. Loveland, 2002.

Foreword

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

Land-change studies attempt to explain the "what, where, when, how, and why" of changes to the vegetation and to the use of the land. Land-change research is aimed specifically at measuring where change is occurring (and where it is not occurring); which land-use and land-cover classes are changing (and what they are changing to); how much land is changing (and how fast); and what drivers are responsible for the measured changes. The goal is not only to understand the scope of change but also to provide the information base necessary to evaluate, predict, and manage the consequences of change.
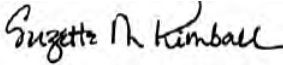
Like many key issues in climate change and ecosystem functioning, land use and land cover are both drivers and indicators of environmental quality. The National Research Council has identified the understanding of land-use dynamics as one of the grand challenges for environmental research—no other global-change parameter is so tightly intertwined with issues of past, present, and future land-use practices, weather patterns, soil and carbon dynamics, ecosystem health and diversity, economic development and policy, technology issues, human population size and distribution, and overall human health. People and their use of the land are interrelated in complex ways, and the effects of land-use and land-cover change can have a huge impact on their quality of life, on the goods and services that they can expect from the land, and on the hazards that they may face. Despite these profound consequences, the Intergovernmental Panel on Climate Change's Third Assessment Report has cited the lack of scientific understanding about the timing, magnitude, and direction of response of ecological, social, and economic systems to the combined effects of climate change and land-use and land-cover change as a key uncertainty in determining societal vulnerabilities and predicting both regional and global impacts of climate change.

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

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

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

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

Suzette M. Kimball

Director, USGS

Preface

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

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Conversion Factors

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

Land-Cover Trends in the Eastern United States—1973 to 2000

By Thomas R. Loveland, William Acevedo, and Kristi L. Sayler

Introduction

Studies of land-use and land-cover change attempt to explain (1) where such change is occurring, (2) what land-use/land-cover classes are changing, (3) what types of transformations are occurring, (4) what the rates and (or) amounts of change are, and (5) what the driving forces and proximate causes of land-use/land-cover change are. The reasons for studying land-use/land-cover change include the following: to understand trends in land change, to evaluate and manage the consequences of land change, and to define future scenarios of land change. Challenging issues associated with studying land-use/land-cover change include the measuring, gathering, and documenting of the characteristics of such change.

The Federal Government has many programs that address land-use/land-cover change. Although excellent programs exist for inventorying forest (Gillespie, 1999) and agriculture land uses (Nusser and Goebel, 1997), the sum of these programs cannot be combined to provide a comprehensive picture of land change across the Nation because of the differences in design, definitions, and geographic coverage of each inventory program. Thus, it has been very difficult to draw conclusions or assess the consequences of contemporary land change in the United States.

To provide estimates of the rates of land-cover and land-use change for the United States, without regard to land ownership or land-use/land-cover class, the U.S. Geological Survey, with support from the U.S. Environmental Protection Agency, initiated a study of the rates, causes, and consequences of contemporary land-use and land-cover change. The "Status and Trends of Land Change" study used land-use/land-cover mapping derived from Landsat satellite imagery (and supported by higher resolution aerial photography), a statistical sampling strategy (Stehman and others, 2003), and geographic regionalization to provide information on the types, amounts, and rates of land change in the United States (Loveland and others, 2002). Level III ecoregions (U.S. Environmental Protection Agency, 1999) were selected as the geographic framework for the study because they have homogenous conditions and similar biotic and abiotic characteristics. The ecoregions collectively represent both the resource potential and probable responses to natural and anthropogenic disturbances.

The defining ecoregion characteristics (for example, climate, topography, geology, soils, natural vegetation) will determine the types of land cover that can exist within an area and also will influence the range of land-use practices that are possible. Estimates of land change are based on the interpretation of five study dates (1973, 1980, 1986, 1992, and 2000) of Landsat Multispectral Scanner, Thematic Mapper, and Enhanced Thematic Mapper Plus data for a set of 10×10 km (or, in some cases, 20×20 km) sample blocks randomly selected for each ecoregion. The goal was to provide estimates that are within one percent of the actual land change at an 85-percent confidence level. This approach—explained in detail in Loveland and others (2002), Sohl and others (2004), and Gallant and others (2004)—provides clear evidence of the geographic variability in the rates, types, and causes of land change across ecoregions.

Regional Synthesis

As part of a national assessment of land change, the U.S. Geological Survey completed an analysis of 20 ecoregions in the Eastern United States (fig. 1*A*). The 20 Eastern United States ecoregions, as defined by the U.S. Environmental Protection Agency (Omernik, 1987; U.S. Environmental Protection Agency, 1999), span about 1,653,852 km^2 (638,555 mi^2). For purposes of discussion, the 20 Eastern United States ecoregions have been divided into four main groups, within which the ecoregions share many similar physical, biological, and land-use characteristics: the Northeastern United States Ecoregions, the Mid-Atlantic Coast Ecoregions, the Appalachian Mountains Ecoregions, and the Southeastern United States Ecoregions (fig. 1*B*).

Areal percentages for all land-use/land-cover classes for all five study dates (1973, 1980, 1986, 1992, and 2000) are presented in table 1. The predominant land-cover class in the Eastern United States in 2000 was forest (52.3 percent); however, the amount of forest land cover declined between 1973 and 2000. Agriculture (21.6 percent) also declined between 1973 and 2000, whereas developed (10.6 percent) increased during that time. Wetland (7.5 percent) and water (4.1 percent) stayed relatively consistent in area between 1973 and 2000.
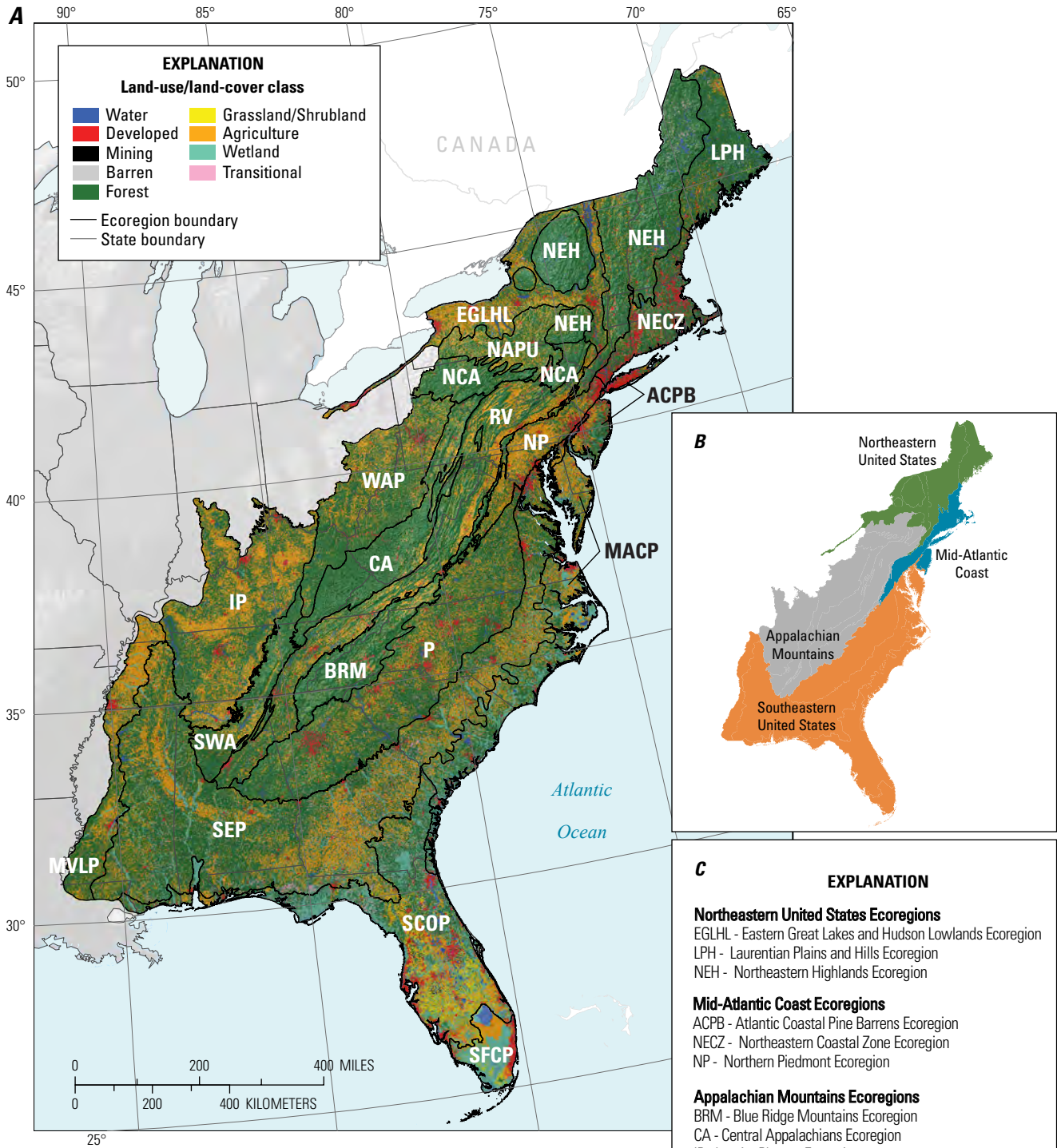
Figure 1. *A*, Map of all 20 ecoregions in Eastern United States, showing land-use/land-cover classes from 1992 National Land-Cover Database (Vogelmann and others, 2001); note that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. *B*, Map showing four main Eastern United States ecoregion groups, modified from U.S. Environmental Protection Agency's (2010) Level II Ecoregions for Eastern United States. Within each ecoregion group, individual ecoregions share many similar physical, biological, and land-use characteristics. *C*, List of four main Eastern United States ecoregion groups depicted in figure 1*B*; also listed are individual ecoregions included in each ecoregion group, as well as ecoregion abbreviations used in figure 1*A*.

Table 1.   Areal percentages of land-use/land-cover classes in all 20 Eastern United States ecoregions for each of five study years (1973, 1980, 1986, 1992, 2000) and corresponding margin-of-error values for 85-percent confidence interval (in brackets).

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

Land-use/land-cover class	1973 [margin of error] (% of area)	1980 [margin of error] (% of area)	1986 [margin of error] (% of area)	1992 [margin of error] (% of area)	2000 [margin of error] (% of area)
Water	4.0 [0.7]	4.0 [0.7]	4.0 [0.7]	4.0 [0.7]	4.1 [0.7]
Developed	8.4 [2.0]	8.8 [2.0]	9.2 [2.1]	9.8 [2.1]	10.6 [2.1]
Mechanically disturbed	1.0 [0.2]	1.2 [0.2]	1.5 [0.3]	2.0 [0.3]	2.3 [0.3]
Mining	0.4 [0.1]	0.5 [0.2]	0.5 [0.2]	0.4 [0.1]	0.4 [0.1]
Barren	0.1 [<0.1]	0.1 [<0.1]	0.1 [<0.1]	0.1 [<0.1]	0.1 [<0.1]
Forest	54.6 [1.9]	53.8 [1.9]	53.2 [1.9]	52.8 [1.9]	52.3 [1.8]
Grassland/Shrubland	0.7 [0.2]	0.8 [0.2]	1.0 [0.2]	1.2 [0.3]	1.2 [0.3]
Agriculture	23.1 [1.7]	23.0 [1.8]	22.7 [1.8]	22.0 [1.7]	21.6 [1.6]
Wetland	7.8 [0.8]	7.7 [0.8]	7.6 [0.8]	7.7 [0.8]	7.5 [0.8]
Nonmechanically disturbed	<0.1 [<0.1]	<0.1 [<0.1]	<0.1 [<0.1]	<0.1 [<0.1]	0.1 [0.1]
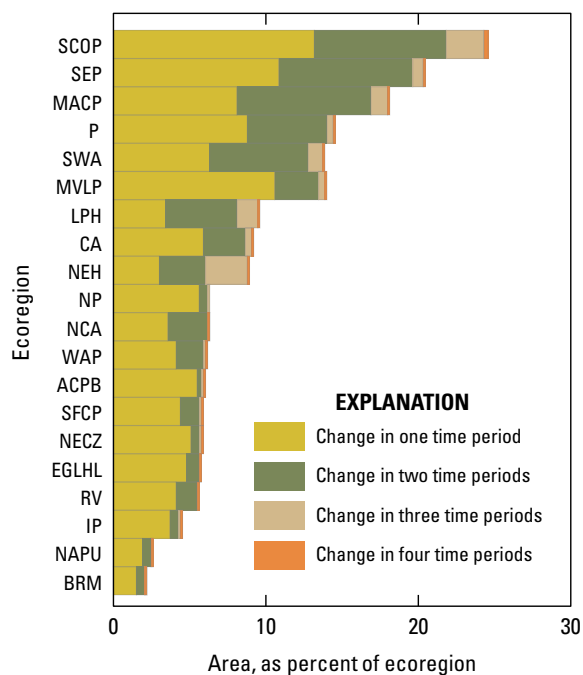
Figure 2.   Overall spatial change from 1973 to 2000 for all 20 Eastern United States ecoregions. Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods (1973–1980, 1980–1986, 1986–1992, 1992–2000). Ecoregions that have larger numbers of changes typically have active forest-harvesting cycles, whereas ecoregions that have low numbers of changes usually are characterized by increased urban development. See appendix 2 for key to ecoregion abbreviations.

The overall spatial change (the percentage of land area that changed at least one time) in the Eastern United States ecoregions between 1973 and 2000 was 12.5 percent (table 2), meaning that 207,177 km^2 of 1,653,852 km^2 changed one or more times. However, the overall amount of change masks the geographic variability of change, which ranged from a low of 2.0 percent in the Blue Ridge Mountains Ecoregion to a high of 24.6 percent in the Southern Coastal Plain Ecoregion (fig. 2). The highest amounts of change generally were in ecoregions that have active timber harvesting, whereas the lowest amounts of change were in ecoregions in which urbanization was the leading driver of land change (table 2). In the Southeastern United States Ecoregions, where change in forest land-cover class was dominant, the overall amount of change was 18.9 percent. In the Appalachian Mountains Ecoregions, where change was far more heterogeneous, the amount of change was 5.8 percent. In the Mid-Atlantic Coast Ecoregions, where urban development dominated land change, the overall amount of change was 5.9 percent. The overall amount of change in the Northeastern United States Ecoregions (8.2 percent) was associated with forest land use.

No single story of land-use/land-cover change in the Eastern United States during the 27-year study period (1973–2000) has emerged. Instead, 20 distinct stories in the 20 ecoregions can be told. Generally speaking, most change was associated with forest harvesting and regrowth, agricultural abandonment, and development. However, in certain ecoregions that have unique natural resources, other conversion mechanisms that correspond to those unique resources were in play. For example, coal mining was an important contributor to land change in the Central Appalachians, Southwestern

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

Ecoregion	Ecoregion area (km²)	Overall spatial change [margin of error]	
		(km²)	(% of ecoregion)
Northeastern United States Ecoregions			
Laurentian Plains and Hills Ecoregion	50,153	4,714 [802]	9.4 [1.6]
Northeastern Highlands Ecoregion	127,107	11,313 [4,195]	8.9 [3.3]
Eastern Great Lakes and Hudson Lowlands Ecoregion	60,591	3,393 [788]	5.6 [1.3]
Totals	237,851	19,420 [4,281]	8.2 [1.8]
Mid-Atlantic Coast Ecoregions			
Northeastern Coastal Zone Ecoregion	37,158	2,118 [334]	5.7 [0.9]
Atlantic Coastal Pine Barrens Ecoregion	19,230	1,115 [404]	5.8 [2.1]
Northern Piedmont Ecoregion	30,120	1,867 [331]	6.2 [1.1]
Totals	86,508	5,101 [606]	5.9 [0.7]
Appalachian Mountains Ecoregions			
Northern Appalachian Plateau and Uplands Ecoregion	29,919	718 [209]	2.4 [0.7]
North Central Appalachians Ecoregion	30,522	1,892 [610]	6.2 [2.0]
Western Allegheny Plateau Ecoregion	84,738	5,169 [1,102]	6.1 [1.3]
Central Appalachians Ecoregion	59,738	5,436 [896]	9.1 [1.5]
Ridge and Valley Ecoregion	111,043	6,107 [1,221]	5.5 [1.1]
Interior Plateau Ecoregion	127,810	5,751 [1,406]	4.5 [1.1]
Southwestern Appalachians Ecoregion	35,341	4,877 [1,308]	13.8 [3.7]
Blue Ridge Mountains Ecoregion	47,791	956 [239]	2.0 [0.5]
Totals	526,901	30,907 [2,634]	5.8 [0.5]
Southeastern United States Ecoregions			
Piedmont Ecoregion	165,460	23,992 [7,611]	14.5 [4.6]
Mississippi Valley Loess Plains Ecoregion	43,775	6,041 [1,488]	13.8 [3.4]
Southeastern Plains Ecoregion	336,141	68,573 [13,109]	20.4 [3.9]
Middle Atlantic Coastal Plain Ecoregion	89,686	16,143 [4,036]	18.0 [4.5]
Southern Coastal Plain Ecoregion	145,123	35,700 [5,370]	24.6 [3.7]
Southern Florida Coastal Plain Ecoregion	22,407	1,300 [515]	5.8 [2.3]
Totals	802,591	151,749 [15,249]	18.9 [1.9]
All Eastern United States ecoregions	1,653,852	207,177 [1,654]	12.5 [1.0]

Appalachians, and Western Allegheny Plateau Ecoregions, as was phosphate mining in the Southern Coastal Plain Ecoregion.

Estimates of gross spatial change and net areal change for each land-cover class in the 20 Eastern United States ecoregions are found in table 3. Both net- and gross-change statistics must be taken into account when considering land change. The net change in a given land-cover class is the result of the losses in that land-cover class subtracted from the gains, thus, representing the difference in land-cover area between two study dates. On the other hand, gross change is the total area gained and lost in a particular land-cover class (for example, the sum of increases and decreases in forest land-cover class), representing the total area modified between study dates. Gross change is important because

it provides a clear indication of the overall amount of change that affected specific land-cover classes, rather than at just two points in time of a specific land-cover class.

The five land-cover classes that had the largest net areal change (either gains or losses) over the entire study period (1973–2000) are as follows (table 3):

- Forest, –37,271 km² (margin of error, 7,003 km²)
- Developed, 36,807 km² (margin of error, 5,156 km²)
- Agriculture, –24,947 km² (margin of error, 5,009 km²)
- Mechanically disturbed, 20,369 km² (margin of error, 4,055 km²)
- Grassland/Shrubland, 8,215 km² (margin of error, 2,412 km²)

Table 3.   Gross spatial changes and net areal changes in land-use/land-cover classes in all 20 Eastern United States ecoregions during entire study period (1973 to 2000) and corresponding margin-of-error values for 85-percent confidence interval (in brackets).

Land-use/land-cover class	Gross spatial change (1973–2000) [margin of error]		Net areal change (1973–2000) [margin of error]	
	(km²)	(% of area)	(km²)	(% change)
Water	3,965 [1,111]	0.2 [0.1]	2,340 [770]	3.6
Developed	37,282 [6,049]	2.3 [0.4]	36,807 [5,156]	26.6
Mechanically disturbed	116,623 [24,564]	7.1 [1.5]	20,369 [4,055]	119.9
Mining	14,241 [4,030]	0.9 [0.2]	−467 [1,876]	−6.8
Barren	154 [86]	<0.1 [<0.1]	4 [24]	0.4
Forest	172,872 [30,572]	10.5 [1.8]	−37,271 [7,003]	−4.1
Grassland/Shrubland	30,531 [5,220]	1.8 [0.3]	8,215 [2,412]	71.2
Agriculture	51,429 [10,068]	3.1 [0.6]	−24,947 [5,009]	−6.5
Wetland	13,000 [3,092]	0.8 [0.2]	−6,053 [2,208]	−4.7
Nonmechanically disturbed	1,971 [1,200]	0.1 [0.1]	1,002 [1,124]	620.1

Table 4.   Net areal changes in land-use/land-cover classes in all 20 Eastern United States 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] (km²)			
	1973–1980	1980–1986	1986–1992	1992–2000
Water	465 [255]	758 [469]	−7 [384]	1,119 [473]
Developed	7,275 [1,615]	6,826 [1,098]	9,289 [1,487]	13,353 [2,180]
Mechanically disturbed	2,733 [3,242]	5,761 [3,060]	7,991 [4,040]	3,848 [4,325]
Mining	1,114 [781]	−37 [520]	−738 [828]	−805 1,461]
Barren	−10 [24]	−13 [14]	6 [9]	20 [27]
Forest	−12,113 [4,462]	−10,109 [3,097]	−7,125 [6,050]	−7,858 [5,597]
Grassland/Shrubland	2,246 [787]	2,924 [1,353]	2,803 [1,504]	228 [1,881]
Agriculture	−447 [1,656]	−4,822 [1,950]	−12,005 [3,297]	−7,629 [2,299]
Wetland	−1,246 [1,084]	−1,609 [638]	82 [683]	−3,270 [1,169]
Nonmechanically disturbed	−18 [215]	321 [350]	−297 [242]	993 [1,133]

The five land-cover classes that had the highest gross spatial change over the entire study period (1973–2000) are as follows (table 3):

- Forest, 172,872 km² (margin of error, 30,572 km²)
- Mechanically disturbed, 116,623 km² (margin of error, 24,564 km²)
- Agriculture, 51,429 km² (margin of error, 10,068 km²)
- Developed, 37,282 km² (margin of error, 6,049 km²)
- Grassland/Shrubland, 30,531 km² (margin of error, 5,220 km²)

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

Forest Land-Cover Class

Forest experienced the largest amount of change of any land-cover class in the 20 Eastern United States ecoregions during the 27-year study period. Between 1973 and 2000, 105,562 km² converted to forest land cover, whereas 142,833 km² of forested land converted to other land-cover classes, resulting in a net loss of 37,271 km² (table 3), a 4.1 percent decrease. This amount of net change, however, masks the true amount of change (that is, turnover) in forested land. The gross change in forest in the Eastern United States was 172,872 km² (table 3), meaning that 10.5 percent experienced a conversion either to or from the forest land-cover class.
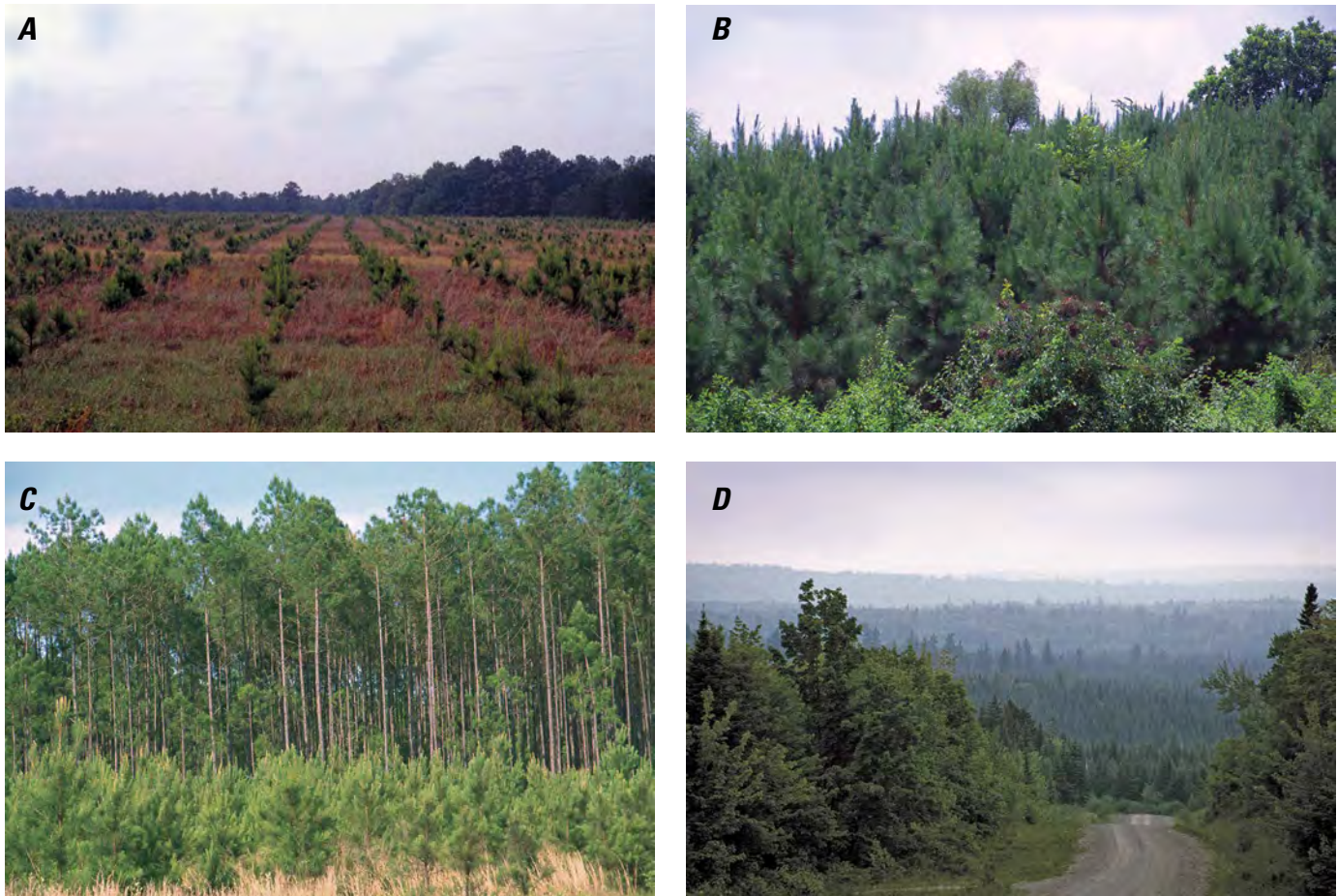
Figure 3.   Forested areas in Eastern United States. *A*, Young pine plantation southwest of Augusta, Georgia, in Southeastern Plains Ecoregion. *B*, Pine plantation north of Jackson, Mississippi, in Mississippi Valley Loess Plains Ecoregion. *C*, Pine plantation that has both young and old trees northeast of Panama City, Florida, in Southern Coastal Plain Ecoregion. *D*, Forest landscape in west-central Maine, in Northeastern Highlands Ecoregion.

Timber production is very important throughout the 20 Eastern United States ecoregions. The Southeastern United States Ecoregions, especially the Southeastern Plains, Southern Coastal Plain, Middle Atlantic Coastal Plain, and Mississippi Valley Loess Plains Ecoregions, contain vast expanses of industrial-scale pine plantations (fig. 3). These ecoregions have a climate advantage that permits harvest cycles of 20 to 25 years for loblolly pine (*Pinus taeda*) and other southern pine species (Gresham, 2002). Large-scale timber production also is important in the Northeastern United States Ecoregions, especially in the Northeastern Highlands Ecoregion and, to a lesser extent, the Laurentian Plains and Hills Ecoregion.

Only the Mississippi Valley Loess Plains Ecoregion experienced an increase in forest (0.6 percent increase); all other Eastern United States ecoregions experienced a decrease. The Piedmont and Southern Coastal Plain Ecoregions experienced the greatest loss of forest (–4.8 and –4.2 percent, respectively). Other ecoregions that experienced significant losses in forest were the Northeastern Highlands (−3.9 percent), Northeastern Coastal Zone (−3.7 percent),

Middle Atlantic Coastal Plain (−3.4 percent), and Central Appalachians (−3.3 percent) Ecoregions (fig. 4*C*).

The principal conversion from forest was to mechanically disturbed, which consists of clearcut and recently harvested forest. More than 31,000 km^2 of forest changed to this transitional land-cover class (fig. 5), suggesting that forest change is very dynamic and cyclic in nature. Southern pine-forest land when harvested or clearcut is classified as mechanically disturbed. The cleared land typically remains in a mechanically disturbed state for a brief period and then is replanted with trees; in some cases, however, the land is left alone for natural regeneration. In much of the South, planted pine trees can reach heights of 2 m within two years. Thus, the conversion from forest to mechanically disturbed is indicative of extensive timber production in the South. In the northern ecoregions and in certain marginal areas in other ecoregions, slower growth rates can result in a longer forest-cutting-and-regrowth cycle; in such areas, the typical conversion cycle is from forest to mechanically disturbed, then to grassland/shrubland and back to forest.
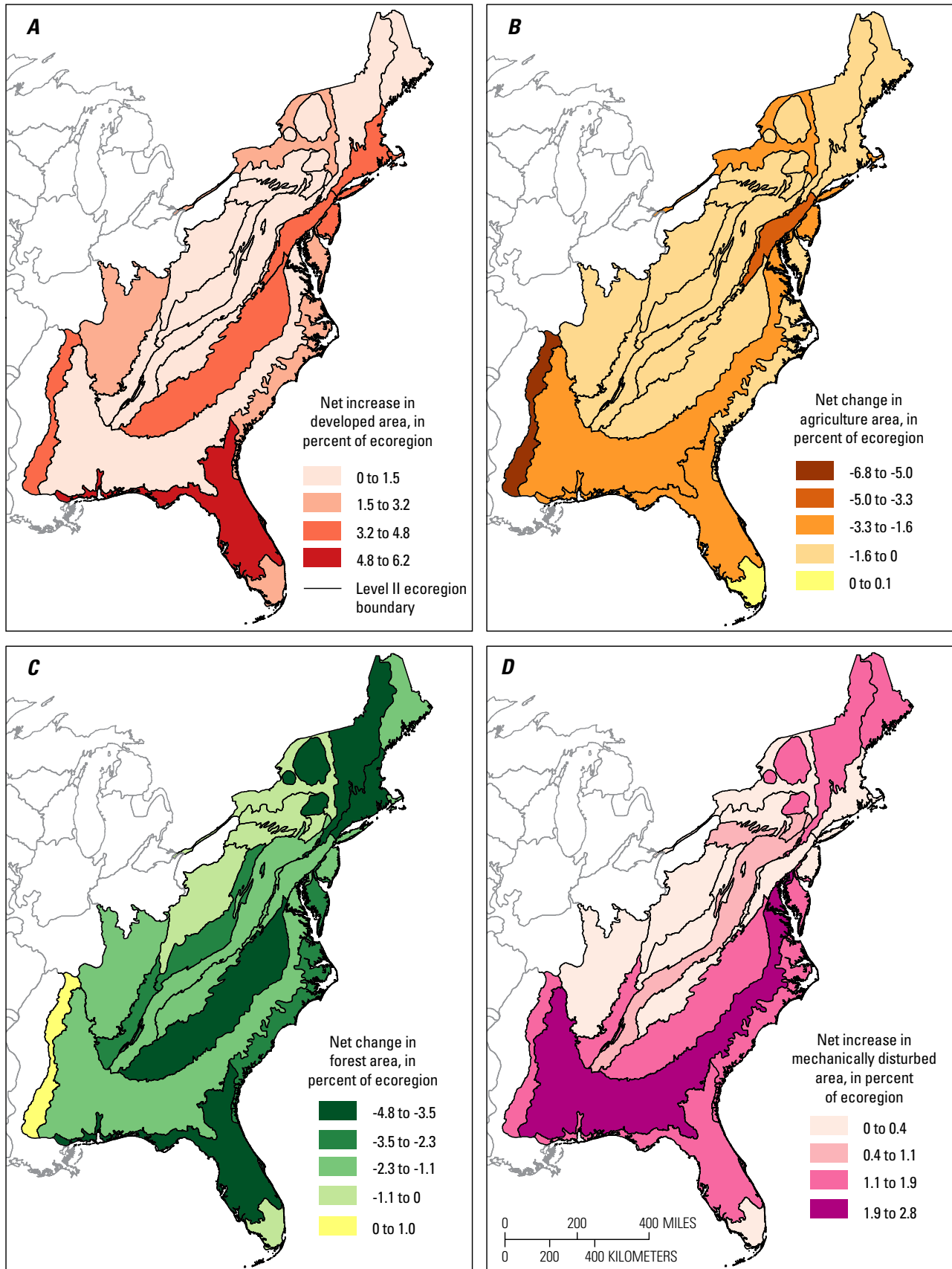
Figure 4. Maps showing net change for (*A*) developed, (*B*) agriculture, (*C*), forest, and (*D*) mechanically disturbed land-cover classes, for all 20 Eastern United States ecoregions.

Approximately 19,000 km^2 of forest converted to developed (fig. 5); in addition, 7,900 km^2 of agricultural land either converted to forest (for example, in Southeastern Plains Ecoregion and in Mississippi Valley Loess Plains Ecoregion) or were abandoned, resulting in afforestation (for example, in Northern Appalachian Plateau and Uplands Ecoregion and in Eastern Great Lakes and Hudson Lowlands Ecoregion). Most conversions from agriculture to forest were motivated by the relative difference in profitability between timber and agricultural uses. After 1986, however, conversion from agriculture to forest and subsequent gains in forest area were often caused by the Conservation Reserve Program, which removed sensitive areas of farmland from production to reduce soil loss.

Forest land use (that is, land managed for the production of forest products or maintained as woody vegetation for indirect benefits such as protection of watersheds or for recreational purposes) declined less rapidly than forest land cover (that is, land covered with trees). Note that harvested forest, where trees may be replanted or regenerated, can be classified as forest land use, even though no trees are present. Although harvested areas generally are replanted with timber, the cycles of forest land use have caused a net decline in the total area of forest land cover. Consider that, in the Eastern United States ecoregions, 78 percent of mechanically disturbed and 73 percent of grassland/shrubland converted back to forest during the study period, implying that the land is continuing to be used for forest production. If those proportions of mechanically disturbed land and grassland/shrubland revert to forest, then the net loss of forest land use in the Eastern United States ecoregions is 15,387 km^2.

Developed Land-Cover Class

Developed land-cover class includes all the built-up surfaces in the 20 Eastern United States Ecoregions. Most are associated with urban and exurban growth, but this land-cover class also includes transportation systems and many other low-density built-up lands (fig. 6). The net increase in the developed land-cover class (36,807 km^2; table 3), a 26.6 percent net increase, was almost equal to the loss in the forest land-cover class (−37,271 km^2; table 3). The gross change in the developed land-cover class was fairly similar (37,282 km^2; table 3) owing to the unidirectional nature of urban growth. Between 1970 and 2000, population in counties within the 20 Eastern United States ecoregions increased by 32.6 percent, from 93.3 million to 123.8 million people (U.S. Census Bureau, 1970–2000 [various years]). The Eastern United States ecoregions that experienced the largest increase in the developed land-cover class during the study period were the Southern Coastal Plain (6.2 percent), Atlantic Coastal Pine Barrens (4.7 percent), Northern Piedmont (4.6 percent), Piedmont (4.5 percent), Mississippi Valley Loess Plains (4.3 percent), and Northeastern Coastal Zone (4.0 percent) Ecoregions (fig. 4A).

Most newly developed land converted from forest (19,145 km^2) or agriculture (11,879 km^2) during the study period (fig. 7). In the Northeastern United States Ecoregions, where agricultural

land preservation is important, conversions to developed from forest were more common than those from agriculture. For example, in the Northeastern Coastal Zone Ecoregion, more forest converted to developed than did agriculture, by a 4-to-1 margin, and, in the Northeastern Highlands Ecoregion, the ratio was 10 to 1. However, in the Mississippi Valley Loess Plains Ecoregion, more development occurred on agricultural land than forested land, by a nearly 3-to-1 margin, and in the Atlantic Coastal Pine Barrens and Northern Piedmont Ecoregions, the ratio was 2 to 1. It is important, however, to recognize that changes over the entire 27-year study period often mask the variability and specific margins of conversion that occurred during each of the four time periods.

EXPLANATION

Land-use/land-cover class

Water	Forest
Developed	Grassland/Shrubland
Transitional	Agriculture
Mining	Wetland
Barren	Ice/Snow
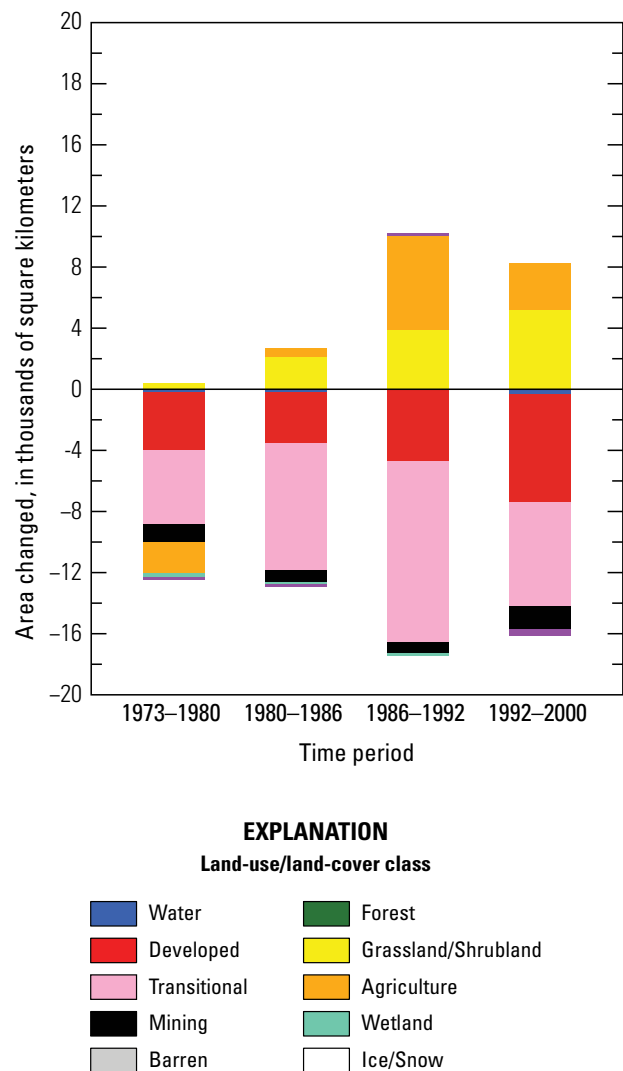
Figure 5.   Gross change (area gained from, and lost to, other land-cover classes) in forest land-cover class in all 20 Eastern United States ecoregions during entire study period (1973–2000). Colored bars above zero axis indicate land-cover classes that lost area to forest and amounts of area lost, whereas colored bars below zero axis indicate land-cover classes that gained area from forest and amounts of area gained.

Figure 6. Developed areas in Eastern United States. *A*, Parkwood Estates housing development northwest of Atlanta, Georgia, in Piedmont Ecoregion. *B*, Subdivision northeast of Memphis, Tennessee, in Mississippi Valley Loess Plains Ecoregion. *C*, New subdivision in New Jersey, south of Philadelphia, Pennsylvania, in Atlantic Coastal Pine Barrens Ecoregion. *D*, Interstate 87, just south of Keeseville, New York, in Northeastern Highlands Ecoregion.
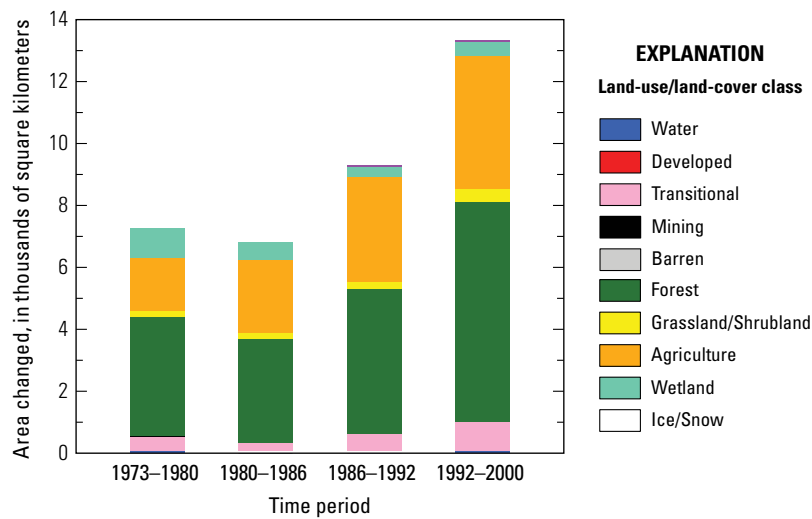
Figure 7. Estimated area gained in developed land-cover class from other land-cover classes in all 20 Eastern United States ecoregions during entire study period (1973–2000). Colored bars indicate land-cover classes that lost area to developed and amounts of area lost.

The amount of developed land increased at an accelerating rate over the 27-year study period (fig. 7). In each of the four time periods between 1973 and 2000, the percentage of developed land increased, having average annual increases of 0.06 percent (1973–1980), 0.07 percent (1980–1986), 0.09 percent (1986–1992), and 0.10 percent (1992–2000). Although the percentage gains in developed land are relatively small in relation to the overall area, the increasing rate of development may have large effects, such as altering hydrological processes, contributing to urban heat-island effects, threatening biodiversity, and resulting in many other environmental consequences.

Agriculture Land-Cover Class

Agriculture was the second most common land-cover class in the 20 Eastern United States ecoregions (fig. 8), with an estimated 21.6 percent of the total area in 2000 (table 1). Agriculture declined almost everywhere, experiencing a 6.5 percent net loss (−24,947 km^2) between 1973 and 2000. Gross change in agriculture was 51,429 km^2 (table 3). The only ecoregion that did not experience a loss of agricultural land was the Southern Florida Coastal Plain Ecoregion (fig. 4B). Note that this ecoregion experienced a significant increase in agricultural land between 1973 and 1980 because of the need to replace the sugar cane whose import from Cuba had been banned (Walker and Solecki, 2004). Even in this ecoregion, however, agricultural land declined after 1980, and the net gain over the entire 27-year study period was less than 0.1 percent.

Conversions from agriculture to developed were some of the most common conversions in the Eastern United States ecoregions (11,878 km^2) (fig. 9), although conversions to forest were more common in the Southeastern United States Ecoregions, where timber production is high. Two ecoregions that experienced substantial conversions from agriculture to developed were the Northern Piedmont and Atlantic Coastal Pine Barrens Ecoregions (3.4 and 3.0 percent, respectively; fig. 4B). Although the drivers behind the higher rates of conversions from agriculture to developed must still be determined for each individual ecoregion, they likely include lower costs to develop relatively level sites that have better soil-engineering properties.

Figure 8.   Agricultural areas in Eastern United States. *A*, Soybean fields with poultry barns in background west of Pageland, South Carolina, in Piedmont Ecoregion. *B*, Cattle in clover pasture southeast of Sayre, Pennsylvania, in Northern Appalachian Plateau and Uplands Ecoregion. *C*, Cornfield northeast of Dyersburg, Tennessee, in Mississippi Valley Loess Plains Ecoregion. *D*, Sugar cane field near housing development west of Pahokee, Florida, in Southern Florida Coastal Plain Ecoregion.

Substantial conversions from agriculture to forest (more than 12,000 km[2]) occurred in the Mississippi Valley Loess Plains and Southeastern Plains Ecoregions. Note that the rate of agriculture loss accelerated between 1986 and 1992 (fig. 9), indicating that an important driver of change was the enrollment of marginal croplands in the Conservation Reserve Program during that time period. An additional factor that was important in the Northeastern and Southeastern United States Ecoregions (for example, in the Eastern Great Lakes and Hudson Lowlands Ecoregion and in the Southern Coastal Plain Ecoregion) is the abandonment of agricultural land. Nearly 4,500 km[2] of agricultural land reverted to grassland/shrubland following cropland abandonment; these lands likely will revert to forest.
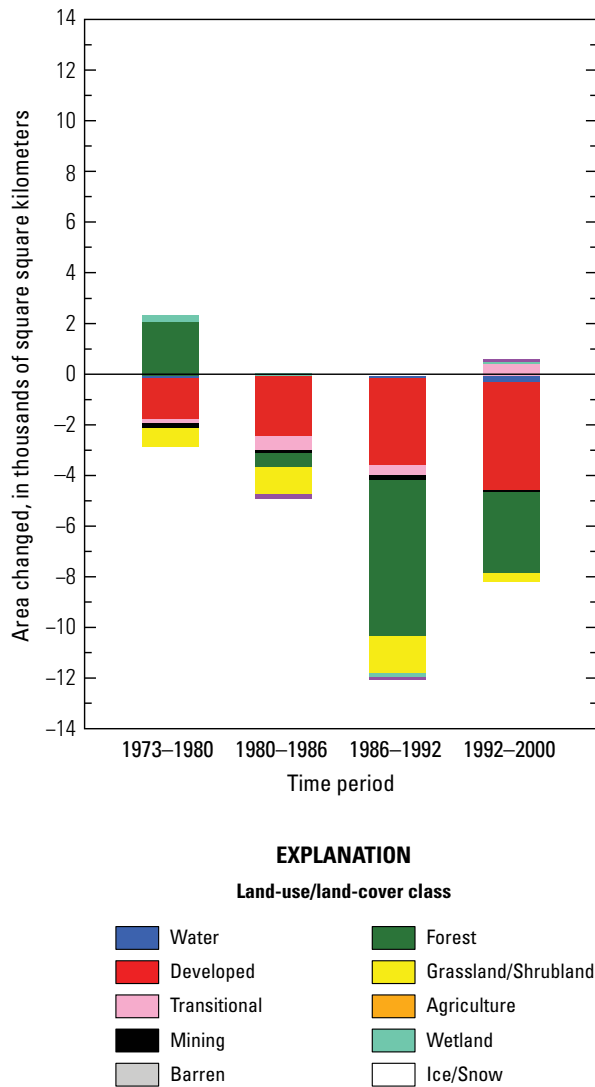
Figure 9. Gross change (area gained from, and lost to, other land-cover classes) in agriculture land-cover class in all 20 Eastern United States ecoregions during entire study period (1973–2000). Colored bars above zero axis indicate land-cover classes that lost area to agriculture and amounts of area lost, whereas colored bars below zero axis indicate land-cover classes that gained area from agriculture and amounts of area gained.

Transitional Land-Cover Classes

A less obvious dimension of change in the 20 Eastern United States ecoregions involves the transitional land-cover classes—mechanically disturbed, nonmechanically disturbed, and grassland/shrubland—that represent transitional stages of land-use/land-cover change (fig. 10). For example, forest that is harvested, whether planned for replanting or regeneration, goes through a transitional stage: in the Southeastern United States Ecoregions, this stage typically is mechanically disturbed; in the Northeastern United States Ecoregions, the typical conversion is from mechanically disturbed to grassland/shrubland. In addition, afforestation associated with abandoned agricultural land typically experiences a grassland/shrubland stage.

At any one time during the 27-year study period, the amount of grassland/shrubland or mechanically disturbed was relatively small. For example, the amount of grassland/shrubland in 1980 was 13,792 km[2], whereas the amount of mechanically disturbed was 19,724 km[2]. Between 1973 and 2000, the net change in grassland/shrubland and mechanically disturbed was 8,215 and 20,369 km[2], respectively (table 3); together, the net gain in these two transitional land-cover classes was 28,584 km[2], the third largest net land-cover change. The gross amount of transitional land during the 27-year study period was 147,154 km[2] (table 3), the second largest gross change in the 20 Eastern United States ecoregions.

All mechanically disturbed lands are transitional, with 78 percent destined for forest land cover. Most of the remaining mechanically disturbed lands reverted to wetlands, primarily owing to timber harvesting of wooded wetlands in the Southeastern United States Ecoregions, although a smaller percentage converted to developed. Approximately 73 percent of grassland/shrubland reverted to forest, and most of the remaining grassland/shrubland converted to agriculture.

The nonmechanically disturbed land-cover class reflects changes associated with wildfires, insect infestations, storms, and other similar naturally occurring events. Overall, very few instances of nonmechanical disturbance occurred in the 20 Eastern United States ecoregions. The major examples of nonmechanical disturbance were fires in the Southern Coastal Plain and Southern Florida Coastal Plain Ecoregions, as well as tornado damage in the North Central Appalachians Ecoregion.

Transitional land-cover classes represent short- to medium-term land disturbances. Mechanically disturbed land is particularly prone to erosion, causing the sedimentation of nearby streams. Mechanical disturbances also affect weather and climate variability by increasing surface albedo (Barnes, 2008). They also can alter regional carbon balances, owing to the removal of significant carbon stocks, and they can adversely affect habitat conditions and, ultimately, biodiversity.

Figure 10. Mechanically disturbed areas in Eastern United States. *A*, Newly clearcut area in southeastern Mississippi, in Southeastern Plains Ecoregion. *B*, Large clearcut area southwest of Jackson, Mississippi, in Mississippi Valley Loess Plains Ecoregion. *C*, Clearcut hillside east of Lebanon, Virginia, in Ridge and Valley Ecoregion. *D*, Cleared land west of Crossville, Tennessee, in Southwestern Appalachians Ecoregion.

Water and Wetland Land-Cover Classes

The water and wetland land-cover classes (fig. 11) covered 4.1 and 7.5 percent, respectively, of the 20 Eastern United States ecoregions in 2000. During the 27-year study period, water increased by 0.1 percent, whereas wetland declined by 0.3 percent (table 1). The largest increases in surface water occurred in the Southern Coastal Plain Ecoregion (0.6 percent) and in the Southern Florida Coastal Plain Ecoregion (0.4 percent). In both ecoregions, dredging or other forms of excavation of wetlands for waterfront residential developments were significant reasons for the increase. In the Piedmont Ecoregion (0.2 percent), the increase was associated with the development of reservoirs to meet the needs of the expanding population base; the Piedmont Ecoregion has limited groundwater resources, thus, the municipal- and industrial-water supply relies on surface-water impoundments (Daniel and Dahlen, 2002).

About one-third of the 20 Eastern United States ecoregions experienced essentially no change in area of wetlands. The ecoregions that experienced a significant loss of wetlands were the Southern Coastal Plain Ecoregion

(–2.4 percent), the Southern Florida Coastal Plain Ecoregion (–1.6 percent), and the Middle Atlantic Coastal Plain Ecoregion (–1.3 percent). All three ecoregions have extensive wetland areas. Agricultural development and urbanization contributed to wetland loss in the Middle Atlantic Coastal Plain and Southern Florida Coastal Plain Ecoregions, whereas urban growth was the primary factor in the Southern Coastal Plain Ecoregion.

Mining Land-Cover Class

Although the area of the mining land-cover class (fig. 12) remained essentially unchanged across the 20 Eastern United States ecoregions between 1973 and 2000 (table 1), it actually represents the balance between ecoregions that experienced expanded mining operations and several ecoregions that had mining losses. For example, the mining land-cover class increased by 1.5 percent in the Central Appalachians Ecoregion because of expanding coal-mining operations, but it shrunk by 1.2 percent in the Southern Coastal Plain Ecoregion owing

Figure 11.   Water and wetland areas in Eastern United States. *A*, Lake Howell (formerly called "Coddle Creek Reservoir"), constructed in 1992–93 west of Kannapolis, North Carolina, in Piedmont Ecoregion. *B*, Wooded wetland in The Everglades, in Southern Florida Coastal Plain Ecoregion.

to a reduction in phosphate mining. Declines in coal mining in the Southwestern Appalachians and Western Allegheny Plateau Ecoregions resulted in a loss of 0.9 and 0.4 percent, respectively, in the mining land-cover class. It is also notable, although to a lesser degree, that rapidly urbanizing ecoregions such as the Northeastern Coastal Zone Ecoregion usually had an increase in aggregate (sand and gravel) mining during the study period. Mined lands in which resources have been exhausted typically were restored to grassland/shrubland or forest.

Barren Land-Cover Class

No significant changes in the barren land-cover class were found in the 20 Eastern United States ecoregions.

Summary

Land change in the Eastern United States during the study period was connected primarily to timber harvesting

and urban growth. The climate in the Southeastern United States provides the foundation for forest activity: short harvest cycles mean that a substantial amount of land is cycling from forest to cleared conditions (mechanically disturbed) and back to forest. Across the East, agricultural land either is being converted to forest (for example, in the Southeastern United States Ecoregions) or is reverting to forest (for example, in the Northeastern United States Ecoregions) owing to agricultural abandonment. Urban growth, as measured by the increase in the developed land-cover class, is expanding and accelerating across the East. All ecoregions are experiencing substantial increases in developed land. Agricultural lands are being lost to urban growth and to forestry practices. Also associated with timber harvesting and expanded urban development is the large amount of transitional, disturbed lands. Timber harvesting and replanting has resulted in conversions from forest to mechanically disturbed to forest in the Southeastern United States Ecoregions and from forest to mechanically disturbed to grassland/shrubland in the Northeastern United States Ecoregions. Transitional land-cover classes represent significant amounts of disturbance that may have adverse consequences for environmental and ecological systems.

Figure 12.   Mining activities in Eastern United States. *A*, Coal mine in Kentucky, in Central Appalachians Ecoregion. *B*, Quarry in north-central Tennessee, in Southwestern Appalachians Ecoregion.

Other land-cover classes such as mining, water, and wetland are changing, but the rates of change are modest. The local importance of such changes may be significant, and they are best understood at the ecoregion level. The diversity in the mosaic of change in the Eastern United States is lost when viewed as a composite. The remaining chapters in this report, which contain summaries of change for each of the 20 Eastern United States ecoregions, document the rates, types, and drivers of late-20th century land-use/land-cover change in the Eastern United States.

References Cited

Barnes, C.A., and Roy, D.P., 2008, Radiative forcing over the conterminous United States due to contemporary land cover land use albedo change: Geophysical Research Letters, v. 35, no. 9, L09706, doi:10.1029/2008GL033567.

Daniel, C.C., III, and Dahlen, P.R., 2002, Preliminary hydrogeologic assessment and study plan for a regional ground-water resource investigation of the Blue Ridge and Piedmont Provinces of North Carolina: U.S. Geological Survey Water-Resources Investigations Report 02–4105, 60 p., available at http://nc.water.usgs.gov/reports/abstracts/wri024105.html.

Gallant, A.L., Loveland, T.R., Sohl, T.L., and Napton, D.E., 2004, Using a geographic framework for analyzing land cover issues: Environmental Management, v. 34, no. S1, p. 89–110.

Gillespie, A.J.R., 1999, Rationale for a national annual forest inventory program: Journal of Forestry, v. 97, no. 12, p. 16–20.

Gresham, C.A., 2002, Sustainability of intensive loblolly pine plantation management in the South Carolina Coastal Plain, USA: Forest Ecology and Management, v. 155, p. 69–80.

Loveland, T.R., Sohl, T.L., Stehman, S.V., Gallant, A.L., Sayler, K.L., and Napton, D.E., 2002, A strategy for estimating the rates of recent United States land cover changes: Photogrammetric Engineering & Remote Sensing, v. 68, no. 10, p. 1,091–1,099.

Nusser, S.M., and Goebel, J.J., 1997, The national resources inventory—A long-term multi-resource monitoring programme: Environmental and Ecological Statistics, v. 4, no. 3, p. 181–204.

Omernik, J.M., 1987, Ecoregions of the conterminous United States: Annals of the Association of American Geographers, v. 77, no. 1, p. 118–125.

Sohl, T.L., Gallant, A.L., and Loveland, T.R., 2004, The characteristics and interpretability of land surface change and implications for project design: Photogrammetric Engineering & Remote Sensing, v. 70, no. 4, p. 439–448.

Stehman, S.V., Sohl, T.L., and Loveland, T.R., 2003, Statistical sampling to characterize recent United States land-cover change: Remote Sensing of Environment, v. 86, no. 4, p. 517–529.

U.S. Census Bureau, 1970–2000 [various years], Census of population and housing: U.S. Census Bureau database, accessed April 29, 2015, at http://www.census.gov/prod/www/decennial.html.

U.S. Environmental Protection Agency, 1999, Level III ecoregions of the continental United States: U.S. Environmental Protection Agency National Health and Environmental Effects Research Laboratory, scale 1:7,500,000, available at ftp://ftp.epa.gov/wed/ecoregions/usgs/useco_March 1999_v5.pdf.

U.S. Environmental Protection Agency, 2010, North American terrestrial ecoregions—Level III: U.S. Environmental Protection Agency database, accessed April 29, 2015, at http://www.epa.gov/wed/pages/ecoregions/na_eco.htm#Downloads.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Walker, R.T., and Solecki, B., 2004, Theorizing land cover and land use change—The case of the Florida Everglades and its degradation: Annals of the Association of American Geographers, v. 94, no. 2, p. 311–328.

Status and Trends of Land Change in the Eastern United States—1973 to 2000
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Chapter 1

Laurentian Plains and Hills Ecoregion

By Thomas R. Moreland, Jr.

Ecoregion Description

The Laurentian Plains and Hills Ecoregion, which is located in the northeastern corner of the conterminous United States, lies entirely within the state of Maine, covering roughly about 50,153 km² (19,364 mi²) in its east half (fig. 1). It is bounded to the north and east by Canada, to the west by the more rugged Northeastern Highlands Ecoregion, and to the south and southeast by the Northeastern Coastal Zone Ecoregion and the Atlantic Ocean. Glacial processes have shaped the entire Laurentian Plains and Hills Ecoregion, creating many lakes and wetland areas, and forests cover nearly three-quarters of the ecoregion (fig. 2). The trees mostly are spruce (*Picea* spp.) and fir (*Abies* spp.), with some maple (*Acer* spp.), beech (*Fagus* spp.), and birch (*Betula* spp.) trees (Wiken and others, 2011). Timber harvesting is one of the most significant activities in the ecoregion; other human-induced alterations to the landscape include agriculture (fig. 3), which is concentrated on the plains in the northern part of the ecoregion, and development. The average annual precipitation in the ecoregion ranges from 1,041 mm (41 in.) in the north to about 1,168 mm (46 in.) in the south. July temperatures average about 15° to 21°C; temperatures are usually warmer along the coast than in inland areas, and they are progressively cooler to the north. Average January temperatures vary from about –8° to –5°C along the coast, becoming increasingly cooler to the north. In the northernmost part of the ecoregion, the average January temperature is below –23°C.

Figure 1. Map of Laurentian Plains and 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 Eastern United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Laurentian Plains and Hills Ecoregion between 1973 and 2000 is estimated at 9.4 percent (table 1). Compared to other Eastern United States ecoregions, change in the Laurentian Plains and Hills Ecoregion was moderate (fig. 4): about 3.3 percent of the total land area changed only one time, 4.8 percent changed two times, and 1.3 percent changed three times. Most of the change is cyclic in nature, resulting from the harvesting of timber (fig. 5) and subsequent forest regrowth.

Change per time period increased throughout the entire study period. Total change increased over the study period from 2.2 percent between 1973 and 1980 to 5.8 percent between 1992 and 2000 (table 2). When normalized to an average annual rate to account for unequal time periods, the average annual change increased from 0.3 percent between 1973 and 1980 to 0.6 percent between 1980 and 1986, peaking at 0.9 percent between 1986 and 1992 and then decreasing slightly to 0.7 percent between 1992 and 2000 (table 2; fig. 6).

Forest was the predominant land-cover class, covering an estimated 72.2 percent of the ecoregion in 1973 and decreasing slightly to 70.1 percent by 2000 (table 3). The area covered by water was very stable, remaining at about 12.0 percent throughout the study period. Agriculture decreased very slightly between 1973 and 2000, from 7.8
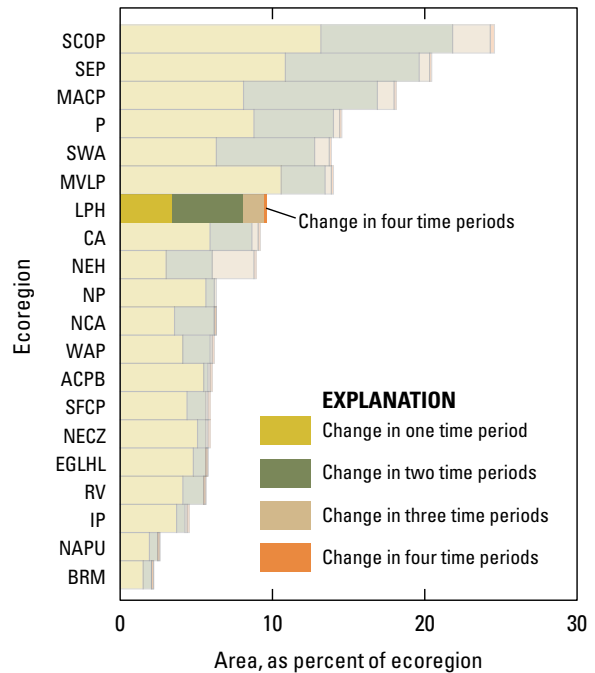
Figure 4. Overall spatial change in Laurentian Plains and Hills Ecoregion (LPH; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Laurentian Plains and 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.

Figure 2. Vista of wetlands in foreground and forested hills in distance, in Laurentian Plains and Hills Ecoregion.

Figure 3. Potato field in Aroostook County, Maine.

Figure 5. Logs being stacked at edge of forest, in Laurentian Plains and Hills Ecoregion.

to 7.5 percent of the ecoregion. The amount of developed land increased slightly, from 1.8 percent of the ecoregion in 1973 to 2.1 percent in 2000. The estimated percentage of the ecoregion covered by mechanically disturbed land increased steadily, from 0.9 percent in 1973 to a high of 2.4 percent in 1992, then decreasing slightly to 2.2 percent in 2000. During the study period, mechanically disturbed land cover almost always was linked to timber harvesting rather than clearing for developed or agriculture.

Net land-cover change in each time period is shown in figure 7. Water, wetland, mining, and barren land-cover classes changed very little in any particular time period, as well as throughout the 27-year study period. Developed increased slightly in each time period, and agriculture decreased gradually in each time period. The amount of forest decreased in each time period except the last, when a slight increase occurred. This change in forested land was mirrored by the increase in the amount of mechanically disturbed land and grassland/shrubland in each time period except the last, when a slight decrease also occurred.

Forest harvesting and regeneration was responsible for most of the change in the ecoregion (table 4). The conversion of forest to mechanically disturbed, an estimated 3,709 km^2 between 1973 and 2000, was the leading change throughout the study period. Much of the timber was harvested to provide pulpwood for the paper industry (Colgan and others, 1986; Irland, 2004) (fig. 8). The conversion of mechanically disturbed to forest, an estimated 1,811 km^2 between 1973 and 2000, was the second leading change overall, and the second leading change in the last two time periods. The third leading change overall, as well as the second leading

change in the first two time periods, was the conversion of mechanically disturbed to grassland/shrubland, an estimated 1,258 km^2 between 1973 and 2000. The conversion of grassland/shrubland to forest, an estimated 1,015 km^2 between 1973 and 2000, was the fourth leading change over the entire study period. A minor change in comparison to the other changes was the conversion of an estimated 109 km^2 of forest to developed between 1973 and 2000. The conversion of forest to developed increased in each time period.

Between 1973 and 2000, the predominately wooded landscape of the Laurentian Plains and Hills Ecoregion experienced a moderate amount of land-cover change. Average annual change increased from the first time period through the third time period, and then it decreased slightly. Although very little of this change resulted in an increase in developed land, about 90 percent of the change can be attributed to the cyclic harvesting of woodlands and their eventual regrowth.
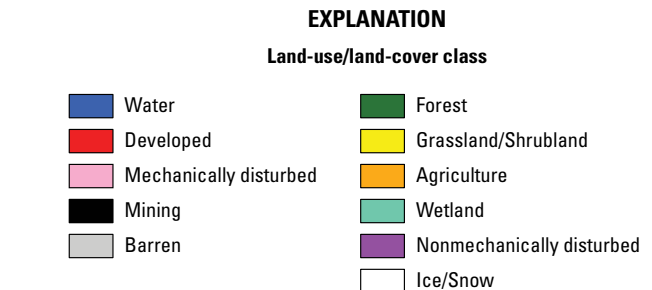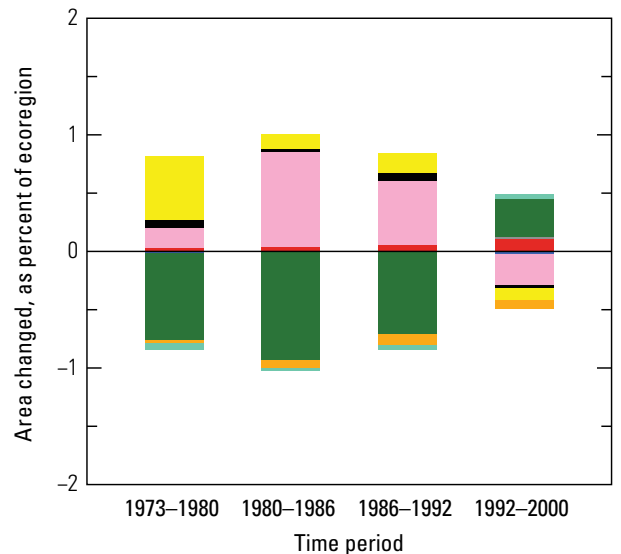
Figure 7.   Normalized average net change in Laurentian Plains and Hills Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Figure 6.   Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Laurentian Plains and Hills Ecoregion are represented by red bars in each time period.

Figure 8.   Paper mill along Penobscot River, in Bucksport, Maine.

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

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

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	3.3	0.5	2.8	3.8	0.4	11.0
2	4.8	1.0	3.8	5.8	0.7	14.3
3	1.3	0.5	0.9	1.8	0.3	22.9
4	0.0	0.0	0.0	0.0	0.0	40.0
Overall spatial change	9.4	1.6	7.8	11.0	1.1	11.7

Table 2.   Raw estimates of change in Laurentian Plains and 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	2.2	0.6	1.6	2.8	0.4	19.0	0.3
1980–1986	3.6	0.9	2.7	4.6	0.6	16.9	0.6
1986–1992	5.3	1.3	4.0	6.6	0.9	16.2	0.9
1992–2000	5.8	1.2	4.6	7.0	0.8	14.1	0.7
Estimate of change, in square kilometers							
1973–1980	1,086	305	781	1,391	206	19	155
1980–1986	1,827	458	1,369	2,285	310	17	305
1986–1992	2,664	638	2,026	3,302	431	16	444
1992–2000	2,896	602	2,294	3,498	407	14	362

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

	Water		Developed		Mecha-nically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
									Area, in percent stratum											
1973	12.0	7.0	1.8	0.6	0.9	0.4	0.1	0.1	0.1	0.1	72.2	2.9	0.2	0.1	7.8	2.3	5.0	1.0	0.0	0.0
1980	12.0	7.0	1.8	0.6	1.0	0.3	0.2	0.1	0.1	0.1	71.4	2.9	0.8	0.3	7.8	2.3	4.9	1.0	0.0	0.0
1986	12.0	7.0	1.9	0.6	1.9	0.6	0.2	0.1	0.1	0.1	70.5	2.8	0.9	0.3	7.7	2.3	4.9	1.0	0.0	0.0
1992	12.0	7.0	1.9	0.7	2.4	0.7	0.2	0.2	0.1	0.1	69.8	2.7	1.1	0.3	7.6	2.3	4.8	1.0	0.0	0.0
2000	12.0	7.0	2.1	0.7	2.2	0.6	0.2	0.1	0.1	0.1	70.1	2.6	0.9	0.5	7.5	2.3	4.9	1.0	0.0	0.0
Net change	0.0	0.0	0.3	0.1	1.3	0.7	0.1	0.1	0.0	0.0	–2.1	0.8	0.7	0.5	–0.2	0.1	–0.1	0.1	0.0	0.0
Gross change	0.0	0.0	0.3	0.1	5.3	1.3	0.2	0.2	0.0	0.0	5.9	1.4	2.8	0.9	0.5	0.2	0.2	0.2	0.0	0.0
									Area, in square kilometers											
1973	6,007	3,499	903	307	440	195	47	26	48	65	36,215	1,470	108	56	3,897	1,167	2,488	524	0	0
1980	6,003	3,499	922	314	525	160	81	50	48	65	35,834	1,479	387	135	3,892	1,166	2,460	509	0	0
1986	6,005	3,500	945	324	938	297	91	55	48	65	35,366	1,426	448	151	3,858	1,144	2,455	507	0	0
1992	6,006	3,500	974	332	1,215	341	122	87	48	65	35,008	1,377	532	152	3,819	1,144	2,430	498	0	0
2000	5,996	3,500	1,034	347	1,083	286	112	69	50	65	35,175	1,298	476	244	3,782	1,134	2,446	503	0	0
Net change	–11	9	131	43	643	353	65	60	2	2	–1,040	398	368	245	–115	70	–42	62	0	0
Gross change	21	10	131	43	2,637	647	103	102	2	2	2,965	715	1,381	467	255	79	125	98	0	0

Table 4.   Principal land-cover conversions in Laurentian Plains and 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	Forest	Mechanically disturbed	521	158	107	1.0	47.9
	Mechanically disturbed	Grassland/Shrubland	276	133	90	0.5	25.4
	Mechanically disturbed	Forest	160	111	75	0.3	14.8
	Wetland	Mining	28	40	27	0.1	2.6
	Forest	Developed	17	9	6	0.0	1.6
	Other	Other	84	n/a	n/a	0.2	7.7
		Totals	1,086			2.2	100.0
1980–1986	Forest	Mechanically disturbed	927	293	198	1.8	50.8
	Mechanically disturbed	Grassland/Shrubland	278	133	90	0.6	15.2
	Grassland/Shrubland	Forest	252	117	79	0.5	13.8
	Mechanically disturbed	Forest	234	94	64	0.5	12.8
	Agriculture	Grassland/Shrubland	30	24	16	0.1	1.7
	Other	Other	106	n/a	n/a	0.2	5.8
		Totals	1,827			3.6	100.0
1986–1992	Forest	Mechanically disturbed	1,202	334	226	2.4	45.1
	Mechanically disturbed	Forest	557	229	155	1.1	20.9
	Mechanically disturbed	Grassland/Shrubland	366	146	99	0.7	13.7
	Grassland/Shrubland	Forest	335	145	98	0.7	12.6
	Agriculture	Grassland/Shrubland	56	33	22	0.1	2.1
	Other	Other	149	n/a	n/a	0.3	5.6
		Totals	2,664			5.3	100.0
1992–2000	Forest	Mechanically disturbed	1,059	282	191	2.1	36.6
	Mechanically disturbed	Forest	861	250	169	1.7	29.7
	Grassland/Shrubland	Forest	414	143	97	0.8	14.3
	Mechanically disturbed	Grassland/Shrubland	339	241	163	0.7	11.7
	Agriculture	Forest	50	33	22	0.1	1.7
	Other	Other	174	n/a	n/a	0.3	6.0
		Totals	2,896			5.8	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	3,709	777	526	7.4	43.8
	Mechanically disturbed	Forest	1,811	497	336	3.6	21.4
	Mechanically disturbed	Grassland/Shrubland	1,258	490	331	2.5	14.9
	Grassland/Shrubland	Forest	1,015	318	215	2.0	12.0
	Forest	Developed	109	38	26	0.2	1.3
	Other	Other	570	n/a	n/a	1.1	6.7
		Totals	8,473			16.9	100.0

References Cited

Colgan, C.S., Irland, L.C., and Benson, J., 1986, The natural resource industries of Maine—An assessment and statistical portrait: Augusta, Financial Authority of Maine and Maine State Planning Office, 135 p.

Irland, L.C., 2004, Maine's forest industry—From one era to another, *in* Barringer, R.E., ed., Changing Maine, 1960–2010: Gardiner, Maine, Tilbury House, p. 362–387.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

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Chapter 2

Northeastern Highlands Ecoregion

By Steven Kambly

Ecoregion Description

The Northeastern Highlands Ecoregion is composed of four physically separate areas that cover 127,107 km^2 (49,076 mi^2) in Maine, New Hampshire, Vermont, New York, Massachusetts, Connecticut, New Jersey, and Pennsylvania (fig. 1). The easternmost part of the ecoregion, the largest, is bounded on the east-southeast by the Laurentian Plains and Hills, Northeastern Coastal Zone, and Northern Piedmont Ecoregions, and, on the west-northwest, by the Ridge and Valley and the Eastern Great Lakes and Hudson Lowlands Ecoregions. Both the next largest and the smallest parts of the ecoregion are entirely surrounded by the Eastern Great Lakes and Hudson Lowlands Ecoregion; the remaining part of the ecoregion, southwest of Albany, New York (fig. 1), is bounded by the North Central Appalachians, the Northern Appalachian Plateau and Uplands, and the Eastern Great Lakes and Hudson Lowlands Ecoregions.

The Northeastern Highlands Ecoregion is, for the most part, sparsely populated and characterized by nutrient-poor soils covered with northern hardwood forests and spruce–fir (*Picea* spp. and *Abries* spp.,

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

respectively) forests (U.S. Environmental Protection Agency, 2013). Landforms in the ecoregion vary from mountains in the southwestern and central parts to open high hills in the northeastern part. Many mountain ranges—including the White Mountains in New Hampshire, the Green Mountains in Vermont, and the Catskill and Adirondack Mountains in New York—lie within the ecoregion. The ecoregion also shows many remnants of glaciation, including rocky soils, glacial lakes, and wetlands (fig. 2). Annual average rainfall ranges from 940 to 1,397 mm (37–55 in.), with significantly higher amounts in mountainous areas. Average daily temperatures range from less than –7°C in January to between 16° and 21°C in July.

Although the ecoregion was heavily forested at the beginning of European settlement, much of it was cleared for farmland in the 19th century. Farmland abandonment, beginning in the mid-1800s and continuing through the 20th century, has led to a natural regrowth of forest. Forest harvesting for wood products has been an ongoing activity since the early 1800s, and clearcutting of forests still is evident in western Maine, where timber companies control large tracts of land. Paper and pulp processing is the leading manufacturing activity in Maine. Further south, in New Hampshire, Vermont, and New York, tourism and small-scale farming are more prevalent.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Northeastern Highlands Ecoregion between 1973 and 2000 is estimated at 8.9 percent (table 1). Compared to other Eastern United States ecoregions, change in the Northeastern Highlands Ecoregion was moderate (fig. 3): about 3.0 percent changed only one time, whereas 3.0 percent and 2.9 percent changed two and three times, respectively. About one-tenth of one percent of the ecoregion's area changed four times (table 1). Total change

per time period increased from 2.2 percent between 1973 and 1980 to 6.2 percent between 1992 and 2000 (table 2). When normalized to an average annual rate to account for uneven time periods, land-cover change increased steadily (from 0.3 to 0.9 percent) in the first three time periods (1973–1980, 1980–1986, 1986–1992) and then slowed to 0.8 percent during the last time period (1992–2000) (fig. 4).

Forest harvesting and regrowth was the dominant pattern of change observed (fig. 5). Both selective cutting and clearcutting of forested land created mechanically disturbed land, which, in turn, became grassland/shrubland. Eventually, grassland/shrubland areas tended to revert to forest. This cycle of change involving mechanically disturbed land and grassland/shrubland occurred over an increasing area in the first three time periods (1973–1980, 1980–1986, 1986–1992) but then decreased in area in the last time period (1992–2000).

Primarily as a result of clearcutting and some selective harvesting, forest decreased during the 27-year study period by an estimated 3.9 percent of the ecoregion, or about 4,904 km² (table 3). However, forest remained the dominant land-cover class, occupying an estimated 81.4 percent of the ecoregion in 2000. As the amount of tree harvesting increased, the percentage of mechanically disturbed land also increased, from 0.6 percent of the ecoregion in 1973 to 2.1 percent in 2000 (table 3). The estimated amount of grassland/
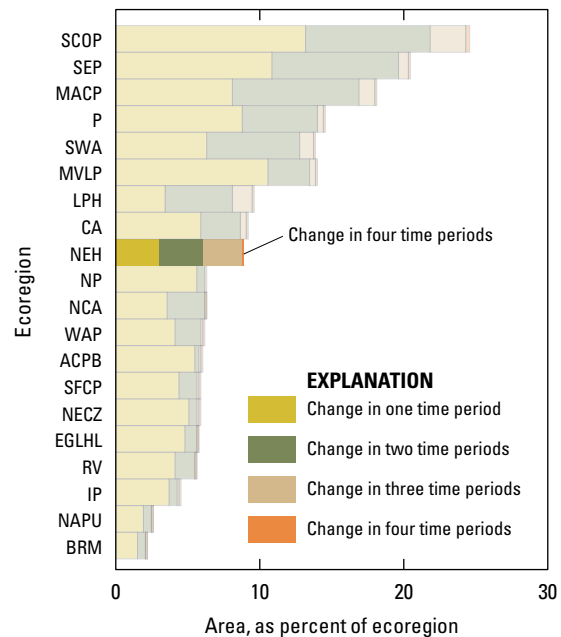
Figure 3.   Overall spatial change in Northeastern Highlands Ecoregion (NEH; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Northeastern Highlands Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Figure 2.   Wetlands area in Northeastern Highlands Ecoregion, many of which are result of glaciation.

shrubland increased in the first three time periods (1973–1980, 1980–1986, 1986–1992), from 0.2 to 2.2 percent, and then it decreased slightly to 2.1 percent in the last time period (1992–2000). Developed land increased from 1.8 to 2.3 percent during the study period (1973–2000), whereas agricultural land remained unchanged during the same period (about 3.3 percent). Forest, mechanically disturbed, and grassland/shrubland were, by far, the most actively changing land-cover classes, accounting for most of the net change in the ecoregion during the study period (table 4; fig. 6).

In terms of individual conversions, forest to mechanically disturbed was the most common conversion overall in all four time periods (table 4). An estimated 9,322 km² converted

EXPLANATION

Land-use/land-cover class

Water	Forest
Developed	Grassland/Shrubland
Mechanically disturbed	Agriculture
Mining	Wetland
Barren	Nonmechanically disturbed
	Ice/Snow

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

Figure 4. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Northeastern Highlands Ecoregion are represented by red bars in each time period.

Figure 5. Logging road out of clearcut area in Maine, in Northeastern Highlands Ecoregion. Most land-cover change in ecoregion is due to extensive clearcutting.
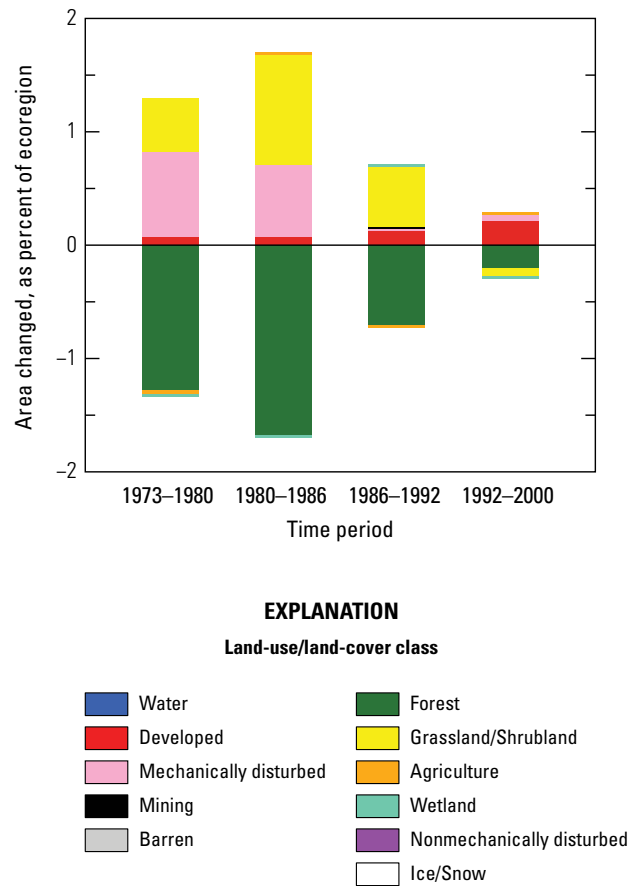
Figure 7. Road into Adirondack State Park, New York, which is example of reserved lands where restrictions are placed on timber harvesting and development.

from forest to mechanically disturbed between 1973 and 2000. The second most common conversion both overall and in the first three time periods was from mechanically disturbed to grassland/shrubland, with 6,983 km^2 converted. Grassland/shrubland to forest was the third most common conversion: about 4,641 km^2 of grassland/shrubland converted to forest during the study period.

Although 150 years of farmland abandonment has led to regrowth of forests in the Northeastern Highlands Ecoregion, forest harvesting clearly was the dominant type of land-cover change during the 27-year study period. The success of the forest-products industry was affected by regional, national, and global market conditions, in addition to the modernization of production processes, the support from State and Federal programs, and the overall health and quality of forested land (Colgan and others, 1986; Irland, 1999). In State- and Federally owned reserved lands, forestry practices are restricted or disallowed altogether, and this may have played a role in limiting forest harvesting (fig. 7). In general, farming, which was scattered and on a small scale, did not change significantly in the ecoregion during the study period (fig. 8). The slight increase in developed land, in the form of new residential communities and tourist resorts, primarily resulted in the conversion of forest to developed.

Figure 8.   Farm in Northeastern Highlands Ecoregion. Although many farms in ecoregion are prosperous, amount of land in agriculture remained relatively stable during study period (1973–2000).

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

[Most sample pixels remained unchanged (91.1 percent), whereas 8.9 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	3.0	0.9	2.1	3.9	0.6	20.6
2	3.0	1.3	1.7	4.3	0.9	29.8
3	2.9	1.4	1.5	4.3	1.0	33.8
4	0.1	0.1	0.0	0.2	0.1	58.9
Overall spatial change	8.9	3.3	5.6	12.2	2.2	24.8

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

[Estimates of change per period normalized to annual rate of change for each 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	2.2	1.3	1.0	3.5	0.9	38.5	0.3
1980–1986	3.9	1.7	2.2	5.7	1.2	29.9	0.7
1986–1992	5.5	2.1	3.4	7.7	1.5	26.5	0.9
1992–2000	6.2	2.4	3.8	8.7	1.6	26.4	0.8
Estimate of change, in square kilometers							
1973–1980	2,855	1,617	1,239	4,472	1,098	38	408
1980–1986	5,010	2,208	2,803	7,218	1,500	30	835
1986–1992	7,006	2,733	4,273	9,738	1,856	26	1,168
1992–2000	7,921	3,076	4,845	10,998	2,090	26	990

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

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	5.1	1.9	1.8	0.8	0.6	0.4	0.1	0.0	0.1	0.1	85.2	2.5	0.2	0.2	3.3	1.4	3.6	0.7	0.0	0.0
1980	5.1	1.9	1.9	0.8	1.4	0.9	0.1	0.0	0.1	0.1	83.9	2.6	0.7	0.4	3.3	1.3	3.6	0.7	0.0	0.0
1986	5.1	1.9	2.0	0.9	2.0	1.0	0.1	0.0	0.1	0.1	82.3	2.8	1.6	1.1	3.3	1.3	3.6	0.7	0.0	0.0
1992	5.1	1.9	2.1	0.9	2.0	1.0	0.1	0.0	0.1	0.1	81.6	2.8	2.2	1.2	3.3	1.3	3.6	0.7	0.0	0.0
2000	5.1	1.9	2.3	1.1	2.1	0.9	0.1	0.0	0.1	0.1	81.4	2.7	2.1	1.1	3.3	1.3	3.6	0.7	0.0	0.0
Net change	0.0	0.0	0.5	0.3	1.5	0.7	0.0	0.0	0.0	0.0	–3.9	1.5	1.9	1.0	0.0	0.2	0.0	0.0	0.0	0.0
Gross change	0.0	0.0	0.5	0.3	6.7	2.7	0.1	0.0	0.0	0.0	7.4	2.7	5.3	2.4	0.3	0.2	0.1	0.0	0.0	0.0
Area, in square kilometers																				
1973	6,479	2,436	2,317	1,006	773	485	66	24	142	98	108,323	3,187	243	202	4,210	1,750	4,554	945	0	0
1980	6,482	2,434	2,419	1,074	1,716	1,148	77	27	142	98	106,701	3,304	852	516	4,165	1,715	4,553	946	0	0
1986	6,496	2,442	2,499	1,126	2,532	1,211	85	30	142	98	104,562	3,597	2,090	1,401	4,165	1,702	4,535	937	0	0
1992	6,498	2,444	2,674	1,174	2,553	1,264	104	42	142	98	103,670	3,535	2,768	1,477	4,157	1,707	4,541	938	0	0
2000	6,491	2,441	2,950	1,380	2,622	1,205	122	61	142	98	103,419	3,475	2,688	1,389	4,160	1,706	4,514	931	0	0
Net change	12	25	632	417	1,849	882	56	49	0	0	–4,904	1,903	2,445	1,292	–51	235	–40	36	0	0
Gross change	60	37	633	417	8,487	3,381	67	49	0	0	9,389	3,423	6,683	3,081	394	250	74	53	0	0

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

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

Period	From class	To class		Area changed (km²)	Margin of error (+/− km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed		1,715	1,148	780	1.3	60.1
	Mechanically disturbed	Grassland/Shrubland		724	488	331	0.6	25.3
	Grassland/Shrubland	Forest		127	133	90	0.1	4.4
	Forest	Developed		85	53	36	0.1	3.0
	Agriculture	Forest		80	107	73	0.1	2.8
	Other	Other		125	n/a	n/a	0.1	4.4
			Totals	2,855			2.2	100.0
1980–1986	Forest	Mechanically disturbed		2,519	1,211	823	2.0	50.3
	Mechanically disturbed	Grassland/Shrubland		1,684	1,149	781	1.3	33.6
	Grassland/Shrubland	Forest		481	298	202	0.4	9.6
	Forest	Agriculture		81	65	44	0.1	1.6
	Forest	Developed		67	52	35	0.1	1.3
	Other	Other		179	n/a	n/a	0.1	3.6
			Totals	5,010			3.9	100.0
1986–1992	Forest	Mechanically disturbed		2,517	1,264	859	2.0	35.9
	Mechanically disturbed	Grassland/Shrubland		2,266	1,226	833	1.8	32.3
	Grassland/Shrubland	Forest		1,619	1,011	687	1.3	23.1
	Mechanically disturbed	Forest		244	146	99	0.2	3.5
	Forest	Developed		161	116	79	0.1	2.3
	Other	Other		199	n/a	n/a	0.2	2.8
			Totals	7,006			5.5	100.0
1992–2000	Forest	Mechanically disturbed		2,571	1,205	819	2.0	32.5
	Grassland/Shrubland	Forest		2,413	1,265	859	1.9	30.5
	Mechanically disturbed	Grassland/Shrubland		2,309	1,278	868	1.8	29.1
	Forest	Developed		194	140	95	0.2	2.4
	Mechanically disturbed	Forest		160	112	76	0.1	2.0
	Other	Other		274	n/a	n/a	0.2	3.5
			Totals	7,921			6.2	100.0
1973–2000 (overall)	Forest	Mechanically disturbed		9,322	3,787	2,572	7.3	40.9
	Mechanically disturbed	Grassland/Shrubland		6,983	3,262	2,216	5.5	30.6
	Grassland/Shrubland	Forest		4,641	2,384	1,619	3.7	20.4
	Forest	Developed		506	293	199	0.4	2.2
	Mechanically disturbed	Forest		454	250	170	0.4	2.0
	Other	Other		887	n/a	n/a	0.7	3.9
			Totals	22,793			17.9	100.0

References Cited

Colgan, C.S., Irland, L.C., and Benson, J., 1986, The natural resource industries of Maine—An assessment and statistical portrait: Augusta, Financial Authority of Maine and Maine State Planning Office, 135 p.

Irland, L.C., 1999, The Northeast's changing forest: Petersham, Mass., Harvard Forest [distributed by Harvard University Press], 427 p.

U.S. Environmental Protection Agency, 2013, Primary distinguishing characteristics of Level III Ecoregions of the continental United States: U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, available at ftp://ftp.epa.gov/wed/ecoregions/us/Eco_Level_III_descriptions.doc.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

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Chapter 3

Eastern Great Lakes and Hudson Lowlands Ecoregion

By Janis L. Taylor

Ecoregion Description

The Eastern Great Lakes and Hudson Lowlands Ecoregion, a glaciated region of irregular plains bordered by hills and lakes, is located mostly in New York, but it also extends eastward into western Vermont, including Lake Champlain; in addition, a long, thin finger extends southwestward along Lake Erie into Pennsylvania and Ohio (fig. 1). The ecoregion, which covers about 60,591 km^2 (23,394 mi^2), primarily is a mix of forested land, agricultural land, and developed land. Water bodies and rivers are a dominant feature of this forested ecoregion (fig. 2): Lake Champlain makes up much of the far-eastern part of the ecoregion, and Lake Erie and Lake Ontario (along with Canada) form the northern boundary

Figure 1. Map of Eastern Great Lakes and Hudson Lowlands 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 Eastern United States ecoregions are listed in appendix 2. Also shown are parts of four Midwest–South Central United States ecoregions: Erie Drift Plains, Eastern Corn Belt Plains (ECBP), Huron/Erie Lake Plains (HELP), and Southern Michigan/Northern Indiana Drift Plains (SMNIDP). See appendix 3 for definitions of land-use/land-cover classifications.
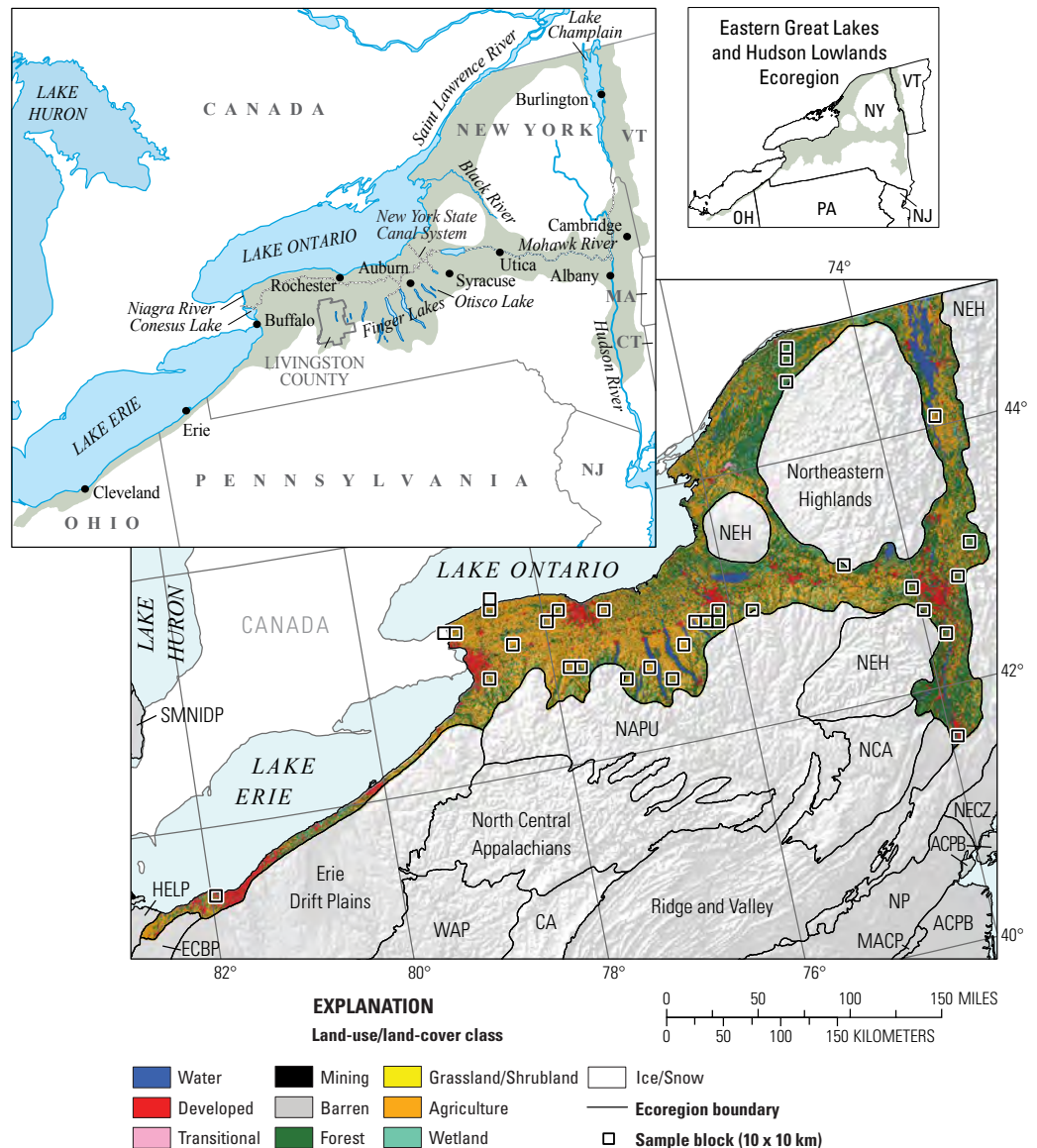
of the ecoregion. The ecoregion is surrounded by, clockwise from east-northeast to west-southwest, the Northeastern Highlands, Ridge and Valley, North Central Appalachians, Northeastern Highlands (again), Northern Appalachian Plateau and Uplands, Erie Drift Plains, Eastern Corn Belt Plains, and Huron/Erie Lake Plains Ecoregions; in addition, it completely surrounds two outliers of the Northeastern Highlands Ecoregion (fig. 1). The Eastern Great Lakes and Hudson Lowlands Ecoregion has less surface irregularity, more agricultural activity, and higher population density than the adjacent Northeastern Highlands and Northern Appalachian Plateau and Uplands Ecoregions (Wiken and others, 2011).

The Eastern Great Lakes and Hudson Lowlands Ecoregion has a severe continental climate that has warm summers, during which temperatures range from 16° to 19°C, and cold, snowy winters, during which temperatures range from −7° to −2°C. Yearly precipitation in the ecoregion ranges from 720 mm (28 in.) to more than 1,200 mm (47 in.). The spodosol soils of the river valleys in the ecoregion, which have developed on glacial deposits, are heavier and of better quality than soils in

Figure 2.   Homes and farm fields on hills surrounding Otisco Lake, east of Auburn, New York.
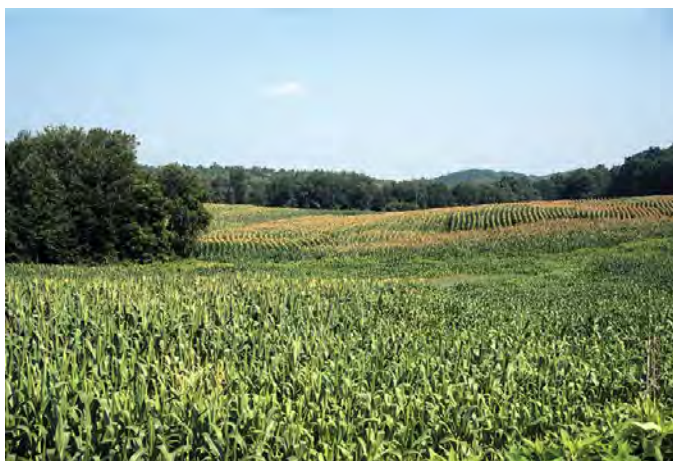
Figure 3.   Corn field surrounded by forest, near Cambridge, New York.

the higher elevations of adjacent ecoregions, and they provide a strong foundation for agriculture. Major crops grown in the ecoregion include apples, grapes, tart cherries, pears, plums, corn, hay, wheat, oats, barley, soybeans, cabbage, and potatoes (fig. 3). Vineyards and wineries thrive along the shores of Lake Erie and in the Finger Lakes region because these areas have a longer growing season, more winter cloudiness, and greater snowfall amounts than the rest of the ecoregion.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land that changed at least one time) in the Eastern Great Lakes and Hudson Lowlands Ecoregion between 1973 and 2000 is estimated at 5.6 percent (table 1). Compared to other Eastern United States ecoregions, change in the Eastern Great Lakes and Hudson Lowlands Ecoregion was fairly low (fig. 4): about 4.8 percent changed one time, and 0.7 percent changed two times (table 1). Total change in each of the four time periods was very similar, ranging from 1.3 to 2.1 percent (table 2).

Figure 4.   Overall spatial change in Eastern Great Lakes and Hudson Lowlands Ecoregion (EGLHL; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Eastern Great Lakes and Hudson Lowlands 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.

When normalized to an average annual rate to account for unequal time periods, the rates ranged from a low of 0.2 percent per year in the first two time periods (1973–1980, 1980–1986) to a high of 0.4 percent per year in the third time period (1986–1992) (table 2; fig. 5).

The amount of area occupied by each land-cover class mapped in each of the five study dates is shown in table 3. Forest, agriculture, and developed were the predominant land-cover classes, accounting for 88.1 percent of the ecoregion in 2000 (table 3). During the study period, the amount of forested land decreased by 0.5 percent, from 39.4 percent of the ecoregion in 1973 to 38.9 percent in 2000. Agricultural land decreased by 2.1 percent, from 39.7 percent of the ecoregion in 1973 to 37.6 percent in 2000. Developed land changed the most, increasing 2.4 percent, from 9.2 percent of the ecoregion in 1973 to 11.6 percent in 2000.

The conversion of forest to developed was the most common conversion overall during the study period (table 4). The second most common conversion overall was from agriculture to developed. Developed land increased in each of the four time periods (fig. 6): in the first two time periods (1973–1980, 1980–1986), most new developed land was converted from forested land; in the last two time periods (1986–1992, 1992–2000), most came from agricultural land (table 4). The third most common conversion overall was from agriculture to grassland/shrubland. The largest conversion of this type occurred between 1986 and 1992, when 243 km^2 of agricultural land was converted to grassland/shrubland (table 4). This type of conversion either was driven by agricultural abandonment or was an intermediate step in the conversion to developed land. Finally, the fourth most common conversion overall was from grassland/shrubland to forest.
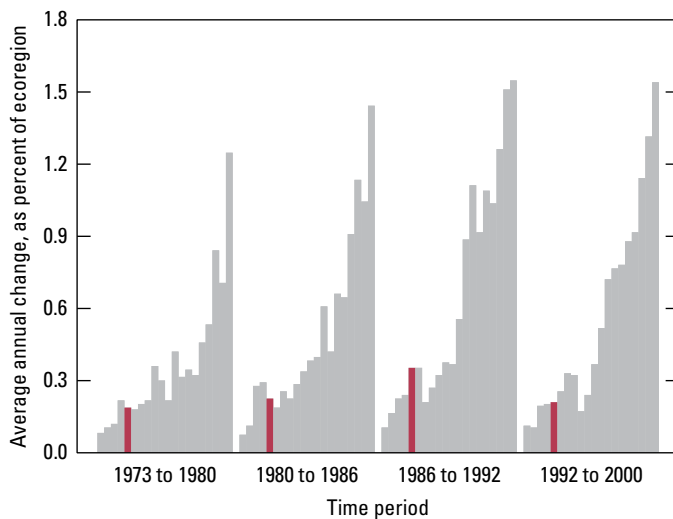
The unidirectional land-cover change from agriculture or forest to developed (fig. 7) was driven by an increase in population in and around several large urban centers in the ecoregion, including Albany, Buffalo, Rochester, Syracuse, and Utica, New York; Burlington, Vermont; Erie, Pennsylvania; and Cleveland, Ohio. In addition, tourism and exurban development have increased along rivers and lakes. Populated areas across this ecoregion have long been tied to waterways, which are important traffic arteries that provide easy passage between the Atlantic Ocean and the Great Lakes. For example, the New York State Canal System, which replaced the Erie Canal in the early 1900s, links together many lakes and rivers in the ecoregion. In addition to being transportation routes, the Hudson River, Saint Lawrence River, Mohawk River, Black River, and Niagara River also are scenic and tourist attractions, as well as sources of hydroelectric power. Despite population increases, the Finger Lakes region in upstate New York, as well as the Lake Champlain Basin in northeastern New York and northwestern Vermont, remain important agricultural areas (fig. 8).
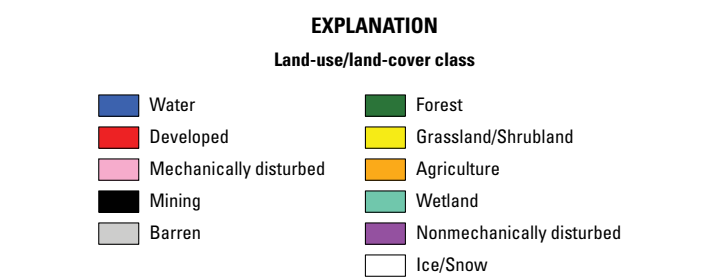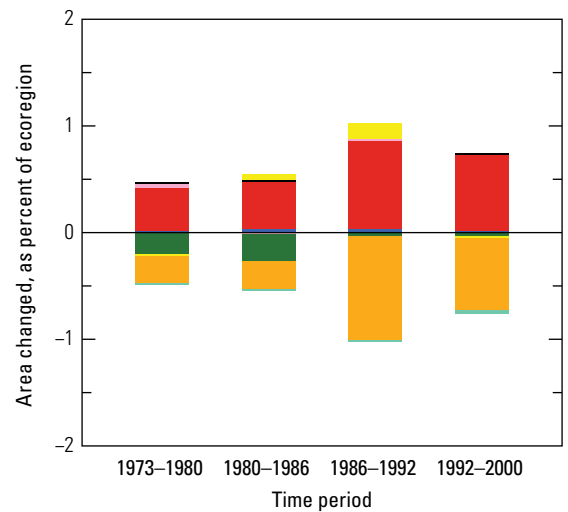
Figure 6. Normalized average net change in Eastern Great Lakes and Hudson Lowlands Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Eastern Great Lakes and Hudson Lowlands Ecoregion are represented by red bars in each time period.

Figure 7.   New subdivision southeast of Buffalo, New York.

Figure 8.   Dairy farm near Conesus Lake, in Livingston County, New York.

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

[Most sample pixels remained unchanged (94.4 percent), whereas 5.6 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	4.8	1.2	3.6	6.1	0.8	17.2
2	0.7	0.2	0.5	0.9	0.1	17.0
3	0.0	0.0	0.0	0.1	0.0	32.8
4	0.0	0.0	0.0	0.0	0.0	71.6
Overall spatial change	5.6	1.3	4.3	6.9	0.9	15.4

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

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

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	1.3	0.3	1.0	1.6	0.2	16.8	0.2
1980–1986	1.3	0.4	1.0	1.7	0.2	18.1	0.2
1986–1992	2.1	0.6	1.5	2.7	0.4	20.1	0.4
1992–2000	1.7	0.4	1.2	2.1	0.3	17.9	0.2
Estimate of change, in square kilometers							
1973–1980	778	193	585	971	130	17	111
1980–1986	805	215	590	1,021	146	18	134
1986–1992	1,283	381	902	1,665	258	20	214
1992–2000	1,008	267	741	1,276	181	18	126

Table 3. Estimated area (and margin of error) of each land-cover class in Eastern Great Lakes and Hudson Lowlands 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	6.8	4.3	9.2	3.0	0.0	0.0	0.4	0.2	0.0	0.0	39.4	4.6	0.5	0.3	39.7	5.0	3.9	1.1	0.0	0.0
1980	6.9	4.3	9.6	3.1	0.1	0.0	0.4	0.2	0.0	0.0	39.2	4.6	0.5	0.2	39.5	5.0	3.9	1.1	0.0	0.0
1986	6.9	4.3	10.0	3.2	0.0	0.0	0.4	0.2	0.0	0.0	38.9	4.6	0.6	0.2	39.2	5.0	3.9	1.1	0.0	0.0
1992	6.9	4.3	10.9	3.4	0.1	0.0	0.4	0.2	0.0	0.0	38.9	4.6	0.7	0.3	38.3	5.0	3.9	1.1	0.0	0.0
2000	7.0	4.3	11.6	3.7	0.1	0.0	0.4	0.2	0.0	0.0	38.9	4.7	0.7	0.3	37.6	5.0	3.8	1.1	0.0	0.0
Net change	0.1	0.1	2.4	1.0	0.0	0.0	0.1	0.1	0.0	0.0	–0.5	0.9	0.2	0.3	–2.1	0.6	–0.1	0.1	0.0	0.0
Gross change	0.1	0.1	2.4	1.0	0.3	0.1	0.2	0.1	0.0	0.0	2.4	0.7	0.9	0.3	2.7	0.5	0.1	0.1	0.0	0.0
Area, in square kilometers																				
1973	4,147	2,624	5,560	1,817	15	13	233	124	1	1	23,863	2,792	310	161	24,080	3,059	2,382	666	0	0
1980	4,155	2,624	5,810	1,872	35	30	246	129	1	1	23,739	2,793	299	137	23,932	3,048	2,375	664	0	0
1986	4,180	2,622	6,078	1,910	28	19	254	130	1	1	23,579	2,808	334	121	23,779	3,057	2,359	658	0	0
1992	4,204	2,621	6,578	2,042	35	26	259	130	1	1	23,561	2,807	421	158	23,192	3,056	2,340	654	0	0
2000	4,214	2,621	7,015	2,213	37	18	272	130	1	1	23,545	2,845	404	172	22,778	3,058	2,325	653	0	0
Net change	67	31	1,455	596	22	14	39	32	0	0	–318	575	94	161	–1,302	340	–57	38	0	0
Gross change	81	45	1,455	596	158	72	102	39	0	0	1,443	450	521	179	1,627	330	75	49	0	0

Table 4. Principal land-cover conversions in Eastern Great Lakes and Hudson Lowlands 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	Agriculture	Forest		180	90	61	0.3	23.1
	Forest	Agriculture		174	66	45	0.3	22.4
	Forest	Developed		160	108	73	0.3	20.6
	Agriculture	Developed		77	47	32	0.1	9.8
	Grassland/Shrubland	Forest		57	33	23	0.1	7.4
	Other	Other		130	n/a	n/a	0.2	16.7
			Totals	778			1.3	100.0
1980–1986	Forest	Developed		168	135	92	0.3	20.9
	Forest	Agriculture		147	66	45	0.2	18.2
	Agriculture	Grassland/Shrubland		122	58	39	0.2	15.2
	Grassland/Shrubland	Forest		89	68	46	0.1	11.1
	Agriculture	Forest		85	48	32	0.1	10.6
	Other	Other		194	n/a	n/a	0.3	24.1
			Totals	805			1.3	100.0
1986–1992	Agriculture	Developed		304	120	81	0.5	23.7
	Agriculture	Grassland/Shrubland		243	99	67	0.4	18.9
	Grassland/Shrubland	Forest		180	80	54	0.3	14.0
	Forest	Developed		172	90	61	0.3	13.4
	Agriculture	Forest		124	56	38	0.2	9.6
	Other	Other		260	n/a	n/a	0.4	20.3
			Totals	1,283			2.1	100.0
1992–2000	Agriculture	Developed		213	87	59	0.4	21.1
	Forest	Developed		185	130	88	0.3	18.3
	Grassland/Shrubland	Forest		164	58	39	0.3	16.3
	Agriculture	Grassland/Shrubland		149	75	50	0.2	14.7
	Agriculture	Forest		76	40	27	0.1	7.6
	Other	Other		221	n/a	n/a	0.4	21.9
			Totals	1,008			1.7	100.0
1973–2000 (overall)	Forest	Developed		685	391	265	1.1	17.7
	Agriculture	Developed		664	225	152	1.1	17.1
	Agriculture	Grassland/Shrubland		554	184	125	0.9	14.3
	Grassland/Shrubland	Forest		491	190	128	0.8	12.7
	Forest	Agriculture		478	176	119	0.8	12.3
	Other	Other		1,004	n/a	n/a	1.7	25.9
			Totals	3,875			6.4	100.0

References Cited

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/ Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_ Ecoregions_Level_3_Final-2june11.pdf.

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Chapter 4

Northeastern Coastal Zone Ecoregion

By Roger F. Auch

Ecoregion Description

The Northeastern Coastal Zone Ecoregion is a northeast-to-southwest-trending ecoregion that covers about 37,158 km^2 (14,347 mi^2) in eight states (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, and New Jersey) (fig. 1). The ecoregion is bounded on the far northeast by the Laurentian Plains and Hills Ecoregion; on the north-northwest, by the Northeastern Highlands Ecoregion; on the far southwest, by the Northern Piedmont Ecoregion; and on the south and east, by two parts of the Atlantic Coastal Pine Barrens Ecoregion, as well as by the Atlantic Ocean.

The Northeastern Coastal Zone Ecoregion's glaciated past is the reason for its irregular topographic relief, which is more irregular than the neighboring Atlantic Coastal Pine Barrens Ecoregion to the south and east but not as hilly and mountainous as the Northeastern Highlands Ecoregion to the north-northwest. The soils in the Northeastern Coastal Zone Ecoregion tend to be rocky and poor in nutrients (Wiken and others, 2011). Natural vegetation is dominated by hardwood and mixed forests, but it also includes more limited coastal and inland wetlands. The Northeastern Coastal Zone Ecoregion has cold winters and warm summers, with 1,000 to 1,500 mm (40–60 in.) of precipitation occurring in an average year.

Together, forested land and developed land accounted for more than 70 percent of the ecoregion during the 27-year study period (table 1; figs. 2A,B). Large areas of developed land are found in the northern part of the

Figure 1. Map of Northeastern Coastal Zone 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 Eastern United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

EXPLANATION

Land-use/land-cover class

- Water
- Developed
- Transitional
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Ice/Snow

— Ecoregion boundary

□ Sample block (10 x 10 km)

New York metropolitan area, as well as eastward along Long Island Sound to New Haven, Connecticut, northward to Hartford, Connecticut, and then along the Connecticut River to Springfield, Massachusetts (fig. 1) (Vogelmann and others, 2001). Other areas of developed land in the ecoregion include metropolitan Providence, Rhode Island, which lies in a ring encircling the upper reaches of Narragansett Bay, and also the radial lines of urbanization that extend from greater Boston, Massachusetts, west to Worcester, Massachusetts, northwest to Nashua, New Hampshire, and south-southeast toward Cape Cod, Massachusetts. Portland, Maine, forms the last urban node in the extreme northeastern part of the ecoregion. According to aggregated county-level data, the ecoregion's population increased by more than 1 million people between 1970 and 2000, reaching 15,269,068 by 2000 (U.S. Census Bureau, 1970–2000 [various years]). Water, wetland, and agriculture are the other common land-cover classes in the ecoregion, but they are smaller and less concentrated than the forest and developed land-cover classes (table 1; figs. 3*A*,*B*). The only notable concentration of agricultural land is found in the Connecticut River valley, north of Hartford, Connecticut.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Northeastern Coastal Zone Ecoregion between 1973 and 2000 is estimated at 5.7 percent (table 2). Compared to other Eastern United States ecoregions, change in the Northeastern Coastal Zone Ecoregion was moderately low (fig. 4). The estimated amount of change in the first two time periods (1973–1980, 1980–1986) was considerably lower than that of the last two time periods (1986–1992, 1992–2000) (table 3). When normalized to an annual rate to account for unequal time periods, land-cover change was highest between 1986 and 1992, at 0.3 percent (table 3; fig. 5). The variability in land-cover change across the ecoregion was low and relatively steady during the study period, as indicated by the low margin of error in the statistical estimates, which range from about 0.2 to about 0.4 percent at an 85-percent confidence level (table 3).

Figure 2.   Forest and developed land in Northeastern Coastal Zone Ecoregion. *A*, Forest along old stone fence in eastern Connecticut. *B*, Typical scene in ecoregion of older housing with forest beyond, on outskirts of Southbridge, Massachusetts.

Figure 3.   Water and agricultural land in Northeastern Coastal Zone Ecoregion. *A*, Marina on Long Island Sound, near Stamford, Connecticut. *B*, Farmhouse and fields, in southeastern New Hampshire.

The dominant land-cover classes, forest and developed, experienced the most net change during the study period (table 1; fig. 6). Developed land increased by an estimated 4.0 percent (1,502 km²) to about 27.2 percent of the ecoregion, one of the highest percentages of developed land of any Eastern United States ecoregion. Much of the new development came from forest land, which decreased by about 3.7 percent (1,361 km²) during the study period (table 1; fig. 7). Agricultural land decreased by about 0.8 percent, and, although this may appear to be a small amount of farmland loss, it represents a loss of about 10.1 percent of the estimated agricultural land present in the ecoregion in 1973 (fig. 8). Other, more minor land-cover changes include slight decreases in wetland and slight increases in mechanically disturbed and mining (fig. 9). Increase in developed was the primary reason for these changes, as wetlands and forested lands were developed and demand for construction aggregates increased mining operations.

The ecoregion gained an estimated 1,502 km² of developed land between 1973 and 2000. Most (about 87 percent) of the net decrease in forest, agriculture, and wetland land-cover classes was due to losses to developed land (table 1; fig. 10). An additional 115 km² of forests were converted to mining land uses between 1973 and 2000, mostly for

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Northeastern Coastal Zone Ecoregion are represented by red bars in each time period.
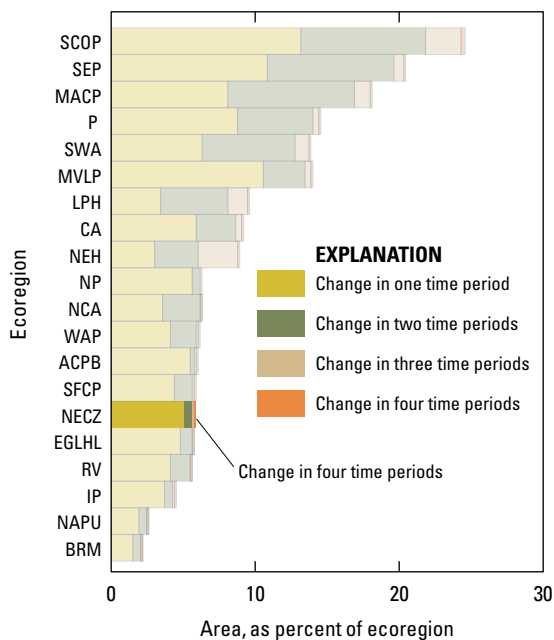
Figure 4. Overall spatial change in Northeastern Coastal Zone Ecoregion (NECZ; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Northeastern Coastal Zone 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 6. Normalized average net change in Northeastern Coastal Zone Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Figure 7. Home site being cleared from forest, in rural southeastern New Hampshire.

Figure 8. New housing subdivision built on former farmland, about 16 km northeast of Hartford, Connecticut.

Figure 9. Aggregate mining operation, in south-central Massachusetts.

construction aggregates to help maintain or increase the built-land infrastructure, although this change did not rank in the top five conversions for every time period (table 4). Conversions from forest to mining are not always a permanent loss because some of these areas revert back to grassland/shrubland or even forest once mining operations cease. The changes from forest to mechanically disturbed mapped in the Northeastern Coastal Zone Ecoregion primarily were driven by the clearing of land for new development, although, in a few locations, some forest harvesting for wood products occurred.

Other changes in the ecoregion include conversion of grassland/shrubland to forest in the middle two time periods (1980–1986, 1986–1992), which may have been related to vegetation succession either on abandoned farmland or on land that had been logged in the past (fig. 11). Minor changes from forest to agriculture and agriculture to forest also occurred, but they were among the top five changes during only two of the four time periods (1973–1980, 1986–1992) (table 4). In both cases, the conversion was from forest to agriculture, as conversions from agriculture to forest did not place among the top five changes during any time period (table 4).

The main story of land-cover change in the Northeastern Coastal Zone Ecoregion during the 27-year study period was increased urbanization, primarily through unidirectional conversion to developed land uses. The amount of change was relatively low, but it was steady across time. Most of this new developed land came from forested land and, to a lesser extent, from farmland.
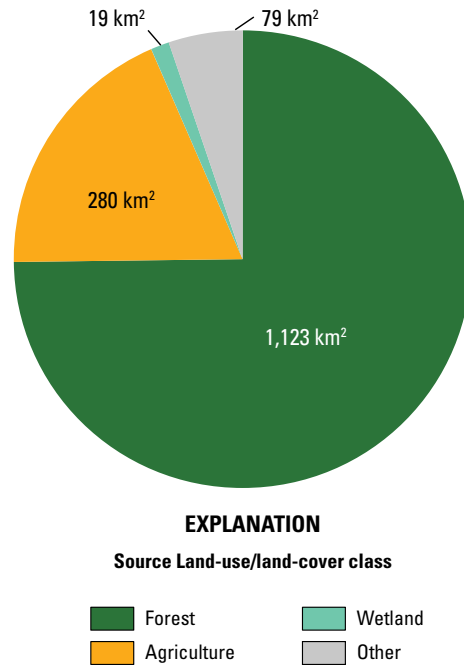
Figure 10. Net areal losses, in square kilometers, of forest, agriculture, wetland, and other land-cover classes to developed land cover in Northeastern Coastal Zone Ecoregion during study period (1973–2000).

Figure 11. Old farm field undergoing succession to grassland/shrubland, about 16 km west of Portland, Maine. Left undisturbed, this field eventually will revert to forest.

Table 1. Estimated area (and margin of error) of each land-cover class in Northeastern Coastal Zone 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	10.6	4.8	23.2	5.6	0.1	0.0	0.4	0.1	0.2	0.2	50.6	5.6	0.3	0.1	8.2	1.5	6.5	1.3	0.0	0.0
1980	10.7	4.7	23.9	5.6	0.1	0.0	0.5	0.1	0.2	0.2	49.8	5.5	0.4	0.1	8.0	1.5	6.4	1.3	0.0	0.0
1986	10.7	4.7	24.5	5.5	0.1	0.0	0.5	0.1	0.2	0.2	49.2	5.4	0.4	0.1	7.9	1.5	6.4	1.3	0.0	0.0
1992	10.7	4.7	25.9	5.5	0.1	0.0	0.5	0.1	0.2	0.2	48.2	5.3	0.4	0.1	7.5	1.5	6.4	1.3	0.0	0.0
2000	10.7	4.7	27.2	5.4	0.3	0.1	0.6	0.1	0.2	0.2	46.9	5.2	0.4	0.1	7.3	1.4	6.4	1.3	0.0	0.0
Net change	0.0	0.0	4.0	0.8	0.2	0.1	0.2	0.1	0.0	0.0	–3.7	0.6	0.1	0.1	–0.8	0.3	–0.1	0.0	0.0	0.0
Gross change	0.1	0.0	4.0	0.8	0.5	0.1	0.3	0.1	0.0	0.0	3.7	0.6	0.4	0.1	1.0	0.3	0.1	0.0	0.0	0.0
											Area, in square kilometers									
1973	3,956	1,765	8,607	2,078	27	10	147	38	88	64	18,791	2,068	107	55	3,037	572	2,399	472	0	0
1980	3,961	1,765	8,893	2,064	49	16	172	46	87	63	18,492	2,039	135	55	2,981	561	2,388	473	0	0
1986	3,960	1,764	9,106	2,052	41	15	183	47	90	66	18,299	2,014	154	55	2,940	558	2,386	472	0	0
1992	3,962	1,764	9,622	2,040	55	18	197	47	89	66	17,902	1,987	149	51	2,802	542	2,380	472	6	9
2000	3,962	1,764	10,108	2,025	104	30	205	53	87	63	17,430	1,948	159	53	2,731	527	2,372	469	0	0
Net change	6	7	1,502	282	77	28	58	34	–1	1	–1,361	234	52	32	–307	129	–27	12	0	0
Gross change	21	10	1,502	282	183	41	109	30	6	8	1,369	234	149	37	383	117	37	14	0	0

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

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

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	5.1	0.8	4.2	5.9	0.6	11.2
2	0.6	0.2	0.4	0.7	0.1	18.7
3	0.1	0.0	0.0	0.1	0.0	27.5
4	0.0	0.0	0.0	0.0	0.0	74.4
Overall spatial change	5.7	0.9	4.8	6.6	0.6	11.0

Table 3. Raw estimates of change in Northeastern Coastal Zone 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	1.3	0.3	0.9	1.6	0.2	16.9	0.2
1980–1986	1.1	0.2	0.9	1.3	0.1	12.6	0.2
1986–1992	2.1	0.4	1.7	2.4	0.2	11.8	0.3
1992–2000	2.0	0.4	1.6	2.4	0.3	13.0	0.2
Estimate of change, in square kilometers							
1973–1980	470	118	353	588	79	16.9	67
1980–1986	405	76	329	481	51	12.6	67
1986–1992	774	135	639	909	91	11.8	129
1992–2000	743	143	600	886	97	13.0	93

Table 4. Principal land-cover conversions in Northeastern Coastal Zone 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)	Stan-dard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Developed		223	73	50	0.6	47.5
	Agriculture	Developed		52	22	15	0.1	11.0
	Forest	Mechanically disturbed		40	14	10	0.1	8.5
	Forest	Mining		31	15	10	0.1	6.7
	Forest	Agriculture		26	13	9	0.1	5.6
	Other	Other		98	n/a	n/a	0.3	20.8
			Totals	470			1.3	100.0
1980–1986	Forest	Developed		162	44	30	0.4	40.1
	Agriculture	Developed		38	19	13	0.1	9.4
	Forest	Mechanically disturbed		36	15	10	0.1	8.9
	Forest	Mining		23	12	8	0.1	5.7
	Grassland/Shrubland	Forest		22	8	6	0.1	5.5
	Other	Other		123	n/a	n/a	0.3	30.5
			Totals	405			1.1	100.0
1986–1992	Forest	Developed		368	85	58	1.0	47.5
	Agriculture	Developed		119	36	24	0.3	15.4
	Forest	Mechanically disturbed		45	17	12	0.1	5.8
	Grassland/Shrubland	Forest		38	15	10	0.1	4.9
	Forest	Agriculture		31	18	12	0.1	4.0
	Other	Other		173	n/a	n/a	0.5	22.3
			Totals	774			2.1	100.0
1992–2000	Forest	Developed		369	83	56	1.0	49.7
	Forest	Mechanically disturbed		95	29	20	0.3	12.7
	Agriculture	Developed		71	29	20	0.2	9.6
	Forest	Mining		32	12	8	0.1	4.3
	Mechanically disturbed	Developed		22	8	6	0.1	2.9
	Other	Other		154	n/a	n/a	0.4	20.8
			Totals	743			2.0	100.0
1973–2000 (overall)	Forest	Developed		1,123	227	153	3.0	47.0
	Agriculture	Developed		280	87	59	0.8	11.7
	Forest	Mechanically disturbed		215	59	40	0.6	9.0
	Forest	Mining		115	35	23	0.3	4.8
	Forest	Agriculture		96	35	24	0.3	4.0
	Other	Other		563	n/a	n/a	1.5	23.5
			Totals	2,392			6.4	100.0

References Cited

U.S. Census Bureau, 1970–2000 [various years], Census of population and housing: U.S. Census Bureau database, accessed May 9, 2013, at http://www.census.gov/prod/www/decennial.html.

Vogelmann, J.M., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

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Chapter 5

Atlantic Coastal Pine Barrens Ecoregion

By Terry L. Sohl

Ecoregion Description

The Atlantic Coastal Pine Barrens Ecoregion is a disjunct ecoregion that covers about 19,230 km^2 (7,425 mi^2) of the coastal plain of New Jersey, as well as Long Island in New York and Cape Cod, Martha's Vineyard, Nantucket, and other nearby islands in Massachusetts (fig. 1). The ecoregion is bounded by, from northeast to southwest, the Northeastern Coastal Zone, Northern Piedmont, and Middle Atlantic Coastal Plain Ecoregions.

The ecoregion has a wide variety of ecological systems, including Atlantic white cedar (*Chamaecyparis thyoides*) swamps, stunted forests of pitch pine (*Pinus rigida*) and oak (*Quercus* spp.), sphagnum (*Sphagnum* spp.) bogs, coastal salt ponds, dune systems, and the only maritime grasslands in the Nation (Wiken and others, 2011). Because of generally acidic soils, agricultural activity often is limited to acid-loving crops such as blueberries and cranberries, although some areas of the ecoregion support cultivation of fruits, vegetables, and other crops (fig. 2). Although parts of the ecoregion represent some of the best-preserved natural habitat in the Eastern United States, other parts are among the most highly developed in the country. The climate is marked by hot summers and cold winters, with an average annual precipitation of about 1,141 mm (45 in.), which is fairly evenly distributed throughout the year.
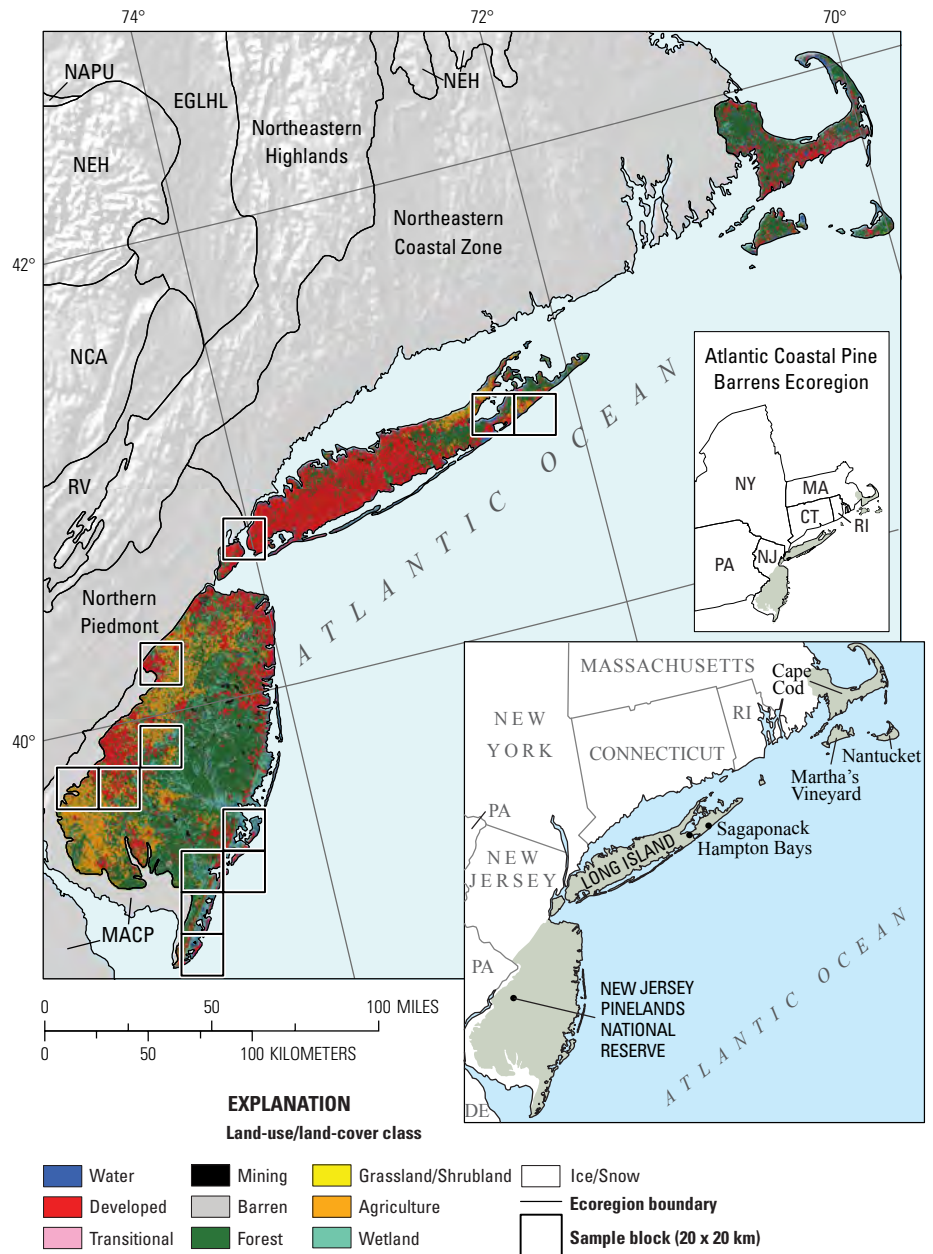
Figure 1. Map of Atlantic Coastal Pine Barrens Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 20 x 20 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Eastern United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Atlantic Coastal Pine Barrens Ecoregion between 1973 to 2000 is estimated at 5.8 percent (table 1). Compared to other Eastern United States ecoregions, change in the Atlantic Coastal Pine Barrens Ecoregion was fairly low (fig. 3): about 5.5 percent changed one time, and 0.3 percent changed two times (table 1). Total change per time period was relatively constant, hovering at around 1.5 percent (table 2). When normalized to an average annual rate to account for unequal time periods, the rates of change peaked in the second time period (1980–1986) and then decreased in the remaining two time periods (1986–1992, 1992–2000) (fig. 4). Although overall change rates were low, significant trends in land-cover change are apparent.

The Atlantic Coastal Pine Barrens Ecoregion experienced a 14.6 percent increase in population between 1970 and 2000, from 9.6 to 11.0 million people (U.S. Census Bureau, 1970–2000 [various years]). Locally, population increases have been more dramatic; for example, Cape Cod doubled in population over the same time period. Accommodation of this growth was the primary driver of land change, as developed land increased steadily from 25.5 to 30.3 percent of the ecoregion between 1973 and 2000 (table 3; fig. 5). Most newly developed land occurred at the expense of agricultural and forested lands, both of which decreased significantly in all four time periods (fig. 6). More than 900 km^2 of land was developed between 1973 and 2000, resulting in the loss of 315 km^2 of forest land and 529 km^2 of agricultural land (tables 3,4). The proportion of all change caused by development steadily increased throughout the study period (table 5).

Agriculture dropped from the third most common land cover in the ecoregion in 1973 to the fifth most common land cover by 2000 (table 3). The decrease in the relative abundance

Figure 3. Overall spatial change in Atlantic Coastal Pine Barrens Ecoregion (ACPB; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Atlantic Coastal Pine Barrens 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.
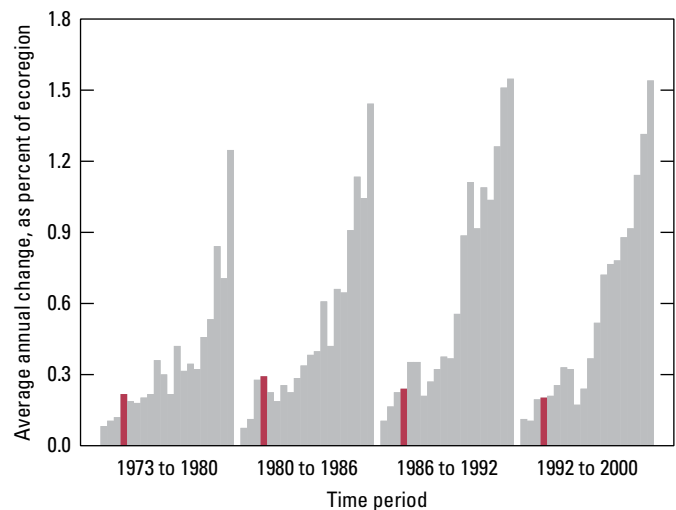
Figure 4. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Atlantic Coastal Pine Barrens Ecoregion are represented by red bars in each time period.

Figure 2. Vineyards in Atlantic Coastal Pine Barrens Ecoregion, a common sight in parts of ecoregion where variety of fruit and vegetable crops are grown.

of agricultural land is related to a strong effort to protect native ecosystems within the region, especially the unique pine barren forest. As less forested land was available for development, the proportion of developed land originating from agricultural land increased steadily and significantly (table 5).

In addition to development pressures, high tax rates have driven many farmers to switch from vegetable and fruit crops to higher valued products such as nursery stock, flowers, and sod (Hart, 1991). These factors prompted the American Farmland Trust organization to name parts of the ecoregion on Long Island and Cape Cod as one of the 20 most threatened agricultural areas in the United States (Sorensen and others, 1997).

Forested land also decreased steadily between 1973 and 2000. However, efforts to conserve these unique habitats slowed the rate of decrease in the latter half of the 27-year study period. For example, parts of the New Jersey Pine Barrens were designated as the Nation's first National Reserve (the New Jersey Pinelands National Reserve) in 1978 and later (1983) as a U.S. Biosphere Reserve (Mason, 1992; Walker and Solecki, 1999).

Forms of land-cover change other than conversion to developed were relatively minor (tables 3,4). Furthermore, changes in the next two most affected land-cover classes (mechanically disturbed and mining) often were driven by the demands of development. The mapping of mechanically disturbed land indicates a temporary, transitory state for a given area, which often leads to permanent development in the ecoregion.

The mining land-cover class showed a small increase during the study period, but most of that increase likely was related to the increased demand for sand and stone aggregates used in construction. Although urban development has occurred throughout the Atlantic Coastal Pine Barrens Ecoregion, recreational opportunities and desire for other coastal amenities also has resulted in concentrations of development along most coastlines in the ecoregion (fig. 7). These and other development pressures likely will continue to drive land-use conversions in the Atlantic Coastal Pine Barrens Ecoregion for the foreseeable future.

EXPLANATION

Land-use/land-cover class

- Water
- Developed
- Mechanically disturbed
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Nonmechanically disturbed
- Ice/Snow

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

Figure 5. Coastal development on Long Island (Hampton Bays, New York), in Atlantic Coastal Plain Pine Barrens Ecoregion.

Figure 7. Coastal housing and sand-dune-stabilization fences on Long Island (Sagaponack, New York), in Atlantic Coastal Pine Barrens Ecoregion.

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

[Most sample pixels remained unchanged (94.2 percent), whereas 5.8 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	5.5	2.0	3.5	7.5	1.2	22.6
2	0.3	0.2	0.2	0.5	0.1	29.5
3	0.0	0.0	0.0	0.0	0.0	42.1
4	0.0	0.0	0.0	0.0	0.0	57.6
Overall spatial change	5.8	2.1	3.8	7.9	1.3	22.5

Table 2.   Raw estimates of change in Atlantic Coastal Pine Barrens 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	0.5	0.9	2.0	0.3	23.2	0.2
1980–1986	1.7	0.6	1.2	2.3	0.4	20.3	0.3
1986–1992	1.4	0.5	0.9	1.9	0.3	22.2	0.2
1992–2000	1.6	0.8	0.8	2.4	0.5	31.1	0.2
Estimate of change, in square kilometers							
1973–1980	285	105	180	391	66	23.2	41
1980–1986	333	107	225	440	67	20.3	55
1986–1992	272	96	176	368	60	22.2	45
1992–2000	312	155	157	467	97	31.1	39

Table 3. Estimated area (and margin of error) of each land-cover class in Atlantic Coastal Pine Barrens 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	16.9	7.4	25.5	8.3	0.2	0.1	0.4	0.2	0.8	0.6	23.3	6.3	0.1	0.1	17.4	8.5	15.3	5.8	0.0	0.0
1980	17.0	7.4	26.5	8.4	0.0	0.0	0.5	0.2	0.8	0.6	22.8	6.1	0.1	0.2	17.0	8.3	15.2	5.9	0.0	0.0
1986	17.0	7.4	27.8	8.4	0.1	0.1	0.6	0.3	0.8	0.5	22.2	6.1	0.2	0.2	16.2	7.8	15.2	5.9	0.0	0.0
1992	17.0	7.4	28.9	8.4	0.1	0.1	0.6	0.3	0.8	0.5	21.9	6.1	0.1	0.1	15.4	7.5	15.2	5.9	0.0	0.0
2000	17.1	7.4	30.3	8.4	0.1	0.1	0.6	0.3	0.8	0.5	21.5	6.0	0.1	0.1	14.5	6.9	15.1	5.9	0.0	0.0
Net change	0.1	0.1	4.7	1.8	–0.1	0.1	0.2	0.1	0.0	0.1	–1.8	0.6	0.0	0.0	–3.0	1.9	–0.2	0.1	0.0	0.0
Gross change	0.2	0.1	4.7	1.8	0.4	0.3	0.3	0.1	0.1	0.1	1.9	0.5	0.1	0.1	3.0	1.9	0.2	0.1	0.0	0.0
Area, in square kilometers																				
1973	3,259	1,429	4,908	1,604	38	20	77	32	153	107	4,482	1,216	19	17	3,350	1,631	2,944	1,122	0	0
1980	3,270	1,425	5,105	1,619	7	4	91	40	152	107	4,385	1,182	27	29	3,266	1,589	2,926	1,127	0	0
1986	3,278	1,425	5,344	1,619	20	19	110	50	147	105	4,270	1,169	29	30	3,112	1,507	2,920	1,129	0	0
1992	3,278	1,423	5,555	1,615	17	15	122	51	147	105	4,202	1,168	21	19	2,971	1,437	2,916	1,126	0	0
2000	3,282	1,423	5,820	1,612	18	13	124	52	146	102	4,127	1,148	20	18	2,782	1,320	2,911	1,126	0	0
Net change	22	23	913	345	–19	22	47	26	–7	12	–355	111	1	2	–568	369	–34	21	0	0
Gross change	42	19	913	345	75	50	54	27	21	17	371	104	21	26	577	366	47	23	0	0

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

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

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Developed	88	45	28	0.5	30.9
	Agriculture	Developed	81	76	47	0.4	28.5
	Mechanically disturbed	Developed	22	18	11	0.1	7.7
	Forest	Mining	12	7	5	0.1	4.1
	Wetland	Agriculture	11	16	10	0.1	3.8
	Other	Other	71	n/a	n/a	0.4	25.0
		Totals	285			1.5	100.0
1980–1986	Agriculture	Developed	138	86	54	0.7	41.4
	Forest	Developed	98	32	20	0.5	29.5
	Forest	Mining	17	13	8	0.1	5.0
	Agriculture	Forest	10	6	4	0.1	3.1
	Agriculture	Mechanically disturbed	10	11	7	0.1	3.0
	Other	Other	60	n/a	n/a	0.3	17.9
		Totals	333			1.7	100.0
1986–1992	Agriculture	Developed	130	68	43	0.7	47.8
	Forest	Developed	61	25	16	0.3	22.4
	Mechanically disturbed	Developed	14	17	11	0.1	5.2
	Agriculture	Mechanically disturbed	9	11	7	0.0	3.2
	Agriculture	Forest	8	7	5	0.0	2.8
	Other	Other	50	n/a	n/a	0.3	18.6
		Totals	272			1.4	100.0
1992–2000	Agriculture	Developed	180	132	83	0.9	57.7
	Forest	Developed	68	24	15	0.4	21.9
	Mechanically disturbed	Developed	12	12	8	0.1	3.8
	Agriculture	Mechanically disturbed	8	11	7	0.0	2.6
	Forest	Mechanically disturbed	6	4	2	0.0	1.9
	Other	Other	38	n/a	n/a	0.2	12.2
		Totals	312			1.6	100.0
1973–2000 (overall)	Agriculture	Developed	529	340	213	2.8	44.0
	Forest	Developed	315	89	56	1.6	26.2
	Mechanically disturbed	Developed	49	40	25	0.3	4.0
	Forest	Mining	36	24	15	0.2	3.0
	Agriculture	Forest	28	17	11	0.1	2.3
	Other	Other	245	n/a	n/a	1.3	20.4
		Totals	1,202			6.2	100.0

Table 5. Areal percentage of all land-cover classes, and percentage of agriculture land-cover class, that changed to developed land-cover class in Atlantic Coastal Pine Barrens Ecoregion during each of four time periods between 1973 and 2000.

[Percentage of all conversions to developed land-cover class increased between 1973 and 2000, whereas percentage of developed land-cover class that converted from agriculture land-cover class also steadily increased]

Period	Developed	
	Total change (% of ecoregion)	Change from agriculture (% of ecoregion)
1973–1980	68.9	41.2
1980–1986	72.1	57.5
1986–1992	77.9	61.5
1992–2000	84.8	69.5

References Cited

Hart, J.F., 1991, The perimetropolitan bow wave: Geographical Review, v. 81, no. 1, p. 35–51.

Mason, R.J., 1992, Contested lands—Conflict and compromise in New Jersey's Pine Barrens: Philadelphia, Pa., Temple University Press, 257 p.

Sorensen, A.A., Greene, R.P., and Russ, K., 1997, Farming on the edge: American Farmland Trust, Center for Agriculture in the Environment, Northern Illinois University.

U.S. Census Bureau, 1970–2000 [various years], Census of population and housing: U.S. Census Bureau database, accessed May 9, 2013, at http://www.census.gov/prod/www/decennial.html.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Walker, R.T., and Solecki, W.D, 1999, Managing land use and land cover change—The New Jersey Pinelands Biosphere Reserve: Annals of the Association of American Geographers, v. 89, no. 2, p. 220–237.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

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Chapter 6

Northern Piedmont Ecoregion

By Roger F. Auch

Ecoregion Description

The Northern Piedmont Ecoregion, which trends northeast to southwest, covers about 30,120 km² (11,629 mi²) in New Jersey, Pennsylvania, Delaware, Maryland, the District of Columbia, and Virginia (fig. 1). The Northern Piedmont Ecoregion includes the western parts of metropolitan areas of New York, New York; Philadelphia, Pennsylvania; Baltimore, Maryland; and Washington, D.C. The ecoregion is surrounded by (counterclockwise, from the northeast) the Northeastern Coastal Zone, Northeastern Highlands, Ridge and Valley, Blue Ridge Mountains, Piedmont, Southeastern Plains, Middle Atlantic Coastal Plain, and Atlantic Coastal Pine Barrens Ecoregions.

The Northern Piedmont Ecoregion lies between the topographically flatter coastal areas to the southeast and the more mountainous regions to the west and north. The landforms include low, rounded hills, irregular plains, and open valleys (Wiken and others, 2011). Soils vary across the ecoregion, ranging from thin, stony soils on prominent ridges and low mountains to fertile, limestone-derived soils in some plains and valleys. The climate includes moderate winters and warm, humid summers, with more than 1,000 mm (40 in.) of precipitation falling in an average year.

Although the population density typically decreases from east to west across the Northern Piedmont Ecoregion, its population grew by nearly 2 million people between 1970 and 2000, reaching 11,434,000 in 2000, according to aggregated county-level data (U.S. Census Bureau, 1970–2000 [various years]). Land use varies from busy urban and suburban areas to intensively farmed and densely populated locales to relatively quiet, pastoral places. The predominant land-cover classes form a mosaic of agricultural, forested, and developed lands, but the mixture varies, depending on local conditions (figs. 2*A*,*B*,*C*). Agricultural lands range from intensively cultivated cornfields and horticultural

Figure 1. Map of Northern Piedmont 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 20 x 20 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Eastern United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

nurseries to less intensively used hayfields and pasturelands (figs. 3*A,B*). Forest typically is on land that has marginal utility for agricultural use, such as that which has steep slopes and poor-quality soils. Forested areas also are often used as various public resources (Morel and Gottmann, 1961, p. 362, 371–383; Marsh and Lewis, 1995, p. 27; Matlack, 1997).

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 Piedmont Ecoregion between 1973 and 2000 is estimated at 6.2 percent (table 1). Compared to other Eastern United States ecoregions, change in the Northern Piedmont Ecoregion was fairly low, but it placed nearly in the median position (fig. 4). Most of the

Figure 2.   Agricultural, forested, and developed lands in Northern Piedmont Ecoregion. *A*, Typical farm in Northern Piedmont Ecoregion, near Frederick, Maryland. *B*, Road through forested area in northern Virginia. *C*, Traffic at intersection in commercial area in King of Prussia, Pennsylvania, about 25 km northwest of downtown Philadelphia.

Figure 3.   Agricultural lands in Northern Piedmont Ecoregion. *A*, Corn field on outskirts of New Holland, in intensively cultivated Lancaster County, Pennsylvania. *B*, Horse fence in pasture, nestled among forested hills near Charlottesville, Virginia. Thoroughbred horse breeding is long-standing tradition in Northern Piedmont Ecoregion.
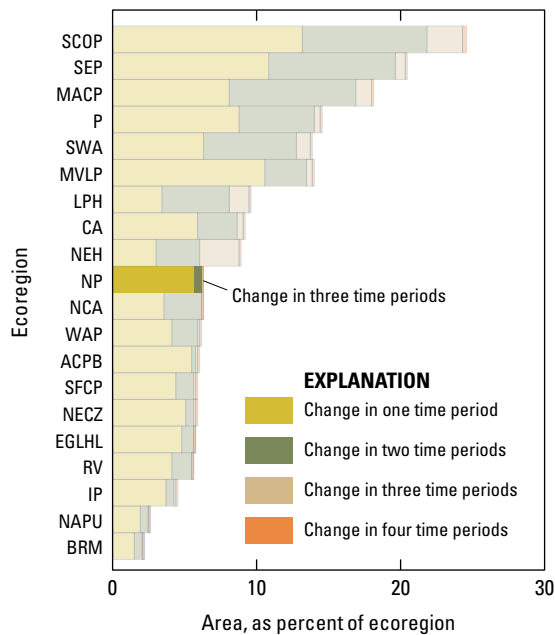
Figure 4. Overall spatial change in Northern Piedmont Ecoregion (NP; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Northern Piedmont Ecoregion (three time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

land-cover change (about 70 percent) was to newly developed land (fig. 5). The amount of change per time period was relatively low, and it was similar over time until the period between 1992 and 2000, which experienced a noticeable increase (table 2). When normalized to an average annual rate to account for uneven time periods, the period between 1992 and 2000 was still the most dynamically changing period (fig. 6). Although rates of change are not very high, they correspond to a steady increase in developed land, a near-permanent type of change. The margin of error in the study's statistical estimates was relatively low, ranging from about 0.3 to about 0.6 percent at an 85-percent confidence interval, indicating that land-cover change was more or less evenly distributed across the ecoregion (table 2).

The Northern Piedmont Ecoregion's predominant land-cover classes—agriculture, forest, and developed—experienced the greatest amounts of net change across the study period (table 3). Although change was comparatively low in the ecoregion, most change was to newly developed land, and, by the end of the study period, the developed land-cover class gained 4.6 percent, occupying more than 27 percent of the ecoregion area (table 3; fig. 7). This was one of the highest percentages of increase in the developed land-cover class among all 20 Eastern United States ecoregions.

The Northern Piedmont Ecoregion, along with the Atlantic Coastal Pine Barrens Ecoregion to the east and the Northeastern Coastal Zone Ecoregion to the northeast, constitute most of Gottmann's (1961) "Megalopolis" region
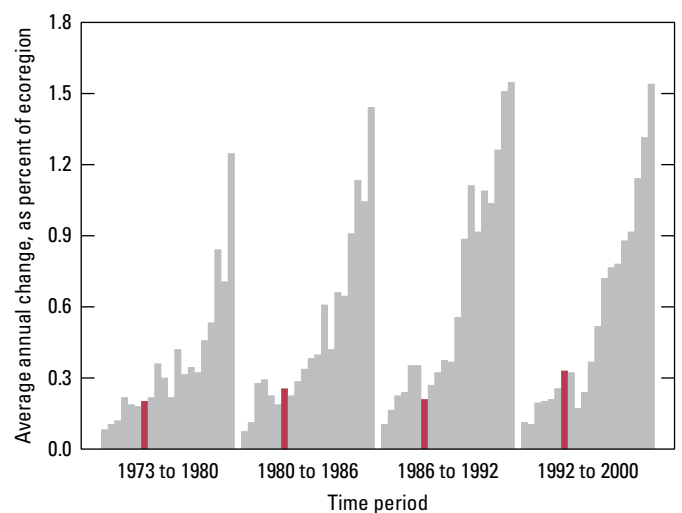
Figure 5. Land being cleared for new development along U.S. Route 322, in southeastern Chester County, Pennsylvania. Houses in background likely were built during study period (1973–2000).

Figure 6. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Northern Piedmont Ecoregion are represented by red bars in each time period.
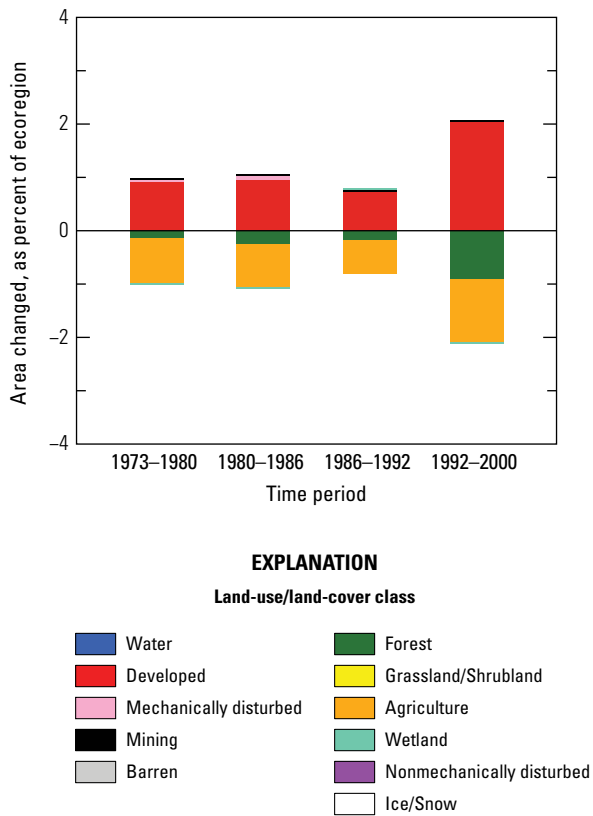
Figure 7. Normalized average net change in Northern Piedmont Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

(that is, the northeastern United States urbanizing corridor). The Northern Piedmont Ecoregion's continued urbanization can be seen in the large gains in absolute population (19.9 percent increase), occupied housing units (43.8 percent increase), and employment (39.5 percent increase) during the 27-year study period (Auch, 2002). The ecoregion continues its transformation from a once-prominent agricultural area to an urban area. In 1997, the American Farmland Trust declared the Northern Piedmont Ecoregion as the second most "endangered" farming region in the United States (Sorensen and others, 1997) (fig. 8).

The leading land-cover conversions in the Northern Piedmont Ecoregion are shown in table 4. The ecoregion gained an estimated 1,396 km^2 of newly developed land between 1973 and 2000 (table 3); most of it came from agriculture (866 km^2), but a considerable amount also came from forest (465 km^2) (table 4). An additional 59 km^2 of developed came from mechanically disturbed, probably the bulldozing or leveling of forested land or farmland for new construction. Less significant changes included conversions back and forth between agriculture and forest (agriculture to forest conversions were more prevalent in earlier time periods) and between forest and mechanically disturbed (likely related to either timber harvesting and regrowth, the clearing of forest for development, or a conversion to agriculture) (fig. 9).

The main story of land-cover change in the Northern Piedmont Ecoregion during the study period was increased urbanization, primarily through the unidirectional land-cover conversion to developed land. The amount of change was comparatively low but steady over time. Most of this newly developed land came at the expense of agricultural land and, to a lesser extent, forested land.

Figure 8. Interface between developed and agricultural land in Frederick County, Maryland, an increasingly common scene in Northern Piedmont Ecoregion.
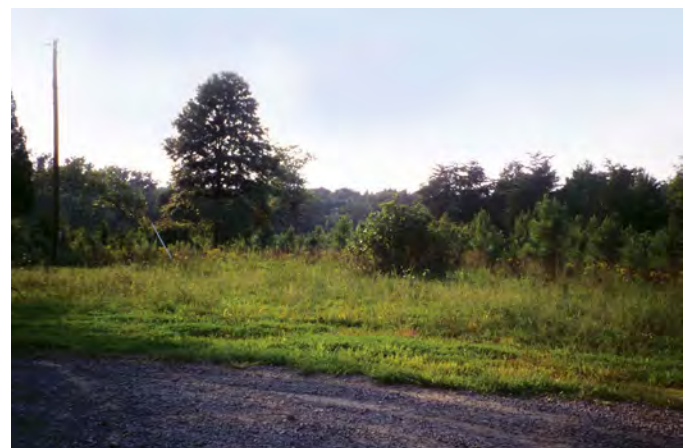
Figure 9. Young stand of planted pines southeast of Warrenton, in Fauquier County, Virginia.

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

[Most sample pixels remained unchanged (93.8 percent), whereas 6.2 percent changed at least once throughout study period. Two dashes (--) indicate that, because zero pixels changed four times during study period, relative error is not calculable]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	5.6	1.0	4.6	6.7	0.7	11.8
2	0.6	0.2	0.4	0.7	0.1	22.1
3	0.0	0.0	0.0	0.0	0.0	35.7
4	0.0	0.0	0.0	0.0	0.0	--
Overall spatial change	6.2	1.1	5.1	7.3	0.7	11.0

Table 2. Raw estimates of change in Northern Piedmont 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	0.5	0.9	1.9	0.3	22.9	0.2
1980–1986	1.5	0.3	1.2	1.9	0.2	14.2	0.3
1986–1992	1.3	0.3	1.0	1.6	0.2	15.1	0.2
1992–2000	2.6	0.6	2.1	3.2	0.3	13.3	0.3
Estimate of change, in square kilometers							
1973–1980	420	151	268	571	96	22.9	60
1980–1986	460	103	357	563	66	14.2	77
1986–1992	380	91	290	471	58	15.1	63
1992–2000	792	166	626	958	105	13.3	99

Table 3.   Estimated area (and margin of error) of each land-cover class in Northern Piedmont 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	1.5	0.5	22.7	11.7	0.1	0.1	0.3	0.1	0.0	0.0	36.9	7.2	0.1	0.1	37.7	9.4	0.8	0.4	0.0	0.0
1980	1.5	0.5	23.6	11.6	0.2	0.1	0.3	0.1	0.0	0.0	36.7	7.2	0.1	0.1	36.9	9.1	0.7	0.4	0.0	0.0
1986	1.5	0.5	24.5	11.7	0.2	0.1	0.3	0.1	0.0	0.0	36.5	7.2	0.0	0.1	36.1	9.0	0.7	0.4	0.0	0.0
1992	1.5	0.5	25.2	11.6	0.2	0.1	0.4	0.1	0.0	0.0	36.3	7.2	0.0	0.0	35.5	8.8	0.7	0.4	0.0	0.0
2000	1.5	0.5	27.3	11.5	0.2	0.2	0.4	0.1	0.0	0.0	35.4	7.0	0.0	0.0	34.4	8.6	0.7	0.4	0.0	0.0
Net change	0.0	0.0	4.6	1.1	0.1	0.1	0.1	0.0	0.0	0.0	–1.5	0.5	0.0	0.1	–3.4	1.2	0.0	0.0	0.0	0.0
Gross change	0.0	0.0	4.6	1.1	0.5	0.1	0.2	0.1	0.0	0.0	1.7	0.5	0.0	0.1	3.4	1.1	0.0	0.0	0.0	0.0
	Area, in square kilometers																			
1973	457	154	6,826	3,509	38	33	83	29	0	0	11,102	2,156	21	29	11,365	2,818	228	121	0	0
1980	460	155	7,100	3,492	47	32	89	28	0	0	11,059	2,163	19	24	11,120	2,733	226	118	0	0
1986	460	155	7,384	3,509	69	31	102	33	0	0	10,985	2,166	15	18	10,880	2,703	225	115	0	0
1992	465	154	7,604	3,502	70	27	112	35	0	0	10,930	2,171	13	15	10,702	2,666	225	115	0	0
2000	465	153	8,222	3,466	75	47	119	35	0	0	10,656	2,110	9	13	10,350	2,605	224	115	0	0
Net change	8	7	1,396	343	37	43	36	15	0	0	–446	141	–12	16	–1,015	348	–4	7	0	0
Gross change	14	7	1,396	343	153	45	46	17	0	0	523	142	14	16	1,029	338	7	6	0	0

Table 4.   Principal land-cover conversions in Northern Piedmont 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	192	151	96	0.6	45.7
	Forest	Developed	79	45	29	0.3	18.9
	Agriculture	Forest	43	34	22	0.1	10.3
	Mechanically disturbed	Forest	27	27	17	0.1	6.4
	Forest	Mechanically disturbed	20	13	9	0.1	4.9
	Other	Other	58	n/a	n/a	0.2	13.8
		Totals	420			1.4	100.0
1980–1986	Agriculture	Developed	186	77	49	0.6	40.4
	Forest	Developed	89	35	22	0.3	19.3
	Agriculture	Forest	54	26	17	0.2	11.7
	Forest	Mechanically disturbed	39	19	12	0.1	8.5
	Mechanically disturbed	Forest	22	18	11	0.1	4.7
	Other	Other	71	n/a	n/a	0.2	15.4
		Totals	460			1.5	100.0
1986–1992	Agriculture	Developed	129	47	30	0.4	33.9
	Forest	Developed	76	36	23	0.3	20.2
	Mechanically disturbed	Forest	37	23	15	0.1	9.8
	Forest	Mechanically disturbed	35	21	13	0.1	9.1
	Agriculture	Forest	29	19	12	0.1	7.6
	Other	Other	75	n/a	n/a	0.2	19.7
		Totals	380			1.3	100.0
1992–2000	Agriculture	Developed	360	136	87	1.2	45.5
	Forest	Developed	221	73	46	0.7	27.9
	Forest	Mechanically disturbed	61	42	27	0.2	7.7
	Mechanically disturbed	Developed	34	17	11	0.1	4.3
	Forest	Agriculture	34	19	12	0.1	4.3
	Other	Other	82	n/a	n/a	0.3	10.3
		Totals	792			2.6	100.0
1973–2000 (overall)	Agriculture	Developed	866	332	211	2.9	42.2
	Forest	Developed	465	135	86	1.5	22.7
	Forest	Mechanically disturbed	156	80	51	0.5	7.6
	Agriculture	Forest	148	74	47	0.5	7.2
	Mechanically disturbed	Forest	108	75	48	0.4	5.3
	Other	Other	309	n/a	n/a	1.0	15.1
		Totals	2,052			6.8	100.0

References Cited

Auch, R.F., 2002, Land use/land cover change in the Northern Piedmont Ecoregion, 1970–2000: Brookings, South Dakota State University, Master's thesis, 211 p.

Gottmann, J., 1961, Megalopolis—The urbanized northeastern seaboard of the United States: New York, The Twentieth Century Fund, 810 p.

Marsh, B., and Lewis, P., 1995, Landforms and human habitat, *in* Miller, E.W., ed., A geography of Pennsylvania: University Park, Pennsylvania State University Press, p. 17–43.

Matlack, R.G., 1997, Four centuries of forest clearance and regeneration in the hinterland of a large city: Journal of Biogeography, v. 24, p. 281–295.

Morel, H., and Gottmann, J., 1961, The woodlands—Their uses and wildlife, *in* Gottmann, J., Megalopolis—The urbanized northeastern seaboard of the United States: New York, The Twentieth Century Fund, p. 341–383.

Sorensen, A.A., Greene, R.B., and Russ, K., 1997, Farming on the edge: DeKalb, Ill., American Farmland Trust, Center for Agriculture in the Environment, 29 p.

U.S. Census Bureau, 1970–2000 [various years], Census of population and housing: U.S. Census Bureau database, accessed May 9, 2013, at http://www.census.gov/prod/www/decennial.html.

Vogelmann, J.M., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

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Chapter 7

Northern Appalachian Plateau and Uplands Ecoregion

By Mark S. Brooks

Ecoregion Description

The Northern Appalachian Plateau and Uplands Ecoregion, which is located in south-central New York and northeastern Pennsylvania, covers about 29,919 km^2 (11,552 mi^2) (fig. 1). The ecoregion is bounded on the north by the Eastern Great Lakes and Hudson Lowlands Ecoregion; on the east, by the Northeastern Highlands and North Central Appalachians Ecoregions; on the south, by the Ridge and Valley and North Central Appalachians Ecoregions; and on the far west, by the Erie Drift Plains Ecoregion. The ecoregion spans the area between the less irregular, more agricultural and urbanized ecoregions to the north and west and the more mountainous and forested, less populated ecoregions to the south and east (Wiken and others, 2011). The landscape is rural, with rolling hills and fertile stream valleys. The climate in the ecoregion is temperate: average temperature in January is –6.1°C and, in July, is 20.7°C; average annual precipitation is more than 940 mm (37 in.) (National Oceanic and Atmospheric Administration, 2002).

Forest and agriculture are the dominant land-cover classes in the Northern Appalachian Plateau and Uplands Ecoregion (fig. 2). The forest is composed of northern hardwoods that include sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), white ash (*Fraxinus americana*), American beech (*Fagus grandifolia*), northern red oak (*Quercus rubra*), sweet cherry (*Prunus avium*), and eastern

EXPLANATION

Land-use/land-cover class

- Water
- Developed
- Mechanically disturbed
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Ice/Snow
- Ecoregion boundary
- Sample block (10 x 10 km)

Figure 1. Map of Northern Appalachian Plateau and Uplands 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 Eastern United States ecoregions are listed in appendix 2. Also shown is part of one Midwest–South Central United States ecoregion, Erie Drift Plains. See appendix 3 for definitions of land-use/land-cover classifications.

hemlock (*Tsuga canadensis*) (Smallidge, 1998). Dairy and cattle farming, along with the production of corn, wheat, and hay, are the major agricultural activities in the ecoregion (Fick and Cox, 1995) (fig. 3).

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 Appalachian Plateau and Uplands Ecoregion between 1973 and 2000 is estimated at 2.4 percent (table 1). Compared to other Eastern United States ecoregions, change in the Northern Appalachian Plateau and Uplands Ecoregion was very low (fig. 4): an estimated 1.8 percent changed land cover one time, and only 0.7 percent changed multiple times (table 1).

The estimated change per time period varied modestly during the 27-year study period (fig. 5). The first two time
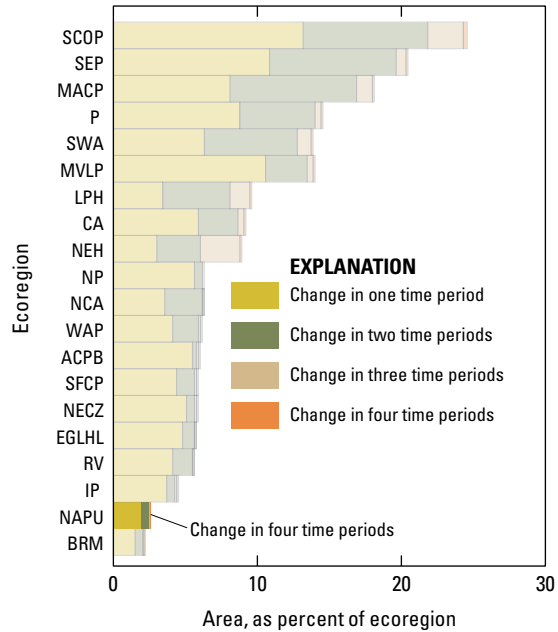
Figure 4. Overall spatial change in Northern Appalachian Plateau and Uplands Ecoregion (NAPU; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Northern Appalachian Plateau and Uplands Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Figure 2. Typical farm in Northern Appalachian Plateau and Uplands Ecoregion.

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Northern Appalachian Plateau and Uplands Ecoregion are represented by red bars in each time period.

Figure 3. Cattle grazing in open pasture, in Northern Appalachian Plateau and Uplands Ecoregion.

periods (1972–1980, 1980–1986) experienced a change of 0.7 percent. The third time period (1986–1992) had the only increase in change, from 0.7 to 1.0 percent. Finally, in the last time period (1992–2000), the change was 0.8 percent. The margin of error at the 85-percent confidence level was very low during all time periods, ranging from about 0.2 to about 0.3 percent. When normalized to an average annual rate to account for uneven time periods, the average annual rate of change for each time period was 0.1 percent, with the exception of the third time period (1986–1992), which had a rate of change of 0.2 percent (table 2). Overall, the land cover in the Northern Appalachian Plateau and Uplands Ecoregion was extremely stable throughout the study period.

The dominant land-cover classes in the Northern Appalachian Plateau and Uplands Ecoregion in 2000
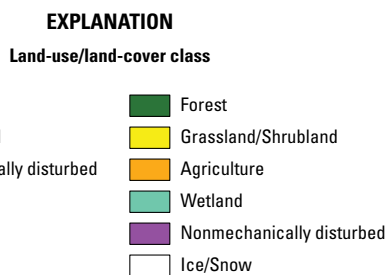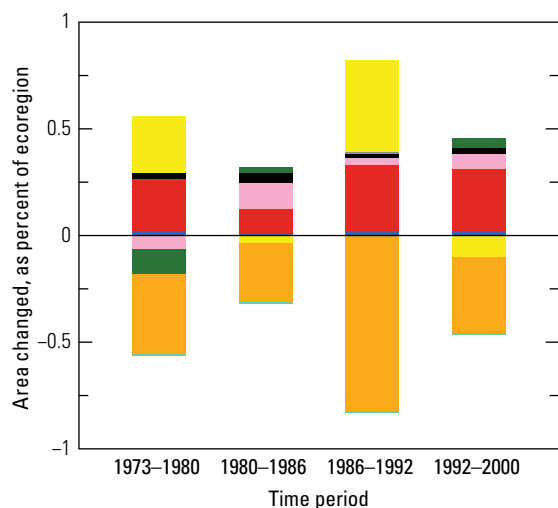
Figure 6. Normalized average net change in Northern Appalachian Plateau and Uplands Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

were forest (60.0 percent), agriculture (33.9 percent), and developed (3.3 percent) (table 3). Net change for all land-cover classes, with the exception of agriculture, was modest during the study period (1973–2000). Agriculture had the largest net change, with a 0.9 percent loss of ecoregion area between 1973 and 2000. Land-cover classes that gained ecoregion area at the expense of agriculture included developed (0.5 percent increase) and grassland/shrubland (0.3 percent increase) (table 3; fig. 6).

The top two land-cover conversions during the study period pointed to the overall loss of agricultural land in the ecoregion: an estimated 161 km^2 of agricultural land converted to grassland/shrubland, and 159 km^2 converted to forest (table 4). The third-leading conversion was from grassland/shrubland to forest (136 km^2). The second- and third-leading conversions resulted from the natural progression of abandoned agricultural land reverting back to forest. Principal factors that contribute to the abandonment of agricultural lands are hilly topography, poor road access, poor drainage, and poor soil (Flinn and others, 2005). The fourth- and fifth-leading conversions involved the clearing of forest for agricultural land (125 km^2) and the mechanical disturbance of forested land because of timber harvesting (85 km^2) (table 4).

Land cover in the Northern Appalachian Plateau and Uplands Ecoregion was stable throughout the study period (1973–2000). The loss of agricultural land was the most significant land-cover change, as farmland decreased in each time period. The greatest amount of agricultural land was abandoned during the period between 1986 and 1992, with an estimated 148 km^2 converting to forested land, grassland/shrubland, or developed land (table 4; fig. 7).

Figure 7. Abandoned agricultural land (pasture) reverting to grassland/shrubland, a common type of land-cover change in Northern Appalachian Plateau and Uplands Ecoregion.

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

[Most sample pixels remained unchanged (97.6 percent), whereas 2.4 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	1.8	0.5	1.3	2.4	0.4	19.6
2	0.6	0.2	0.3	0.8	0.2	30.4
3	0.1	0.0	0.0	0.1	0.0	30.0
4	0.0	0.0	0.0	0.0	0.0	94.8
Overall spatial change	2.4	0.7	1.8	3.1	0.4	18.4

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

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

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	0.7	0.3	0.4	1.0	0.2	29.7	0.1
1980–1986	0.7	0.2	0.5	0.8	0.1	17.4	0.1
1986–1992	1.0	0.3	0.7	1.3	0.2	20.4	0.2
1992–2000	0.8	0.3	0.5	1.1	0.2	24.0	0.1
Estimate of change, in square kilometers							
1973–1980	215	94	121	310	64	29.7	31
1980–1986	196	50	146	246	34	17.4	33
1986–1992	294	89	206	383	60	20.4	49
1992–2000	236	84	152	319	57	24.0	29

Table 3.   Estimated area (and margin of error) of each land-cover class in Northern Appalachian Plateau and Uplands 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	0.9	0.2	2.8	0.8	0.0	0.0	0.1	0.0	0.0	0.0	60.1	2.3	0.1	0.0	34.9	2.4	1.2	0.4	0.0	0.0
1980	0.9	0.2	2.9	0.8	0.0	0.0	0.1	0.0	0.0	0.0	60.0	2.3	0.2	0.1	34.7	2.5	1.2	0.4	0.0	0.0
1986	0.9	0.2	3.0	0.8	0.1	0.0	0.1	0.1	0.0	0.0	60.0	2.3	0.2	0.1	34.5	2.5	1.2	0.4	0.0	0.0
1992	0.9	0.2	3.1	0.9	0.1	0.0	0.1	0.1	0.0	0.0	60.0	2.2	0.4	0.2	34.1	2.5	1.2	0.4	0.0	0.0
2000	0.9	0.2	3.3	0.9	0.1	0.1	0.2	0.1	0.0	0.0	60.0	2.2	0.3	0.1	33.9	2.5	1.2	0.4	0.0	0.0
Net change	0.0	0.0	0.5	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.3	0.1	–0.9	0.6	0.0	0.0	0.0	0.0
Gross change	0.0	0.0	0.5	0.2	0.4	0.1	0.1	0.0	0.0	0.0	1.3	0.3	0.7	0.3	1.6	0.5	0.0	0.0	0.0	0.0
									Area, in square kilometers											
1973	264	55	829	234	14	12	29	13	0	0	17,973	697	17	11	10,429	733	365	128	0	0
1980	267	55	866	246	6	5	34	15	0	0	17,954	693	56	26	10,373	747	364	128	0	0
1986	269	56	885	245	23	9	40	17	0	0	17,958	688	51	22	10,331	744	362	128	0	0
1992	271	56	932	256	27	13	44	19	1	1	17,958	673	116	51	10,208	753	362	128	0	0
2000	274	56	975	269	39	22	47	20	1	1	17,966	662	101	43	10,155	755	361	128	0	0
Net change	10	4	146	74	24	25	18	10	1	1	–7	97	84	39	–273	177	–3	3	0	0
Gross change	12	5	146	74	112	30	21	10	1	1	392	90	219	93	466	151	4	3	0	0

Table 4.   Principal land-cover conversions in Northern Appalachian Plateau and Uplands 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	Forest	59	48	32	0.2	27.4
	Forest	Agriculture	49	39	26	0.2	22.9
	Agriculture	Grassland/Shrubland	36	23	16	0.1	16.7
	Forest	Developed	24	15	10	0.1	11.0
	Agriculture	Developed	13	10	7	0.0	6.1
	Other	Other	34	n/a	n/a	0.1	15.9
		Totals	215			0.7	100.0
1980–1986	Grassland/Shrubland	Forest	41	24	16	0.1	20.7
	Agriculture	Grassland/Shrubland	34	17	11	0.1	17.5
	Forest	Agriculture	33	18	12	0.1	16.9
	Agriculture	Forest	32	14	10	0.1	16.1
	Forest	Mechanically disturbed	20	9	6	0.1	10.4
	Other	Other	36	n/a	n/a	0.1	18.4
		Totals	196			0.7	100.0
1986–1992	Agriculture	Grassland/Shrubland	67	42	29	0.2	22.8
	Agriculture	Forest	52	24	16	0.2	17.8
	Agriculture	Developed	29	23	15	0.1	9.9
	Grassland/Shrubland	Forest	29	14	9	0.1	9.8
	Forest	Agriculture	27	13	9	0.1	9.2
	Other	Other	90	n/a	n/a	0.3	30.5
		Totals	294			1.0	100.0
1992–2000	Grassland/Shrubland	Forest	62	39	27	0.2	26.2
	Forest	Mechanically disturbed	34	19	13	0.1	14.3
	Agriculture	Grassland/Shrubland	24	18	12	0.1	10.3
	Agriculture	Developed	22	13	9	0.1	9.5
	Mechanically disturbed	Grassland/Shrubland	21	12	8	0.1	8.9
	Other	Other	73	n/a	n/a	0.2	30.9
		Totals	236			0.8	100.0
1973–2000 (overall)	Agriculture	Grassland/Shrubland	161	89	60	0.5	17.2
	Agriculture	Forest	159	60	40	0.5	16.9
	Grassland/Shrubland	Forest	136	69	47	0.5	14.4
	Forest	Agriculture	124	68	46	0.4	13.1
	Forest	Mechanically disturbed	85	25	17	0.3	9.1
	Other	Other	276	n/a	n/a	0.9	29.4
		Totals	941			3.1	100.0

References Cited

Fick, Gary W., and Cox, William J., 1995, The agronomy of dairy farming in New York State: Ithaca, N.Y., Cornell University, Department of Soil, Crop and Atmospheric Sciences, SCAS Teaching Series No. T95-1, 8 p.

Flinn, Kathryn M., Vellend, Mark, and Marks, P.L., 2005, Environmental causes and consequences of forest clearance and agricultural abandonment in central New York, USA: Journal of Biogeography, v. 32, p. 439–452.

National Oceanic and Atmospheric Administration, 2002, Monthly station normals of temperature, precipitation, and heating and cooling degree days, 1971–2000—New York [revised]: National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Climatography of the United States No. 81, 36 p., accessed November 6, 2013, at http://www.ncdc.noaa.gov/climatenormals/clim81/NYnorm.pdf.

Smallidge, Peter, 1998, New York's forests—Then and now: The New York Forest Owner, v. 36, no. 1, p. 8-9.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

Status and Trends of Land Change in the Eastern United States—1973 to 2000
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Chapter 8

North Central Appalachians Ecoregion

By Kristi L. Sayler

Ecoregion Description

The North Central Appalachians Ecoregion is a forested, sedimentary upland area punctuated by high hills and low mountains (Woods and others, 1996). The ecoregion, which covers about 30,522 km^2 (11,784 mi^2), consists of two parts (fig. 1). The unglaciated western part of the ecoregion is surrounded by (clockwise, from the north) the Northern Appalachian Plateau and Uplands, Ridge and Valley, Central Appalachians, Western Allegheny Plateau, and Erie Drift Plains Ecoregions. This part of the ecoregion, which lies along the headwaters of the Allegheny and Susquehanna Rivers in northern-central Pennsylvania, with a small fraction in southern New York, is at the northern fringe of the Appalachian coal belt and includes substantial parts of Pennsylvania's oil and gas production (Woods and others, 1996). This forested landscape also supports the major economic activities of forestry and recreation (figs. 2,3). The eastern part of the ecoregion is surrounded by (clockwise, from the north) the Northeastern Highlands, Eastern Great Lakes and Hudson Lowlands, Ridge and Valley, and Northern Appalachian Plateau and Uplands Ecoregions. This part of the ecoregion includes the Pocono Mountains of Pennsylvania and parts of the Catskill Mountains of New York and New Jersey, which range from low mountains to rolling hills, as well as a dissected plateau at the east edge of the Allegheny Front (Ackroyd-Kelly, 1987). This area historically has provided an accessible, rural recreation oasis for generations of residents of nearby New York and Philadelphia. The climate of the North Central Appalachians Ecoregion is continental, with cool summers and cold winters. The average annual precipitation ranges from 825 to 1,250 mm (33 to 50 in.).

Figure 1. Map of North Central Appalachians 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 20 x 20 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Eastern United States ecoregions are listed in appendix 2. Also shown is part of one Midwest–South Central United States ecoregion, Erie Drift Plains. See appendix 3 for definitions of land-use/land-cover classifications.

Figure 2.   Area of predominately forest and scattered agriculture, in North Central Appalachians Ecoregion.

Figure 3.   Recreation area along Allegheny River, near Tidioute, Pennsylvania.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the North Central Appalachians Ecoregion between 1973 and 2000 is estimated at 6.2 percent (table 1). Compared to other Eastern United States ecoregions, change in the North Central Appalachians Ecoregion was fairly low (fig. 4): of the 6.2 percent that changed, nearly one-half changed multiple times. When normalized to an average annual rate to account for uneven time periods, the change per time period ranged from 1.5 to 2.9 percent, with margins of error ranging from 0.7 to 1.4 percent at the 85-percent confidence level (table 2). The average annual rates of change were highest during the period between 1980 and 1986, with an average rate of 0.4 percent per year (fig. 5; table 2); however, this number would have been substantially lower had there not been a cluster of about 42 tornadoes on May 31, 1985 (Monfredo, 1999), which deforested a significant part of the ecoregion. The tornado damage and subsequent return of the affected land
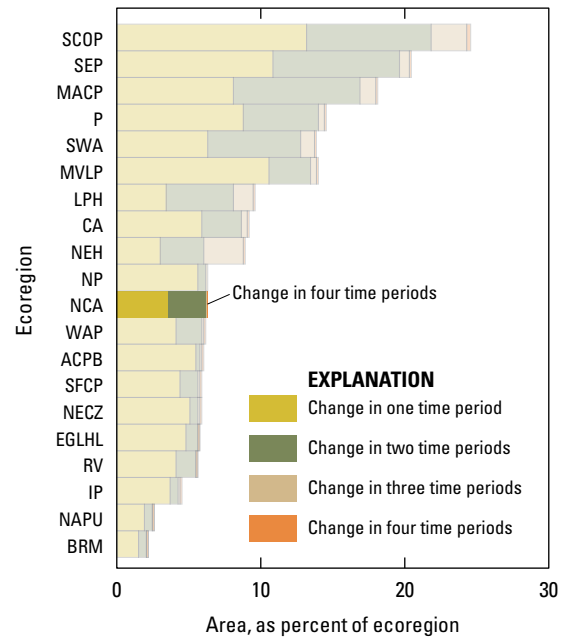
Figure 4.   Overall spatial change in North Central Appalachians Ecoregion (NCA; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in North Central Appalachians 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 20 Eastern United States ecoregions (gray bars). Estimates of change for North Central Appalachians Ecoregion are represented by red bars in each time period.

cover to prestorm conditions constituted about 8.1 percent of the total change between 1980 and 2000 in the ecoregion.

Forest constituted 87.4 percent of the ecoregion land cover in 1973, and it decreased by only 0.8 percent during the study period to 86.6 percent in 2000 (table 3). This decrease mostly is attributed to forest clearcutting in the ecoregion and also forest loss caused by the tornado activity in 1985 (fig. 6). These clearcuts, which primarily represent the harvesting of hardwood trees for lumber and other wood products, are shown as conversions from forest to mechanically disturbed (fig. 7). The ecoregion is known for its exceptionally high quality of sweet cherry (*Prunus avium*); other hardwoods commonly harvested include yellow poplar (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), red maple (*Acer rubrum*), and sugar maple (*Acer saccharum*) (Napton and others, 2003).

Both mining and developed had either very small or zero percent increases in all time periods. Surface coal mining, quarries, gravel pits, and natural-gas-field developments
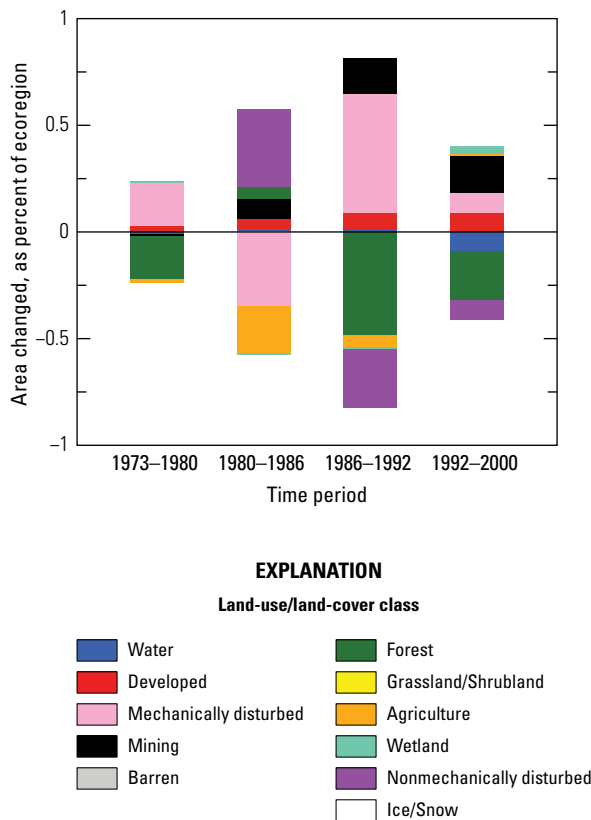
Figure 7. Small sawmill in North Central Appalachians Ecoregion, about 16 km northwest of Port Jervis, New York.

Figure 8. Modular homes waiting to be transferred to housing sites, in North Central Appalachians Ecoregion.

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

all contributed to the 0.3 percent increase in mining in the ecoregion. Developed increased slightly (0.3 percent), primarily in the eastern part of the ecoregion where nearness to the Pocono and Catskill Mountains enables individuals to have second homes and still live and work near New York City (fig. 8).

All the leading land-cover conversions were related to the vast forests of the North Central Appalachians Ecoregion. Forest to mechanically disturbed and also mechanically disturbed to forest were the top two land-cover conversions during all time periods (table 4). These two conversions were related to the forest harvest-and-regrowth cycles of the timber industry. The other main agent of land-cover change was tornado activity, shown as the conversion from forest to nonmechanically disturbed between 1980 and 1986 and then the subsequent conversion of nonmechanically disturbed to forest as the affected forest areas regenerated (table 4). Overall, these conversions accounted for 80.5 percent of the area that changed in the ecoregion during the 27-year study period.

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

[Most sample pixels remained unchanged (93.8 percent), whereas 6.2 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	3.5	0.9	2.5	4.4	0.6	17.2
2	2.6	1.1	1.5	3.7	0.7	27.4
3	0.1	0.0	0.0	0.1	0.0	31.8
4	0.0	0.0	0.0	0.0	0.0	42.3
Overall spatial change	6.2	2.0	4.2	8.1	1.3	20.3

Table 2. Raw estimates of change in North Central Appalachians 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	0.8	0.8	2.3	0.5	31.7	0.2
1980–1986	2.3	1.4	0.9	3.7	0.9	39.2	0.4
1986–1992	2.2	0.7	1.5	3.0	0.5	21.2	0.4
1992–2000	2.9	0.7	2.2	3.7	0.5	16.2	0.4
Estimate of change, in square kilometers							
1973–1980	463	231	232	693	147	31.7	66
1980–1986	694	429	266	1,123	272	39.2	116
1986–1992	676	225	451	901	143	21.2	113
1992–2000	898	229	669	1,126	145	16.2	112

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

	Water		Developed		Me-chanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
	Area, in percent stratum																			
1973	1.5	0.9	1.3	0.9	1.0	0.5	0.4	0.3	0.0	0.0	87.4	3.9	0.0	0.0	7.4	3.8	1.0	0.7	0.0	0.0
1980	1.5	0.9	1.3	0.9	1.2	0.6	0.4	0.3	0.0	0.0	87.2	3.9	0.0	0.0	7.4	3.8	1.0	0.7	0.0	0.0
1986	1.5	0.9	1.4	1.0	0.8	0.3	0.5	0.4	0.0	0.0	87.3	3.8	0.0	0.0	7.2	3.8	1.0	0.7	0.4	0.4
1992	1.5	0.9	1.5	1.1	1.4	0.5	0.6	0.6	0.0	0.0	86.8	3.8	0.0	0.0	7.1	3.8	1.0	0.7	0.1	0.1
2000	1.4	0.9	1.6	1.1	1.5	0.4	0.8	0.8	0.0	0.0	86.6	3.8	0.0	0.0	7.1	3.8	1.1	0.7	0.0	0.0
Net change	–0.1	0.1	0.3	0.2	0.5	0.6	0.4	0.5	0.0	0.0	–0.9	1.0	0.0	0.0	–0.3	0.3	0.0	0.0	0.0	0.0
Gross change	0.1	0.1	0.3	0.2	1.7	0.6	0.6	0.5	0.0	0.0	2.8	0.8	0.0	0.0	0.3	0.3	0.1	0.1	0.7	0.8
	Area, in square kilometers																			
1973	451	284	400	283	297	151	118	93	1	1	26,684	1,203	1	1	2,256	1,157	313	204	0	0
1980	447	282	409	289	358	186	117	94	1	1	2,6621	1,192	1	1	2,252	1,152	315	206	0	0
1986	451	284	426	299	251	102	143	110	1	1	26,638	1,156	1	1	2,186	1,149	312	203	112	117
1992	455	287	452	321	420	146	195	169	1	1	26,490	1,173	1	1	2,171	1,145	309	202	28	28
2000	428	261	481	333	448	137	247	233	1	1	26,418	1,160	1	1	2,175	1,147	321	208	2	3
Net change	–22	25	81	54	151	186	129	159	0	0	–267	297	0	0	–82	97	8	9	2	3
Gross change	40	38	86	53	522	182	174	150	0	0	845	255	0	0	102	98	27	31	222	232

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

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

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	210	115	73	0.7	45.3
	Mechanically disturbed	Forest	162	81	51	0.5	34.9
	Forest	Mining	22	16	10	0.1	4.7
	Agriculture	Forest	16	18	12	0.1	3.4
	Mining	Mechanically disturbed	14	21	13	0.0	3.1
	Other	Other	40	n/a	n/a	0.1	8.6
		Totals	463			1.5	100.0
1980–1986	Mechanically disturbed	Forest	268	170	108	0.9	38.6
	Forest	Mechanically disturbed	162	83	53	0.5	23.3
	Forest	Nonmechanically disturbed	108	114	73	0.4	15.5
	Agriculture	Forest	63	92	58	0.2	9.0
	Forest	Mining	35	31	20	0.1	5.0
	Other	Other	60	n/a	n/a	0.2	8.6
		Totals	694			2.3	100.0
1986–1992	Forest	Mechanically disturbed	305	118	75	1.0	45.1
	Mechanically disturbed	Forest	136	73	46	0.4	20.2
	Nonmechanically disturbed	Forest	83	89	57	0.3	12.4
	Forest	Mining	61	63	40	0.2	9.1
	Forest	Developed	27	17	11	0.1	3.9
	Other	Other	63	n/a	n/a	0.2	9.4
		Totals	676			2.2	100.0
1992–2000	Forest	Mechanically disturbed	379	119	75	1.2	42.2
	Mechanically disturbed	Forest	362	134	85	1.2	40.3
	Forest	Mining	56	69	44	0.2	6.2
	Forest	Developed	27	14	9	0.1	3.0
	Nonmechanically disturbed	Forest	26	26	16	0.1	2.9
	Other	Other	48	n/a	n/a	0.2	5.4
		Totals	898			2.9	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	1,055	348	221	3.5	38.6
	Mechanically disturbed	Forest	928	390	248	3.0	34.0
	Forest	Mining	174	163	104	0.6	6.4
	Nonmechanically disturbed	Forest	110	114	72	0.4	4.0
	Forest	Nonmechanically disturbed	108	114	73	0.4	3.9
	Other	Other	357	n/a	n/a	1.2	13.1
		Totals	2,730			8.9	100.0

References Cited

Ackroyd-Kelly, I.H., 1987, The near country—The historical geography of Pocono resorts: The Pennsylvania Geographer, v. 25, no. 1, p. 18–23.

Monfredo, W., 1999, Significant tornado activity in southwestern Pennsylvania: The Pennsylvania Geographer, v. 37, no. 2, p. 43–63.

Napton, D., Sohl, T.L., Auch, R.F., and Loveland, T.R., 2003, Land use and land cover change in the North Central Appalachians ecoregion: The Pennsylvania Geographer, v. 41, no.2, p. 46–66.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Woods, A.J., Omernik, J.M., Brown, D.D., and Kiilsgaard, C.W., 1996, Level III and IV ecoregions of Pennsylvania and the Blue Ridge Mountains, the Ridge and Valley, and Central Appalachians of Virginia, West Virginia, and Maryland: U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oreg., EPA/600/R-96/077, 50 p.

Status and Trends of Land Change in the Eastern United States—1973 to 2000
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Chapter 9

Western Allegheny Plateau Ecoregion

By Kristi L. Sayler

Ecoregion Description

The Western Allegheny Plateau Ecoregion covers about 84,738 km² (32,717 mi²) (fig. 1) in parts of southwestern Pennsylvania, southeastern Ohio, northwestern West Virginia, and northeastern Kentucky (Wiken and others, 2011). The ecoregion is surrounded by (clockwise, from the northernmost part) the North Central Appalachians, Central Appalachians, Southwestern Appalachians, Interior Plateau, Eastern Corn Belt Plains, and Erie Drift Plains Ecoregions.

The Western Allegheny Plateau Ecoregion's forest mostly is mixed oak (*Quercus* spp.), and mixed-temperate forests still exist today (2016) on most of the remaining rounded hills that have not been mined. Dairy, livestock, and general farming, as well as residential developments, are concentrated in the valleys (fig. 2). Pittsburgh, Pennsylvania, which is the largest urban area in the ecoregion, has shown some expansion despite an overall population decrease in the ecoregion. Coal mining is still active in parts of Pennsylvania, West Virginia, Kentucky, and, to a lesser extent, Ohio (figs. 3,4). The Ohio and Allegheny Rivers have been adversely affected in the ecoregion in the past by acid-mine drainage and industrial pollution, which has caused degradation of the stream habitats and loss of fish species (Cooper, 1983); however, water quality has improved somewhat, and a few species have returned to the area.

Figure 1. Map of Western Allegheny 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 Eastern United States ecoregions are listed in appendix 2. Also shown are parts of three Midwest–South Central United States ecoregions: Eastern Corn Belt Plains, Erie Drift Plains, and Huron/Erie Lake Plains (HELP). See appendix 3 for definitions of land-use/land-cover classifications.
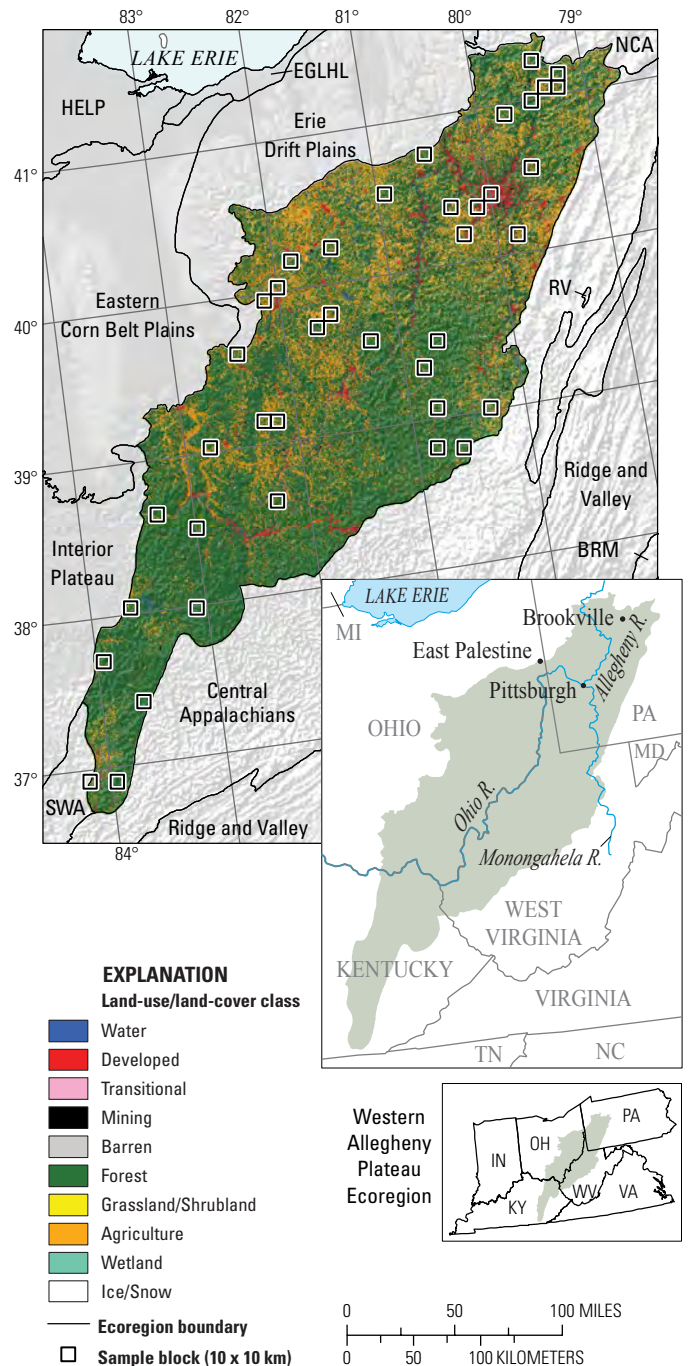
Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Western Allegheny Plateau Ecoregion between 1973 and 2000 is estimated at 6.1 percent (table 1). Compared to other Eastern United States ecoregions, change in the Western Allegheny Plateau Ecoregion was low (fig. 5): an estimated 4.0 percent changed only one time. The other 2.1 percent that changed multiple times (table 1) likely was the result of coal-mining and timber-harvesting activities, which tend to cycle through multiple land-cover conversions. The change per time period ranged from 1.9 to 2.2 percent, with margins of error ranging from 0.5 to 0.8 percent at the 85-percent confidence level (table 2). When normalized to an average annual rate to account for unequal time periods, the period between 1986 and 1992 had the greatest rate of change, at 0.4 percent (table 2; fig. 6). This was a period of change for the coal-mining regions of Ohio and West Virginia: Ohio coal production was decreasing

because of stricter regulations on surface mining and higher environmental emission standards than at previous times (Crowell, 1995), whereas West Virginia showed an increase in the extraction of low-sulfur coal (Fox, 1999) in order to meet the Federal standards of the 1990 Clean Air Act.

Most land-cover classes in the Western Allegheny Plateau Ecoregion experienced little change during the 27-year

Figure 4. Coal mining south of East Palestine, Ohio.

Figure 2. Fields of corn and oats in valley and forested hills in background, in Western Allegheny Plateau Ecoregion.

Figure 3. Hayfield in foreground and coal mine on horizon, southwest of Brookville, Pennsylvania.
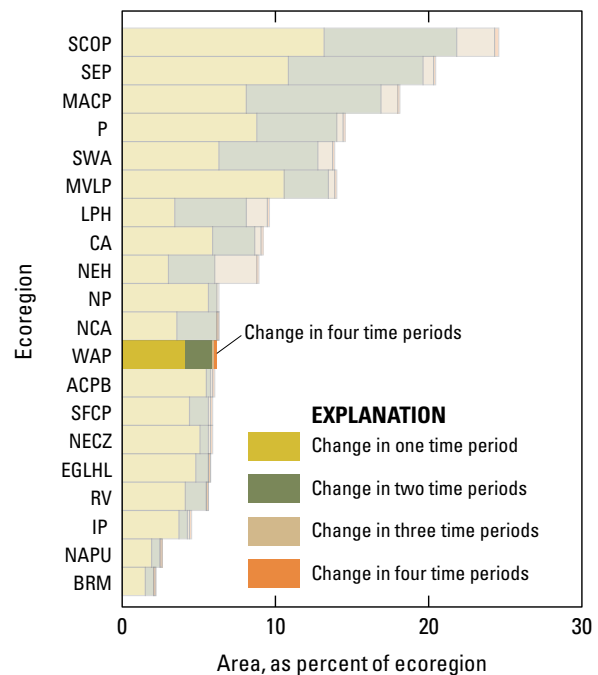
Figure 5. Overall spatial change in Western Allegheny Plateau Ecoregion (WAP; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Western Allegheny 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.

study period (table 3). Forest and agriculture showed steady decreases, whereas developed increased during each time period, resulting in an increase of 423 km² between 1973 and 2000 (table 3; fig. 7). Grassland/shrubland increased from 1.5 percent of the ecoregion in 1973 to 2.6 percent in 2000. Grassland/shrubland had net increases in all four time periods, whereas mining and forest showed decreases in most time periods. Net changes in other land-cover classes fluctuated throughout the study period (1973–2000) (fig. 8).

   With a few exceptions for timber cutting, the top three leading land-cover conversions during each time period (that is, mining to grassland/shrubland, grassland/shrubland to forest, and forest to mining) were related to coal-mining activities in the ecoregion (table 4). Mining and forest-clearing activities caused the most common net changes in the Western Allegheny Plateau Ecoregion.
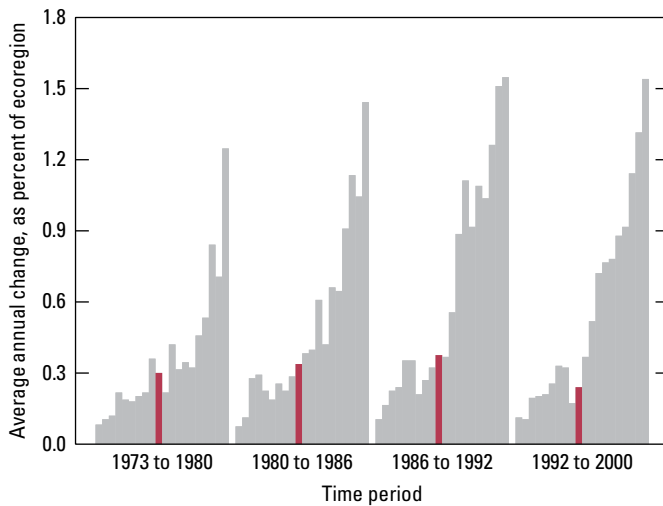
Figure 6.   Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Western Allegheny Plateau Ecoregion are represented by red bars in each time period.

Figure 7.   New housing tract in suburb southeast of Pittsburgh, Pennsylvania.

EXPLANATION

Land-use/land-cover class

- Water
- Developed
- Mechanically disturbed
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Nonmechanically disturbed
- Ice/Snow
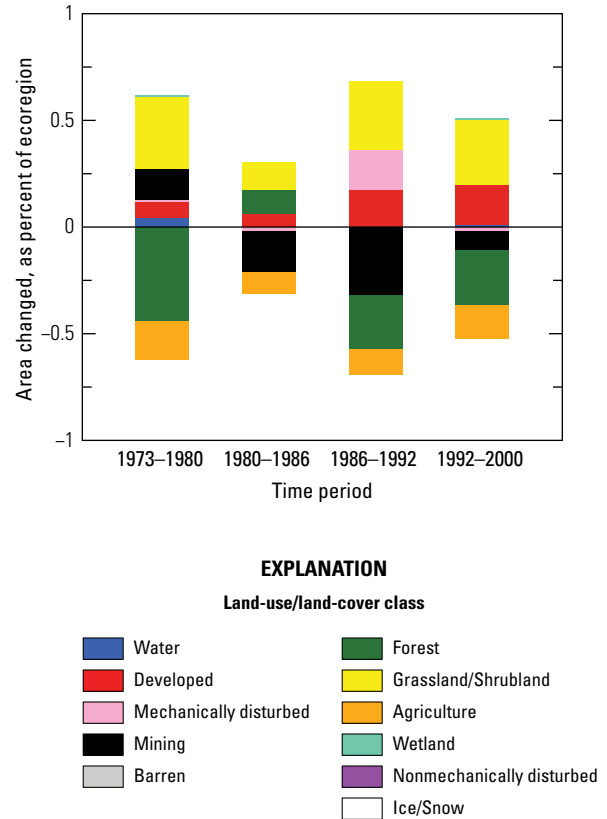
Figure 8.   Normalized average net change in Western Allegheny Plateau Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

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

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

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	4.0	0.7	3.3	4.8	0.5	12.1
2	1.9	0.6	1.3	2.5	0.4	22.3
3	0.2	0.1	0.1	0.2	0.1	32.6
4	0.0	0.0	0.0	0.0	0.0	48.6
Overall spatial change	6.1	1.3	4.8	7.4	0.9	14.7

Table 2. Raw estimates of change in Western Allegheny 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 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	0.6	1.5	2.6	0.4	18.4	0.3
1980–1986	2.0	0.8	1.2	2.8	0.5	26.4	0.3
1986–1992	2.2	0.6	1.7	2.8	0.4	17.9	0.4
1992–2000	1.9	0.5	1.5	2.4	0.3	16.8	0.2
Estimate of change, in square kilometers								
1973–1980	1,755	474	1,281	2,230	323	18.4	251
1980–1986	1,721	666	1,055	2,387	454	26.4	287
1986–1992	1,898	500	1,398	2,398	341	17.9	316
1992–2000	1,635	403	1,233	2,038	274	16.8	204

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

	Water		Developed		Mechanical-ly disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	1.3	0.4	6.9	3.1	0.1	0.0	1.1	0.4	0.0	0.0	64.6	3.7	1.5	0.8	24.4	2.7	0.1	0.1	0.0	0.0
1980	1.3	0.4	7.0	3.1	0.1	0.1	1.2	0.5	0.0	0.0	64.1	3.6	1.9	0.7	24.2	2.7	0.2	0.1	0.0	0.0
1986	1.3	0.4	7.1	3.1	0.1	0.0	1.0	0.4	0.0	0.0	64.2	3.6	2.0	0.7	24.1	2.7	0.2	0.1	0.0	0.0
1992	1.3	0.4	7.2	3.2	0.3	0.1	0.7	0.2	0.0	0.0	64.0	3.7	2.3	0.9	24.0	2.7	0.2	0.1	0.0	0.0
2000	1.3	0.4	7.4	3.2	0.3	0.1	0.6	0.2	0.0	0.0	63.7	3.7	2.6	1.0	23.9	2.7	0.2	0.1	0.0	0.0
Net change	0.1	0.1	0.5	0.2	0.2	0.1	–0.5	0.3	0.0	0.0	–0.8	0.7	1.1	0.8	–0.5	0.3	0.0	0.0	0.0	0.0
Gross change	0.1	0.1	0.5	0.2	0.8	0.2	1.6	0.6	0.0	0.0	2.7	0.6	2.2	0.8	1.3	0.3	0.0	0.0	0.0	0.0
Area, in square kilometers																				
1973	1,081	373	5,878	2,621	75	37	906	329	0	0	54,703	3,136	1,289	655	20,682	2,284	124	54	0	0
1980	1,118	374	5,940	2,624	84	47	1,033	416	0	0	54,331	3,085	1,576	617	20,524	2,257	130	55	0	0
1986	1,120	374	5,993	2,625	74	31	863	332	0	0	54,429	3,087	1,683	621	20,445	2,256	130	55	0	0
1992	1,122	372	6,136	2,670	244	104	593	202	0	0	54,214	3,153	1,954	763	20,345	2,272	130	55	0	0
2000	1,128	373	6,301	2,694	231	67	512	189	0	0	53,998	3,132	2,209	851	20,217	2,300	141	60	0	0
Net change	47	49	423	143	156	71	–393	271	0	0	–705	573	920	706	–465	227	17	17	0	0
Gross change	57	49	424	143	693	210	1,370	502	0	0	2,327	484	1,829	664	1,110	213	17	17	0	0

Table 4. Principal land-cover conversions in Western Allegheny 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.

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

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mining	333	165	112	0.4	19.0
	Mining	Grassland/Shrubland	259	126	86	0.3	14.7
	Grassland/Shrubland	Forest	194	107	73	0.2	11.1
	Forest	Grassland/Shrubland	173	111	76	0.2	9.8
	Forest	Agriculture	119	52	36	0.1	6.8
	Other	Other	677	n/a	n/a	0.8	38.6
		Totals	1,755			2.1	100.0
1980–1986	Grassland/Shrubland	Forest	414	249	169	0.5	24.0
	Mining	Grassland/Shrubland	407	271	185	0.5	23.6
	Forest	Mining	202	105	71	0.2	11.7
	Forest	Agriculture	113	53	36	0.1	6.5
	Agriculture	Mining	82	78	53	0.1	4.8
	Other	Other	504	n/a	n/a	0.6	29.3
		Totals	1,721			2.0	100.0
1986–1992	Mining	Grassland/Shrubland	372	221	151	0.4	19.6
	Grassland/Shrubland	Forest	238	72	49	0.3	12.5
	Forest	Mechanically disturbed	223	102	70	0.3	11.7
	Forest	Mining	186	88	60	0.2	9.8
	Forest	Grassland/Shrubland	149	88	60	0.2	7.8
	Other	Other	730	n/a	n/a	0.9	38.5
		Totals	1,898			2.2	100.0
1992–2000	Forest	Mechanically disturbed	215	117	80	0.3	13.1
	Mining	Grassland/Shrubland	214	67	45	0.3	13.1
	Grassland/Shrubland	Forest	142	42	29	0.2	8.7
	Forest	Grassland/Shrubland	138	99	68	0.2	8.4
	Mechanically disturbed	Forest	135	72	49	0.2	8.2
	Other	Other	792	n/a	n/a	0.9	48.4
		Totals	1,635			1.9	100.0
1973–2000 (overall)	Mining	Grassland/Shrubland	1,253	666	453	1.5	17.9
	Grassland/Shrubland	Forest	987	379	258	1.2	14.1
	Forest	Mining	849	333	227	1.0	12.1
	Forest	Mechanically disturbed	580	151	103	0.7	8.3
	Forest	Grassland/Shrubland	528	257	175	0.6	7.5
	Other	Other	2,813	n/a	n/a	3.3	40.1
		Totals	7,010			8.3	100.0

References Cited

Cooper, E.L., 1983, Fishes of Pennsylvania and the north-eastern United States: University Park, Pennsylvania State University Press, 183 p.

Crowell, D.L., 1995, History of the coal-mining industry in Ohio: Ohio Division of Geological Survey Bulletin 72, 204 p.

Fox, J., 1999, Mountaintop removal in West Virginia—An environmental sacrifice zone: Organization and Environment, v. 12, no. 2, p. 163–183.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

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Chapter 10

Central Appalachians Ecoregion

By Kristi L. Sayler

Ecoregion Description

The Central Appalachians Ecoregion, which covers about 59,738 km^2 (23,065 mi^2) (fig. 1), stretches from central Pennsylvania through Maryland, West Virginia, Virginia, and Kentucky, into northern Tennessee (Wiken and others, 2011). The ecoregion is surrounded by (clockwise, from the northernmost part) the North Central Appalachians, Ridge and Valley, Southwestern Appalachians, and Western Allegheny Plateau Ecoregions.

The Central Appalachians Ecoregion primarily is a dissected and rugged high plateau underlain by sandstone, shale, conglomerate, and coal. Local relief varies from less than 15 to more than 594 m, and the highest mountain elevations range from about 366 to 1,402 m (Woods and others, 1996). The climate is variable because of topographic influences in the ecoregion. Precipitation is distributed uniformly throughout the year, but the late summer and early fall seasons tend to be drier, with an average annual precipitation of about 1,125 mm (45 in.) (Raitz and Ulack, 1984). The rugged terrain, cool climate, and infertile soils limit agriculture, and the resulting land cover is mostly forest. A mixed mesophytic forest consisting of areas of oak (*Quercus* spp.) and northern hardwood trees covers the high hills and low mountains (fig. 2). Coal mining is common in the ecoregion and is one of the major drivers of land-cover change (fig. 3). Agricultural land is in the valleys, where the annual growing season can be as long as 165 days (Woods and others, 1996) (fig. 4). The main agricultural activities include livestock and dairy farming, as well as the growing of Christmas trees on plantations.

Figure 1. Map of Central Appalachians 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 Eastern United States ecoregions are listed in appendix 2. Also shown are parts of three Midwest–South Central United States ecoregions: Eastern Corn Belt Plains, Erie Drift Plains (EDP), and Huron/Erie Lake Plains (HELP). See appendix 3 for definitions of land-use/land-cover classifications.
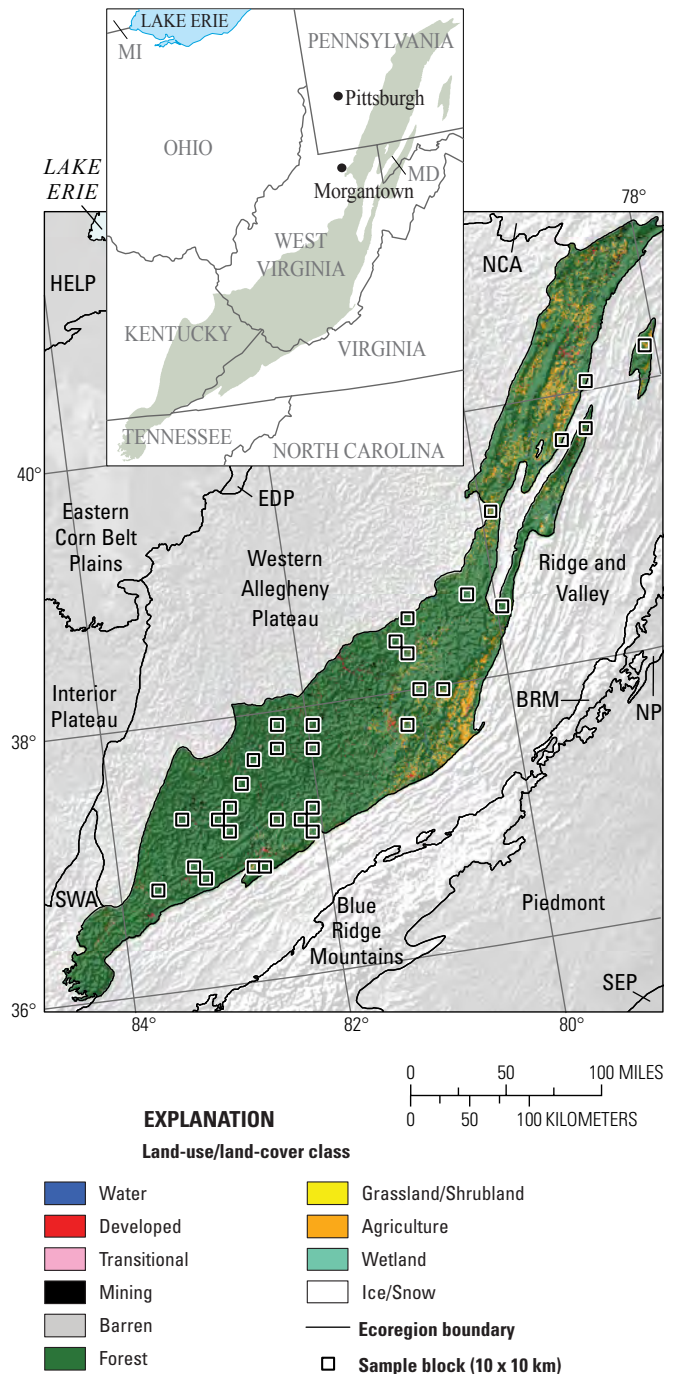
Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Central Appalachians Ecoregion between 1973 and 2000 is estimated at 9.1 percent (fig. 5). Compared to other Eastern United States ecoregions, change in the Central Appalachians Ecoregion was moderate (fig. 5). An estimated 5.9 percent of the ecoregion changed only one time, and an estimated 3.2 percent changed multiple times (table 1). Most of the change in the ecoregion was tied closely to coal mining, and the highest amounts of change were concentrated in coal mining areas. Most of the multiple-change areas represent, first, the conversion of forest to mechanically disturbed, mining, and grassland/shrubland, as coal mines become established and expand in forested areas, and, second, the subsequest conversion of mining to grassland/shrubland and forest, as mines eventually close down and are abandoned or reclaimed. The total change per time period ranged from 2.4 to 4.1 percent (table 2). When normalized to an average annual rate to account for unequal time periods, the

period between 1986 and 1992 had the highest rate of change, at 0.6 percent (table 2; fig. 6), likely because of a resurgence of coal mining in West Virginia in the 1990s (Fox, 1999).

The mining, grassland/shrubland, and forest land-cover classes experienced the most change during the 27-year study period (table 3). Mining nearly doubled, from 1.7 percent of the ecoregion in 1973 to 3.2 percent in 2000. Conversely,

Figure 4.   Forested hills and agriculture in valley in Central Appalachians Ecoregion.
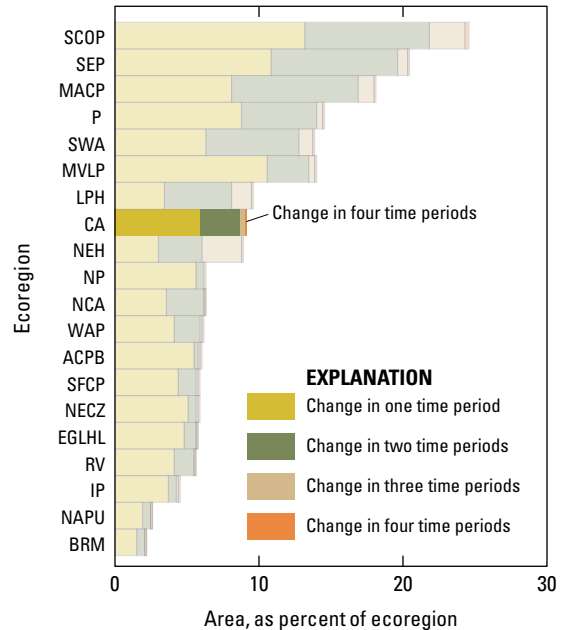
Figure 5.   Overall spatial change in Central Appalachians Ecoregion (CA; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Central Appalachians Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Figure 2.   Road through forested hills, in Central Appalachians Ecoregion.

Figure 3.   Coal mine in southern West Virginia.

forest decreased, from 86.6 percent in 1973 to 83.2 percent in 2000 (fig. 7). Grassland/shrubland increased throughout the study period as old mining areas reverted to forest. Agriculture decreased slightly because of abandonment and subsequent reversion to forest. Developed increased slightly during the four time periods, in contrast to the population of the ecoregion, which has steadily decreased since the 1980s (fig. 8). The net changes in land-cover classes in the ecoregion during the study period are shown in figure 9. The changes were relatively minor until the period between 1992 and 2000, when a resurgence in forest clearing for mining activities occurred.

The leading land-cover conversions also were all related to coal mining in the ecoregion. Forest to mining was the most common conversion during all time periods, ranging from 458 to 1,099 km^2 per time period (table 4). During every time period, at least 65 percent of all changes were connected to mining activities in the ecoregion.

Figure 7.   Active logging of hardwood forests in Central Appalachians Ecoregion.
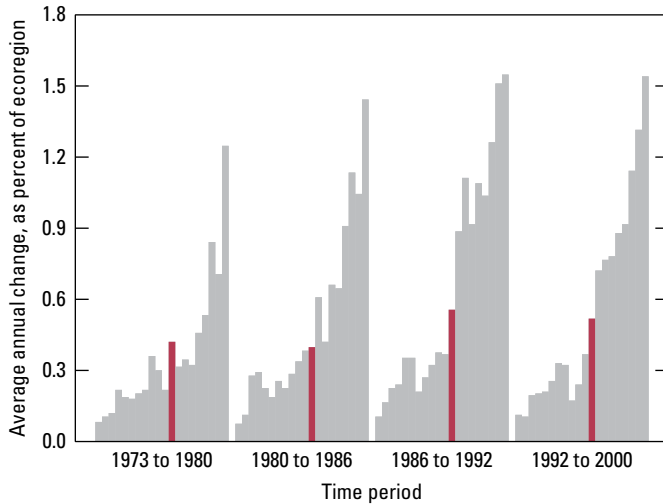
Figure 6.   Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Central Appalachians Ecoregion are represented by red bars in each time period.
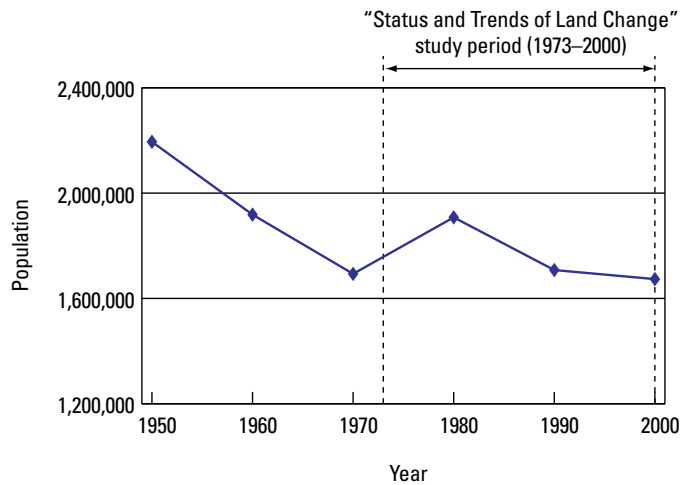
Figure 8.   Population levels in Central Appalachians Ecoregion between 1950 and 2000 (U.S. Census Bureau, 1970–2000 [various years]).

EXPLANATION

Land-use/land-cover class

■ Water	■ Forest
■ Developed	■ Grassland/Shrubland
■ Mechanically disturbed	■ Agriculture
■ Mining	■ Wetland
■ Barren	■ Nonmechanically disturbed
	□ Ice/Snow
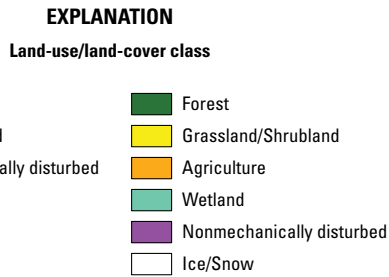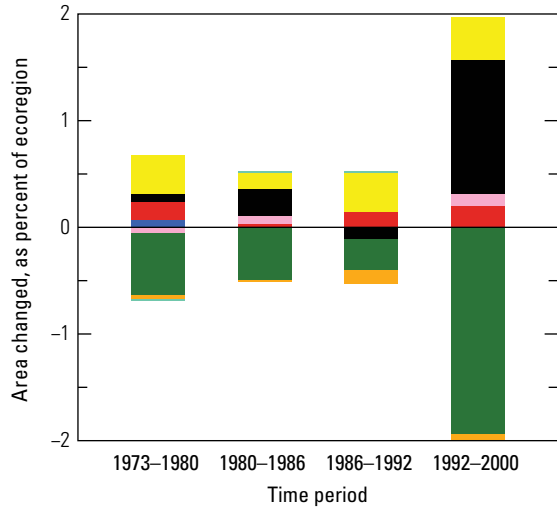
Figure 9.   Normalized average net change in Central Appalachians Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

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

[Most sample pixels remained unchanged (90.9 percent), whereas 9.1 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	5.9	1.1	4.8	7.0	0.7	12.6
2	2.8	0.6	2.2	3.4	0.4	14.1
3	0.4	0.1	0.3	0.5	0.1	23.4
4	0.0	0.0	0.0	0.0	0.0	29.6
Overall spatial change	9.1	1.5	7.6	10.6	1.0	11.0

Table 2. Raw estimates of change in Central Appalachians 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	2.9	0.7	2.3	3.6	0.4	15.1	0.4
1980–1986	2.4	0.5	1.9	2.9	0.4	15.0	0.4
1986–1992	3.3	0.6	2.7	3.9	0.4	12.1	0.6
1992–2000	4.1	1.1	3.1	5.2	0.7	17.3	0.5
Estimate of change, in square kilometers							
1973–1980	1,754	390	1,364	2,145	265	15.1	251
1980–1986	1,423	316	1,107	1,738	214	15.0	237
1986–1992	1,981	354	1,627	2,335	240	12.1	330
1992–2000	2,471	632	1,839	3,103	428	17.3	309

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

	Water		Developed		Me-chanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
											Area, in percent stratum										
1973	0.5	0.3	3.1	0.6	0.3	0.2	1.7	0.5	0.0	0.0	86.6	2.0	0.5	0.2	7.0	2.0	0.3	0.2	0.0	0.0
1980	0.6	0.3	3.2	0.7	0.2	0.1	1.8	0.5	0.0	0.0	86.0	2.0	0.9	0.3	7.0	2.0	0.2	0.2	0.0	0.0
1986	0.6	0.3	3.3	0.7	0.3	0.1	2.1	0.5	0.0	0.0	85.5	2.0	1.0	0.3	7.0	2.0	0.2	0.2	0.0	0.0
1992	0.6	0.3	3.4	0.7	0.3	0.1	2.0	0.5	0.0	0.0	85.2	2.0	1.4	0.4	6.9	2.0	0.3	0.2	0.0	0.0
2000	0.6	0.3	3.6	0.8	0.4	0.2	3.2	1.0	0.0	0.0	83.2	2.0	1.8	0.5	6.8	2.0	0.3	0.2	0.0	0.0
Net change	0.1	0.1	0.5	0.2	0.1	0.3	1.5	0.9	0.0	0.0	–3.3	1.0	1.3	0.4	–0.2	0.2	0.0	0.0	0.0	0.0
Gross change	0.1	0.1	0.5	0.2	1.3	0.4	3.7	0.9	0.0	0.0	5.0	1.0	1.9	0.5	0.4	0.2	0.0	0.0	0.0	0.0
											Area, in square kilometers										
1973	308	159	1,834	375	181	128	1,041	282	2	2	51,718	1,222	307	132	4,194	1,190	151	141	0	0
1980	355	165	1,932	390	149	73	1,081	285	2	2	51,368	1,206	527	174	4,179	1,193	145	133	0	0
1986	355	165	1,957	394	188	86	1,236	296	2	2	51,072	1,205	615	176	4,168	1,190	146	134	0	0
1992	358	165	2,038	417	185	81	1,178	276	3	2	50,889	1,223	840	211	4,096	1,174	151	141	0	0
2000	366	165	2,156	449	247	132	1,938	583	2	2	49,731	1,171	1,073	315	4,074	1,166	151	141	0	0
Net change	58	64	322	133	66	177	897	552	0	0	–1,987	593	765	250	–121	91	0	0	0	0
Gross change	58	64	323	133	794	226	2,215	566	0	0	2,958	571	1,135	271	260	90	11	16	0	0

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

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

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mining	539	186	126	0.9	30.7
	Mining	Forest	427	219	149	0.7	24.3
	Forest	Grassland/Shrubland	185	78	53	0.3	10.6
	Forest	Mechanically disturbed	121	63	43	0.2	6.9
	Mining	Grassland/Shrubland	80	40	27	0.1	4.6
	Other	Other	402	n/a	n/a	0.7	22.9
		Totals	1,754			2.9	100.0
1980–1986	Forest	Mining	458	141	95	0.8	32.2
	Mining	Forest	188	120	82	0.3	13.2
	Forest	Mechanically disturbed	158	74	50	0.3	11.1
	Grassland/Shrubland	Forest	154	64	44	0.3	10.8
	Mining	Grassland/Shrubland	121	39	27	0.2	8.5
	Other	Other	344	n/a	n/a	0.6	24.2
		Totals	1,423			2.4	100.0
1986–1992	Forest	Mining	530	143	97	0.9	26.7
	Mining	Forest	365	169	115	0.6	18.4
	Mining	Grassland/Shrubland	240	77	52	0.4	12.1
	Grassland/Shrubland	Forest	169	60	41	0.3	8.5
	Forest	Mechanically disturbed	161	75	51	0.3	8.1
	Other	Other	517	n/a	n/a	0.9	26.1
		Totals	1,981			3.3	100.0
1992–2000	Forest	Mining	1,099	500	339	1.8	44.5
	Mining	Grassland/Shrubland	263	126	85	0.4	10.7
	Forest	Mechanically disturbed	231	130	88	0.4	9.3
	Forest	Grassland/Shrubland	182	88	59	0.3	7.4
	Grassland/Shrubland	Forest	178	86	58	0.3	7.2
	Other	Other	518	n/a	n/a	0.9	21.0
		Totals	2,471			4.1	100.0
1973–2000 (overall)	Forest	Mining	2,626	714	484	4.4	34.4
	Mining	Forest	1,094	420	284	1.8	14.3
	Mining	Grassland/Shrubland	705	195	132	1.2	9.2
	Forest	Mechanically disturbed	671	248	168	1.1	8.8
	Forest	Grassland/Shrubland	597	184	125	1.0	7.8
	Other	Other	1,936	n/a	n/a	3.2	25.4
		Totals	7,629			12.8	100.0

References Cited

Fox, J., 1999, Mountaintop removal in West Virginia—An environmental sacrifice zone: Organization and Environment, v. 12, no. 2, p. 163–183.

Raitz, K.B., and Ulack, R., 1984, Appalachia, a regional geography—Land, people, and development: Boulder, Colo., Westview Press, 396 p.

U.S. Census Bureau, 1970–2000 [various years], Census of population and housing: U.S. Census Bureau database, accessed May 9, 2013, at http://www.census.gov/prod/www/decennial.html.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

Woods, A.J., Omernik, J.M., Brown, D.D., and Kiilsgaard, C.W., 1996, Level III and IV ecoregions of Pennsylvania and the Blue Ridge Mountains, the Ridge and Valley, and Central Appalachians of Virginia, West Virginia, and Maryland: U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oreg., EPA/600/R-96/077, 50 p.

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Chapter 11

Ridge and Valley Ecoregion

By Beverly A. Friesen and Michael P. Stier

Ecoregion Description

The Ridge and Valley Ecoregion is a long, narrow ecoregion that covers 111,043 km² (42,874 mi²), stretching about 1,600 km from the southeastern corner of New York to northeastern Alabama and including parts of seven states in between: New Jersey, Pennsylvania, Maryland, West Virginia, Virginia, Tennessee, and Georgia (fig. 1). Major cities within this ecoregion are Birmingham, Alabama, and Chattanooga and

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

EXPLANATION

Land-use/land-cover class

- Water
- Developed
- Transitional
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Ice/Snow
- Ecoregion boundary
- □ Sample block (10 x 10 km)
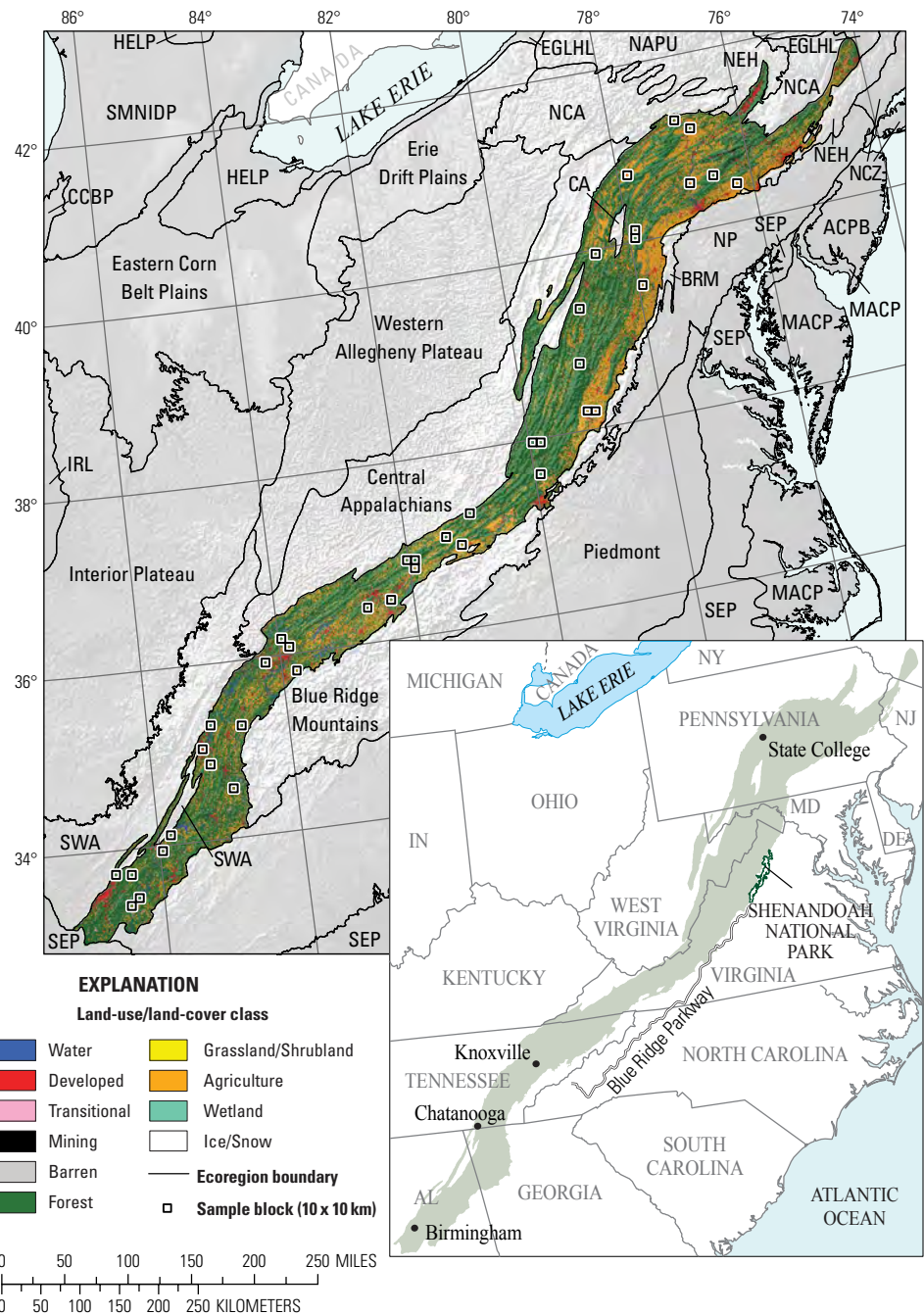
Knoxville, Tennessee. The ecoregion is surrounded by (clockwise, from its northeasternmost tip) the Eastern Great Lakes and Hudson Lowlands, Northeastern Highlands, Northern Piedmont, Blue Ridge Mountains, Piedmont, Southeastern Plains, Southwestern Appalachians, Central Appalachians, North Central Appalachians, and Northern Appalachian Plateau and Uplands Ecoregions.

This northeast-southwest-trending ecoregion is nestled between generally higher areas of more rugged, mountainous terrain that, in general, has more forested land. The roughly parallel ridges and lowland valleys that make up this area are the result of extreme folding and faulting events (Wiken and others, 2011) (fig. 2). Elevations range from 152 to 1,311 m. Managed lands constitute more than 13 percent of the ecoregion area, ranging from State parks to wild and scenic rivers (Conservation Biology Institute, 2001). The Blue Ridge Parkway, a designated parkway administered by the National Park Service, dips into the eastern part of the ecoregion in Virginia, as do small parts of Shenandoah National Park.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Ridge and Valley Ecoregion between 1973 and 2000 is estimated at 5.5 percent (table 1). Compared to other Eastern United States ecoregions, change in the Ridge and Valley Ecoregion was relatively low (fig. 3): of the land that changed, 4.1 percent changed one time, and 1.5 percent changed two or more times (table 1). In this ecoregion, multiple changes often indicate cyclic disturbances; most of the multiple changes in this ecoregion represent areas of clearcuts and subsequent forest regrowth (fig. 4).

The overall change per time period for the Ridge and Valley Ecoregion ranges from a low of 1.3 percent between 1980 and 1986 to a high of 2.6 percent between 1992 and

2000 (table 2). All estimates have an associated margin of error of less than about 1.0 percent, although the margin of error increases with the higher amount of change in the period between 1992 and 2000 (table 2). When normalized to an average annual rate to account for uneven time periods, change per time period gradually increased over the study period, from 0.2 to 0.3 percent annual change (table 2; fig. 5). The period between 1992 and 2000 was the most actively changing period.

Forest, agriculture, and developed land-cover classes accounted for almost 96 percent of the ecoregion area during the 27-year study period. The percentages of each land-cover class for the five mapped dates between 1973 and 2000 are shown in table 3: forest decreased from 57.3 percent in 1973 to 55.8 percent in 2000 (table 3), and mechanically disturbed (clearcuts) increased, starting in the period between 1986 and 1992. A small decrease in agriculture, from 31.2 to 30.4 percent, was recorded between 1973 and 2000; this decrease was due to both the abandonment of agricultural fields and the conversion of agricultural land to developed land. Decreases in forest and agriculture were countered by a 1.4 percent net increase in developed, from 7.9 percent of the ecoregion in 1973 to 9.3
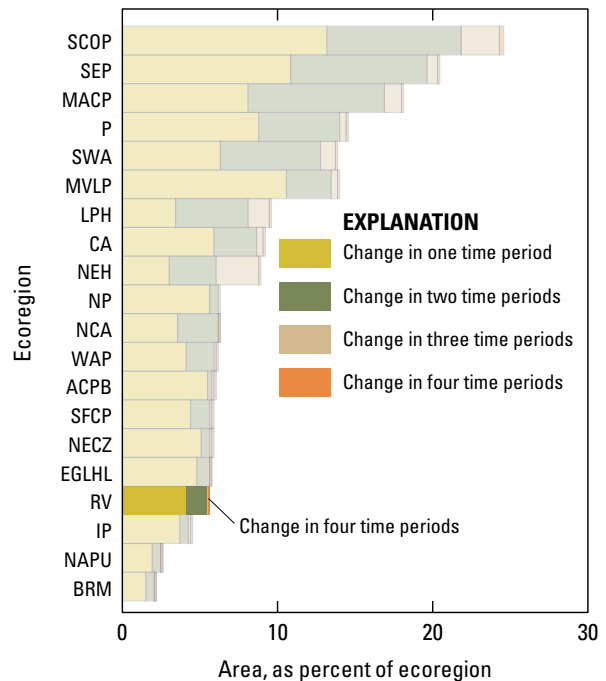
Figure 3. Overall spatial change in Ridge and Valley Ecoregion (RV; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Ridge and Valley Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Figure 2. Typical scene in Ridge and Valley Ecoregion of forested areas dominating hilly topography and developed and agricultural lands occupying valleys.

percent in 2000. These net changes are summarized by land-cover class for each time period in figure 6.

The five most common land-cover conversions by time period are reported in table 4. The greatest consistent change over the 27-year study period was the conversion of forest to mechanically disturbed, followed by the reversion of mechanically disturbed to forest (forest regrowth). The amount of land that changed from forest to mechanically disturbed more than doubled between the second period (1986–1992; 535 km^2) and the fourth period (1992–2000; 1,169 km^2), owing to the clearing of trees. In contrast, only 482 km^2 of mechanically disturbed reverted to forest between 1992 and 2000. Other leading conversions were the cyclic changes from forest to agriculture and from agriculture to forest, as well as the unidirectional changes from agriculture and forest to developed.

The amount of land that converted from both forest and agriculture to developed more than doubled between 1992 and 2000, when compared to any previous period; this was the same time period in which the amount of clearcutting more than doubled. Although many clearcut areas have reverted to forest, mechanically disturbed represents a temporary state that also can lead to permanent conversion to developed.

The quantity of clearcuts, coupled with the increased amount of forest and agriculture converting to developed, highlights the net loss of forest in this ecoregion during the 27-year study period. These changes also suggest a possible accelerating trend in the clearing of forested and agricultural land for development. Increases in developed and mechanically disturbed lands and decreases in forested and agricultural lands in the Ridge and Valley Ecoregion were corroborated by a Southern Forest Resource Assessment from the National Resource Inventory data of the U.S. Department of Agriculture, Natural Resources Conservation Service (Wear, 2002). This study showed that, for the southern states between 1982 and 1997, strong economic growth led to population growth and increased urbanization at the expense of agricultural and forested lands. This trend was more noticeable in the southern part of the ecoregion than

Figure 5. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Ridge and Valley Ecoregion are represented by red bars in each time period.
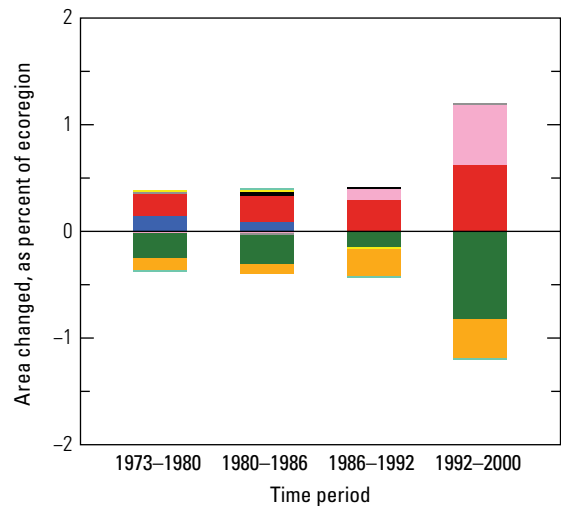
EXPLANATION

Land-use/land-cover class

Water	Forest
Developed	Grassland/Shrubland
Mechanically disturbed	Agriculture
Mining	Wetland
Barren	Nonmechanically disturbed
Ice/Snow	

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

Figure 4. Regrowth in clearcut area, in central Alabama.

in the northern part, which also coincides with the largest urban centers in the ecoregion (Birmingham, Alabama, and Chattanooga and Knoxville, Tennessee) (fig. 7). Forecasts for the northern, central, and southern parts of the Ridge and Valley Ecoregion showed continued and increased loss of

forest between 1992 and 2020, with higher losses predicted for the southern part of the ecoregion (Wear, 2002). In addition, pressures from development likely will continue to drive land-use conversions in the Ridge and Valley Ecoregion for the foreseeable future (fig. 8).

Figure 7. Paper mill in Ridge and Valley Ecoregion. Industry is fairly common in ecoregion, especially along interstate highways and exits in its northern part, in Pennsylvania and Virginia, and in its southern part, around Birmingham, Alabama, and Chattanooga and Knoxville, Tennessee.

Figure 8. Overpass under construction, near State College, Pennsylvania.

Table 1. Percentage of Ridge and Valley 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	4.1	0.8	3.3	4.8	0.5	12.8
2	1.4	0.4	1.0	1.8	0.3	19.5
3	0.1	0.0	0.0	0.1	0.0	37.4
4	0.0	0.0	0.0	0.0	0.0	57.1
Overall spatial change	5.5	1.1	4.4	6.6	0.7	13.3

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

[Estimates of change per period normalized to annual rate of change for each 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	20.0	0.2
1980–1986	1.3	0.4	1.0	1.7	0.3	19.0	0.2
1986–1992	1.6	0.4	1.2	2.0	0.2	15.1	0.3
1992–2000	2.6	0.6	2.0	3.2	0.4	15.8	0.3
Estimate of change, in square kilometers							
1973–1980	1,693	497	1,196	2,190	338	20.0	242
1980–1986	1,482	414	1,067	1,896	282	19.0	247
1986–1992	1,778	395	1,383	2,173	269	15.1	296
1992–2000	2,878	668	2,210	3,545	455	15.8	360

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

	Water		Developed		Me-chanically disturbed		Mining		Barren		Forest		Grassland/Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	2.2	0.9	7.9	3.0	0.4	0.2	0.2	0.1	0.0	0.0	57.3	5.1	0.1	0.1	31.2	4.6	0.7	0.3	0.0	0.0
1980	2.3	0.9	8.1	3.0	0.4	0.2	0.2	0.1	0.0	0.0	57.0	5.1	0.1	0.1	31.1	4.6	0.7	0.3	0.0	0.0
1986	2.4	0.9	8.4	3.0	0.4	0.2	0.2	0.1	0.0	0.0	56.7	5.0	0.1	0.1	31.0	4.5	0.7	0.3	0.0	0.0
1992	2.4	0.9	8.7	3.0	0.5	0.2	0.2	0.1	0.0	0.0	56.6	5.0	0.1	0.1	30.7	4.5	0.7	0.3	0.0	0.0
2000	2.4	0.9	9.3	3.0	1.1	0.4	0.3	0.1	0.0	0.0	55.8	4.9	0.1	0.1	30.4	4.4	0.7	0.3	0.0	0.0
Net change	0.3	0.3	1.4	0.4	0.6	0.3	0.1	0.0	0.0	0.0	–1.5	0.6	0.0	0.0	–0.8	0.4	0.0	0.0	0.0	0.0
Gross change	0.3	0.3	1.4	0.4	1.9	0.5	0.1	0.1	0.0	0.0	2.9	0.6	0.1	0.1	1.4	0.3	0.0	0.0	0.0	0.0
Area, in square kilometers																				
1973	2,433	1,019	8,802	3,280	487	182	222	144	8	7	63,600	5,659	88	94	34,635	5,070	767	369	0	0
1980	2,594	1,023	9,039	3,280	481	213	223	125	20	18	63,321	5,609	89	81	34,513	5,071	763	368	0	0
1986	2,704	1,052	9,301	3,288	459	195	253	140	11	9	63,006	5,570	120	89	34,425	5,049	764	369	0	0
1992	2,710	1,051	9,623	3,314	577	168	264	136	11	9	62,843	5,583	111	91	34,140	5,006	763	369	0	0
2000	2,717	1,050	10,305	3,386	1,207	481	278	139	11	9	61,929	5,480	111	83	33,727	4,930	757	364	0	0
Net change	283	367	1,504	430	719	354	56	46	3	7	–1,671	638	23	54	–908	405	–10	12	0	0
Gross change	293	366	1,514	429	2,144	579	125	65	21	27	3,211	650	107	61	1,581	329	17	13	0	0

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

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

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	420	189	129	0.4	24.7
	Mechanically disturbed	Forest	387	155	106	0.3	22.8
	Forest	Agriculture	159	67	46	0.1	9.4
	Agriculture	Forest	159	64	44	0.1	9.4
	Forest	Developed	148	70	48	0.1	8.7
	Other	Other	421	n/a	n/a	0.4	24.9
		Totals	1,693			1.5	100.0
1980–1986	Forest	Mechanically disturbed	375	166	113	0.3	25.3
	Mechanically disturbed	Forest	339	159	108	0.3	22.9
	Forest	Agriculture	173	67	46	0.2	11.7
	Agriculture	Developed	145	68	46	0.1	9.8
	Forest	Developed	110	39	26	0.1	7.5
	Other	Other	338	n/a	n/a	0.3	22.8
		Totals	1,482			1.3	100.0
1986–1992	Forest	Mechanically disturbed	535	166	113	0.5	30.1
	Mechanically disturbed	Forest	419	193	131	0.4	23.6
	Agriculture	Forest	247	101	69	0.2	13.9
	Agriculture	Developed	155	60	41	0.1	8.7
	Forest	Developed	152	66	45	0.1	8.6
	Other	Other	270	n/a	n/a	0.2	15.2
		Totals	1,778			1.6	100.0
1992–2000	Forest	Mechanically disturbed	1,169	471	321	1.1	40.6
	Mechanically disturbed	Forest	482	147	100	0.4	16.8
	Agriculture	Developed	331	154	105	0.3	11.5
	Forest	Developed	317	126	86	0.3	11.0
	Agriculture	Forest	269	167	114	0.2	9.3
	Other	Other	309	n/a	n/a	0.3	10.8
		Totals	2,878			2.6	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	2,498	826	562	2.2	31.9
	Mechanically disturbed	Forest	1,627	543	370	1.5	20.8
	Agriculture	Forest	770	250	170	0.7	9.8
	Forest	Developed	727	262	178	0.7	9.3
	Agriculture	Developed	710	258	176	0.6	9.1
	Other	Other	1,498	n/a	n/a	1.3	19.1
		Totals	7,831			7.1	100.0

References Cited

Conservation Biology Institute, 2001, Protected areas database PAD-US (CBI edition), version 2: Corvallis, Ore., Conservation Biology Institute database, available at http://consbio.org/products/projects/pad-us-cbi-edition.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wear, D.N., 2002, Land use, *in* Wear, D.N., and Greis, J.G., eds., Southern forest resource assessment: U.S. Forest Service, Southern Research Station, General Technical Report SRS 53, p. 153–173, available at http://www.srs.fs.usda.gov/pubs/4833.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013 at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

Chapter 12

Interior Plateau Ecoregion

By Mark A. Drummond

Ecoregion Description

The Interior Plateau Ecoregion covers large areas (about 127,810 km^2; 49,348 mi^2) of Kentucky and central Tennessee, as well as parts of Ohio, Indiana, and Alabama (Wiken and others, 2011; fig. 1). The ecoregion is surrounded by (clockwise, from the north) the Eastern Corn Belt Plains, Western Allegheny Plateau, Southwestern Appalachians, Southeastern Plains, Mississippi Valley Loess Plains, and Interior River Lowland Ecoregions. The Ohio River, which forms the north border of Kentucky, drains most of the northern part of the ecoregion.

The Interior Plateau Ecoregion is a series of grassland plateaus and forested uplands that generally are lower in elevation than the Appalachian Mountains to the east but higher than the plains to the south. The relatively flat and fertile lowlands, which include the "Bluegrass region" (central Kentucky) and the Nashville Basin (mainly in central Tennessee but also in southern Kentucky and northern Alabama), attracted early settlement and farming. Today, these are highly populated areas that include the cities of Louisville, Kentucky, and Nashville, Tennessee. The Pennyroyal Plateau in south-central Kentucky and northern Tennessee is an intensely cultivated agricultural area that also has a distinctive "flatwood" ecosystem, which is characterized by oak (*Quercus* spp.) forests and wet conditions that are caused by an underlying hard, dense fragipan soil (Chester and others, 1995).

Rapid subsurface drainage occurs in sinkhole areas such as south-central Kentucky, where extensive cave systems
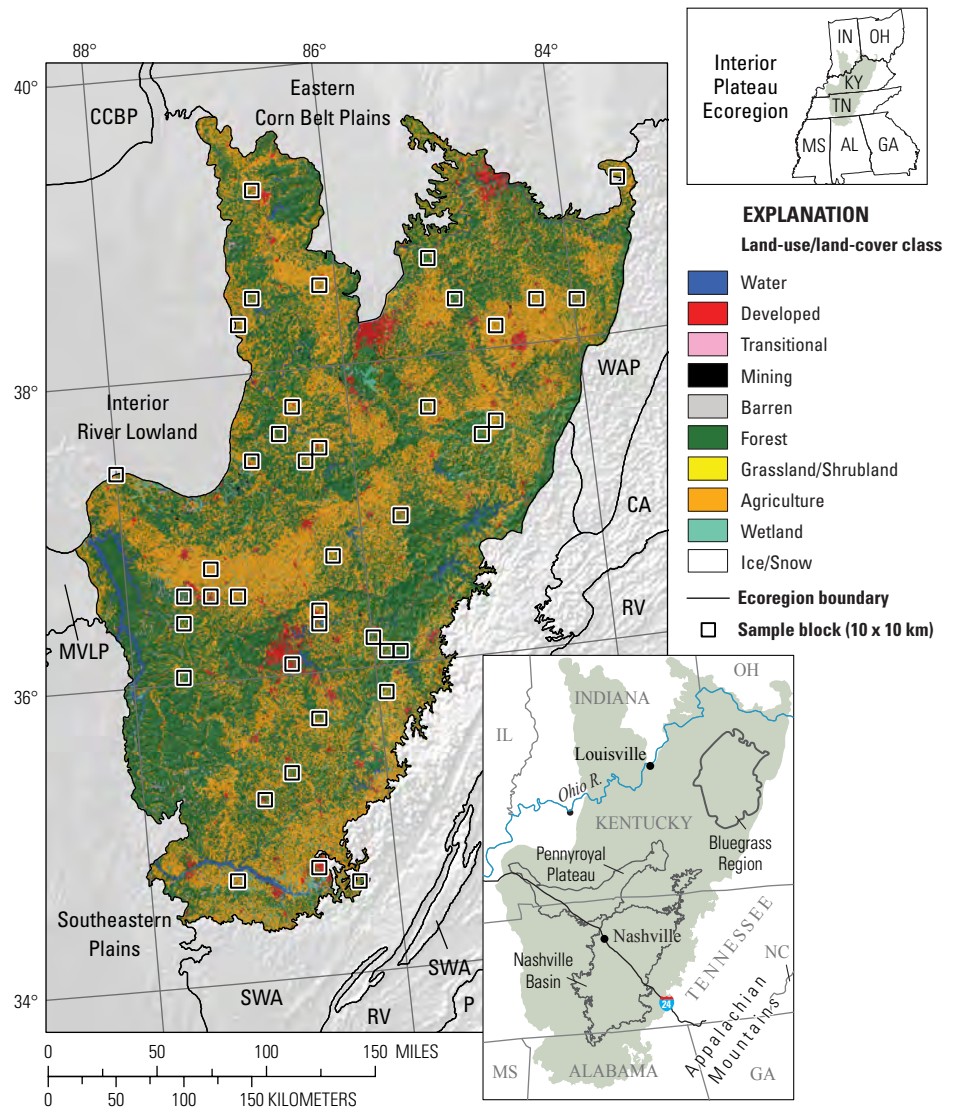
Figure 1. Map of Interior Plateau Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and 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 Eastern United States ecoregions are listed in appendix 2. Also shown are parts of three Midwest–South Central United States ecoregions: Central Corn Belt Plains (CCBP), Eastern Corn Belt Plains, and Interior River Lowland. See appendix 3 for definitions of land-use/land-cover classifications.

wind through the karst limestone landscape. Water quality of the associated aquifers and streams is a special concern in watersheds where agriculture and coal mining are prevalent.

Across the Interior Plateau Ecoregion, climate conditions are humid temperate, with annual precipitation averaging about 1,200 mm (47.2 in.). Oak-hickory (*Quercus* spp. and *Carya* spp., respectively) stands are the most common forest type, although mixed stands of eastern red-cedar (*Juniperus virginiana*) and hardwoods grow in many rocky areas and limestone glades (fig. 2). Bluestem (*Andropogon* spp.) prairie is the most common type of grassland. Historically, fire was an important natural process for maintaining open-canopied, savannalike conditions on the plateaus (Chester and others, 1995; Hudson, 2002).

Population in the Interior Plateau Ecoregion has increased steadily by about 40 percent between 1970 and 2000, from 4.4 million to 6.2 million people (U.S. Census Bureau, 1970–2000 [various years]). Automobile manufacturing has expanded into the ecoregion from other industrial areas of the United States, and tourism and service industries also are important at several locations. Major agricultural products include soybeans, corn, tobacco, and dairy (fig. 3). The Bluegrass area has unique land uses, including a tradition of racehorse breeding and training farms, as well as the production of high-value burley tobacco.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Interior Plateau Ecoregion between 1973 and 2000 is estimated at 4.5 percent (table 1), meaning that 95.5 percent of the total area was stable. Compared to other Eastern United States ecoregions, change in the Interior Plateau Ecoregion was relatively low (fig. 4): an estimated 3.7 percent of the ecoregion changed only one time. The percentage of ecoregion area that changed multiple times also was relatively low: an estimated 0.8 percent changed twice, and 0.1 percent changed three times (table 1). When normalized to an average annual rate to account for unequal time periods, the highest total change occurred during the period between 1980 and 1986 (1.7 percent), with an annual rate of 0.3 percent (table 2; fig. 5). The lowest rate of change occurred during the period between 1973 and 1980, when total change was less than 1 percent (0.8 percent), and the annual rate was 0.1 percent.

Agricultural land, forested land, and developed land accounted for more than 96 percent of the ecoregion

Figure 2.   Roadside vista of pastureland, forest, and farms in south-central Kentucky, in central part of Interior Plateau Ecoregion.

Figure 3.   Tobacco field in central Tennessee.
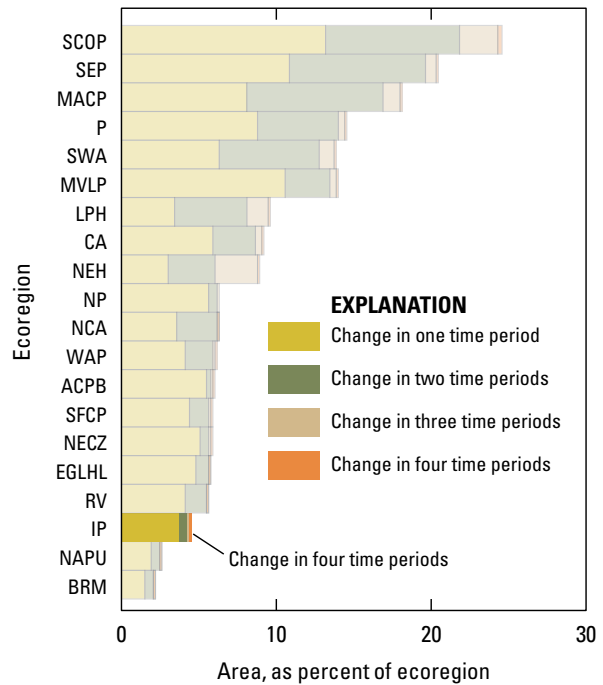
Figure 4.   Overall spatial change in Interior Plateau Ecoregion (IP; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Interior 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.

area in 2000. Agriculture is the most common land cover, and it constituted 50.9 percent of the ecoregion in 1973, decreasing to 50.0 percent in 2000 (table 3). Forest was the next most common land cover, with a high of 39.0 percent of the ecoregion in 1973 and a low of 37.7 percent in 2000. Developed had a steady gain, from 6.9 percent of the ecoregion in 1973 to 8.6 percent in 2000 (fig. 6). Other small gains of about 0.2 percent each occurred between 1973 and 2000 in mechanically disturbed and grassland/shrubland. Developed experienced the greatest increase (1.7 percent) in ecoregion area between 1973 and 2000 (table 3). Net losses occurred in forest (1.3 percent) and agriculture (0.8 percent). Although the increase in developed generally accelerated over the 27-year study period (fig. 7), the highest rate of increase was between 1980 and 1986 (0.6 percent), which is also the period that has

the highest overall rate of ecoregion change (1.7 percent). Most of the land converting to developed (nearly 60 percent) came from agriculture. Conversely, most of the loss in agriculture was to developed, except in the period between 1973 and 1980, when the conversion of agricultural land to grassland/shrubland was highest.

Between 1973 and 2000, the most common land-cover conversion (1,373 km^2) was from forest to agriculture (table 4). However, this conversion did not result in a net increase in agricultural land because, at the same time, agricultural land was being converted to developed land and to grassland/shrubland at an overall higher rate. Conversion from agricultural land to developed land was the second most common change (1,250 km^2). The various gains and losses of agricultural land during the study period are masked by a low net rate of change (–0.8 percent) (table 3). Cyclic changes involving mechanical disturbance of forested areas and subsequent reforestation were less common, although they did increase through time (fig. 8).
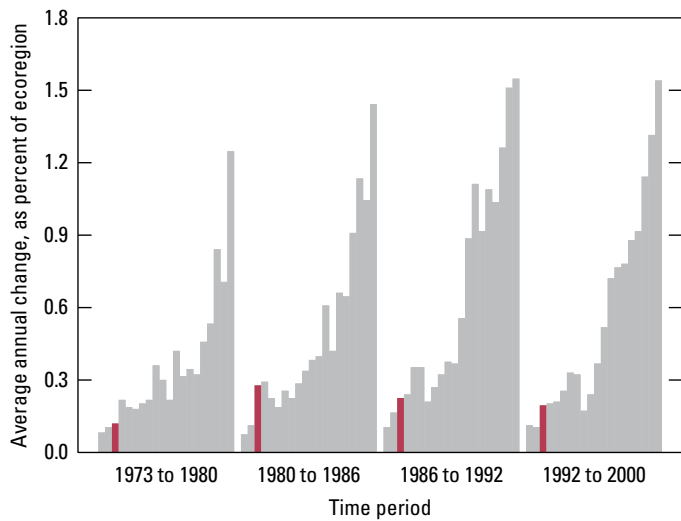
Figure 5.   Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Interior Plateau Ecoregion are represented by red bars in each time period.
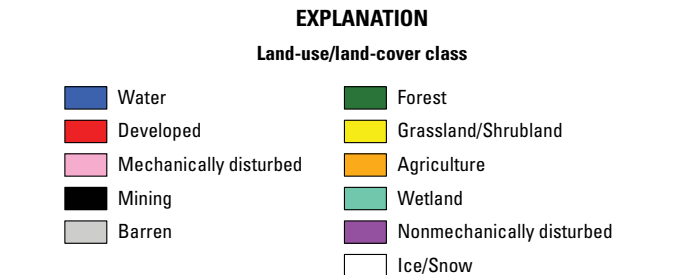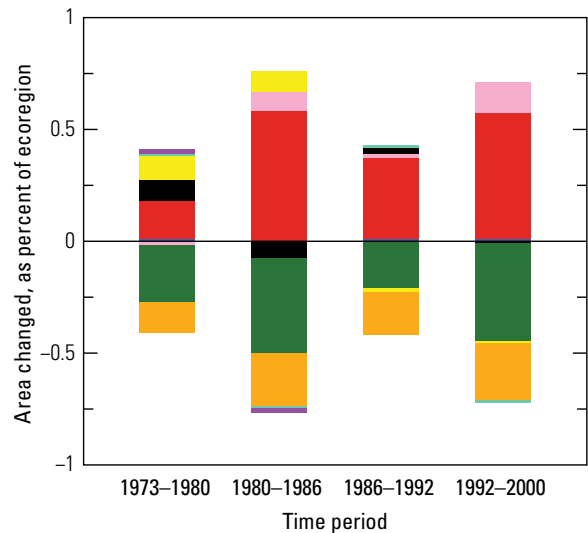
Figure 6.   Suburban development next to Interstate 24, outside of Nashville, Tennessee.

EXPLANATION

Land-use/land-cover class

Water	Forest
Developed	Grassland/Shrubland
Mechanically disturbed	Agriculture
Mining	Wetland
Barren	Nonmechanically disturbed
	Ice/Snow

Figure 7.   Normalized average net change in Interior 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 and land-cover classifications.

Figure 8.   Forest being cleared near east edge of Interior Plateau Ecoregion.

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

[Most sample pixels remained unchanged (95.5 percent), whereas 4.5 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	3.7	0.9	2.8	4.6	0.6	16.8
2	0.8	0.2	0.5	1.0	0.2	21.4
3	0.1	0.0	0.0	0.1	0.0	34.3
4	0.0	0.0	0.0	0.0	0.0	67.7
Overall spatial change	4.5	1.1	3.4	5.6	0.7	16.2

Table 2.   Raw estimates of change in Interior 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 time period]

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	0.8	0.2	0.6	1.1	0.2	20.0	0.1
1980–1986	1.7	0.5	1.2	2.1	0.3	19.2	0.3
1986–1992	1.4	0.4	1.0	1.7	0.3	20.1	0.2
1992–2000	1.6	0.4	1.2	2.0	0.3	17.6	0.2
Estimate of change, in square kilometers							
1973–1980	1,080	318	762	1,397	216	20.0	154
1980–1986	2,135	603	1,532	2,738	411	19.2	356
1986–1992	1,726	508	1,218	2,235	346	20.1	288
1992–2000	1,984	513	1,471	2,497	349	17.6	248

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

	Water		Developed		Mecha-nically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	1.5	0.9	6.9	3.1	0.0	0.0	0.1	0.0	0.0	0.0	39.0	4.4	0.8	0.7	50.9	5.0	0.7	0.3	0.0	0.0
1980	1.6	0.9	7.1	3.1	0.0	0.0	0.2	0.1	0.0	0.0	38.8	4.5	0.9	0.7	50.7	5.0	0.7	0.3	0.0	0.0
1986	1.6	0.9	7.7	3.4	0.1	0.1	0.1	0.0	0.0	0.0	38.3	4.5	1.0	0.7	50.5	5.1	0.7	0.3	0.0	0.0
1992	1.6	0.9	8.1	3.5	0.1	0.1	0.1	0.1	0.0	0.0	38.1	4.5	1.0	0.7	50.3	5.1	0.7	0.3	0.0	0.0
2000	1.6	0.9	8.6	3.7	0.3	0.1	0.1	0.1	0.0	0.0	37.7	4.5	1.0	0.7	50.0	5.2	0.7	0.3	0.0	0.0
Net change	0.0	0.0	1.7	0.8	0.2	0.1	0.0	0.0	0.0	0.0	–1.3	0.6	0.2	0.3	–0.8	0.7	0.0	0.0	0.0	0.0
Gross change	0.1	0.0	1.7	0.8	0.5	0.2	0.3	0.3	0.0	0.0	1.9	0.6	0.7	0.3	2.0	0.6	0.0	0.0	0.0	0.0
Area, in square kilometers																				
1973	1,976	1,173	8,859	3,900	37	23	111	45	1	1	49,864	5,674	1,021	949	65,005	6,357	935	440	0	0
1980	1,986	1,172	9,087	3,971	18	11	230	162	1	1	49,532	5,707	1,161	926	64,830	6,390	943	441	21	30
1986	1,993	1,172	9,829	4,338	127	76	138	54	1	1	48,981	5,707	1,278	931	64,524	6,502	938	440	0	0
1992	2,009	1,171	10,291	4,485	150	78	176	75	1	1	48,710	5,785	1,265	910	64,269	6,574	939	437	0	0
2000	2,024	1,168	11,013	4,690	322	145	161	88	1	1	48,149	5,729	1,263	915	63,938	6,597	938	438	0	0
Net change	48	25	2,154	978	285	145	51	56	0	0	–1,715	755	243	393	–1,067	905	3	11	0	0
Gross change	92	24	2,160	978	656	274	358	376	0	0	2,430	707	916	405	2,545	762	34	27	42	61

Table 4.   Principal land-cover conversions in Interior 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.

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

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Agriculture	218	104	71	0.2	20.2
	Agriculture	Grassland/Shrubland	210	75	51	0.2	19.4
	Grassland/Shrubland	Forest	124	52	36	0.1	11.4
	Forest	Developed	105	73	49	0.1	9.7
	Agriculture	Developed	103	61	41	0.1	9.6
	Other	Other	320	n/a	n/a	0.3	29.7
		Totals	1,080			0.8	100.0
1980–1986	Agriculture	Developed	464	247	168	0.4	21.7
	Forest	Agriculture	460	168	115	0.4	21.6
	Forest	Developed	235	176	120	0.2	11.0
	Agriculture	Grassland/Shrubland	207	109	74	0.2	9.7
	Grassland/Shrubland	Forest	195	61	42	0.2	9.1
	Other	Other	575	n/a	n/a	0.4	26.9
		Totals	2,135			1.7	100.0
1986–1992	Forest	Agriculture	365	252	171	0.3	21.1
	Agriculture	Developed	281	170	116	0.2	16.3
	Grassland/Shrubland	Forest	218	91	62	0.2	12.6
	Agriculture	Grassland/Shrubland	193	76	52	0.2	11.2
	Forest	Developed	125	125	85	0.1	7.2
	Other	Other	545	n/a	n/a	0.4	31.6
		Totals	1,726			1.4	100.0
1992–2000	Agriculture	Developed	403	165	112	0.3	20.3
	Forest	Agriculture	330	218	149	0.3	16.6
	Forest	Mechanically disturbed	288	144	98	0.2	14.5
	Forest	Developed	240	137	93	0.2	12.1
	Agriculture	Forest	165	130	89	0.1	8.3
	Other	Other	559	n/a	n/a	0.4	28.2
		Totals	1,984			1.6	100.0
1973–2000 (overall)	Forest	Agriculture	1,373	597	407	1.1	19.8
	Agriculture	Developed	1,250	566	386	1.0	18.1
	Forest	Developed	704	480	327	0.6	10.2
	Agriculture	Grassland/Shrubland	694	247	168	0.5	10.0
	Grassland/Shrubland	Forest	663	214	146	0.5	9.6
	Other	Other	2,241	n/a	n/a	1.8	32.4
		Totals	6,925			5.4	100.0

References Cited

Chester, E.W., Noel, S.M., Baskin, J.M., Baskin, C.C., and McReynolds, M.L., 1995, A phytosociological analysis of an old-growth upland wet woods on the Pennyroyal Plain, southcentral Kentucky, USA: Natural Areas Journal, v. 15, p. 297–307.

Hudson, J.C., 2002, Across this land—A regional geography of the United States and Canada: Baltimore, The Johns Hopkins University Press, 474 p.

U.S. Census Bureau, 1970–2000 [various years], Census of population and housing: U.S. Census Bureau database, accessed May 9, 2013, at http://www.census.gov/prod/www/decennial.html.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

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

Southwestern Appalachians Ecoregion

By Terry L. Sohl

Ecoregion Description

The Southwestern Appalachians Ecoregion covers about 35,341 km^2 (13,645 mi^2), stretching from north-central Alabama to southeastern Kentucky (fig. 1) and including part of east-central Tennessee and the northwestern tip of Georgia. The ecoregion is bounded on the north-northwest by the Interior Plateau Ecoregion; on the east-northeast, by the Western Allegheny Plateau and Central Appalachians Ecoregions; on the southeast, by the Ridge and Valley Ecoregion; and on the southwest, by the Southeastern Plains Ecoregion.

Much of the Southwestern Appalachians Ecoregion consists of open low mountains, but some parts have steep slopes with local relief of as much as 300 m. About three-fourths of the ecoregion is covered by forest, primarily mixed oak (*Quercus* spp.) communities and shortleaf pines (*Pinus echinata*) (fig. 2). Agriculture is practiced on lower slopes and valley floors, the greatest concentration of agricultural land being in northeastern Alabama. Mining is a locally significant land-use activity, especially in the southern part of the ecoregion where the local abundance of coal, limestone, and iron deposits led to a booming steel industry in the first half of the 20th century. No large cities (that is, cities that have populations greater than 100,000) are completely within the ecoregion's borders, but the greater metropolitan areas of Birmingham and Huntsville, Alabama, and Chattanooga, Tennessee, are partly within the ecoregion.

Figure 1. Map of Southwestern Appalachians 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 Eastern United States ecoregions are listed in appendix 2. Also shown is part of one Midwest–South Central United States ecoregion, Interior River Lowland. See appendix 3 for definitions of land-use/land-cover classifications.
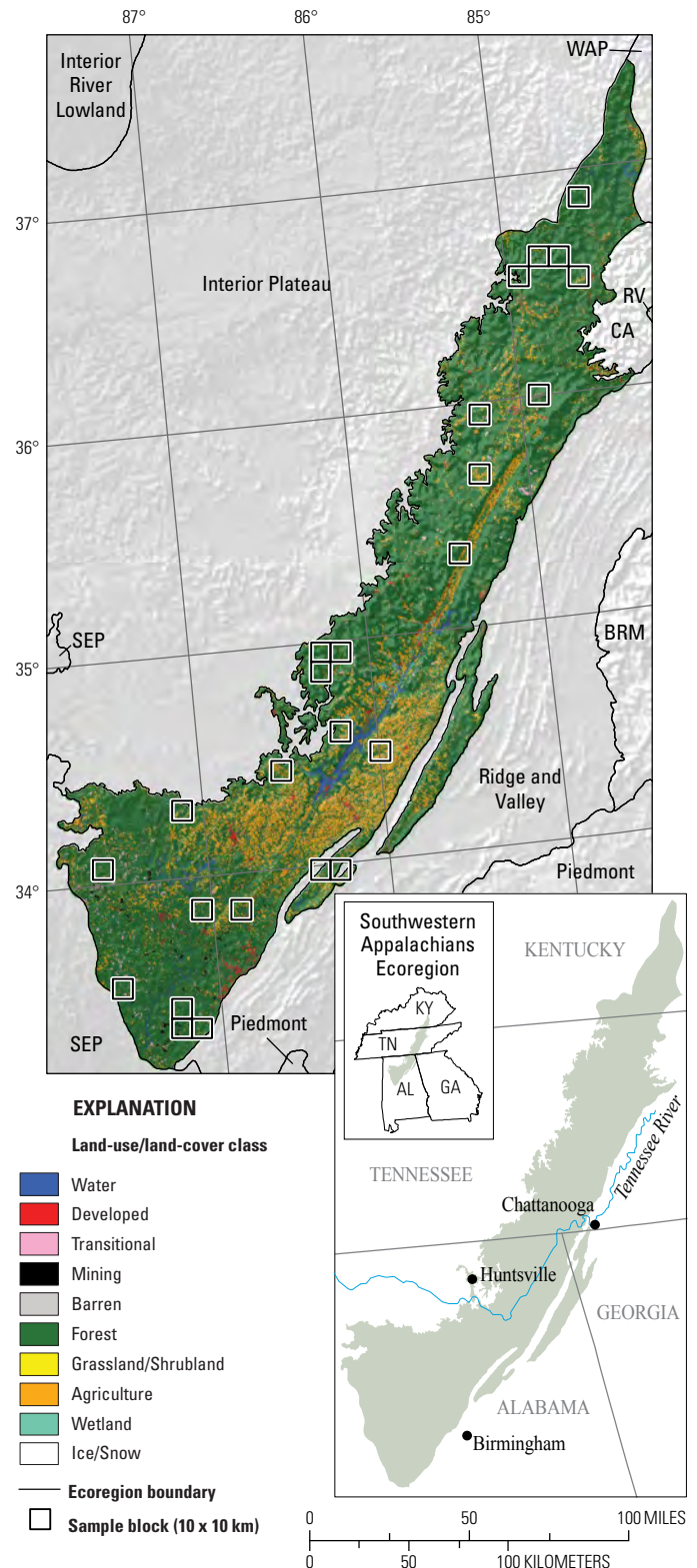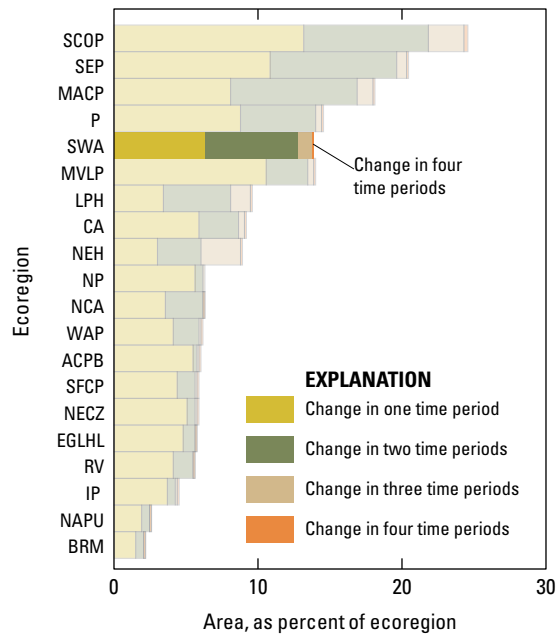
Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Southwestern Appalachians Ecoregion between 1973 and 2000 is estimated at 13.8 percent (table 1). Compared to other Eastern United States ecoregions, change in the Southwestern Appalachians Ecoregion is moderately high (fig. 3). The total amount of change increased in each successive time period (table 2). When normalized to an average annual rate to account for unequal time periods, change was lower during the first time period (1973–1980), and it was both higher and relatively steady for the last three time periods (1980–1986, 1986–1992, 1992–2000) (table 2; fig. 4).

No individual land-cover class changed by more than 2.7 percent of the total ecoregion area during the 27-year study period (table 3). However, two factors that notably drove land-cover conversion in the ecoregion were forestry activity and mining activity. Forest consistently showed some of the largest amount of net change, with fairly consistent decreases in all four time periods (fig. 5). The conversion from forest to mechanically disturbed was the most common land-cover conversion in all four time periods, whereas the conversion from mechanically disturbed to forest (representing regeneration of cut forest land) was the second or third most common conversion (table 4). Forestry-related activities (both cutting and regeneration) clearly were one of the most significant factors affecting land-cover change in the ecoregion in all time periods (figs. 6,7).

Mining activity was the second most important factor that drove land-cover change in the ecoregion (fig. 6). Much of the surface mining in the ecoregion, especially in northern Alabama, is for coal, iron, and limestone, all primary materials required for the production of steel. The Birmingham, Alabama,

Figure 3. Overall spatial change in Southwestern Appalachians Ecoregion (SWA; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Southwestern Appalachians Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Figure 2. Forested hills in Southwestern Appalachians Ecoregion. Forests, which cover about three-fourths of ecoregion, are prevalent on most hilly and mountainous slopes.

Figure 4. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Southwestern Appalachians Ecoregion are represented by red bars in each time period.

metropolitan area, which is partly within the southern part of the ecoregion, was once known as the "Pittsburgh of the South" (Lewis, 2008). The related mining and steel industries were key components of much of the area's economy in much of the 20th century; however, the local steel industry began to decline in the second half of the 20th century. Imports of less expensive foreign steel into the United States increased significantly after 1980, contributing to additional closures of steel facilities in the ecoregion (L.W. Gerard, 2001, written commun.). With these declines, local demand for the raw materials needed by the industry also declined. As production halted at the surface mines, many were revegetated, thus converting to grassland/shrubland and eventually reverting to forest. Although 610 km² of newly mined lands were established between 1973 and 2000, more than 1,000 km² of mined lands were reclaimed during the same time period, resulting in a net decline of

more than 300 km² (table 3; fig. 8). The most significant decline was between 1980 and 1986, when mined land area decreased by more than 50 percent within the ecoregion, with very minor decreases in the last two time periods (table 3; fig. 5). Changes related to the reclamation of mined lands (including mining converting to grassland/shrubland and eventually reverting to forest) were significant land-cover conversions during all time periods (table 4).

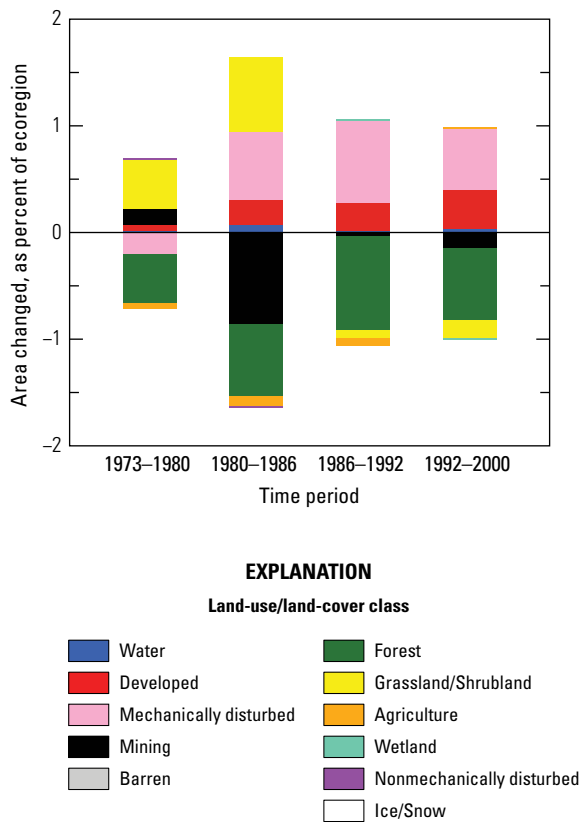Other land-cover conversions generally were minor in the ecoregion. Developed steadily increased throughout the study period, resulting in a net gain of more than 300 km² between 1973 and 2000. Urban centers on the fringes of the ecoregion (for example, Birmingham, Alabama) showed only minor population gains or even decreased in population during the study period, but growth in the surrounding suburbs was the primary driver behind the net gain in developed land.

EXPLANATION

Land-use/land-cover class

- Water
- Developed
- Mechanically disturbed
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Nonmechanically disturbed
- Ice/Snow

Figure 5. Normalized average net change in Southwestern Appalachians Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.
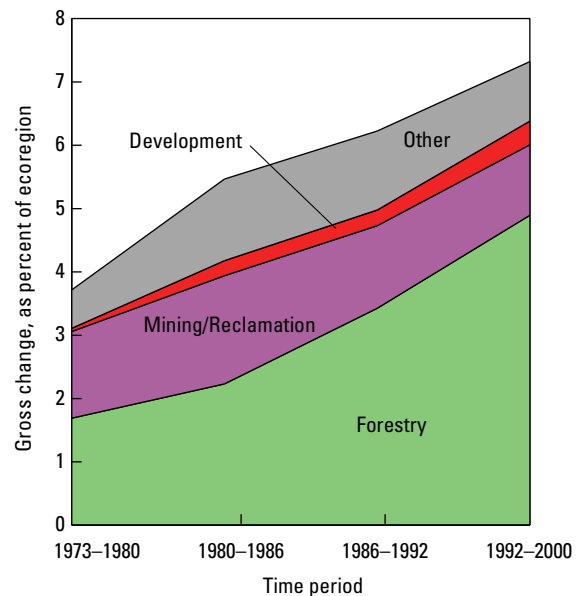
Figure 6. Gross changes in forestry (which includes both forest and mechanically disturbed land-cover classes), mining/reclamation (which includes both mining and grassland/shrubland land-cover classes), development (developed land-cover class), and other land uses in Southwestern Appalachians Ecoregion during 27-year study period. Forestry activity (forest cutting and regeneration) and mining activity (new mining and mining reclamation) accounted for most change in ecoregion.

Figure 7. Timber-harvesting operation in Southwestern Appalachians Ecoregion. Most logged lands were either replanted or allowed to regenerate naturally to forest.

Figure 8. Gravel mine in Southwestern Appalachians Ecoregion. Mining activity historically has been important component of economy in much of ecoregion; however, amount of actively mined lands decreased during 27-year study period, and many older mines were either reclaimed or allowed to revegetate naturally.

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

[Most sample pixels remained unchanged (86.2 percent), whereas 13.8 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	6.3	1.5	4.8	7.7	1.0	15.7
2	6.3	2.0	4.3	8.3	1.3	21.3
3	1.1	0.4	0.7	1.5	0.3	24.2
4	0.1	0.1	0.0	0.2	0.0	37.9
Overall spatial change	13.8	3.7	10.1	17.6	2.5	18.1

Table 2. Raw estimates of change in Southwestern Appalachians 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	3.7	1.2	2.5	5.0	0.8	22.4	0.5
1980–1986	5.5	1.5	3.9	7.0	1.0	19.0	0.9
1986–1992	6.2	1.8	4.4	8.0	1.2	19.7	1.0
1992–2000	7.3	2.3	5.1	9.6	1.5	20.8	0.9
Estimate of change, in square kilometers							
1973–1980	1,313	438	875	1,750	294	22.4	188
1980–1986	1,931	545	1,386	2,477	367	19.0	322
1986–1992	2,199	646	1,553	2,845	434	19.7	367
1992–2000	2,587	799	1,787	3,386	538	20.8	323

Table 3. Estimated area (and margin of error) of each land-cover class in Southwestern Appalachians 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	0.5	0.2	1.8	0.6	1.1	0.6	1.6	0.8	0.0	0.0	78.0	3.9	0.4	0.2	16.5	4.1	0.2	0.1	0.0	0.0
1980	0.5	0.2	1.8	0.7	0.9	0.3	1.7	0.7	0.0	0.0	77.6	3.9	0.9	0.4	16.4	4.1	0.2	0.1	0.0	0.0
1986	0.6	0.2	2.1	0.8	1.5	0.5	0.8	0.5	0.0	0.0	76.9	3.9	1.6	0.5	16.3	4.1	0.2	0.1	0.0	0.0
1992	0.6	0.2	2.3	0.9	2.3	1.0	0.8	0.6	0.0	0.0	76.0	3.8	1.5	0.6	16.3	4.1	0.2	0.1	0.0	0.0
2000	0.6	0.2	2.7	1.0	2.9	1.0	0.7	0.4	0.0	0.0	75.4	4.0	1.3	0.6	16.3	4.1	0.2	0.1	0.0	0.0
Net change	0.2	0.1	0.9	0.5	1.8	0.8	–0.9	0.8	0.0	0.0	–2.7	1.1	0.9	0.4	–0.2	0.3	0.0	0.0	0.0	0.0
Gross change	0.2	0.1	0.9	0.5	4.6	1.2	2.7	1.2	0.0	0.0	6.0	1.4	2.2	0.7	0.9	0.2	0.0	0.0	0.0	0.1
											Area, in square kilometers									
1973	165	59	634	224	384	195	551	295	1	1	27,583	1,374	139	62	5,823	1,443	60	32	0	0
1980	175	61	652	232	314	119	600	263	1	1	27,425	1,362	305	135	5,803	1,441	60	32	7	10
1986	201	74	736	277	543	168	295	160	1	1	27,186	1,372	549	187	5,772	1,445	60	32	0	0
1992	209	74	824	314	819	366	281	204	1	1	26,875	1,344	528	205	5,745	1,445	60	32	0	0
2000	221	81	955	368	1,020	350	233	127	1	1	26,635	1,409	467	208	5,750	1,452	59	32	0	0
Net change	56	40	321	162	636	297	–318	270	0	0	–948	405	327	159	–74	111	–1	1	0	0
Gross change	56	40	321	162	1,642	416	937	412	0	0	2,109	494	786	242	332	87	1	1	14	20

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

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

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	302	115	77	0.9	23.0
	Mechanically disturbed	Forest	295	186	125	0.8	22.4
	Forest	Mining	239	116	78	0.7	18.2
	Mining	Forest	115	101	68	0.3	8.7
	Mining	Grassland/Shrubland	101	94	63	0.3	7.7
	Other	Other	262	n/a	n/a	0.7	20.0
		Totals	1,313			3.7	100.0
1980–1986	Forest	Mechanically disturbed	531	164	110	1.5	27.5
	Mining	Grassland/Shrubland	298	142	95	0.8	15.4
	Mechanically disturbed	Forest	256	107	72	0.7	13.3
	Grassland/Shrubland	Forest	187	99	67	0.5	9.7
	Mining	Forest	154	84	56	0.4	8.0
	Other	Other	505	n/a	n/a	1.4	26.2
		Totals	1,931			5.5	100.0
1986–1992	Forest	Mechanically disturbed	789	351	236	2.2	35.9
	Mechanically disturbed	Forest	421	148	100	1.2	19.1
	Grassland/Shrubland	Forest	283	93	62	0.8	12.9
	Mining	Grassland/Shrubland	136	76	51	0.4	6.2
	Forest	Mining	134	94	63	0.4	6.1
	Other	Other	435	n/a	n/a	1.2	19.8
		Totals	2,199			6.2	100.0
1992–2000	Forest	Mechanically disturbed	1,003	346	233	2.8	38.8
	Mechanically disturbed	Forest	726	356	239	2.1	28.1
	Grassland/Shrubland	Forest	244	104	70	0.7	9.4
	Mining	Grassland/Shrubland	136	122	82	0.4	5.3
	Forest	Mining	94	61	41	0.3	3.6
	Other	Other	384	n/a	n/a	1.1	14.9
		Totals	2,587			7.3	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	2,626	876	589	7.4	32.7
	Mechanically disturbed	Forest	1,698	709	477	4.8	21.1
	Grassland/Shrubland	Forest	750	274	184	2.1	9.3
	Mining	Grassland/Shrubland	671	359	241	1.9	8.4
	Forest	Mining	610	314	211	1.7	7.6
	Other	Other	1,675	n/a	n/a	4.7	20.9
		Totals	8,030			22.7	100.0

References Cited

Lewis, H.J., 2008, Birmingham: Encyclopedia of Alabama, accessed September 4, 2015, at http://www.encyclopediaofalabama.org/article/h-1421.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

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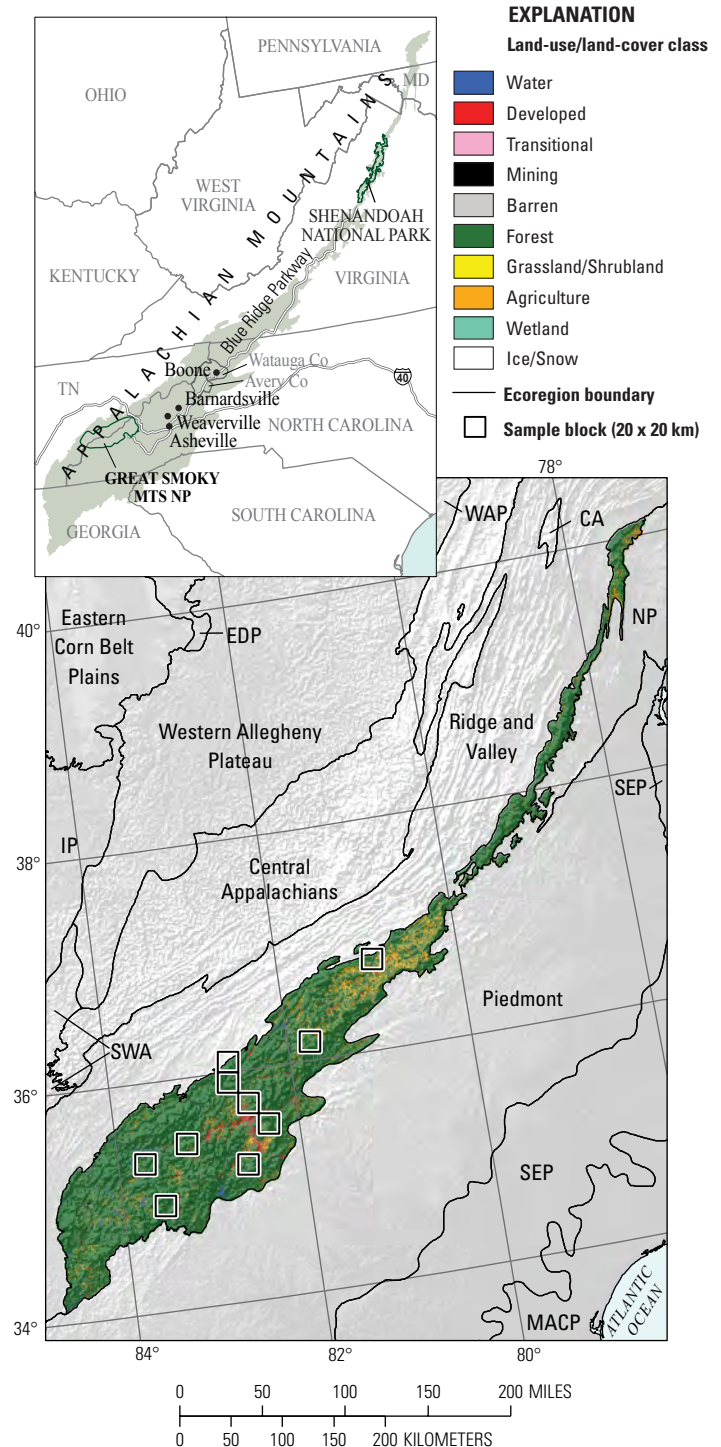
Chapter 14

Blue Ridge Mountains Ecoregion

By Janis L. Taylor, Rachel M.K. Headley, and Darrell E. Napton

Ecoregion Description

The Blue Ridge Mountains Ecoregion, in the southern Appalachian Mountains, is the easternmost of the Appalachian highland ecoregions (fig. 1). More than 1,100 km long and ranging between 8 and 80 km wide, the ecoregion covers about 47,791 km^2 (18,452 mi^2) in eight states: Georgia, South Carolina, North Carolina, Tennessee, Virginia, West Virginia, Maryland, and Pennsylvania. The ecoregion is bounded on the west-northwest by the Ridge and Valley Ecoregion; and on the east-southeast, by the Piedmont and Northern Piedmont Ecoregions.

The Blue Ridge Mountains Ecoregion primarily is forested, with cool summers and cold winters. Almost one-third of the ecoregion is under public ownership, including two national parks (Great Smoky Mountains National Park and Shenandoah National Park), the Blue Ridge Parkway, seven national forests, and 29 wilderness areas (Nash, 1999). Areas within the Great Smoky Mountains National Park have been declared an International Biosphere Reserve because of the large number of endemic species of flora and fauna present there (Bousquet, 2000). The overall landscape is a mosaic of large continuous blocks of forest intermixed with agriculture and dotted with small parcels of developed land.

Figure 1. Map of Blue Ridge Mountains Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 20 x 20 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Eastern United States ecoregions are listed in appendix 2. Also shown are parts of two Midwest–South Central United States ecoregions: Eastern Corn Belt Plains and Erie Drift Plains. See appendix 3 for definitions of land-use/land-cover classifications.

Contemporary Land-Cover Change (1973 to 2000)

Land cover in the Blue Ridge Mountains Ecoregion is fairly stable. The overall spatial change (the percentage of land area that changed at least one time) in the Blue Ridge Mountains Ecoregion between 1973 and 2000 is estimated at 2.0 percent (table 1). Compared to other Eastern United States ecoregions, change in the Blue Ridge Mountains Ecoregion was the lowest of all (fig. 2): of the land that changed, three-fourths changed only one time, whereas one-fourth changed twice (table 1). Estimated changes in each of the four time periods were low, ranging from 0.4 percent between 1980 and 1986 to 0.9 percent between 1992 and 2000 (table 2). When normalized to an average annual rate to account for uneven time periods, change per time period was 0.1 percent per year in all time periods (table 2; fig. 3).

The percentage of each land-cover class on each of five mapped dates between 1973 and 2000 is shown in table 3. Three land-cover classes (forest, agriculture, and developed) accounted for about 99.2 percent of the ecoregion in 2000.

Forest, the most common land-cover class, makes up nearly 80 percent of the ecoregion. During the entire study period, forest decreased from 79.5 percent of the ecoregion in 1973 to 78.3 percent in 2000, a 1.2 percent decrease. Changes to forest during the study period included both unidirectional and cyclical conversions. Some forest was converted to developed, whereas some forested land was harvested for timber and then reverted to forest in subsequent years. Agriculture was the second most common land-cover class, occupying about 13.7 percent of the ecoregion in 2000 (table 3; fig. 4). During the entire study period, agriculture remained relatively stable, experiencing minor gains and losses in each time period.
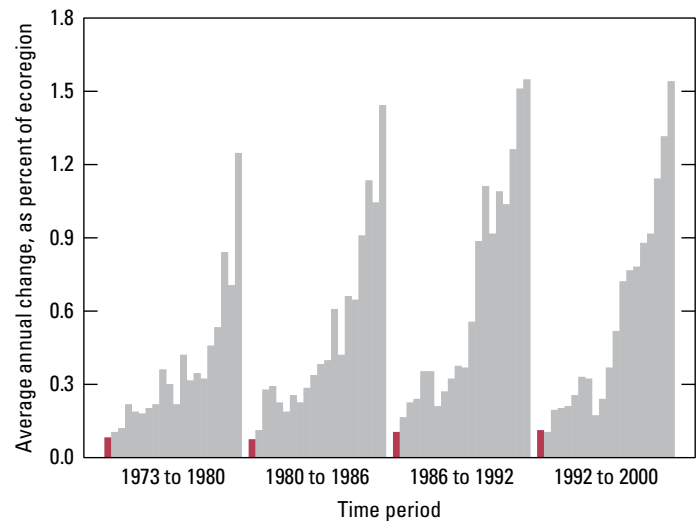
Figure 3. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Blue Ridge Mountains Ecoregion are represented by red bars in each time period.

Figure 2. Overall spatial change in Blue Ridge Mountains Ecoregion (BRM; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Blue Ridge Mountains Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Figure 4. Tobacco field next to school, in Barnardsville, North Carolina.

Developed, the third most common land-cover class, increased by 1.1 percent of the ecoregion, from 6.1 percent in 1972 to 7.2 percent in 2000 (table 3; figs. 5,6).

The conversion of forest to developed dominated in three of the four study periods (1973–1980, 1980–1986, 1992–2000) (table 4; fig. 7). The most common conversion of this type occurred between 1992 and 2000, when 191 km^2 of forest converted to developed (table 4; fig. 8). Between 1986 and 1992, the most common land-cover conversion was from forest to mechanically disturbed: about 87 km^2 of forest was cut, likely a result of commercial timber harvesting for pulpwood used to produce paper and packaging materials (Southern Appalachian Man and the Biosphere, 1996).

Overall, little change occurred in this amenity-rich ecoregion between 1973 and 2000. Most of the land-cover change that occurred was to developed, as existing urban areas expanded and exurban development increased. Between 1970 and 2000, population within the ecoregion increased by 63 percent, almost double the national increase of 34 percent (U.S. Census Bureau, 1970–2000 [various years]). Seasonal residents are drawn to the mountains, both in the summer, for a respite from the warmth and humidity of the South, and in the winter, for snow-related recreation such as skiing (Gade and others, 2002); accordingly, an increase in seasonal housing was seen in Avery and Watauga Counties, North Carolina, between 1970 and 2000 (U.S. Census Bureau, 1970–2000 [various years]).
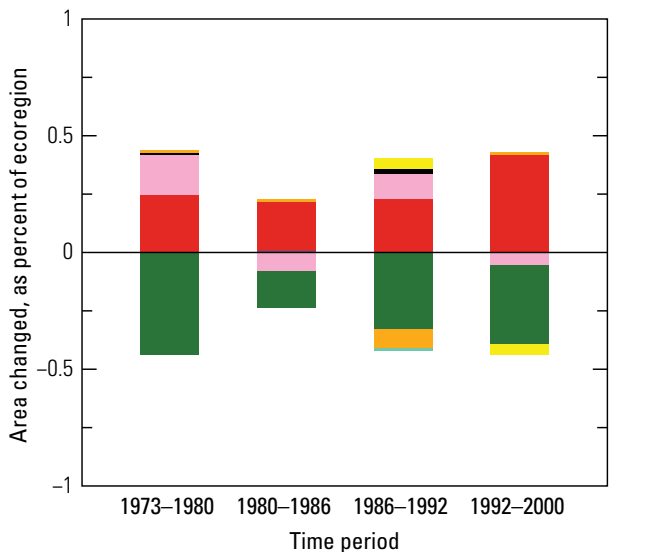
Figure 6. Homes built along ridgeline, near Boone, North Carolina.

EXPLANATION

Land-use/land-cover class

- Water
- Developed
- Mechanically disturbed
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Nonmechanically disturbed
- Ice/Snow

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

Figure 7. Gas station and strip mall on Interstate 40, near Asheville, North Carolina.

Figure 8. Land being cleared for new development in Twin Brook Hills subdivision, near Weaverville, North Carolina.

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

[Most sample pixels remained unchanged (98.0 percent), whereas 2.0 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	1.5	0.4	1.1	2.0	0.3	18.7
2	0.5	0.2	0.3	0.6	0.1	20.1
3	0.0	0.0	0.0	0.0	0.0	91.8
4	0.0	0.0	0.0	0.0	0.0	95.7
Overall spatial change	2.0	0.5	1.5	2.5	0.3	14.5

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

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

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
Estimate of change, in percent stratum							
1973–1980	0.5	0.2	0.4	0.7	0.1	19.1	0.1
1980–1986	0.4	0.2	0.3	0.6	0.1	24.6	0.1
1986–1992	0.6	0.2	0.4	0.8	0.1	23.7	0.1
1992–2000	0.9	0.2	0.7	1.1	0.1	12.7	0.1
Estimate of change, in square kilometers							
1973–1980	255	76	178	331	49	19.1	36
1980–1986	209	81	128	289	51	24.6	35
1986–1992	295	110	185	406	70	23.7	49
1992–2000	430	86	344	515	54	12.7	54

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

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
									Area, in percent stratum											
1973	0.5	0.3	6.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	79.5	5.4	0.1	0.1	13.7	4.7	0.0	0.0	0.0	0.0
1980	0.5	0.3	6.3	2.1	0.2	0.1	0.1	0.0	0.0	0.0	79.1	5.3	0.1	0.1	13.7	4.7	0.0	0.0	0.0	0.0
1986	0.5	0.3	6.5	2.2	0.1	0.1	0.1	0.0	0.0	0.0	79.0	5.4	0.1	0.1	13.7	4.7	0.0	0.0	0.0	0.0
1992	0.5	0.3	6.7	2.2	0.2	0.1	0.1	0.0	0.0	0.0	78.6	5.3	0.1	0.1	13.6	4.7	0.0	0.0	0.0	0.0
2000	0.5	0.3	7.2	2.3	0.2	0.1	0.1	0.1	0.0	0.0	78.3	5.4	0.1	0.1	13.7	4.7	0.0	0.0	0.0	0.0
Net change	0.0	0.0	1.1	0.4	0.2	0.1	0.0	0.0	0.0	0.0	–1.3	0.4	0.0	0.0	–0.1	0.1	0.0	0.0	0.0	0.0
Gross change	0.0	0.0	1.1	0.4	0.7	0.3	0.0	0.0	0.0	0.0	1.5	0.4	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0
									Area, in square kilometers											
1973	242	134	2,896	1,007	15	9	21	22	2	2	38,017	2,566	28	25	6,555	2,235	14	10	0	0
1980	243	134	3,014	1,011	98	43	27	21	2	2	37,809	2,518	28	25	6,556	2,225	14	10	0	0
1986	247	133	3,115	1,060	60	37	31	22	2	2	37,734	2,560	28	25	6,560	2,234	14	10	0	0
1992	248	133	3,223	1,048	116	56	38	23	2	2	37,580	2,541	50	43	6,521	2,230	14	10	0	0
2000	248	133	3,426	1,083	91	55	38	24	2	2	37,417	2,559	31	28	6,524	2,231	14	10	0	0
Net change	6	8	529	214	76	50	17	10	0	0	–600	190	3	4	–31	39	0	0	0	0
Gross change	6	8	529	214	342	122	21	13	0	0	715	169	47	67	92	59	0	0	0	0

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

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

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Developed	112	59	37	0.2	43.9
	Forest	Mechanically disturbed	83	44	28	0.2	32.7
	Forest	Agriculture	23	19	12	0.0	8.9
	Mechanically disturbed	Forest	8	7	5	0.0	3.2
	Agriculture	Forest	8	8	5	0.0	3.1
	Other	Other	21	n/a	n/a	0.0	8.1
		Totals	255			0.5	100.0
1980–1986	Forest	Developed	95	68	43	0.2	45.4
	Mechanically disturbed	Forest	61	36	23	0.1	29.1
	Forest	Mechanically disturbed	28	19	12	0.1	13.5
	Forest	Agriculture	10	10	6	0.0	4.8
	Agriculture	Developed	6	8	5	0.0	2.8
	Other	Other	9	n/a	n/a	0.0	4.4
		Totals	209			0.4	100.0
1986–1992	Forest	Mechanically disturbed	87	43	27	0.2	29.3
	Forest	Developed	66	53	34	0.1	22.3
	Agriculture	Developed	42	41	26	0.1	14.2
	Mechanically disturbed	Forest	31	19	12	0.1	10.6
	Forest	Grassland/Shrubland	22	33	21	0.0	7.5
	Other	Other	47	n/a	n/a	0.1	16.1
		Totals	295			0.6	100.0
1992–2000	Forest	Developed	191	71	45	0.4	44.4
	Mechanically disturbed	Forest	104	55	35	0.2	24.2
	Forest	Mechanically disturbed	85	56	35	0.2	19.9
	Grassland/Shrubland	Forest	15	22	14	0.0	3.4
	Grassland/Shrubland	Agriculture	8	11	7	0.0	1.8
	Other	Other	27	n/a	n/a	0.1	6.3
		Totals	430			0.9	100.0
1973–2000 (overall)	Forest	Developed	463	195	124	1.0	39.0
	Forest	Mechanically disturbed	284	94	60	0.6	23.9
	Mechanically disturbed	Forest	204	77	49	0.4	17.2
	Agriculture	Developed	61	51	33	0.1	5.1
	Forest	Agriculture	52	40	25	0.1	4.4
	Other	Other	124	n/a	n/a	0.3	10.4
		Totals	1,188			2.5	100.0

References Cited

Bousquet, Woodward S., 2000, Outdoor recreation, *in* Orr, Douglas M., Jr., and Stuart, A.W., The North Carolina atlas—Portrait for a new century: Chapel Hill, The University of North Carolina Press, p. 409–433.

Gade, O., Rex, A.B., Young, J.E., and Perry, L.B., 2002, North Carolina—People and environments (2d ed.): Boone, N.C., Parkway Publishers, Inc., 602 p.

Nash, Steve, 1999, Blue Ridge 2020—An owner's manual: Chapel Hill, The University of North Carolina Press, 211 p.

Southern Appalachian Man and the Biosphere, 1996, The southern Appalachian assessment: Southern Appalachian Man and the Biosphere, v. 1–5, available at http://www.samab.org/site/publications/.

U.S. Census Bureau, 1970–2000 [various years], Census of population and housing: U.S. Census Bureau database, accessed May 9, 2013, at http://www.census.gov/prod/www/decennial.html.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

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Chapter 15

Piedmont Ecoregion

By Darrell E. Napton

Ecoregion Description

The Piedmont Ecoregion, which lies in the area between the flat coastal plains to the southeast and the Appalachian Mountains to the northwest, covers 165,460 km² (63,884 mi²) across parts of five states (Alabama, Georgia, South Carolina, North Carolina, and Virginia) (fig. 1). The ecoregion is bounded on the east and southeast by the Southeastern Plains Ecoregion,

and, on the northwest, by the Ridge and Valley, Blue Ridge Mountains, and Northern Piedmont Ecoregions. The Piedmont Ecoregion, the landscape of which is rolling, with steep-sided hills and some plains, is underlain by metamorphic and igneous rocks (Wiken and others, 2011). The pre-European vegetation mostly was forests of oak–hickory (*Quercus* spp.
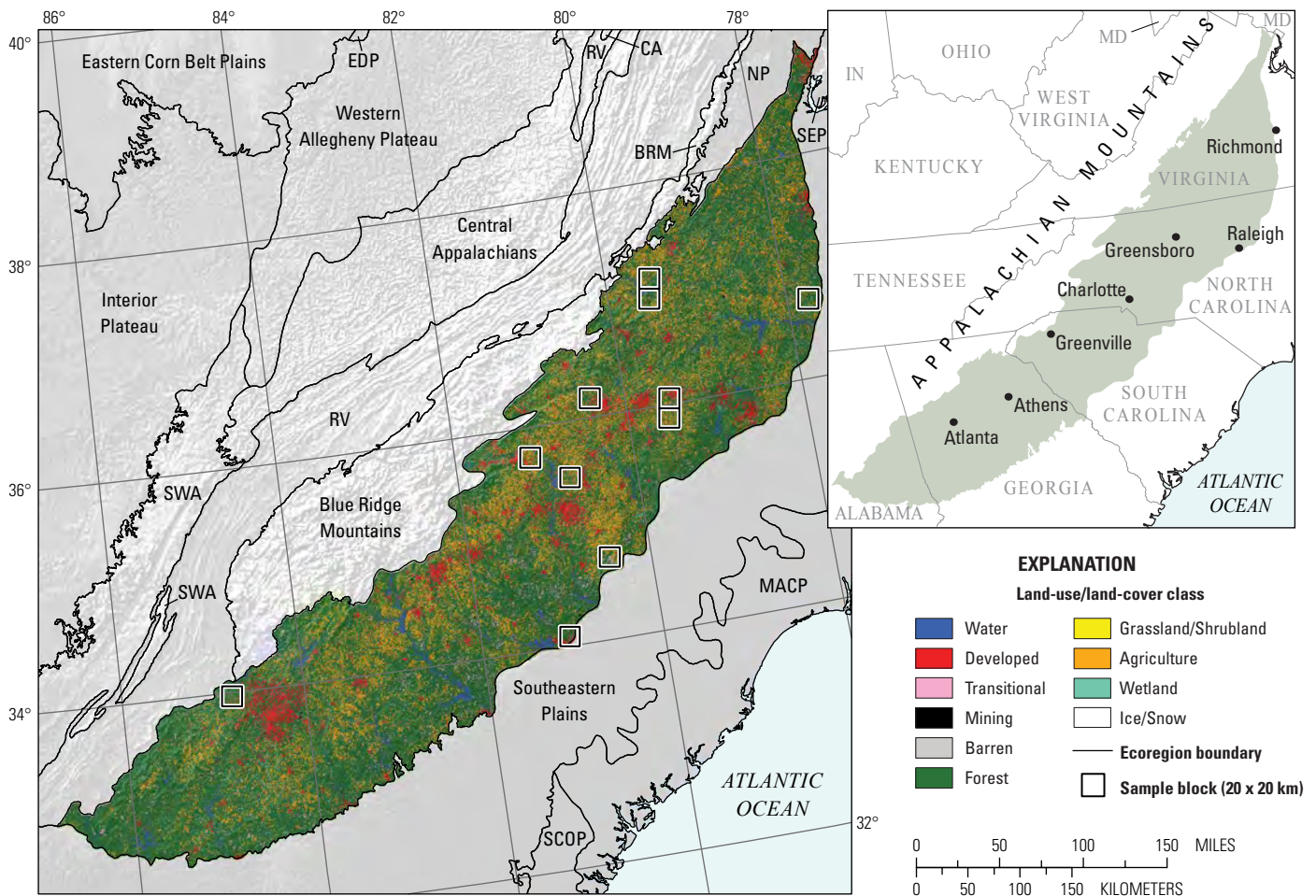
Figure 1. Map of Piedmont Ecoregion and surrounding ecoregions, showing land-use/land-cover classes from 1992 National Land Cover Dataset (Vogelmann and others, 2001); note that not all land-use/land-cover classes shown in explanation may be depicted on map; note also that, for this "Status and Trends of Land Change" study, transitional land-cover class was subdivided into mechanically disturbed and nonmechanically disturbed classes. Squares indicate locations of 20 x 20 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Eastern United States ecoregions are listed in appendix 2. Also shown are parts of two Midwest–South Central United States ecoregions: Erie Drift Plains (EDP) and Eastern Corn Belt Plains. See appendix 3 for definitions of land-use/land-cover classifications.

and *Carya* spp., respectively) and mixed oak–pine (*Quercus* spp. and *Pinus* spp., respectively) (Johnson and Sharpe, 1976). The Piedmont Ecoregion became an important farming region during the 19th century; however, beginning with the Civil War, large areas of farmland have reverted to forest during each economic downturn. During this time, Piedmont Ecoregion farmers have faced competition from other ecoregions while coping with soil erosion, declining soil fertility, and increased expenses associated with boll weevil (*Anthonomus grandis*) management (Manners, 1979; Hart, 1980). Additionally, the small fields and steep slopes of the ecoregion hindered the use of farm machinery (Hart, 1978). As Piedmont Ecoregion farmers lost their competitive advantage, forestry and land development became more competitive uses of land, and the ecoregion gradually reverted to pine and hardwoods intermixed with farms and developed areas (fig. 2) (Brender, 1974).
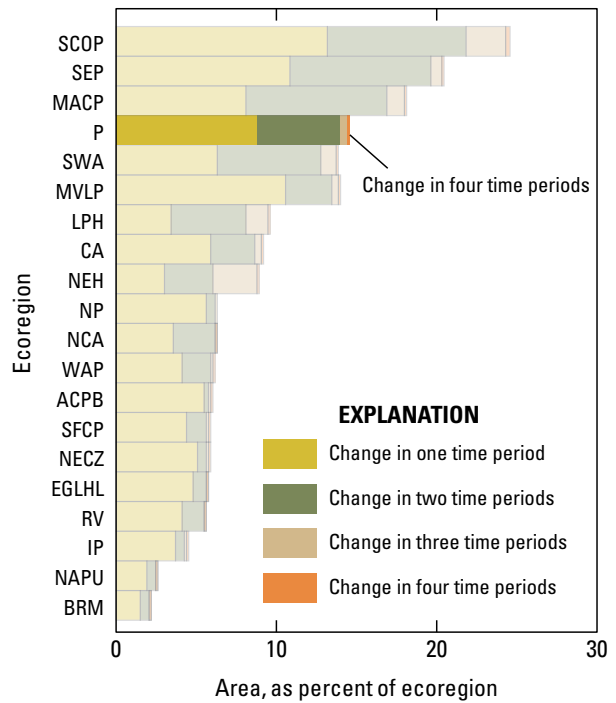
Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Piedmont Ecoregion between 1973 and 2000 is estimated at 14.5 percent (table 1). Compared to other Eastern United States ecoregions, change in the Piedmont Ecoregion was relatively high (fig. 3): about three-fifths of the area changed only one time, whereas two-fifths changed two, three, or, in a handful of cases, four times. Most Piedmont Ecoregion land was stable (85.5 percent) and did not convert to a different land-cover class. Land-conversion rates, when normalized to an average annual rate to account for uneven time periods, varied temporally (fig. 4), ranging from a low of 0.5 percent annually between 1973 and 1980 to a high of 1.1 percent annually between 1986 and 1992 (table 2).

An overview of the net land-cover change in the Piedmont Ecoregion by time period is shown in figure

Figure 3.   Overall spatial change in Piedmont Ecoregion (P; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Piedmont Ecoregion (four time periods) labeled for clarity. See table 2 for years covered by each time period. See appendix 2 for key to ecoregion abbreviations.

Figure 2.   Typical rural landscape in Piedmont Ecoregion, with pasture amidst forest.
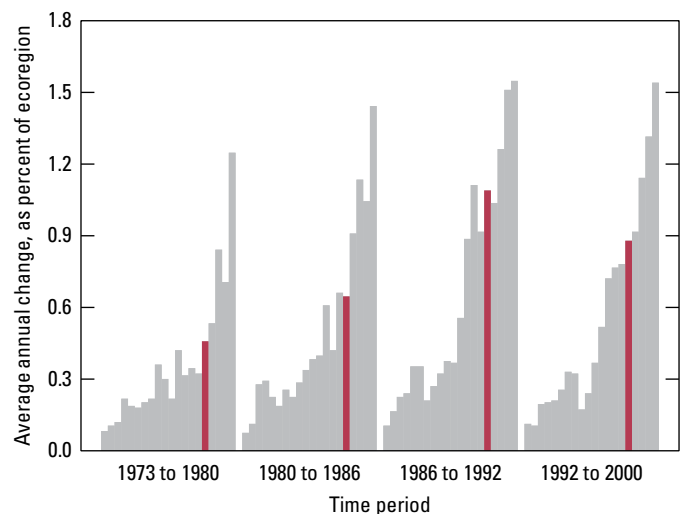
Figure 4.   Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Piedmont Ecoregion are represented by red bars in each time period.

5. Developed land increased steadily and more rapidly throughout the 27-year study period, except between 1980 and 1986. This brief decrease in the rate of land-cover change may have resulted from national efforts to curb inflation, resulting in greatly reduced new housing construction through the early 1980s (National Association of Home Builders, 1973–2000 [various years]). The area of the mechanically disturbed land-cover class increased during the first three time periods (1973–1980, 1980–1986, 1986–1992), and then it decreased during the last time period (1992–2000), possibly because of the decrease in commercial f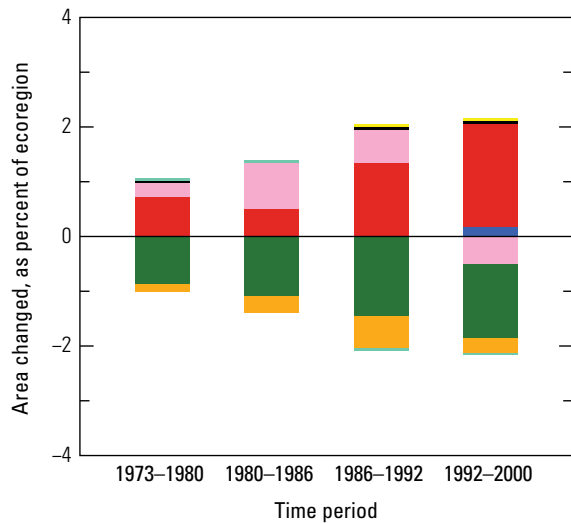orest harvesting associated with the ecoregion's population growth (van Lear and others, 2004). Forest and agriculture steadily decreased as more land was converted to developed land to accommodate the growing population of the ecoregion.

The top five common land-cover conversions accounted for 89 percent (by area) of the change in the Piedmont Ecoregion (table 3). The top two conversions were from forest to mechanically disturbed and from mechanically disturbed to forest, which represents the cyclical process of forest harvesting and regrowth (fig. 6). Three common conversions resulted in one-way conversions from forest, agriculture, and mechanically disturbed to developed, and the forest-to-water conversion likely was caused by the need to provide potable water for the growing population in the ecoregion.

The major land-cover classes in the Piedmont Ecoregion include forest, agriculture, developed, and water (table 4), which accounted for 97.0 percent or more of the ecoregion in both the beginning (1973) and the end (2000) of the study period, but their relative proportions changed during the study period. For example, developed increased 37.8 percent, from 11.9 to 16.4 percent of the ecoregion. The Piedmont Ecoregion is in the Sun Belt, an area that grew rapidly during the latter part of the 20th century. After 1960, the population of the Piedmont Ecoregion increased faster than that of the rest of the Nation, and it continued through the remainder of the 20th century: the population increased from 7.6 to 13.8 million between 1970 and 2000 (U.S. Census Bureau, 1970–2000 [various years]), an 81.6 percent increase, much higher than the 38.0 percent increase for the conterminous United States. The new residents placed demands on the ecoregion's land, resulting in the development of additional land (fig. 7). Meanwhile, water bodies increased

Figure 6. Recently cut forest in Piedmont Ecoregion. Commercial forestry is common in Piedmont Ecoregion.

EXPLANATION

Land-use/land-cover class

- Water
- Developed
- Mechanically disturbed
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Nonmechanically disturbed
- Ice/Snow

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

Figure 7. Large industrial plant in rural setting of Piedmont Ecoregion. Such plants provide many new jobs in ecoregion.

in area by 9.8 percent, most likely to meet the increased need for public drinking water in the Piedmont Ecoregion, an area with scant groundwater resources (Hodler and Schretter, 1986). Forest decreased from 59.8 to 55.1 percent of the ecoregion (a decrease of 7.9 percent from its 1973 level), but forest still accounted for more than one-half of the ecoregion in 2000 (table 4). Forest constituted 71.3 percent of the land that was converted to developed (figs. 8,9). Agricultural land accounted for almost one-quarter (24.3 percent) of the newly developed land, which was about equivalent to its proportion of the ecoregion.

During the past 200 years, most of the original forests in the Piedmont Ecoregion were converted to farmland, but when the farms were unable to remain competitive nationally, much of the ecoregion reverted to forested land. During the last one-third of the 20th century, the Piedmont Ecoregion was one of the fastest developing regions in the Nation.

Figure 8.   New subdivision built in forested area, in Piedmont Ecoregion.

EXPLANATION

SOURCE LAND-USE/LAND-COVER CLASS

▮ Water		▮ Forest	
▮ Mechanically disturbed		▮ Agriculture	
▮ Mining		▮ Wetland	
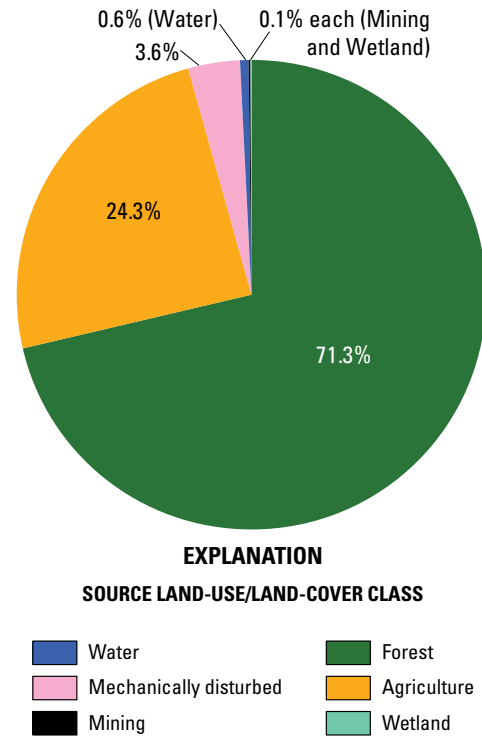
Figure 9.   Areal percentages of sources of developed land in Piedmont Ecoregion during study period (1973–2000).

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

[Most sample pixels remained unchanged (85.5 percent), whereas 14.5 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	8.8	2.2	6.6	11.0	1.4	16.1
2	5.2	2.6	2.7	7.8	1.7	31.7
3	0.4	0.3	0.1	0.7	0.2	49.2
4	0.0	0.0	0.0	0.1	0.0	49.4
Overall spatial change	14.5	4.6	9.9	19.1	3.0	20.4

Table 2. Raw estimates of change in Piedmont 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	3.2	1.3	1.9	4.5	0.8	26.3	0.5
1980–1986	3.9	1.9	1.9	5.8	1.2	32.0	0.6
1986–1992	6.5	2.5	4.0	9.0	1.6	24.7	1.1
1992–2000	7.0	2.4	4.6	9.5	1.6	22.3	0.9
Estimate of change, in square kilometers							
1973–1980	5,276	2,164	3,112	7,441	1,388	26.3	754
1980–1986	6,419	3,207	3,213	9,626	2,057	32.0	1,070
1986–1992	10,784	4,155	6,629	14,939	2,665	24.7	1,797
1992–2000	11,604	4,039	7,565	15,643	2,591	22.3	1,451

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

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

Period	From class	To class	Area changed (km²)	Margin of error (+/− km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	1,564	980	628	0.9	29.6
	Mechanically disturbed	Forest	1,168	794	509	0.7	22.1
	Forest	Developed	980	895	574	0.6	18.6
	Forest	Agriculture	556	261	168	0.3	10.5
	Agriculture	Forest	537	537	344	0.3	10.2
	Other	Other	472	n/a	n/a	0.3	8.9
		Totals	5,276			3.2	100.0
1980–1986	Forest	Mechanically disturbed	2,822	2,090	1,341	1.7	44.0
	Mechanically disturbed	Forest	1,437	832	533	0.9	22.4
	Agriculture	Forest	650	734	471	0.4	10.1
	Forest	Agriculture	533	372	239	0.3	8.3
	Forest	Developed	503	201	129	0.3	7.8
	Other	Other	474	n/a	n/a	0.3	7.4
		Totals	6,419			3.9	100.0
1986–1992	Forest	Mechanically disturbed	3,885	1,817	1,165	2.3	36.0
	Mechanically disturbed	Forest	2,914	2,222	1,425	1.8	27.0
	Forest	Developed	1,569	859	551	0.9	14.5
	Agriculture	Forest	791	928	595	0.5	7.3
	Agriculture	Developed	611	241	155	0.4	5.7
	Other	Other	1,014	n/a	n/a	0.6	9.4
		Totals	10,784			6.5	100.0
1992–2000	Mechanically disturbed	Forest	3,669	1,865	1,196	2.2	31.6
	Forest	Mechanically disturbed	3,177	2,581	1,655	1.9	27.4
	Forest	Developed	2,263	1,374	882	1.4	19.5
	Agriculture	Developed	653	515	330	0.4	5.6
	Forest	Agriculture	558	272	174	0.3	4.8
	Other	Other	1,285	n/a	n/a	0.8	11.1
		Totals	11,604			7.0	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	11,447	6,997	4,488	6.9	33.6
	Mechanically disturbed	Forest	9,188	5,322	3,414	5.6	27.0
	Forest	Developed	5,314	2,792	1,791	3.2	15.6
	Agriculture	Forest	2,291	2,240	1,437	1.4	6.7
	Forest	Agriculture	2,208	1,035	664	1.3	6.5
	Other	Other	3,635	n/a	n/a	2.2	10.7
		Totals	34,084			20.6	100.0

Table 4. Estimated area (and margin of error) of each land-cover class in Piedmont 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-mechani-cally disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
										Area, in percent stratum										
1973	2.2	1.1	11.9	5.5	0.9	0.5	0.1	0.0	0.0	0.0	59.8	6.0	0.0	0.0	24.4	5.8	0.8	0.5	0.0	0.0
1980	2.2	1.1	12.7	6.1	1.1	0.6	0.1	0.1	0.0	0.0	59.0	6.1	0.0	0.0	24.2	6.0	0.8	0.5	0.0	0.0
1986	2.2	1.1	13.2	6.1	1.9	1.4	0.1	0.1	0.0	0.0	57.9	5.6	0.0	0.0	23.9	6.0	0.8	0.5	0.0	0.0
1992	2.2	1.1	14.5	6.3	2.5	1.1	0.2	0.1	0.0	0.0	56.4	5.9	0.0	0.0	23.3	6.1	0.8	0.5	0.0	0.0
2000	2.4	1.1	16.4	6.8	2.0	1.6	0.2	0.1	0.0	0.0	55.1	5.8	0.0	0.0	23.1	6.1	0.7	0.4	0.0	0.0
Net change	0.2	0.2	4.5	2.1	1.1	1.1	0.2	0.1	0.0	0.0	–4.8	2.1	0.0	0.0	–1.3	1.0	0.0	0.0	0.0	0.0
Gross change	0.3	0.2	4.5	2.1	4.4	1.8	0.2	0.1	0.0	0.0	6.6	1.8	0.1	0.1	2.2	0.9	0.0	0.0	0.0	0.0
										Area, in square kilometers										
1973	3,585	1,887	19,692	9,135	1,413	842	120	78	4	4	99,023	9,864	10	14	40,329	9,663	1,284	752	0	0
1980	3,574	1,885	20,938	10,035	1,815	1,011	174	99	4	4	97,579	10,138	14	15	40,076	9,845	1,286	751	0	0
1986	3,573	1,885	21,803	10,143	3,183	2,311	194	103	4	4	95,798	9,264	23	22	39,594	9,935	1,286	751	0	0
1992	3,613	1,883	24,020	10,476	4,156	1,845	325	148	4	4	93,382	9,739	61	58	38,621	10,128	1,277	751	0	0
2000	3,937	1,818	27,128	11,274	3,303	2,637	406	194	4	3	91,152	9,561	68	77	38,222	10,079	1,239	732	0	0
Net change	352	359	7,436	3,400	1,890	1,873	286	150	0	1	–7,871	3,546	58	64	–2,107	1,607	–45	48	0	0
Gross change	421	349	7,436	3,400	7,273	2,952	294	152	0	1	10,923	2,985	119	93	3,585	1,507	52	48	0	0

References Cited

Brender, E.V., 1974, Impact of past land use on the lower Piedmont forest: Journal of Forestry, v. 72, p. 34–36.

Hart, John Fraser, 1978, Cropland concentrations in the South: Annals of the Association of American Geographers, v. 68, no. 4, p. 505–517.

Hart, John Fraser, 1980, Land use change in a Piedmont county: Annals of the Association of American Geographers, v. 70, no. 4, p. 492–527.

Hodler, Thomas W., and Schretter, Howard A., 1986, The atlas of Georgia: Athens, The Institute of Community and Area Development and the University of Georgia, 273 p.

Johnson, Carter W., and Sharpe, David M., 1976, An analysis of forest dynamics in the northern Georgia Piedmont: Forest Science, v. 22, no. 3, p. 307–322.

Manners, Ian R., 1979, The persistent problem of the boll weevil—Pest control in principle and practice: Geographical Review, v. 69, no. 1, p. 25–42.

National Association of Home Builders, 1973–2000 [various years], Housing starts: National Association of Home Builders Web site, accessed June 12, 2013, at http://www.nahbclassic.org/generic.aspx?sectionID=819&genericContentID=45409&channelID=311.

U.S. Census Bureau, 1970–2000 [various years], Census of population and housing: U.S. Census Bureau database, accessed May 9, 2013, at http://www.census.gov/prod/www/decennial.html.

van Lear, D.H., Harper, R.A., Kapeluck, P.R., and Carroll, W.D., 2004, History of Piedmont forests—Implications for current pine management: U.S. Forest Service, Southern Research Station, General Technical Report SRS-71, p. 127–131, accessed November 5, 2013, at http://www.srs.fs.usda.gov/pubs/viewpub.php?index=6620.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

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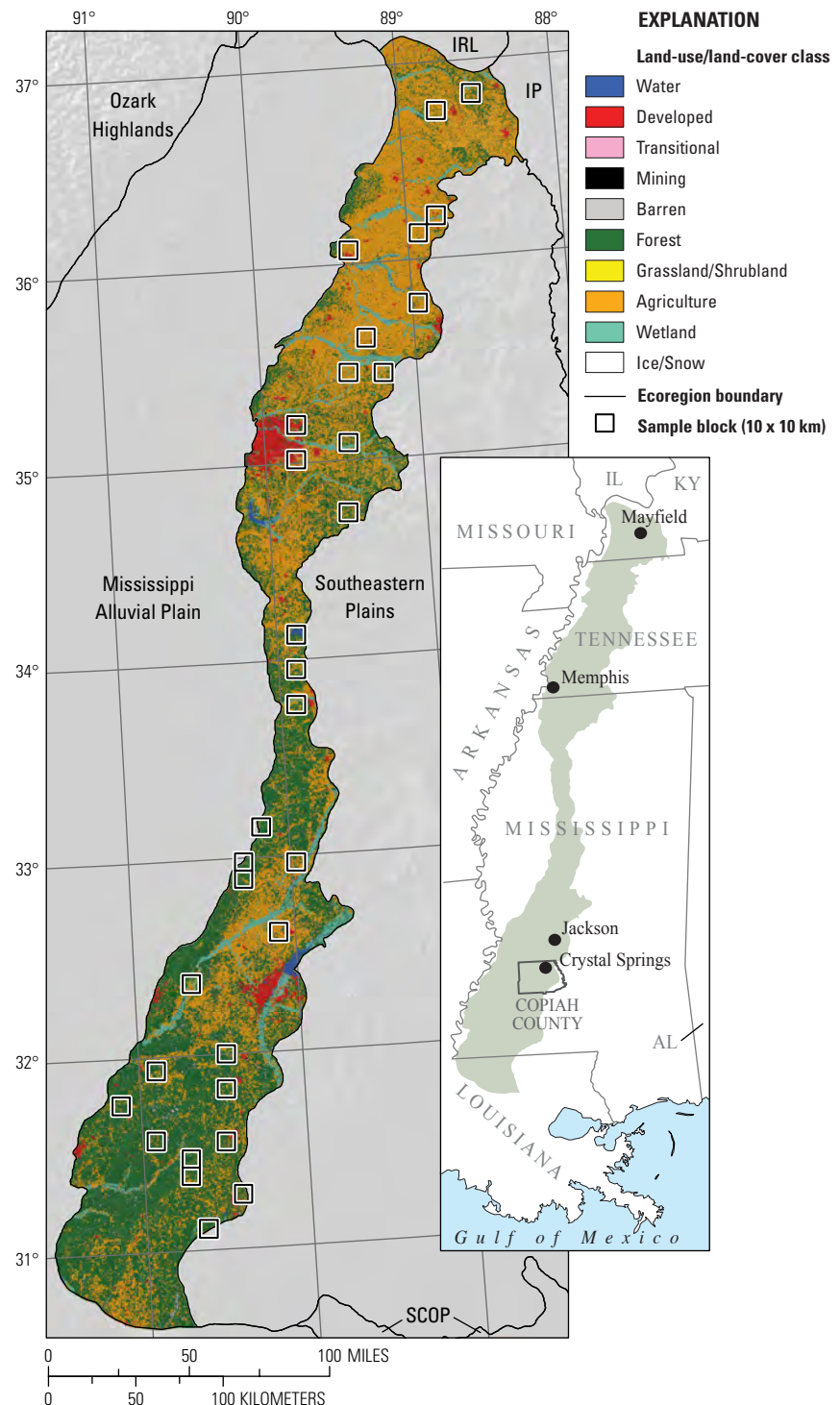U.S. Geological Survey Professional Paper 1794–D, 2016

Chapter 16

Mississippi Valley Loess Plains Ecoregion

By Janis L. Taylor

Ecoregion Description

The Mississippi Valley Loess Plains Ecoregion, which extends from western Kentucky south through western Tennessee and Mississippi into Louisiana, is about 750 km long and as much as 110 km wide, covering about 43,775 km^2 (16,901 mi^2) (fig. 1). Most of the Mississippi Valley Loess Plains Ecoregion is sandwiched between the Mississippi Alluvial Plain Ecoregion to the west and the Southeastern Plains Ecoregion to the east; in addition, the extreme northern part of the ecoregion is abutted by the Interior River Lowland and Interior Plateau Ecoregions. The topography consists primarily of irregular plains. A thick, highly erodible layer of loess—a unique geologic deposit composed almost entirely of wind-transported, silt-sized grains of quartz and other common

Figure 1. Map of Mississippi Valley Loess 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 Eastern United States ecoregions are listed in appendix 2. Also shown are parts of three Midwest–South Central United States ecoregions: Interior River Lowland (IRL), Mississippi Alluvial Plain, and Ozark Highlands. See appendix 3 for definitions of land-use/land-cover classifications.

EXPLANATION

Land-use/land-cover class
- Water
- Developed
- Transitional
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Ice/Snow

— Ecoregion boundary
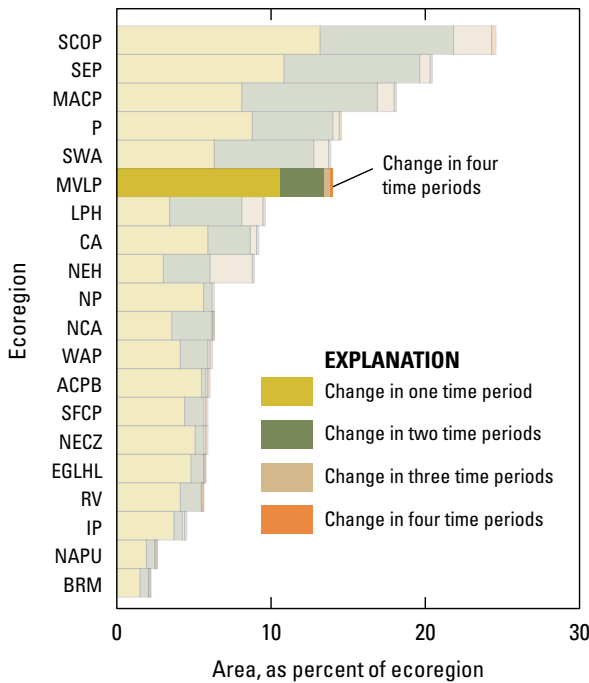
□ Sample block (10 x 10 km)

minerals—is the distinguishing characteristic of this ecoregion (Wiken and others, 2011). The principal soils are finely textured, acidic, red and yellow podzols developed from the underlying clays, sands, and loess (Faulkner, 2005). These erodible soils characteristically are poor in organic matter and nutrients but are easily cultivated by using fertilizers.

Average annual temperatures range from 16° to 20°C, and annual precipitation ranges from 1,150 to 1,525 mm (45 to 60 in.), both of which increase from north to south. Most precipitation is in the form of rain, and it occurs mainly during the winter and spring. The annual frost-free period is 200 days or more in most of the ecoregion, but it is as long as 290 days in the southernmost part (U.S. Department of Agriculture, 2006).

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Mississippi Valley Loess Plains Ecoregion between 1973 and 2000 is estimated at 13.8 percent (table 1). Compared to other Eastern United States

ecoregions, change in the Mississippi Valley Loess Plains Ecoregion was moderately high (fig. 2): 10.5 percent of the ecoregion changed only one time, 2.9 percent changed two times, and 0.4 percent changed three times (table 1). Estimates of change ranged from a low of 2.4 percent between 1973 and 1980 to a high of 6.6 percent between 1986 and 1992 (table 2). When normalized to an average annual rate to account for unequal time periods, total change ranged from a low of 0.3 percent between 1973 and 1980 to a high of 1.1 percent between 1986 and 1992 (table 2; fig. 3).

The areal percentage of each land-cover class mapped during each of the five study dates between 1973 and 2000 is shown in table 3. Forest, agriculture, and developed land-cover classes accounted for more than 90.0 percent of the ecoregion. During the 27-year study period, agriculture decreased in every time period, from 46.0 percent of the ecoregion in 1973 to 39.3 percent in 2000 (table 3; fig. 4). The most significant decrease in agriculture, which occurred between 1986 and 1992, was accompanied by increases in both forest and developed. Developed increased in each of the four time periods, from 3.6 percent of the ecoregion in 1973 to 7.8 percent in 2000. The amount of forest changed little between 1973 and 2000, from 43.3 percent in 1973 to 43.9 percent in 2000.

The most common land-cover conversion during the 27-year study period was from forest to mechanically disturbed (table 4). Agriculture to forest was the second most common conversion during the study period, whereas agriculture to developed was the third most common conversion (table 4). Finally, the fourth most common conversion was from mechanically disturbed to forest.
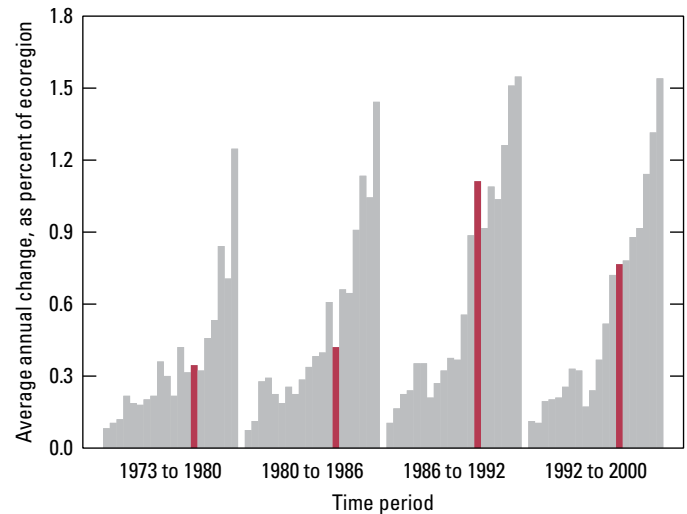

Figure 2.   Overall spatial change in Mississippi Valley Loess Plains Ecoregion (MVLP; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Mississippi Valley Loess 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 3.   Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Mississippi Valley Loess Plains Ecoregion are represented by d bars in each time period.
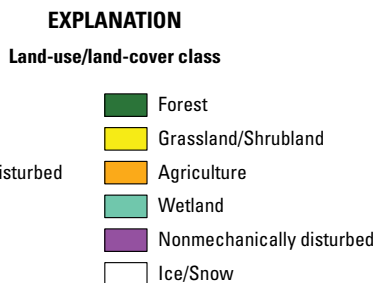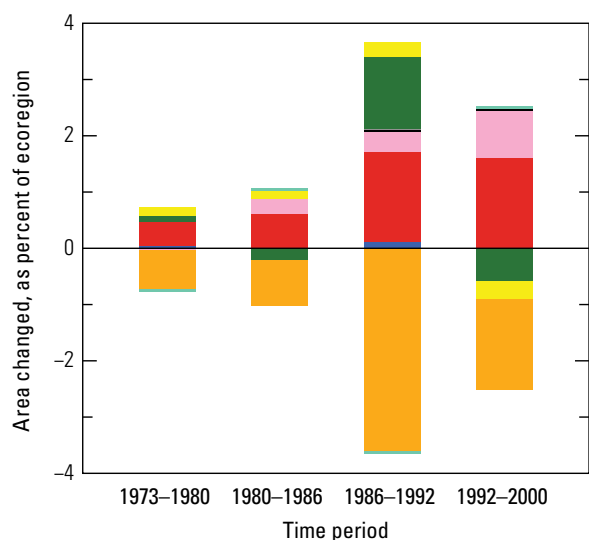
The southern part of the ecoregion is a mosaic of forested land and cropland, whereas the northern part is dominated by agricultural land. Trees, cotton, corn, soybeans, strawberries, and tobacco are crops commonly grown throughout the ecoregion (fig. 5). In the southern part, longleaf pine (*Pinus palustris)* is the principal commercially harvested tree in densely forested areas; in the northern part, loblolly pine (*Pinus taeda)*, slash pine (*Pinus elliottii)*, and shortleaf pine (*Pinus echinata*) are the most common (fig. 6).

The conversion of agriculture to forest is the result of several factors. In 1985, the Food Security Act initiated the Conservation Reserve Program (CRP) (Johnson and Maxwell, 2001), which encouraged the planting of hardwood trees on marginal farmland. In the years 1987, 1992, and 1997, many counties within the ecoregion showed a significant increase in the amount of land enrolled in the CRP (U.S. Department of

Agriculture, 1970–2000 [various years]). In addition, the U.S. Forest Service during this time promoted afforestation, which is the restoration of forest on abandoned agricultural land (Stanturf and Gardiner, 2000).

During the 27-year study period, many forested areas in the ecoregion were managed as pine plantations. Additionally, the common conversions from forest to mechanically disturbed and from mechanically disturbed to forest represent the short harvest cycles of pine plantations in the ecoregion (fig. 7). Within the ecoregion, the socioeconomic benefits derived from forested land include the sale of hunting leases, carbon credits for sequestration, improvements in water quality, and the production of biofuels and fiber. The unidirectional land-cover conversion to developed land was driven by population increases in and around Memphis, Tennessee, and Jackson, Mississippi, the two largest cities in the ecoregion (fig. 8).

EXPLANATION

Land-use/land-cover class

Water — Forest — Developed — Grassland/Shrubland — Mechanically disturbed — Agriculture — Mining — Wetland — Barren — Nonmechanically disturbed — Ice/Snow

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

Figure 5. Tobacco field and shed northeast of Mayfield, in western Kentucky.

Figure 6. Replanted pine plantation west of Crystal Springs, Mississippi.

Figure 7.   Pile of new logs in huge clearcut just west of Crystal Springs, in Copiah County, Mississippi.

Figure 8.   Recently cleared site for new subdivision northeast of Memphis, Tennessee. Existing subdivision is in background.

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

[Most sample pixels remained unchanged (86.2 percent), whereas 13.8 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	10.5	3.0	7.5	13.5	2.0	19.3
2	2.9	0.8	2.1	3.7	0.5	18.7
3	0.4	0.2	0.2	0.6	0.1	33.6
4	0.0	0.0	0.0	0.1	0.0	41.4
Overall spatial change	13.8	3.4	10.4	17.3	2.3	16.8

Table 2.   Raw estimates of change in Mississippi Valley Loess 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	2.4	0.5	1.9	2.9	0.3	13.6	0.3
1980–1986	2.5	0.8	1.7	3.3	0.5	20.8	0.4
1986–1992	6.6	1.8	4.9	8.4	1.2	18.1	1.1
1992–2000	6.1	1.5	4.6	7.6	1.0	16.4	0.8
Estimate of change, in square kilometers							
1973–1980	1,050	211	840	1,261	143	13.6	150
1980–1986	1,099	337	762	1,436	228	20.8	183
1986–1992	2,910	777	2,133	3,688	527	18.1	485
1992–2000	2,675	646	2,029	3,321	438	16.4	334

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

	Water		Developed		Mechanical-ly disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mecha-nically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
Area, in percent stratum																				
1973	1.7	1.4	3.6	1.4	0.5	0.3	0.1	0.0	0.1	0.1	43.3	6.4	0.2	0.1	46.0	5.9	4.6	1.4	0.0	0.0
1980	1.7	1.4	4.0	1.6	0.5	0.2	0.1	0.0	0.1	0.1	43.4	6.5	0.4	0.2	45.3	5.9	4.6	1.4	0.0	0.0
1986	1.7	1.3	4.6	1.9	0.8	0.4	0.1	0.0	0.1	0.1	43.2	6.5	0.5	0.2	44.5	6.0	4.6	1.4	0.0	0.0
1992	1.8	1.4	6.2	3.1	1.1	0.4	0.1	0.0	0.1	0.1	44.5	6.5	0.7	0.3	40.8	6.1	4.6	1.4	0.0	0.0
2000	1.8	1.3	7.8	4.2	1.9	0.8	0.1	0.1	0.1	0.1	43.9	6.5	0.4	0.1	39.3	6.2	4.6	1.4	0.0	0.0
Net change	0.2	0.1	4.3	3.2	1.4	0.7	0.1	0.1	0.0	0.0	0.6	1.4	0.2	0.1	–6.7	2.7	0.0	0.1	0.0	0.0
Gross change	0.5	0.3	4.3	3.2	3.4	1.3	0.1	0.1	0.0	0.0	5.8	1.4	1.2	0.4	7.4	2.6	0.6	0.3	0.0	0.0
Area, in square kilometers																				
1973	734	616	1,567	609	226	137	29	18	50	29	18,933	2,798	89	36	20,128	2,587	2,018	630	0	0
1980	752	609	1,753	695	210	79	28	19	51	29	18,981	2,840	156	68	19,830	2,596	2,014	620	0	0
1986	757	565	2,017	851	329	169	31	18	51	29	18,895	2,828	212	88	19,466	2,607	2,018	614	0	0
1992	807	613	2,719	1,358	499	195	35	21	51	29	19,465	2,851	314	114	17,881	2,660	2,003	619	0	0
2000	805	578	3,435	1,838	853	333	59	40	51	29	19,216	2,841	168	60	17,182	2,715	2,005	615	0	0
Net change	71	52	1,868	1,379	627	306	30	29	1	2	283	613	79	44	–2,946	1,177	–13	56	0	0
Gross change	216	131	1,870	1,379	1,480	558	47	30	3	2	2,541	613	544	191	3,229	1,150	244	142	0	0

Table 4.   Principal land-cover conversions in Mississippi Valley Loess 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	Forest	190	69	47	0.4	18.1
	Mechanically disturbed	Forest	164	127	86	0.4	15.6
	Forest	Mechanically disturbed	148	57	39	0.3	14.1
	Agriculture	Developed	135	98	67	0.3	12.8
	Forest	Agriculture	103	34	23	0.2	9.8
	Other	Other	311	n/a	n/a	0.7	29.6
		Totals	1,050			2.4	100.0
1980–1986	Forest	Mechanically disturbed	281	169	114	0.6	25.5
	Agriculture	Developed	191	154	104	0.4	17.3
	Agriculture	Forest	158	91	62	0.4	14.4
	Mechanically disturbed	Forest	92	45	31	0.2	8.4
	Agriculture	Grassland/Shrubland	52	33	23	0.1	4.7
	Other	Other	327	n/a	n/a	0.7	29.7
		Totals	1,099			2.5	100.0
1986–1992	Agriculture	Forest	908	349	236	2.1	31.2
	Agriculture	Developed	522	453	307	1.2	17.9
	Forest	Mechanically disturbed	410	169	114	0.9	14.1
	Mechanically disturbed	Forest	258	155	105	0.6	8.9
	Forest	Developed	147	118	80	0.3	5.0
	Other	Other	665	n/a	n/a	1.5	22.8
		Totals	2,910			6.6	100.0
1992–2000	Forest	Mechanically disturbed	801	327	222	1.8	29.9
	Agriculture	Developed	400	285	193	0.9	14.9
	Mechanically disturbed	Forest	397	166	112	0.9	14.8
	Agriculture	Forest	284	99	67	0.6	10.6
	Forest	Developed	228	172	117	0.5	8.5
	Other	Other	566	n/a	n/a	1.3	21.2
		Totals	2,675			6.1	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	1,640	591	400	3.7	21.2
	Agriculture	Forest	1,539	440	298	3.5	19.9
	Agriculture	Developed	1,247	983	666	2.8	16.1
	Mechanically disturbed	Forest	910	382	259	2.1	11.8
	Forest	Developed	437	316	214	1.0	5.7
	Other	Other	1,961	n/a	n/a	4.5	25.4
		Totals	7,735			17.7	100.0

References Cited

Faulkner, S.P., 2005, Southern Mississippi Valley silty uplands (loess bluffs), *in* Major land resources of Mississippi: Samuel P. Faulkner, PhD, Web site, accessed June 13, 2013, at http://www.marshdoc1.com/major-land-areas-of-ms.html.

Johnson, J., and Maxwell, B., 2001, The role of the Conservation Reserve Program in controlling rural residential development: Journal of Rural Studies, v. 17, p. 323–332.

Stanturf, John A., and Gardiner, Emile S., 2000, Restoration of bottomland hardwoods in the Lower Mississippi Alluvial Valley, *in* Sustaining Southern forests—The science of forest assessment: Atlanta, Ga., Southern Forest Resource Assessment, accessed June 13, 2013, at http://www.srs.fs.usda.gov/sustain/conf/fulltext.htm.

U.S. Department of Agriculture, 1970–2000 [various years], Historical census publications: U.S. Census Bureau database, accessed June13, 2013, at http://www.agcensus.usda.gov/Publications/Historical_Publications/index.php.

U.S. Department of Agriculture, 2006, Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin: U.S. Department of Agriculture, National Resources Conservation Service, U.S. Department of Agriculture Handbook 296, 663 p.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

Chapter 17

Southeastern Plains Ecoregion

By Terry L. Sohl

Ecoregion Description

The Southeastern Plains Ecoregion, which is the largest of the Eastern United States ecoregions, covers about 336,141 km[2] (129,785 mi[2]) across 11 states and the District of Columbia, extending from near the Gulf of Mexico in the south to Delaware in the north (Wiken and others, 2011; fig. 1). The ecoregion is bounded on the north and northwest by the Northern Piedmont, Piedmont, Ridge and Valley, Southwestern Appalachians, and Interior Plateau Ecoregions; on the west, by the Mississippi Valley Loess Plains Ecoregion; and on the south and east, by the Mississippi Alluvial Plain, Southern Coastal Plain, and Middle Atlantic Coastal Plain Ecoregions.

Figure 1. Map of Southeastern 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 20 x 20 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Eastern United States ecoregions are listed in appendix 2. Also shown are parts of seven Midwest–South Central United States ecoregions: Central Corn Belt Plains (CCBP), Eastern Corn Belt Plains, Erie Drift Plains (EDP), Huron/Erie Lake Plains (HELP), Interior River Lowland, Mississippi Alluvial Plain (MAP), and Southern Michigan/Northern Indiana Drift Plains (SMNIDP). See appendix 3 for definitions of land-use/land-cover classifications.
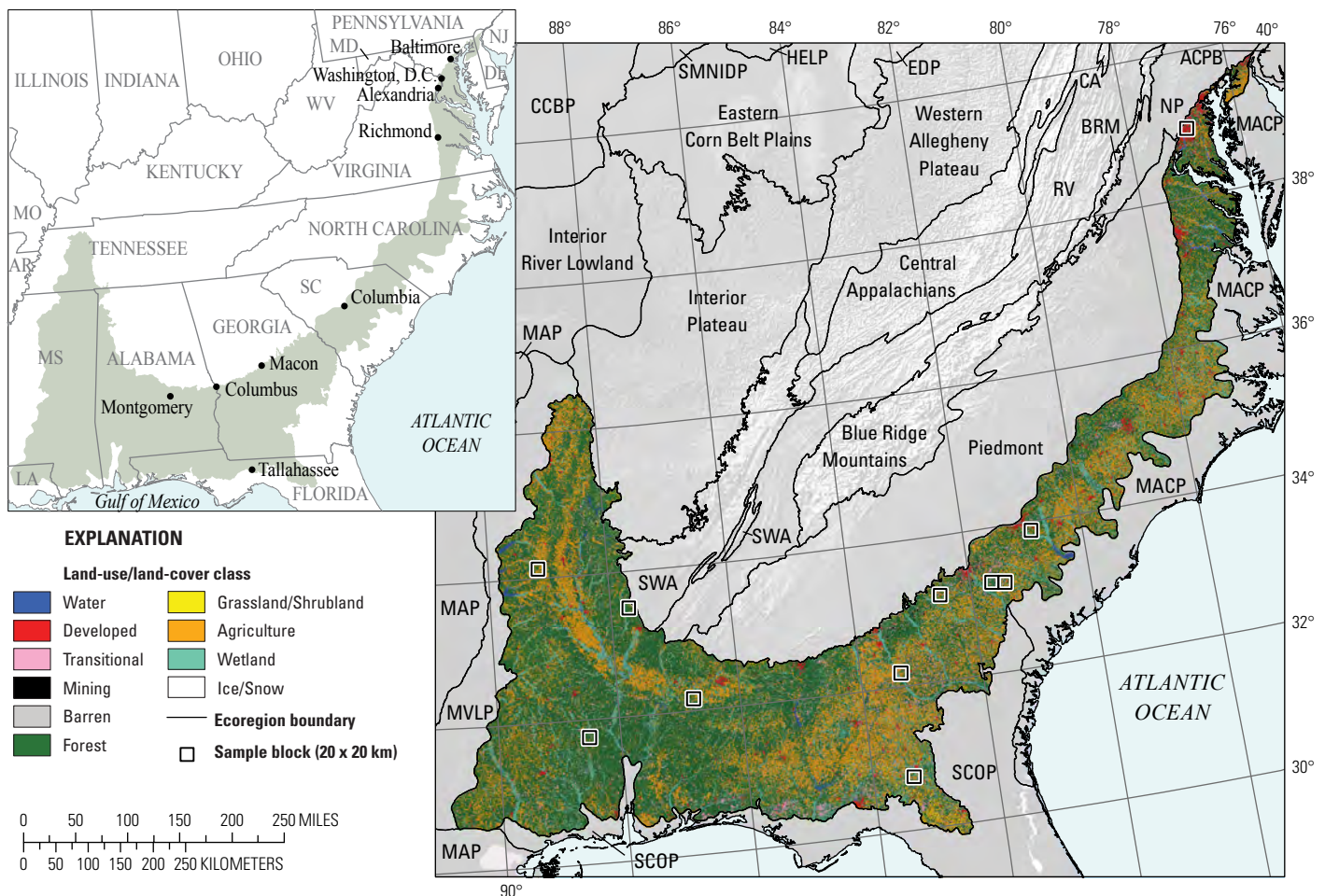
The relatively flat, irregular plains of the Southeastern Plains Ecoregion are covered by a mosaic of cropland, pastureland, forested land, and wetlands. However, although the ecoregion is characterized by a long growing season and abundant rainfall, the relatively poor, sandy soils present in much of the ecoregion limit its agricultural uses, in comparison to other nearby ecoregions. Natural forests of pine (*Pinus* spp.), hickory (*Carya* spp.), and oak (*Quercus* spp.) once covered most of the ecoregion, but much of the natural forest has been replaced by heavily managed timberlands. Montgomery, Alabama, is the only significant urban center (population greater than 100,000) in the interior of the ecoregion, although several urban centers are scattered on or near the edge of the ecoregion (for example, Baltimore, Maryland; Washington, D.C.; Alexandria and Richmond, Virginia; Columbia, South Carolina; Columbus and Macon, Georgia; and Tallahassee, Florida).

## Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Southeastern Plains Ecoregion between 1973 and 2000 is estimated at 20.4 percent (table 1). Compared to other Eastern United States Ecoregions, change in the Southeastern Plains Ecoregion was very high (fig. 2); in addition, the rates of change per time period increased steadily across the 27-year study period (table 2). When normalized to an average annual rate to account for uneven time periods, the rates of change increased during the first three time periods (1973–1980, 1980–1986, 1986–1992), peaking between 1986 and 1992, then decreased slightly during the last time period (1992–2000) (table 2; fig. 3).

Despite the high overall rates of change, the net-change statistics for individual land-cover classes during the study period (1973–2000) (table 3) mask the dynamically changing nature of the ecoregion. Forest had a modest net decrease of 1.2 percent (4,119 km[2)] between 1973 and 2000, even though the Southeastern Plains Ecoregion is home to an extremely dynamic timber industry (fig. 4). Pine plantations were rare in the ecoregion in 1950, but by 2000 they constituted nearly 50 percent of all pine forests in the southeastern United States (Conner and Hartsell, 2002) (fig. 5).

The most common land-cover conversion in every time period was from forest to mechanically disturbed, a conversion that primarily represents clearcutting of forested land (table 4); more than 41,000 km^2 of forest experienced this conversion during the study period. The second most common conversion in every time period was from mechanically disturbed to forest, a conversion that represents the regrowth of forest on previously cut lands. Nearly 33,000 km^2 of mechanically disturbed land experienced this conversion during the study period, and the mechanically disturbed class showed net increases for all time periods (fig. 6). Newly cut

forest patches quickly revegetate to forest, whether through natural regeneration or through direct replanting. Managed pine plantations in the ecoregion have planting-and-cutting cycles as short as 20 years (fig. 7), which leads to a relatively rapid cyclic pattern of forest management, as is shown by the high percentage of areas experiencing two or more conversions during the study period (1973–2000) (table 1). This cyclic nature of forest cutting in the ecoregion results in the low net change in the forest land-cover class but the high overall rates of change for each time period.

Although forest decreased slightly between 1973 and 2000, forestry, as defined by aggregating both forest and mechanically disturbed land-cover classes, showed a different pattern (table 5). Forestry decreased slightly between 1973 and 1986, but it increased significantly between 1986 and 2000. These figures correspond well with the U.S. Department of Agriculture's Forest Inventory and Analysis data, which identify 1987 as the milestone year when the "South" (that is, States in the southeastern one-quarter of the United States, including most of the Southeastern Plains Ecoregion) started to gain more forested land than it lost, reversing a long-term downward trend in forested land (Conner and Hartsell, 2002). The third most common
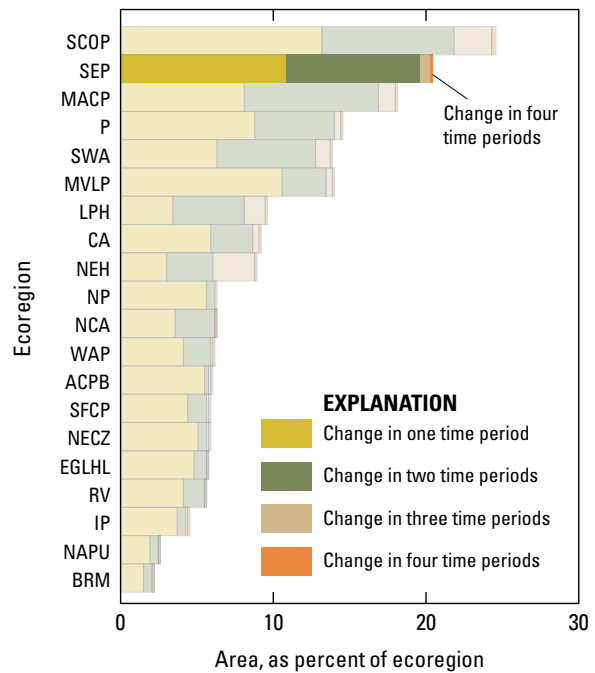
Figure 2.   Overall spatial change in Southeastern Plains Ecoregion (SEP; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Southeastern 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.

land-cover conversion in three of the four time periods, from agriculture to forest, was strongly related to the post-1986 increase in forestry. Declining profits from agriculture relative to forestry in the ecoregion led many farmers either to abandon their cropland (which then naturally reverted to forest) or to plant pine as a managed timber crop (Wear, 2002). Programs such as the Conservation Reserve Program (CRP), which was implemented as part of the 1985 Farm Bill legislation, led to widespread conversion of marginal agricultural land to forested land or grassland/shrubland.

More than 4,400 km^2 of forest converted to agriculture between 1973 and 2000, most of the change occurring in the earliest time periods (table 4; fig. 8); however, almost 12,000 km^2 of agriculture converted to forest (table 4), with additional amounts of agriculture converting to developed. The net result of all the change in agriculture was a decrease of nearly 9,500 km^2 of agriculture during the study period (table 3).

The other primary driver of land-cover change in the ecoregion was the conversion of forest and agriculture to developed. Between 1970 and 2000, human population
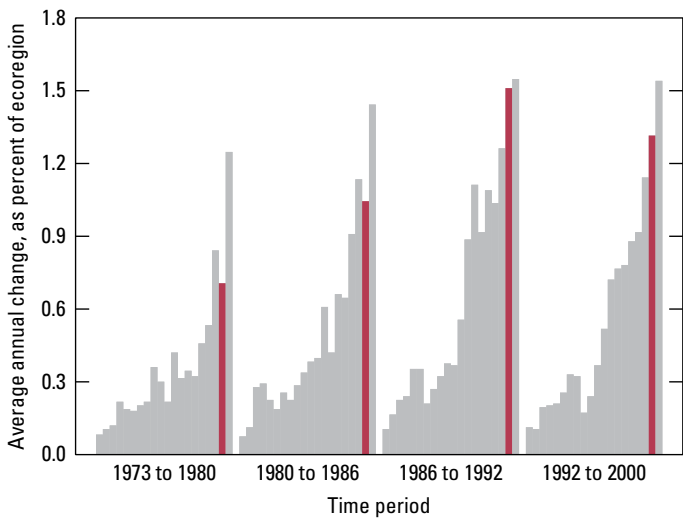
Figure 3. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Southeastern Plains Ecoregion are represented by red bars in each time period.

Figure 4. Pine plantation, which is large tract of land planted with regularly spaced pine trees, an increasingly common sight in Southeastern Plains Ecoregion.
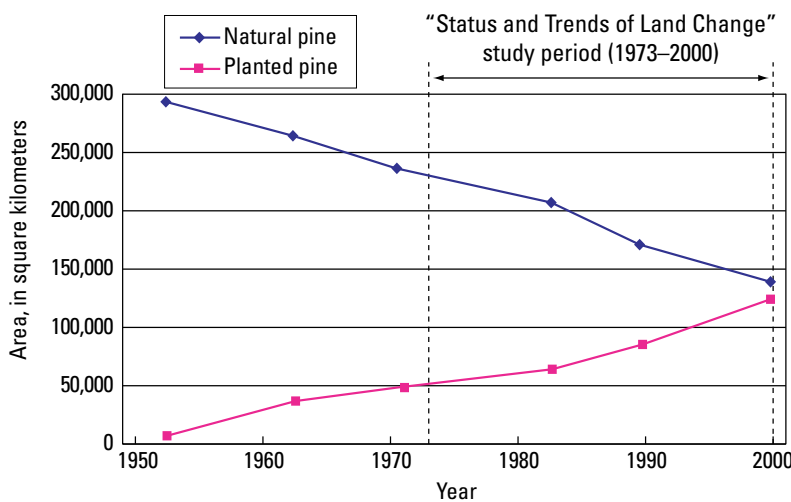
Figure 5. Areal changes in natural pine (in forests) and in planted pine (in commercial pine plantations) in the South between early 1950s and 2000, showing increase in planted pine and decrease in natural pine. Planted pine was nearly absent in early 1950s, but, by 2000, it covered area nearly as large as that of natural pine in forests (Conner and Hartsell, 2002).

within the ecoregion increased from 11.2 million to 14.4 million (U.S. Census Bureau, 1970–2000 [various years]). Nearly 4,400 km² of land were developed between 1973 and 2000 (table 3), most of which came from forest. Forest was consistently developed at two to three times the rate of agriculture in all four time periods.

In terms of net change, the Southeastern Plains Ecoregion experienced only moderate rates of change between 1973 and 2000, with a 2.8 percent decrease in agriculture, a 2.8 percent increase in mechanically disturbed, a 1.3 percent increase in developed, and only a 1.2 percent decrease in forest (table 3). However, in terms of gross change, the Southeastern Plains Ecoregion is one of the most actively changing ecoregions among the Eastern United States ecoregions, with the cyclical cutting and replanting of pine being the most common land-cover conversion in the ecoregion. Mechanically disturbed to

forest was the second most common land-cover conversion for all time periods. Despite the 1.2 percent loss of forest in terms of total ecoregion area, forestry actually increased because most mechanically disturbed land in the ecoregion is associated with timber harvest. Significant losses of agriculture also occurred, most losses coming from changes to forest. Agriculture changes likely were associated with farmers converting agricultural fields to higher profit pine plantations, and they also happened in concurrence with implementation of the CRP, with the highest rate of conversion occurring between 1986 and 1992.
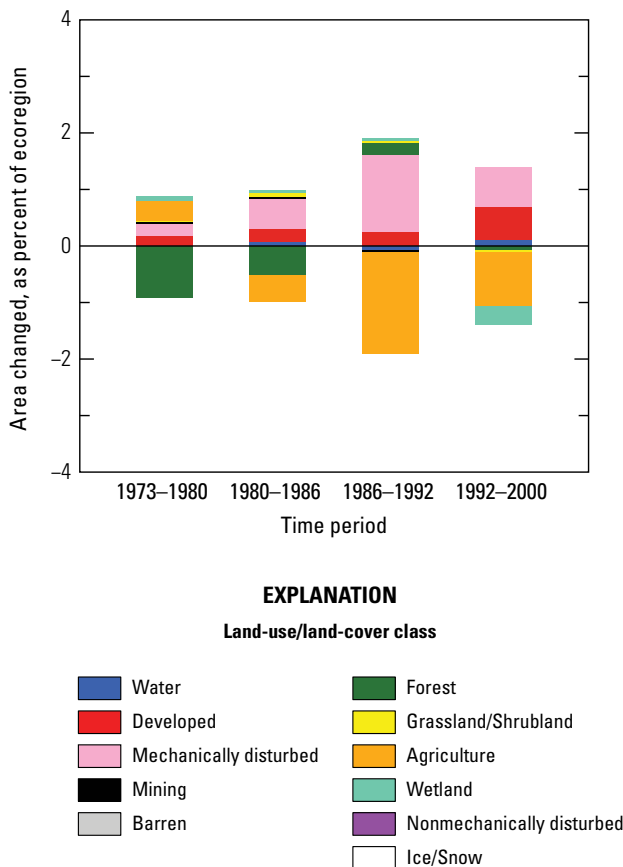
Figure 7.   Newly cut forest in Southeastern Plains Ecoregion. Although forest cutting dramatically alters local ecosystem, favorable climate of Southeastern Plains Ecoregion results in rapid vegetation regrowth, whether land is replanted or allowed to regenerate naturally.

EXPLANATION

Land-use/land-cover class

Water		Forest	
Developed		Grassland/Shrubland	
Mechanically disturbed		Agriculture	
Mining		Wetland	
Barren		Nonmechanically disturbed	
		Ice/Snow	

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

Figure 8.   Newly planted tobacco field in Southeastern Plains Ecoregion. Although agricultural land declined by nearly 9,500 km² between 1973 and 2000 in Southeastern Plains Ecoregion, high-value crops such as tobacco are still economically important in some areas.

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

[Most sample pixels remained unchanged (79.6 percent), whereas 20.4 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	10.8	1.6	9.2	12.4	1.0	9.5
2	8.8	2.3	6.5	11.1	1.5	16.9
3	0.7	0.3	0.4	1.0	0.2	24.0
4	0.1	0.0	0.0	0.1	0.0	27.3
Overall spatial change	20.4	3.9	16.5	24.3	2.5	12.3

Table 2.   Raw estimates of change in Southeastern 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	4.9	1.2	3.8	6.1	0.7	15.0	0.7
1980–1986	6.2	1.6	4.6	7.9	1.1	16.9	1.0
1986–1992	9.1	2.3	6.8	11.4	1.5	16.2	1.5
1992–2000	10.5	2.3	8.2	12.8	1.5	13.9	1.3
Estimate of change, in square kilometers							
1973–1980	16,630	3,899	12,731	20,530	2,501	15.0	2,376
1980–1986	21,004	5,545	15,459	26,549	3,557	16.9	3,501
1986–1992	30,513	7,727	22,786	38,240	4,956	16.2	5,086
1992–2000	35,334	7,644	27,690	42,978	4,903	13.9	4,417

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

	Water		Developed		Mechanically disturbed		Mining		Barren		Forest		Grassland/ Shrubland		Agriculture		Wetland		Non-mecha-nically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
								Area, in percent stratum												
1973	1.0	0.3	9.0	9.6	2.1	0.9	0.0	0.0	0.0	0.0	53.1	8.4	0.0	0.0	24.3	7.5	10.5	3.9	0.0	0.0
1980	1.0	0.3	9.2	9.7	2.3	0.7	0.1	0.0	0.0	0.0	52.2	8.7	0.0	0.0	24.7	7.8	10.6	4.0	0.0	0.0
1986	1.1	0.4	9.4	9.8	2.9	0.9	0.1	0.1	0.0	0.0	51.7	8.6	0.1	0.1	24.2	7.8	10.6	3.9	0.0	0.0
1992	1.0	0.3	9.7	9.9	4.2	1.3	0.1	0.1	0.0	0.0	51.9	8.3	0.1	0.1	22.4	7.4	10.6	4.0	0.0	0.0
2000	1.1	0.4	10.3	10.0	4.9	1.3	0.1	0.0	0.0	0.0	51.8	7.9	0.1	0.1	21.5	6.8	10.3	3.8	0.0	0.0
Net change	0.1	0.1	1.3	0.5	2.8	1.0	0.0	0.0	0.0	0.0	–1.2	1.6	0.1	0.1	–2.8	1.3	–0.2	0.3	0.0	0.0
Gross change	0.3	0.3	1.3	0.5	6.4	1.4	0.1	0.1	0.0	0.0	7.9	2.2	0.2	0.2	4.3	1.9	0.8	0.5	0.0	0.0
								Area, in square kilometers												
1973	3,279	1,031	30,196	32,321	7,093	2,951	151	120	3	4	178,350	28,226	11	11	81,677	25,367	35,383	13,189	0	0
1980	3,295	1,037	30,850	32,595	7,807	2,433	223	160	3	4	175,341	29,156	13	14	82,961	26,292	35,648	13,282	0	0
1986	3,598	1,280	31,615	32,932	9,598	3,168	296	187	3	4	173,634	28,853	343	492	81,404	26,147	35,651	13,254	0	0
1992	3,321	1,081	32,538	33,297	14,074	4,214	271	169	3	4	174,407	27,977	420	425	75,332	24,880	35,775	13,289	0	0
2000	3,693	1,177	34,574	33,685	16,370	4,445	266	159	3	4	174,231	26,617	206	227	72,201	23,010	34,598	12,740	0	0
Net change	414	357	4,378	1,833	9,278	3,485	115	156	0	0	–4,119	5,506	195	223	–9,476	4,485	–785	976	0	0
Gross change	1,090	1,001	4,383	1,831	21,541	4,795	379	240	0	0	26,423	7,277	788	822	14,553	6,278	2,614	1,569	0	0

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

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

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	6,602	2,112	1,354	2.0	39.7
	Mechanically disturbed	Forest	5,864	2,903	1,862	1.7	35.3
	Forest	Agriculture	2,125	1,332	855	0.6	12.8
	Agriculture	Forest	625	478	307	0.2	3.8
	Forest	Developed	483	325	208	0.1	2.9
	Other	Other	931	n/a	n/a	0.3	5.6
		Totals	16,630			4.9	100.0
1980–1986	Forest	Mechanically disturbed	8,230	2,834	1,818	2.4	39.2
	Mechanically disturbed	Forest	6,540	2,255	1,446	1.9	31.1
	Agriculture	Forest	2,249	1,343	861	0.7	10.7
	Forest	Agriculture	1,347	953	611	0.4	6.4
	Forest	Developed	578	367	235	0.2	2.8
	Other	Other	2,061	n/a	n/a	0.6	9.8
		Totals	21,004			6.2	100.0
1986–1992	Forest	Mechanically disturbed	12,649	3,884	2,491	3.8	41.5
	Mechanically disturbed	Forest	8,659	2,927	1,878	2.6	28.4
	Agriculture	Forest	5,510	3,351	2,149	1.6	18.1
	Forest	Developed	578	330	212	0.2	1.9
	Forest	Agriculture	393	293	188	0.1	1.3
	Other	Other	2,724	n/a	n/a	0.8	8.9
		Totals	30,513			9.1	100.0
1992–2000	Forest	Mechanically disturbed	14,026	4,091	2,624	4.2	39.7
	Mechanically disturbed	Forest	11,936	3,839	2,462	3.6	33.8
	Agriculture	Forest	3,604	2,270	1,456	1.1	10.2
	Forest	Developed	1,415	713	457	0.4	4.0
	Wetland	Mechanically disturbed	1,340	794	509	0.4	3.8
	Other	Other	3,014	n/a	n/a	0.9	8.5
		Totals	35,334			10.5	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	41,506	11,143	7,148	12.3	40.1
	Mechanically disturbed	Forest	32,999	9,426	6,046	9.8	31.9
	Agriculture	Forest	11,988	5,442	3,491	3.6	11.6
	Forest	Agriculture	4,463	2,305	1,478	1.3	4.3
	Forest	Developed	3,055	1,365	875	0.9	3.0
	Other	Other	9,472	n/a	n/a	2.8	9.2
		Totals	103,482			30.8	100.0

Table 5.   Amount of forestry, as defined by both forest and mechanically disturbed land-cover classes, as percentage of ecoregion in Southeastern Plains Ecoregion, calculated five times between 1973 and 2000.

	Amount of forestry (% of ecoregion)
1973	55.2
1980	54.5
1986	54.6
1992	56.1
2000	56.7

References Cited

Conner, R.C., and Hartsell, A.J., 2002, Forest area and conditions, *in* Wear, D.N., and Greis, J.G., eds., Southern forest resource assessment: U.S. Forest Service, Southern Research Station, General Technical Report SRS 53, p. 357–402, available at http://www.srs.fs.usda.gov/pubs/4833.

U.S. Census Bureau, 1970–2000 [various years], Census of population and housing: U.S. Census Bureau database, available at http://www.census.gov/prod/www/decennial.html.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wear, D.N., 2002, Land use, *in* Wear, D.N., and Greis, J.G., eds., Southern forest resource assessment: U.S. Forest Service, Southern Research Station, General Technical Report SRS 53, p. 153–173, available at http://www.srs.fs.usda.gov/pubs/4833.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

Status and Trends of Land Change in the Eastern United States—1973 to 2000
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Chapter 18

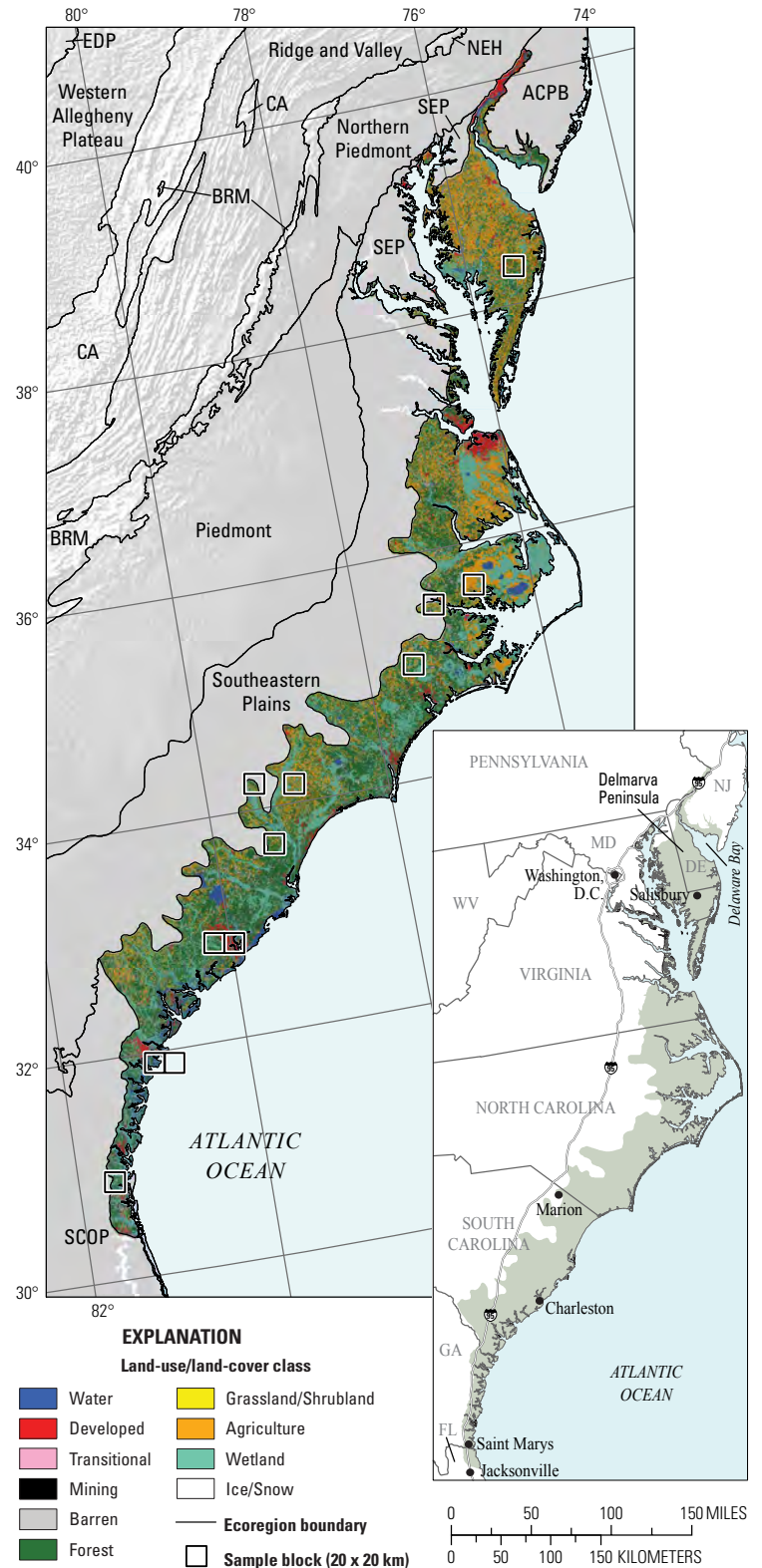# Middle Atlantic Coastal Plain Ecoregion

By Roger F. Auch

Ecoregion Description

The Middle Atlantic Coastal Plain Ecoregion is a linear ecoregion that covers about 89,686 km^2 (34,628 mi^2), stretching from Delaware Bay and the Delmarva Peninsula in the north nearly to Jacksonville, Florida, in the south. The ecoregion, which includes parts of nine states (New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, and Florida) (fig. 1), ranges in width from only a few miles, in areas inland of Delaware Bay and in extreme northeastern Florida, to about 70 miles, in parts of North Carolina and South Carolina. The ecoregion is surrounded by (counterclockwise, from the northeast) the Atlantic Coastal Pine Barrens, Northern Piedmont, Southeastern Plains, and Southern Coastal Plain Ecoregions. The topography primarily is flat, and many soil types are poorly drained (Wiken and others, 2011). The ecoregion has moderate to mild winters and hot, humid summers, with an average annual precipitation of 1,000 to 1,500 mm (40–60 in.).

The predominant land uses in the Middle Atlantic Coastal Plain Ecoregion are farming and forestry, but urban development also is significant locally. Land cover primarily is a mosaic of forest, wetland, and agriculture. Agricultural land is composed mainly of cropland: soybeans, cotton, and some tobacco in the south, and soybeans and corn farther north (fig. 2). Livestock production most

Figure 1. Map of Middle Atlantic 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 20 x 20 km sample blocks analyzed in study. Index map shows locations of geographic features mentioned in text. Abbreviations for Eastern United States ecoregions are listed in appendix 2. Also shown is part of one Midwest–South Central United States ecoregion, Erie Drift Plains (EDP). See appendix 3 for definitions of land-use/land-cover classifications.

EXPLANATION

Land-use/land-cover class

- Water
- Developed
- Transitional
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Ice/Snow
- Ecoregion boundary
- Sample block (20 x 20 km)

commonly is confined animal-feeding operations, for hogs in North Carolina and poultry on the Delmarva Peninsula (fig. 3) (U.S. Department of Agriculture, 1999). Upland forested areas are composed predominantly of pine (*Pinus* spp.) or mixed pine and hardwood communities (fig. 4). Wetlands, which are common across the ecoregion, include coastal marshes, bottomland hardwood forests, and shrub bogs (pocosins) (figs. 5*A,B*). Other land-cover classes that have less extensive areas include water and mechanically disturbed.

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land area that changed at least one time) in the Middle Atlantic Coastal Plain Ecoregion between 1973 and 2000 is estimated at 18.0 percent (table 1). Compared to other Eastern United

Figure 4.   Plantation of even-aged loblolly pine (*Pinus taeda*), near Marion, South Carolina.

Figure 2.   Farm growing corn and soybeans near Salisbury, Maryland.

Figure 5.   Wetland areas in Middle Atlantic Coastal Plain Ecoregion. *A*, Forested wetland (bottomland hardwoods) in South Carolina. *B*, Coastal wetland in extreme southeastern Georgia.
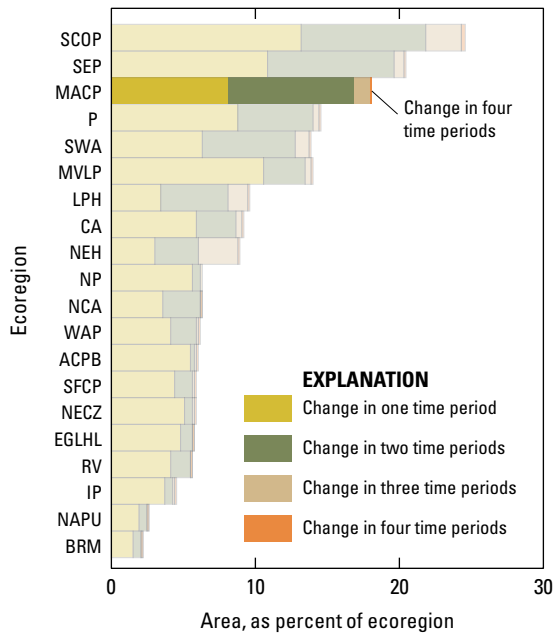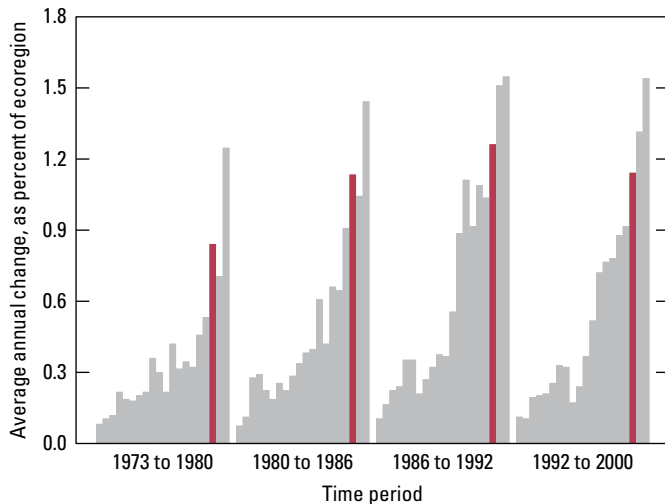

Figure 3.   Cotton field and confined animal-feeding units, raising either hogs or poultry, on farm in North Carolina, in Middle Atlantic Coastal Plain Ecoregion.

Figure 6. Overall spatial change in Middle Atlantic Coastal Plain Ecoregion (MACP; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Middle Atlantic Coastal 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 20 Eastern United States ecoregions (gray bars). Estimates of change for Middle Atlantic Coastal Plain Ecoregion are represented by red bars in each time period.

States ecoregions, change in the Middle Atlantic Coastal Plain Ecoregion was high, ranking third overall (fig. 6). The amount of area that changed per time period was relatively high, and it increased during the 27-year study period: the period between 1973 and 1980 experienced the least change, and the period between 1992 and 2000 experienced the most change (table 2). When normalized to an average annual rate to account for uneven time periods, the period between 1973 and 1980 still had the lowest rate of change (at 0.8 percent per year), and the period between 1986 and 1992 still had the highest rate of change (1.3 percent per year). Although the period between 1986 and 1992 was the most dynamic, two other periods (1980–1986, 1992–2000) also had normalized rates that exceeded 1.0 percent per year, a high rate of change among those estimated for all Eastern United States ecoregions (fig. 7).

Two of the Middle Atlantic Coastal Plain Ecoregion's dominant land-cover classes, forest and wetland, experienced considerable net change, although this change was uneven for these classes across time periods (table 3). Forest decreased in the first three time periods, ranging from 35.5 to 31.9 percent of the ecoregion, but it increased to 32.1 percent in the last time period, for a net loss in area of 3.4 percent between 1973 and 2000 (table 3; fig. 8). Some of this net loss is due to the conversion of forest to mechanically disturbed, the result of timber harvesting; however, this land is expected to return to forest at a later date. Wetland decreased noticeably in two time periods (1980–1986, 1992–2000), with losses of 0.6 and 0.8 percent, respectively, but it had almost no change during the other two time periods (1973–1980, 1986–1992). Overall, wetland had a net decrease of 1.3 percent during the study period, but some of the wetland that converted to mechanically disturbed in the last time period likely will return to wetland at a later date. The third most common land-cover class, agriculture, did not have a noticeable net change between 1973 and 2000, although it gained a small amount of area between 1973 and 1980 that was offset by losses during two subsequent time periods. The less prevalent land-cover classes of developed and mechanically disturbed had substantial net gains in area, but they experienced somewhat different patterns of change. The total amount of developed had a nearly consistent increase across each time period, ranging from 6.5 percent in 1973 to 9.0 percent in 2000, whereas mechanically disturbed showed more fluctuations in the rate of change, ranging from 2.3 percent in 1973 to 4.2 percent in 2000 (table 3). The developed land-cover class in urban areas almost always has a net increase, as it tends to be a permanent change, whereas other land-cover classes, such as forest, agriculture, wetland, and mechanically disturbed, may experience fluctuating net changes as part of cyclic land uses.

The high rates of land-cover change in the Middle Atlantic Coastal Plain Ecoregion were driven by forest harvesting and regeneration (together representing 72.0 percent of the total change), indicative of cyclic wood production (table 4). Conversions from forest to mechanically disturbed and from mechanically disturbed to forest were the leading land-cover

conversions for each time period (table 4; figs. 9*A,B*). Overall, 19,001 km^2 of land fluctuated between these two land-cover classes. Forest may be clearcut for wood harvesting but, subsequently, may return to forest. In addition, land used for farming or forestry may be converted to another use to take advantage of changing economic markets. Another way to consider forest land cover in this ecoregion is to compare the percentage of land that was consistently forest between 1973 and 2000 ("stable" forest, unaltered forest that is at least 30 years of age) with the percentage of land that was forest only part of the time ("dynamic" forest). More than one-half (59.5 percent) of the forested areas remained as forest throughout the study period, whereas 40.5 percent was converted to (or from) forest (table 5). The percentage of stable forest in the Middle Atlantic Coastal Plain Ecoregion was one of the lowest percentages of all Eastern United States ecoregions.

Other leading land-cover changes included disturbances in wetlands and increases in developed land (fig. 10). An estimated 1,963 km^2 of wetlands underwent some sort of change (table 3); most of this change was to mechanically disturbed land, but
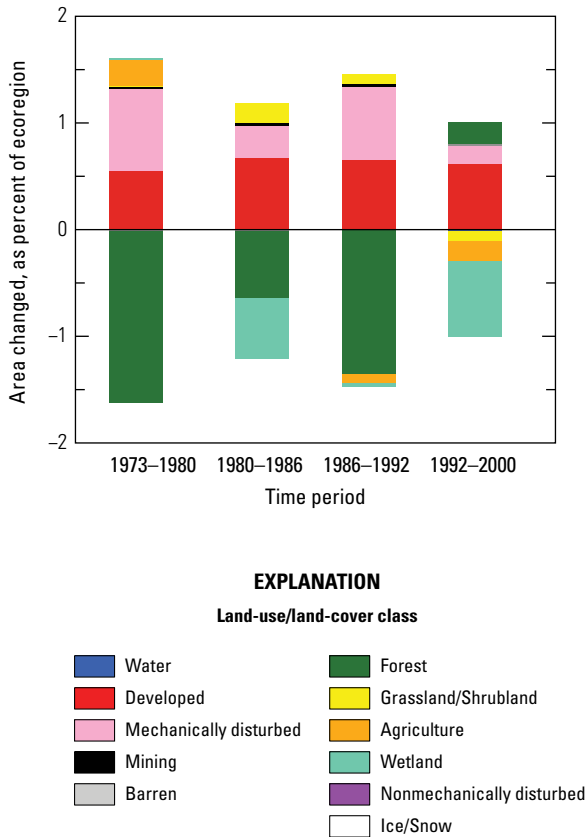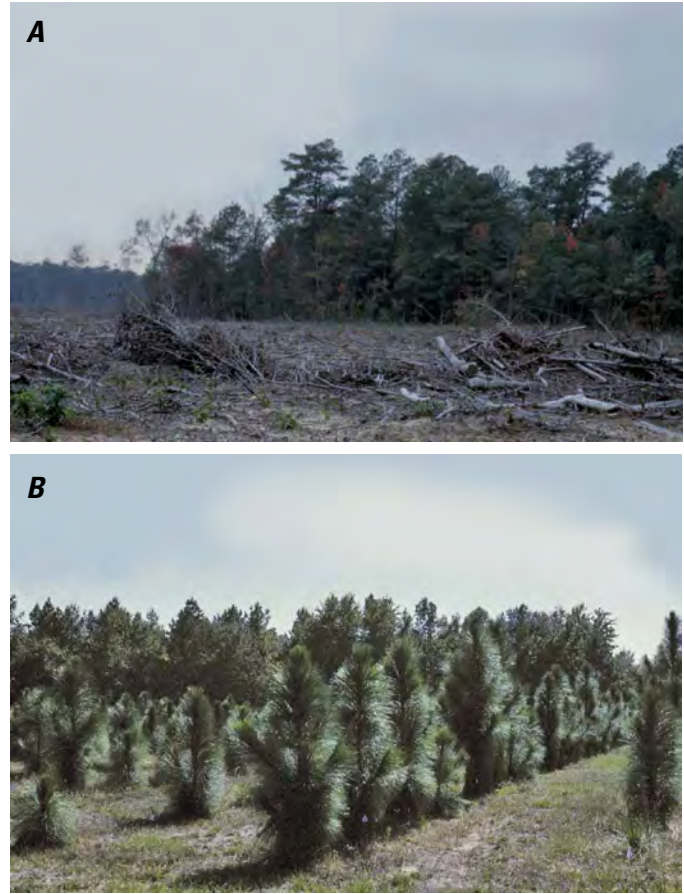
Figure 9. Conversions between forested land and mechanically disturbed land in Middle Atlantic Coastal Plain Ecoregion. *A*, Tree debris, or slash, remaining after forest clearcut (classified as mechanically disturbed), on eastern shore of Maryland. *B*, Planted field of young pine trees west of Charleston, South Carolina.

EXPLANATION

Land-use/land-cover class

Water	Forest
Developed	Grassland/Shrubland
Mechanically disturbed	Agriculture
Mining	Wetland
Barren	Nonmechanically disturbed
	Ice/Snow

Figure 8. Normalized average net change in Middle Atlantic 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 and land-cover classifications.

Figure 10. Subdivision near Interstate 95, west of Saint Marys, Georgia.

about one-half of the wetlands that converted to mechanically disturbed land subsequently reverted to wetland conditions. The conversions back and forth between wetland and mechanically disturbed were the third-leading (wetland to mechanically disturbed) and fifth-leading (mechanically disturbed to wetland) changes overall (table 4); harvesting of timber in forested wetlands, such as bottomland hardwoods, appeared to account for most of these conversions. An estimated 134 km² of wetland change, however, was an outright conversion to developed land or forested land. In addition, the conversion of forest to developed was either the third or fourth most common land-cover change in area by time period: the ecoregion gained an estimated 2,247 km² of new developed land during the study period (table 3), most of it from forested land (1,741 km²) (table 4), and most of the rest came from either agricultural land (253 km²) or wetlands (134 km²).

Table 1. Percentage of Middle Atlantic 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 (82.0 percent), whereas 18.0 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	8.0	1.3	6.7	9.3	0.8	10.3
2	8.7	3.0	5.7	11.6	1.9	22.0
3	1.2	0.7	0.5	1.9	0.5	39.5
4	0.1	0.1	0.0	0.2	0.1	43.5
Overall spatial change	18.0	4.5	13.5	22.5	2.9	15.9

Table 2. Raw estimates of change in Middle Atlantic Coastal 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	5.9	1.6	4.2	7.5	1.0	17.7	0.8
1980–1986	6.8	2.3	4.5	9.1	1.5	22.0	1.1
1986–1992	7.6	2.5	5.1	10.1	1.6	21.1	1.3
1992–2000	9.2	2.6	6.5	11.8	1.7	18.5	1.1
Estimate of change, in square kilometers							
1973–1980	5,262	1,454	3,808	6,715	932	17.7	752
1980–1986	6,108	2,091	4,017	8,199	1,341	22.0	1,018
1986–1992	6,805	2,235	4,571	9,040	1,433	21.1	1,134
1992–2000	8,215	2,373	5,842	10,588	1,522	18.5	1,027

Table 3. Estimated area (and margin of error) of each land-cover class in Middle Atlantic 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	6.7	5.1	6.5	4.5	2.3	0.7	0.0	0.0	0.1	0.2	35.5	7.3	0.3	0.4	22.7	9.1	26.0	3.6	0.0	0.0
1980	6.7	5.1	7.0	4.7	3.1	1.3	0.1	0.1	0.1	0.2	33.9	6.8	0.3	0.4	22.9	9.2	26.0	3.7	0.0	0.0
1986	6.7	5.1	7.7	4.9	3.4	1.4	0.1	0.1	0.1	0.2	33.2	6.8	0.5	0.5	22.9	9.2	25.4	3.5	0.0	0.0
1992	6.7	5.1	8.3	5.1	4.0	1.5	0.1	0.2	0.1	0.2	31.9	6.5	0.6	0.5	22.8	9.2	25.4	3.7	0.0	0.0
2000	6.7	5.1	9.0	5.3	4.2	1.2	0.1	0.2	0.2	0.2	32.1	7.0	0.5	0.5	22.7	9.3	24.6	3.5	0.0	0.0
Net change	0.0	0.0	2.5	1.2	1.9	0.9	0.1	0.1	0.0	0.0	–3.4	1.8	0.2	0.3	0.0	0.6	–1.3	0.7	0.0	0.0
Gross change	0.0	0.0	2.5	1.2	6.1	1.9	0.1	0.1	0.0	0.1	7.1	2.0	0.4	0.6	1.1	0.5	2.2	0.8	0.0	0.0
Area, in square kilometers																				
1973	5,978	4,568	5,800	4,019	2,061	646	37	40	132	199	31,814	6,529	243	346	20,343	8,121	23,278	3,252	0	0
1980	5,986	4,576	6,299	4,197	2,757	1,185	49	50	125	189	30,365	6,064	252	345	20,556	8,276	23,298	3,294	0	0
1986	5,994	4,585	6,900	4,434	3,022	1,244	75	87	120	181	29,807	6,089	426	408	20,549	8,290	22,793	3,176	0	0
1992	6,002	4,585	7,485	4,607	3,625	1,311	109	138	124	184	28,598	5,830	516	483	20,471	8,273	22,755	3,284	0	0
2000	5,994	4,574	8,047	4,797	3,768	1,076	114	141	143	212	28,773	6,266	424	407	20,319	8,350	22,104	3,157	0	0
Net change	16	18	2,247	1,103	1,707	797	77	102	10	13	–3,041	1,606	180	260	–24	499	–1,173	671	0	0
Gross change	41	34	2,247	1,103	5,468	1,699	77	102	35	50	6,407	1,801	400	495	983	481	1,963	683	0	0

Table 4.   Principal land-cover conversions in Middle Atlantic 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 (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	2,408	1,135	728	2.7	45.8
	Mechanically disturbed	Forest	1,646	538	345	1.8	31.3
	Forest	Developed	444	270	173	0.5	8.4
	Forest	Agriculture	277	233	149	0.3	5.3
	Mechanically disturbed	Wetland	191	98	63	0.2	3.6
	Other	Other	295	n/a	n/a	0.3	5.6
		Totals	5,262			5.9	100.0
1980–1986	Forest	Mechanically disturbed	2,128	968	621	2.4	34.8
	Mechanically disturbed	Forest	2,116	895	574	2.4	34.6
	Wetland	Mechanically disturbed	592	295	189	0.7	9.7
	Forest	Developed	498	336	215	0.6	8.1
	Mechanically disturbed	Grassland/Shrubland	179	260	167	0.2	2.9
	Other	Other	596	n/a	n/a	0.7	9.8
		Totals	6,108			6.8	100.0
1986–1992	Forest	Mechanically disturbed	2,811	1,339	859	3.1	41.3
	Mechanically disturbed	Forest	1,928	919	590	2.2	28.3
	Forest	Developed	493	305	196	0.5	7.2
	Mechanically disturbed	Wetland	426	199	127	0.5	6.3
	Wetland	Mechanically disturbed	392	217	139	0.4	5.8
	Other	Other	755	n/a	n/a	0.8	11.1
		Totals	6,805			7.6	100.0
1992–2000	Mechanically disturbed	Forest	3,098	1,226	787	3.5	37.7
	Forest	Mechanically disturbed	2,866	923	592	3.2	34.9
	Wetland	Mechanically disturbed	791	281	180	0.9	9.6
	Forest	Developed	306	178	114	0.3	3.7
	Mechanically disturbed	Wetland	191	109	70	0.2	2.3
	Other	Other	964	n/a	n/a	1.1	11.7
		Totals	8,215			9.2	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	10,213	3,975	2,550	11.4	38.7
	Mechanically disturbed	Forest	8,788	3,196	2,050	9.8	33.3
	Wetland	Mechanically disturbed	1,903	730	468	2.1	7.2
	Forest	Developed	1,741	1,006	646	1.9	6.6
	Mechanically disturbed	Wetland	942	304	195	1.1	3.6
	Other	Other	2,803	n/a	n/a	3.1	10.6
		Totals	26,390			29.4	100.0

Table 5.   Amounts of "stable" versus "dynamic" forest land cover (as number and percentage of pixels) in sample blocks in Middle Atlantic Coastal Plain Ecoregion throughout study period (1973–2000).

["Stable" forest, forested land that has remained unaltered for at least 30 years; "dynamic" forest, land that was forested only part of that time]

Amount of forest land cover, between 1973 and 2000	Number of forest pixels	Percentage of forest pixels
Total amount of forest land cover during study period	464,020	100.0
Amount of stable forest land cover (that is, amount unchanged)	276,005	59.5
Amount of dynamic forest land cover (that is, amount affected by, or resulting from, change)	188,015	40.5

References Cited

U.S. Department of Agriculture, 1999, 1997 Census of agriculture—Agricultural atlas of the United States, v. 2, subject series, part 1: Washington, D.C., U.S. Government Printing Office, U.S. Department of Agriculture, 163 p.

Vogelmann, J.M., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

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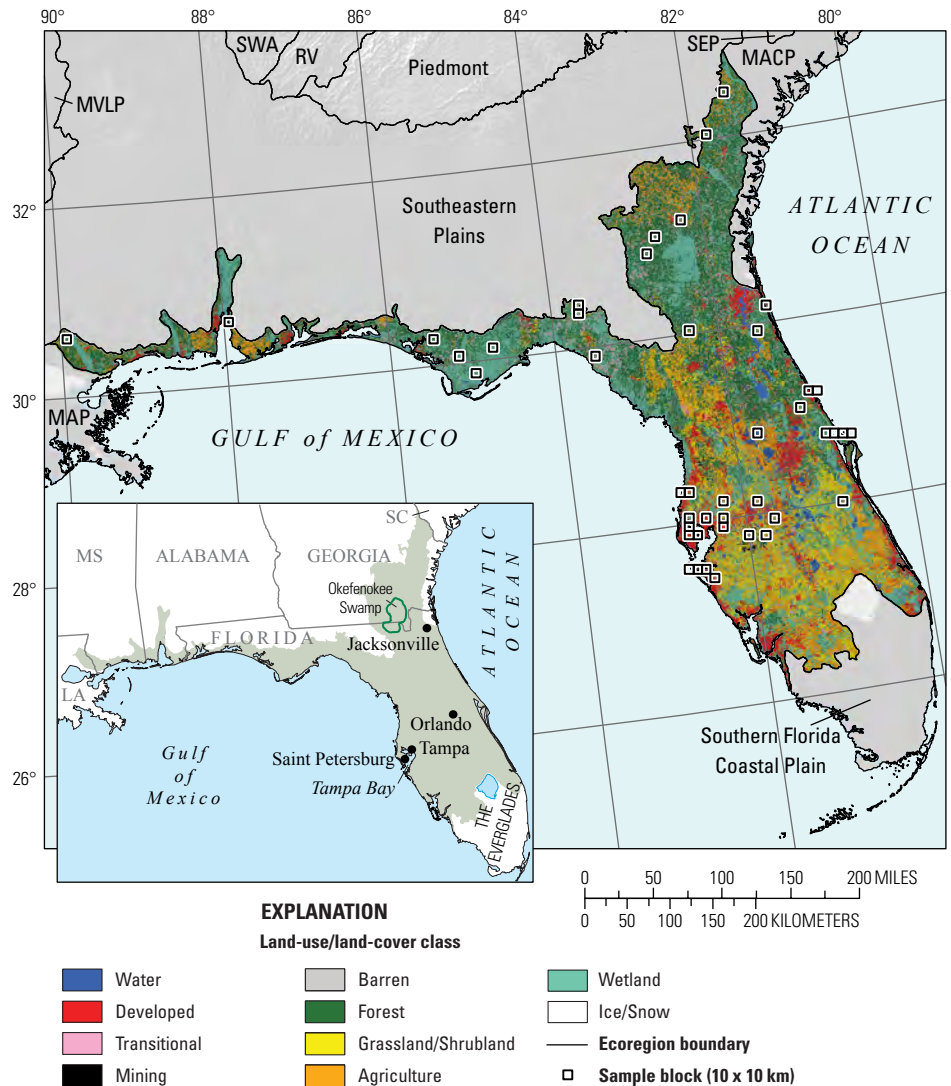
Chapter 19

Southern Coastal Plain Ecoregion

By Mark A. Drummond

Ecoregion Description

The Southern Coastal Plain Ecoregion is a subtropical, low-elevation ecoregion situated between the Gulf of Mexico and the Atlantic Ocean (Wiken and others, 2011) (fig. 1). The ecoregion, which covers about 145,123 km² (56,032 mi²), includes parts of central and northern Florida and southeastern Georgia; a very small part of South Carolina; and the Gulf Coasts of Mississippi, Alabama, and a small part of southeastern Louisiana. The ecoregion is bounded on the far west by the Mississippi Alluvial Plain Ecoregion, on the north by the Southeastern Plains Ecoregion, on the northeast by the Middle Atlantic Coastal Plain Ecoregion, and on the far south by the Southern Florida Coastal Plain Ecoregion.

A discontinuous series of barrier islands, beaches, and sand dunes line the coast of the Southern Coastal Plain Ecoregion. The interior of the ecoregion has many large lakes, karst springs, and sandy hills. Swamps and marshlands are present across the ecoregion, from the large Okefenokee Swamp in the north to the northern part of The Everglades tropical wetlands system, most of which lies in the adjacent Southern Florida Coastal Plain Ecoregion to the south. Large natural disturbances that affect the area relatively frequently include hurricanes and tropical storms, as well as wildland fires.

The climate of the ecoregion is warm and humid, and the ecoregion receives abundant precipitation of between 1,000 and 1,500 mm (40 and 60 in.) annually. The combination of long, frost-free periods of more than 240 days and plentiful water historically has enabled the production

Figure 1. Map of Southern 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 Eastern United States ecoregions are listed in appendix 2. Also shown is part of one Midwest–South Central United States ecoregion, Mississippi Alluvial Plain (MAP). See appendix 3 for definitions of land-use/land-cover classifications.

of specialized crops. The citrus industry focused its intensive orange production on the southern interior and southeastern coastal parts of the ecoregion (fig. 2), although there has been a recent southward translocation of orange-production operations to avoid tree-killing frosts aggravated by wetland loss (Marshall and others, 2003). Pastureland also has been an important agricultural resource in the ecoregion. Extensive pine (*Pinus* spp.) plantations for timber production are common (fig. 3). Stands of commercially harvested pine, which regenerate relatively quickly after harvest, constitute about one-third of Florida's forested land, primarily in the northern part of the state (Carter and Jokela, 2002).

Substantial population growth has occurred in the Southern Coastal Plain Ecoregion, causing an expansion of urban and developed land (fig. 4). Between 1970 and 2000, the population increased by more than 140 percent, from 4.2 million to 10.3 million people (U.S. Census Bureau, 1970–2000 [various years]). Large urban areas are prevalent on the Florida peninsula, including Orlando, Jacksonville, Saint Petersburg, and Tampa. Tampa Bay is one of the ten largest ports in the United States. In addition to agriculture and the extensive pine plantations, tourism and associated service industries are important to Florida's economy. Mining of rich phosphate reserves for use in agricultural fertilizers also is significant (fig. 5).

Pine and mixed-hardwood forests originally covered much of the ecoregion. The native longleaf pine (*Pinus palustris*) was the dominant tree species; however, by about 2000, its extent had been reduced by as much as 98 percent (Wear and Greis, 2002). Forested areas were cleared for lumber and then converted to plantations that favor the faster growing species such as slash pine (*Pinus elliottii*) and loblolly pine (*Pinus taeda*). Forests of longleaf pine and other native trees also have been converted to cropland, pastureland, mining, and urban uses.

Figure 2.   Orange grove ready for harvesting in southern interior of Southern Coastal Plain Ecoregion.

Figure 4.   Large waterfront homes and apartment complex, examples of intensive development along Tampa Bay, Florida.

Figure 3.   Managed pine stand in northern-central part of Southern Coastal Plain Ecoregion.


Figure 5.   Reclaimed strip mine in central Florida.

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 Coastal Plain Ecoregion between 1973 and 2000 is estimated at 24.6 percent (table 1). Compared to other Eastern United States ecoregions, change in the Southern Coastal Plain Ecoregion was highest overall (fig. 6): an estimated 13.2 percent of the ecoregion changed only one time, and 11.3 percent changed two or more times. Multiple changes are indicative of cycles of timber harvesting and reforestation that occurred throughout the study period. When normalized to an average annual rate to account for unequal time periods, the highest rates of change occurred in the last two time periods (1986–1992, 1992–2000), when the average annual rate was 1.5 percent (table 2; fig. 7). The lowest rate of change occurred between 1973 and 1980, when the average annual rate was 1.2 percent.

Land-cover statistics show that forest is the predominant land-cover class, despite a decrease from a high of 28.2 percent of the ecoregion in 1973 to a low of 24.0 percent in 2000 (table 3). Wetland also decreased, from 22.8 percent of the ecoregion in 1973 to 20.4 percent in 2000. Agriculture
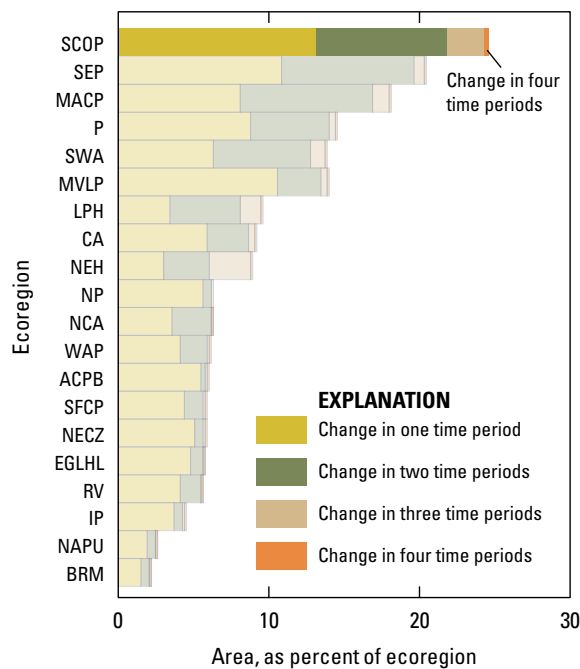
decreased similarly, from 10.7 percent of the ecoregion to 7.9 percent between 1973 and 2000. The study also showed a substantial decrease in mining, from 2.0 percent of the ecoregion to 0.8 percent, as the total area of phosphate mines declined.

Developed had a large overall gain during the 27-year study period, from 14.7 percent of the ecoregion to 20.8 percent, becoming the second most common land-cover class in the ecoregion by 2000. Grassland/shrubland increased from 5.1 percent of the ecoregion to 6.8 percent between 1973 and 2000. The mechanically disturbed and nonmechanically disturbed land-cover classes both had moderate increases in land area. Overall (1973–2000), mechanically disturbed increased from 2.3 to 3.8 percent of the ecoregion. Forest, wetland, and developed each covered more than 20 percent of the ecoregion in 2000, suggesting a highly variable pattern of land use and land cover.

Net-change statistics show that developed increased by 6.2 percent of the ecoregion between 1973 and 2000 (table 3). Grassland/shrubland had the next highest gain at 1.7 percent of the ecoregion. Mechanically disturbed increased by 1.5 percent of the ecoregion, primarily owing to the cutting of forest. The largest net decrease in ecoregion area was a 4.2 percent loss of forest between 1973 and 2000. Other net changes in ecoregion area during the study period included decreases in agriculture (–2.8 percent), wetland (–2.4 percent), and mining (–1.2 percent) (table 3; fig. 8).

The leading land-cover change in all four time periods was from forest to mechanically disturbed (through timber harvest), which accounted for 25.0 percent (14,163 km^2) of all
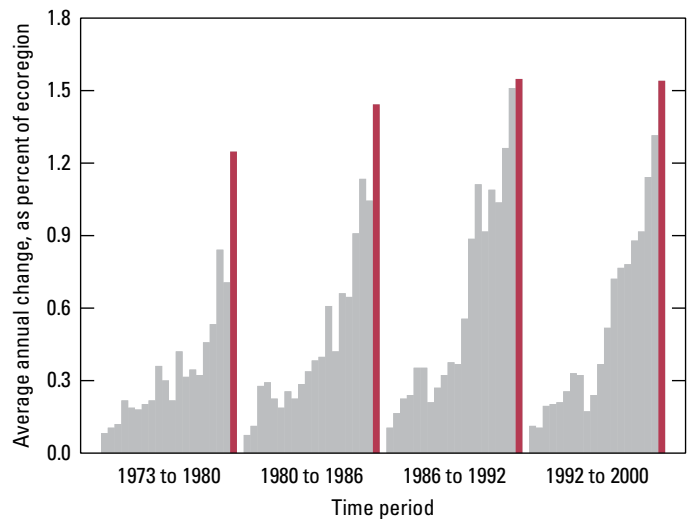

Figure 6. Overall spatial change in Southern Coastal Plain Ecoregion (SCOP; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Southern Coastal 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 20 Eastern United States ecoregions (gray bars). Estimates of change for Southern Coastal Plain Ecoregion are represented by red bars in each time period.

change in the ecoregion during the study period (1973–2000) (table 4). The reforestation of mechanically disturbed land was the second most common conversion. These changes typically are cyclic, owing to forest harvesting and regrowth. Net-change statistics in the Southern Coastal Plain Ecoregion tend to mask much larger gross changes (total losses and gains) that may have occurred in a land-cover class. For example, the ecoregion experienced significant losses of forested land owing to mechanical disturbance (timber harvesting), but it also experienced significant gains in forested land owing to reforestation. Additional decreases in forested land most likely occurred from the loss of forested wetlands.

The 6.2 percent increase in developed land relative to the entire ecoregion area was the highest net increase in all 20 Eastern United States ecoregions during the study period. Overall, development occurred primarily on agricultural land (2,707 km^2), forested land (2,637 km^2), and wetlands (2,024 km^2). Between 1973 and 1980, wetlands were the largest source of land that converted to developed land (937 km^2), although the extent of the conversions had decreased by 2000 (table 4). Agricultural land was the dominant source for developed land in the period between 1992 and 2000, when an estimated 987 km^2 were converted (table 4).

Although much of the overall change in the Southern Coastal Plain Ecoregion resulted from conversions caused by the timber-harvest-and-regrowth cycle, the rapid expansion of developed land throughout the ecoregion represented a significant and permanent change. Developed land expanded into areas formerly occupied by a number of other land covers. Although former agricultural land accounted for much of the newly developed land, agriculture remained an important component of human use of the ecoregion, even as it experienced a shift in geographic range as the needs of the citrus industry changed. Although wetland still occupied one-fifth of the ecoregion in 2000 (table 3), large areas of wetland were lost to developed, a conversion that may continue into the future.
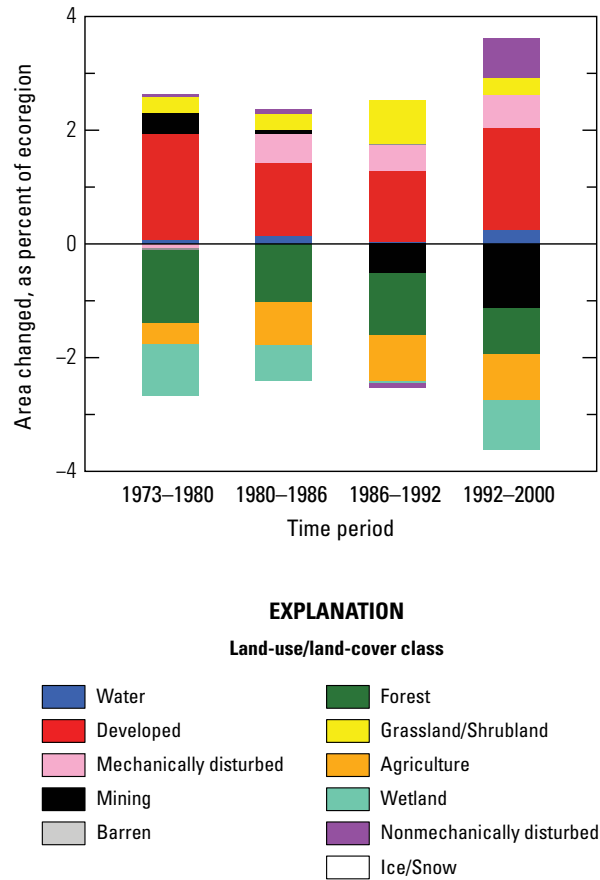
Figure 8.   Normalized average net change in Southern Coastal Plain Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Table 1. Percentage of Southern 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 (75.4 percent), whereas 24.6 percent changed at least once throughout study period]

Number of changes	Percent of ecoregion	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)
1	13.2	2.0	11.2	15.2	1.4	10.3
2	8.6	2.2	6.5	10.8	1.5	17.1
3	2.5	0.9	1.6	3.4	0.6	24.8
4	0.2	0.1	0.1	0.3	0.1	30.9
Overall spatial change	24.6	3.7	20.9	28.3	2.5	10.2

Table 2. Raw estimates of change in Southern Coastal 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	8.7	1.9	6.8	10.7	1.3	15.0	1.2
1980–1986	8.6	1.8	6.9	10.4	1.2	13.9	1.4
1986–1992	9.3	2.1	7.2	11.4	1.4	15.5	1.5
1992–2000	12.3	2.3	10.0	14.6	1.6	12.6	1.5
Estimate of change, in square kilometers							
1973–1980	12,667	2,799	9,868	15,466	1,900	15	1,810
1980–1986	12,541	2,567	9,974	15,108	1,743	14	2,090
1986–1992	13,475	3,072	10,403	16,547	2,086	15	2,246
1992–2000	17,887	3,330	14,557	21,217	2,261	13	2,236

Table 3.   Estimated area (and margin of error) of each land-cover class in Southern 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-mecha-nically disturbed	
	%	+/−	%	+/−	%	+/−	%	+/−	%	+/−	%	+/−	%	+/−	%	+/−	%	+/−	%	+/−
								Area, in percent stratum												
1973	14.0	6.8	14.7	5.3	2.3	0.9	2.0	1.5	0.1	0.1	28.2	5.0	5.1	2.5	10.7	2.7	22.8	3.8	0.0	0.0
1980	14.1	6.8	16.5	5.9	2.2	0.8	2.4	1.8	0.1	0.1	26.9	5.0	5.4	2.4	10.3	2.7	21.9	3.7	0.1	0.1
1986	14.3	6.8	17.8	6.2	2.7	1.0	2.5	1.9	0.1	0.1	25.9	4.9	5.7	2.3	9.6	2.5	21.3	3.7	0.2	0.2
1992	14.3	6.8	19.0	6.4	3.2	1.2	1.9	1.4	0.1	0.1	24.8	4.7	6.5	2.7	8.7	2.4	21.3	3.7	0.1	0.1
2000	14.6	6.8	20.8	6.7	3.8	1.3	0.8	0.7	0.1	0.1	24.0	4.5	6.8	3.2	7.9	2.1	20.4	3.4	0.8	0.8
Net change	0.6	0.3	6.2	2.1	1.5	0.8	−1.2	1.2	0.0	0.0	−4.2	1.4	1.7	1.3	−2.8	1.1	−2.4	1.3	0.7	0.8
Gross change	0.8	0.3	6.2	2.1	7.8	2.3	2.7	2.0	0.0	0.0	9.6	2.3	5.3	1.6	3.6	1.1	3.5	1.3	1.2	0.8
								Area, in square kilometers												
1973	20,322	9,911	21,265	7,731	3,340	1,259	2,910	2,207	213	153	40,950	7,285	7,409	3,603	15,532	3,932	33,151	5,586	31	45
1980	20,463	9,907	23,963	8,608	3,230	1,160	3,436	2,639	201	152	39,044	7,261	7,818	3,486	15,006	3,852	31,847	5,328	116	168
1986	20,689	9,892	25,813	9,007	3,958	1,412	3,558	2,809	204	151	37,577	7,067	8,257	3,328	13,865	3,637	30,981	5,327	223	227
1992	20,756	9,863	27,619	9,350	4,626	1,787	2,809	2,052	205	152	35,973	6,805	9,370	3,939	12,696	3,460	30,930	5,356	140	203
2000	21,130	9,860	30,228	9,752	5,470	1,927	1,176	1,080	207	152	34,824	6,483	9,824	4,626	11,504	3,089	29,655	4,970	1,104	1,129
Net change	808	485	8,963	3,053	2,130	1,150	−1,733	1,771	−6	16	−6,126	2,021	2,415	1,859	−4,028	1,629	−3,496	1,924	1,073	1,131
Gross change	1,110	486	8,990	3,049	11,270	3,287	3,966	2,906	30	18	13,890	3,278	7,733	2,347	5,276	1,619	5,034	1,859	1,784	1,230

Table 4. Principal land-cover conversions in Southern 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 (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Forest	Mechanically disturbed	2,598	1,064	723	1.8	20.5
	Mechanically disturbed	Forest	2,049	935	635	1.4	16.2
	Grassland/Shrubland	Mining	1,067	996	676	0.7	8.4
	Wetland	Developed	937	841	571	0.6	7.4
	Mining	Grassland/Shrubland	845	752	510	0.6	6.7
	Other	Other	5,170	n/a	n/a	3.6	40.8
		Totals	12,667			8.7	100.0
1980–1986	Forest	Mechanically disturbed	3,084	1,240	842	2.1	24.6
	Mechanically disturbed	Forest	1,726	862	585	1.2	13.8
	Mechanically disturbed	Grassland/Shrubland	817	384	261	0.6	6.5
	Mining	Grassland/Shrubland	768	682	463	0.5	6.1
	Grassland/Shrubland	Forest	738	315	214	0.5	5.9
	Other	Other	5,407	n/a	n/a	3.7	43.1
		Totals	12,541			8.6	100.0
1986–1992	Forest	Mechanically disturbed	4,079	1,754	1,191	2.8	30.3
	Mechanically disturbed	Forest	2,237	1,069	725	1.5	16.6
	Mining	Grassland/Shrubland	1,106	1,120	760	0.8	8.2
	Grassland/Shrubland	Forest	858	363	246	0.6	6.4
	Mechanically disturbed	Grassland/Shrubland	784	439	298	0.5	5.8
	Other	Other	4,411	n/a	n/a	3.0	32.7
		Totals	13,475			9.3	100.0
1992–2000	Forest	Mechanically disturbed	4,401	1,693	1,149	3.0	24.6
	Mechanically disturbed	Forest	3,471	1,659	1,126	2.4	19.4
	Mining	Grassland/Shrubland	1,400	1,210	821	1.0	7.8
	Grassland/Shrubland	Forest	1,262	665	452	0.9	7.1
	Agriculture	Developed	987	462	313	0.7	5.5
	Other	Other	6,365	n/a	n/a	4.4	35.6
		Totals	17,887			12.3	100.0
1973–2000 (overall)	Forest	Mechanically disturbed	14,163	4,896	3,324	9.8	25.0
	Mechanically disturbed	Forest	9,483	3,794	2,575	6.5	16.8
	Mining	Grassland/Shrubland	4,120	3,572	2,425	2.8	7.3
	Grassland/Shrubland	Forest	3,110	1,114	756	2.1	5.5
	Mechanically disturbed	Grassland/Shrubland	2,768	1,102	748	1.9	4.9
	Other	Other	22,926	n/a	n/a	15.8	40.5
		Totals	56,570			39.0	100.0

References Cited

Carter, D.R., and Jokela, E.J., 2002, Florida's renewable forest resources: Gainesville, University of Florida, Institute of Food and Agricultural Sciences, Florida Cooperative Extension Service, CIR 1433, 9 p.

Marshall, C.H., Pielke, R.A., Sr., and Steyaert, L.T., 2003, Crop freezes and land-use change in Florida: Nature, v. 426, p. 29–30.

U.S. Census Bureau, 1970–2000 [various years], Census of population and housing: U.S. Census Bureau database, accessed May 9, 2013, at http://www.census.gov/prod/www/decennial.html.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wear, D.N., and Greis, J.G., eds., 2002, Southern forest resource assessment: U.S. Forest Service, Southern Research Station, General Technical Report SRS 53, 635 p, accessed November 15, 2013, at http://www.srs.fs.usda.gov/pubs/4833.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

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U.S. Geological Survey Professional Paper 1794–D, 2016

Chapter 20

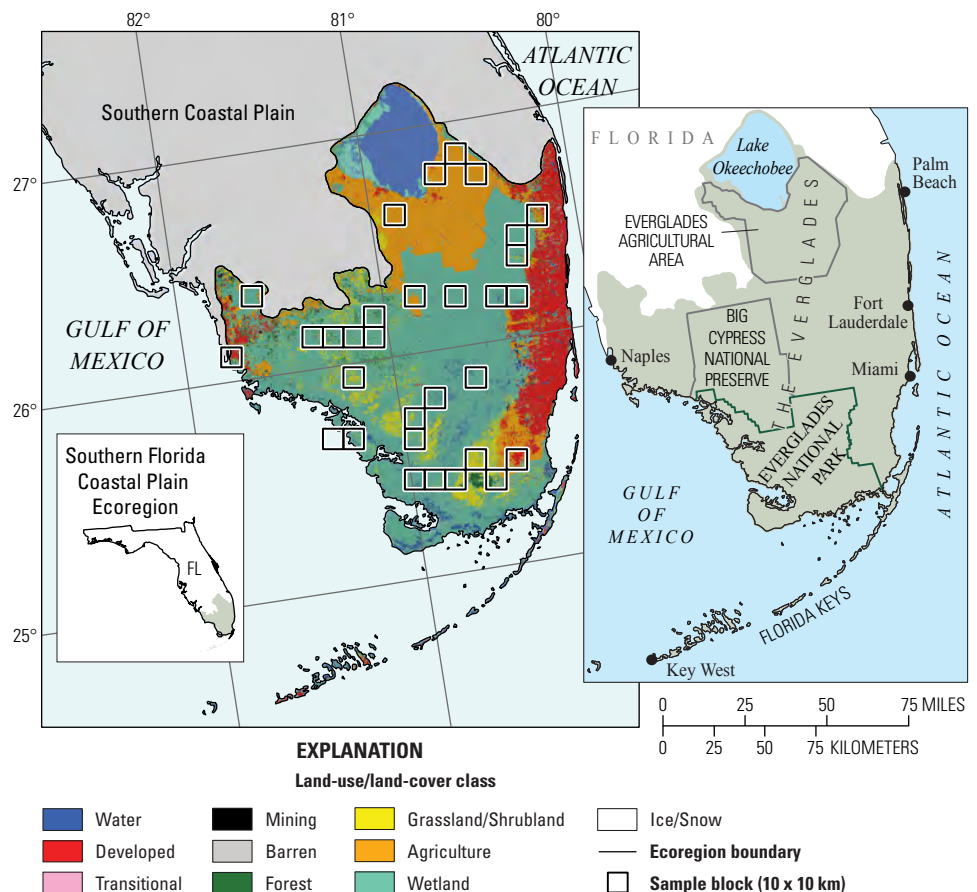# Southern Florida Coastal Plain Ecoregion

By Steven Kambly

Ecoregion Description

The Southern Florida Coastal Plain Ecoregion covers 22,407 km^2 (8,651 mi^2) across the southern part of the Florida peninsula, from Lake Okeechobee southward through the Florida Keys. It is bounded on the north by the Southern Coastal Plain Ecoregion (fig. 1).

The ecoregion is composed of "flat plains with wet soils, marshland and swamp land cover with everglades and palmetto prairie vegetation types" (Wiken and others, 2011). The ecoregion's climate generally is subtropical and frost free, with a dry season and a wet season. About 1,400 mm (55 in.) of rain falls annually in the ecoregion, about 1,060 mm (42 in.) of which falls during the wet season between June and September. The long, warm, dry season, from October to May, allows for year-round crop production, and

it has been essential to the cultivation of commercially grown winter vegetable crops. Sugarcane also is widely grown, forming the basis of the domestic sugar industry since the early 1960s (fig. 2). The nutrient-poor Everglades, with its flat and expansive terrain, is subject to urban and agricultural runoff. Surface-water levels and areas of sheet flow are affected by even slight variations in topography, which can have significant effects on plant and animal communities. The ecoregion experienced extensive land-cover change between 1950 and 1970, owing largely to the implementation of mosquito- and water-control measures, the widespread use of air conditioning, the improvements in transportation infrastructure, and the efforts by developers and government officials to promote Florida's growth potential (Solecki, 2001; see also, figs. 3,4).

Figure 1. Map of Southern Florida 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 Eastern United States ecoregions are listed in appendix 2. See appendix 3 for definitions of land-use/land-cover classifications.

EXPLANATION

Land-use/land-cover class

- Water
- Developed
- Transitional
- Mining
- Barren
- Forest
- Grassland/Shrubland
- Agriculture
- Wetland
- Ice/Snow
- Ecoregion boundary
- Sample block (10 x 10 km)

Contemporary Land-Cover Change (1973 to 2000)

The overall spatial change (the percentage of land that changed at least one time) in the Southern Florida Coastal Plain Ecoregion between 1973 and 2000 is estimated at 5.8 percent (table 1). Compared to other Eastern United States ecoregions, change in the Southern Florida Coastal Plain Ecoregion was moderate, particularly when compared to the neighboring Southern Coastal Plain Ecoregion, which experienced a 24.8 percent change (fig. 5): an estimated 4.4 percent of the Southern Florida Coastal Plain ecoregion (986 km^2) changed only one time; 1.4 percent (314 km^2) changed two or more times; and an estimated 94.2 percent of the ecoregion remained unchanged (table 1). The spatial distribution of change was uneven; most change occurred in urbanizing coastal areas, and relatively little change occurred inland. When normalized to an average annual rate to account for unequal time periods, the estimated change per time period varied from a high of 2.5 percent between 1973 and 1980 to a low of 1.4 percent

Figure 2.   Sugarcane-cultivation and -processing operations, in Everglades Agricultural Area (Conservancy of Southwest Florida, 2013), south of Lake Okeechobee, Florida.

Figure 3.   Flow regulator in Southern Florida Coastal Plain Ecoregion, part of water-control and -allocation infrastructure of Central and Southern Florida Flood Control Project, which was authorized by Congress in 1948 and constructed by U.S. Army Corps of Engineers, thereby ensuring continuation of urban and agricultural growth after World War II.

Figure 4.   Field being cleared for development in Southern Florida Coastal Plain Ecoregion, as demand for housing and associated amenities continues to rise in coastal areas.
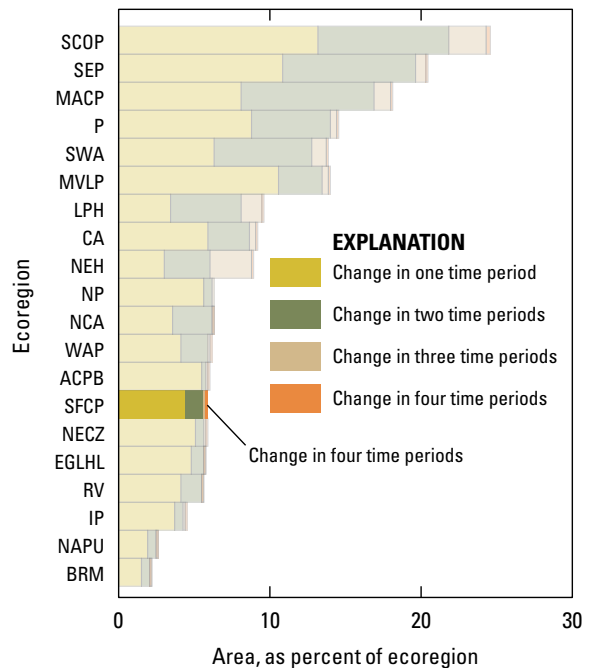

Figure 5.   Overall spatial change in Southern Florida Coastal Plain Ecoregion (SFCP; darker bars) compared with that of all 20 Eastern United States ecoregions (lighter bars). Each horizontal set of bars shows proportions of ecoregion that changed during one, two, three, or four time periods; highest level of spatial change in Southern Florida Coastal 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.

between 1992 and 2000 (table 2). The two intervening time periods (1980–1986, 1986–1992) had rates of change of 1.7 and 1.9 percent, respectively. The estimated average annual rate of change was 0.3 percent across all time periods. The period between 1973 and 1980 had the highest annual rate of change, at 0.4 percent of the ecoregion (80 km^2) (table 2; fig. 6); during this time period, the leading conversions were from wetland to agriculture and from nonmechanically disturbed to wetland, as wetlands recovered from the effects of fire. The time period between 1992 and 2000 had the lowest annual rate of change, at 0.2 percent of the ecoregion; the leading conversions during this time period were from agriculture to developed and from wetland to nonmechanically disturbed (the latter, owing to the occurrence of fire in wetland areas).

Changes in ecoregion land area by land-cover class are indicated in table 3. Developed increased in each time period, from 2.3 percent of the ecoregion in 1973 to 4.1 percent in 2000. Agriculture increased from 17.2 percent of the ecoregion in 1973 to 18.4 percent in 1980, and then it decreased in each subsequent period, occupying 17.3 percent of the ecoregion in 2000. In the time periods between 1973 and 1992, nonmechanically disturbed land fluctuated between 0.0 and 0.6 percent of the ecoregion, reflecting the natural cycle of fire and regrowth in the Everglades; by 2000, nonmechanically disturbed represented an estimated 0.3 percent of the ecoregion. Wetland decreased from 73.7 percent of the ecoregion in 1973 to 72.1 percent in 2000, primarily the result of increases in agriculture and developed (fig. 7).

Wetland to agriculture was the most common land-cover conversion overall (between 1973 and 2000), with an estimated 348 km^2 converted (table 4), the highest amount of
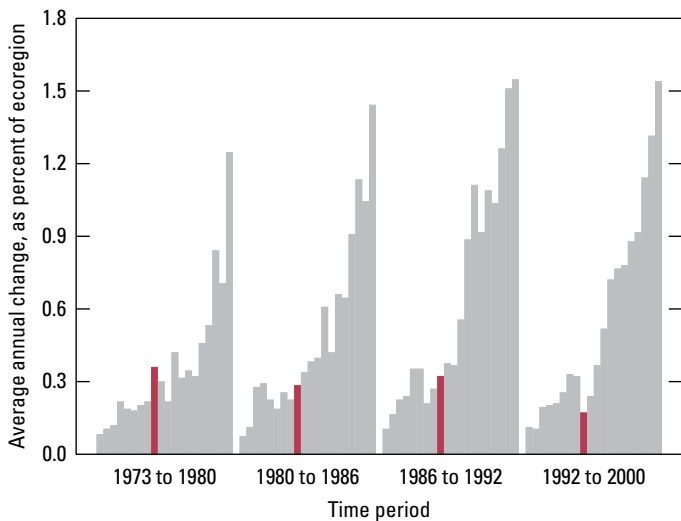
change (284 km^2) occurring in the first time period (1973–1980). Conversions between nonmechanically disturbed and wetland, which represent the natural role of fire and habitat renewal in wetland areas, accounted for the second and fourth most common conversions overall. Agriculture to developed was the third most common conversion overall. Between 1973 and 2000, an estimated 414 km^2 were converted to developed land. As a result, the developed land-cover class was involved in more than one-quarter of all changes, the most of any land-cover class during the study period. Conversions to developed increased after 1980, as a significant amount of agriculture that had been converted earlier from wetland became urbanized. Despite a continual decrease between 1973 and 2000, wetland remained the dominant land-cover class.

Several factors contributed to land-cover change in the Southern Florida Coastal Plain Ecoregion during the study period (1973–2000). Extensive drainage- and flood-control measures, which were begun in the early 1950s by the U.S. Army Corps of Engineers, ensured continual increases in
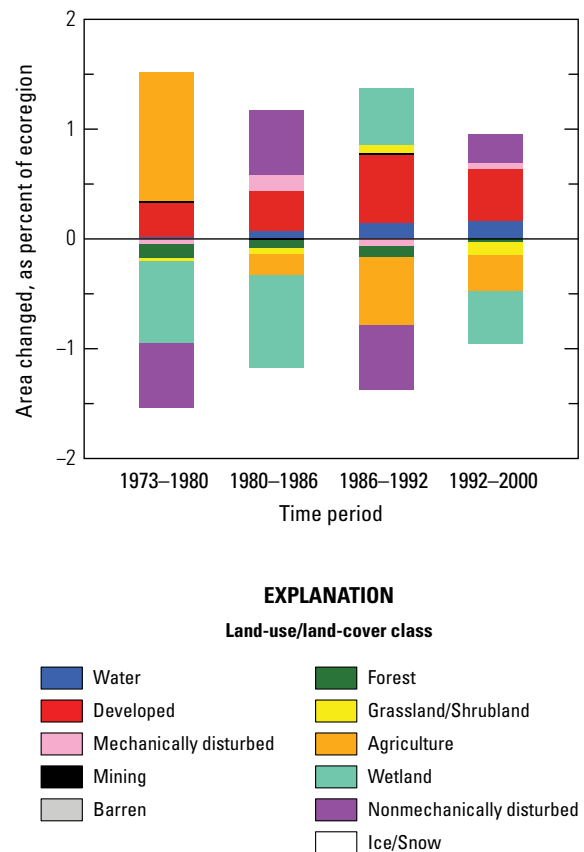
Figure 7. Normalized average net change in Southern Florida Coastal Plain Ecoregion by time period for each land-cover class. Bars above zero axis represent net gain, whereas bars below zero represent net loss. Note that not all land-cover classes shown in explanation may be represented in figure. See appendix 3 for definitions of land-use and land-cover classifications.

Figure 6. Estimates of land-cover change per time period, normalized to annual rates of change for all 20 Eastern United States ecoregions (gray bars). Estimates of change for Southern Florida Coastal Plain Ecoregion are represented by red bars in each time period.

agricultural and development activities. Improvements to the transportation infrastructure to support these land uses made the ecoregion more accessible to tourists and new residents, and it also eased the movement of goods. The advent of private and public pensions and health-care programs enabled large numbers of retirees to settle in the ecoregion (Solecki, 2001).

National and state parks and wildlife refuges played a role in limiting new development, especially in wetland areas. Such protected lands constituted about 30 percent of the ecoregion (fig. 8). A growing awareness of environmental impacts has led to measures protecting ecologically sensitive areas, such as the creation of the Big Cypress National Preserve in 1974 and the ongoing efforts at restoring The Everglades (Carter, 1974; McCally, 1999).

Figure 8.   Roadside marker for Everglades National Park, established in 1947 in Southern Florida Coastal Plain Ecoregion. Although presence of Everglades National Park limits development, both plant and animal species within park are greatly affected by agricultural and urban areas beyond its borders.

Table 1.   Percentage of Southern Florida 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 (94.2 percent), whereas 5.8 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	4.4	1.7	2.7	6.1	1.1	26.1
2	1.2	0.7	0.5	1.9	0.5	40.1
3	0.2	0.2	0.0	0.4	0.1	63.9
4	0.0	0.0	0.0	0.0	0.0	90.5
Overall spatial change	5.8	2.3	3.5	8.1	1.5	26.3

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

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

Period	Total change (% of ecoregion)	Margin of error (+/– %)	Lower bound (%)	Upper bound (%)	Standard error (%)	Relative error (%)	Average rate (% per year)
			Estimate of change, in percent stratum				
1973–1980	2.5	1.3	1.2	3.8	0.9	34.6	0.4
1980–1986	1.7	0.9	0.8	2.6	0.6	36.7	0.3
1986–1992	1.9	1.1	0.8	3.0	0.7	38.8	0.3
1992–2000	1.4	0.7	0.7	2.0	0.5	33.1	0.2
			Estimate of change, in square kilometers				
1973–1980	559	286	273	845	194	34.6	80
1980–1986	380	206	174	587	140	36.7	63
1986–1992	426	244	182	671	165	38.8	71
1992–2000	305	150	156	455	101	33.1	38

Table 3.   Estimated area (and margin of error) of each land-cover class in Southern Florida 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		Grass-land/ Shrubland		Agriculture		Wetland		Non-mechanically disturbed	
	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–	%	+/–
						Area, in percent stratum														
1973	2.7	2.2	2.3	1.7	0.1	0.1	0.0	0.0	0.0	0.0	2.9	1.5	0.4	0.3	17.2	8.2	73.7	9.0	0.6	0.8
1980	2.8	2.2	2.6	1.9	0.1	0.1	0.0	0.0	0.0	0.0	2.8	1.4	0.3	0.2	18.4	8.3	73.0	9.2	0.0	0.0
1986	2.8	2.2	3.0	2.1	0.2	0.3	0.0	0.0	0.0	0.0	2.7	1.3	0.3	0.2	18.2	8.2	72.1	9.1	0.6	0.8
1992	3.0	2.2	3.6	2.3	0.2	0.1	0.0	0.0	0.0	0.0	2.6	1.3	0.4	0.2	17.6	8.1	72.6	9.2	0.0	0.0
2000	3.1	2.2	4.1	2.5	0.2	0.2	0.0	0.0	0.0	0.0	2.6	1.2	0.3	0.2	17.3	8.1	72.1	9.2	0.3	0.4
Net change	0.4	0.3	1.8	1.1	0.1	0.2	0.0	0.0	0.0	0.0	–0.3	0.5	–0.1	0.1	0.1	1.8	–1.6	1.6	–0.3	0.9
Gross change	0.5	0.3	1.8	1.1	0.6	0.4	0.0	0.0	0.0	0.0	0.5	0.5	0.4	0.3	3.1	1.6	4.1	2.6	2.0	2.4
							Area, in square kilometers													
1973	616	498	516	379	31	32	1	1	6	7	648	343	82	58	3,859	1,833	16,517	2,018	131	180
1980	620	498	586	429	19	15	3	4	6	7	619	317	77	50	4,124	1,865	16,350	2,057	0	0
1986	636	497	671	463	52	56	0	0	6	7	602	300	64	40	4,085	1,836	16,160	2,041	131	180
1992	667	497	814	514	36	31	3	3	6	7	583	283	79	48	3,943	1,815	16,275	2,060	0	0
2000	705	497	922	553	46	44	2	2	6	7	575	280	56	39	3,871	1,805	16,166	2,061	58	79
Net change	89	63	406	242	15	54	0	3	0	0	–73	105	–26	33	11	394	–351	348	–73	199
Gross change	113	71	406	242	141	98	9	8	0	0	116	105	100	69	694	365	910	586	449	542

Table 4. Principal land-cover conversions in Southern Florida 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" class are combined totals of values for other land-cover classes not listed in that time period. Abbreviations: n/a, not applicable]

Period	From class	To class	Area changed (km²)	Margin of error (+/– km²)	Standard error (km²)	Percent of ecoregion	Percent of all changes
1973–1980	Wetland	Agriculture	284	224	151	1.3	50.9
	Nonmechanically disturbed	Wetland	130	179	121	0.6	23.3
	Forest	Developed	25	34	23	0.1	4.5
	Mechanically disturbed	Developed	19	27	18	0.1	3.5
	Agriculture	Developed	17	14	9	0.1	3.0
	Other	Other	83	n/a	n/a	0.4	14.8
		Totals	559			2.5	100.0
1980–1986	Wetland	Nonmechanically disturbed	131	180	122	0.6	34.3
	Agriculture	Mechanically disturbed	37	46	31	0.2	9.7
	Wetland	Agriculture	37	35	23	0.2	9.6
	Agriculture	Developed	34	24	16	0.2	8.9
	Forest	Developed	18	23	16	0.1	4.7
	Other	Other	124	n/a	n/a	0.6	32.7
		Totals	380			1.7	100.0
1986–1992	Nonmechanically disturbed	Wetland	131	180	122	0.6	30.6
	Agriculture	Developed	86	64	43	0.4	20.3
	Agriculture	Grassland/Shrubland	31	28	19	0.1	7.3
	Mechanically disturbed	Developed	27	30	20	0.1	6.3
	Forest	Developed	22	29	20	0.1	5.2
	Other	Other	129	n/a	n/a	0.6	30.3
		Totals	426			1.9	100.0
1992–2000	Agriculture	Developed	60	51	35	0.3	19.6
	Wetland	Nonmechanically disturbed	57	78	53	0.3	18.5
	Wetland	Agriculture	22	27	18	0.1	7.1
	Wetland	Water	19	18	12	0.1	6.2
	Agriculture	Mechanically disturbed	18	22	15	0.1	6.0
	Other	Other	130	n/a	n/a	0.6	42.6
		Totals	305			1.4	100.0
1973–2000 (overall)	Wetland	Agriculture	348	277	187	1.6	20.8
	Nonmechanically disturbed	Wetland	261	359	243	1.2	15.6
	Agriculture	Developed	197	138	93	0.9	11.8
	Wetland	Nonmechanically disturbed	187	193	131	0.8	11.2
	Agriculture	Mechanically disturbed	80	88	60	0.4	4.8
	Other	Other	598	n/a	n/a	2.7	35.8
		Totals	1,671			7.5	100.0

References Cited

Carter, Luther J., 1974, The Florida experience—Land and water policy in a growth state: Baltimore, Md., The Johns Hopkins University Press, 354 p.

Conservancy of Southwest Florida, 2013, Everglades Agricultural Area: Conservancy of Southwest Florida Web site, accessed May 1, 2013, at http://www.conservancy.org/our-work/everglades-agricultural-area.

McCally, David, 1999, The Everglades—An environmental history: Gainesville, University Press of Florida, 215 p.

Solecki, W.D., 2001, South Florida—The role of global-to-local linkages in land use/land cover change in South Florida: Ecological Economics, v. 37, p. 339–356.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.

Wiken, E., Jiménez Nava, F., and Griffith, G., 2011, North American terrestrial ecoregions—Level III: Montreal, Canada, Commission for Environmental Cooperation, 149 p., accessed May 1, 2013, at http://www.cec.org/Storage/133/15860_QA07.30-32_NP_NA_Terrestrial_Ecoregions_Level_3_Final-2june11.pdf.

Appendixes 1–4

Appendix 1.   Map of Ecoregions in Conterminous United States

This volume—U.S. Geological Survey Professional Paper 1794–D, which covers 20 ecoregions in the Eastern United States—provides an assessment of the rates and causes of land-use and land-cover change in the Eastern United States region between 1973 and 2000. The other three volumes of this Professional Paper (1794–A, 1794–B, and 1794–C) provide similar analyses for the Western United States, the Great Plains of the United States, and the Midwest–South Central United States regions, respectively.

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

References Cited

Homer, C., Huang, C., Yang, L., Wylie, B., and Coan, M., 2004, Development of a 2001 National Land-Cover Database for the United States: Photogrammetric Engineering and Remote Sensing, v. 70, no. 7, p. 829–840.

Omernik, J.M., 1987, Ecoregions of the conterminous United States: Annals of the Association of American Geographers, v. 77, no. 1, p. 118–125.

U.S. Environmental Protection Agency, 1997, Descriptions of level III ecological regions for the CEC report on ecological regions of North America: U.S. Environmental Protection Agency database, accessed April 12, 2006, at http://www.epa.gov/wed/pages/ecoregions/na_eco.htm#Downloads.

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.

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 Eastern United States

ACPB   Atlantic Coastal Pine Barrens Ecoregion

BRM   Blue Ridge Mountains Ecoregion

CA   Central Appalachians Ecoregion

EGLHL   Eastern Great Lakes and Hudson Lowlands Ecoregion

IP   Interior Plateau Ecoregion

LPH   Laurentian Plains and Hills Ecoregion

MACP   Middle Atlantic Coastal Plain Ecoregion

MVLP   Mississippi Valley Loess Plains Ecoregion

NAPU   Northern Appalachian Plateau and Uplands Ecoregion

NCA   North Central Appalachians Ecoregion

NECZ   Northeastern Coastal Zone Ecoregion

NEH   Northeastern Highlands Ecoregion

NP   Northern Piedmont Ecoregion

P   Piedmont Ecoregion

RV   Ridge and Valley Ecoregion

SCOP   Southern Coastal Plain Ecoregion

SEP   Southeastern Plains Ecoregion

SFCP   Southern Florida Coastal Plain Ecoregion

SWA   Southwestern Appalachians Ecoregion

WAP   Western Allegheny Plateau 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).

Reference Cited

Anderson, J.R., Hardy, E.E., Roach, J.T., and Witmer, R.E., 1976, A Land Use and Land Cover Classification System for Use with Remote Sensor Data: U.S. Geological Survey Professional Paper 964, 28 p., available at http://pubs.usgs.gov/pp/0964/report.pdf.

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.
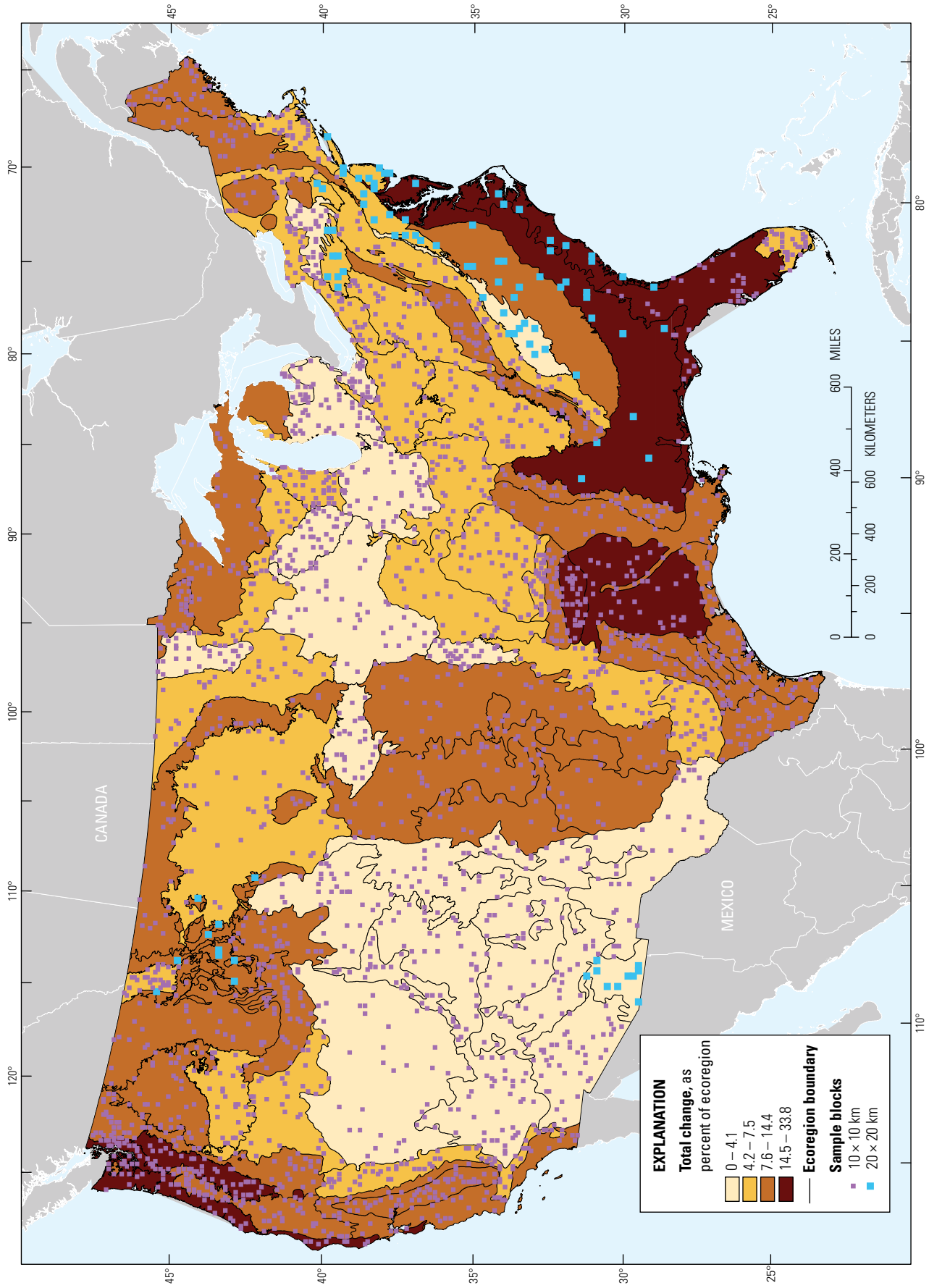
Figure 4.1.   Map of ecoregions in conterminous United States, showing locations of 2,688 sample blocks that were used in "Status and Trends of Land Change" study (purple and blue squares indicate locations of 10 × 10 km and 20 × 20 km sample blocks, respectively). Also shown are amounts of total change in each ecoregion between 1973 and 2000, as percent of ecoregion.
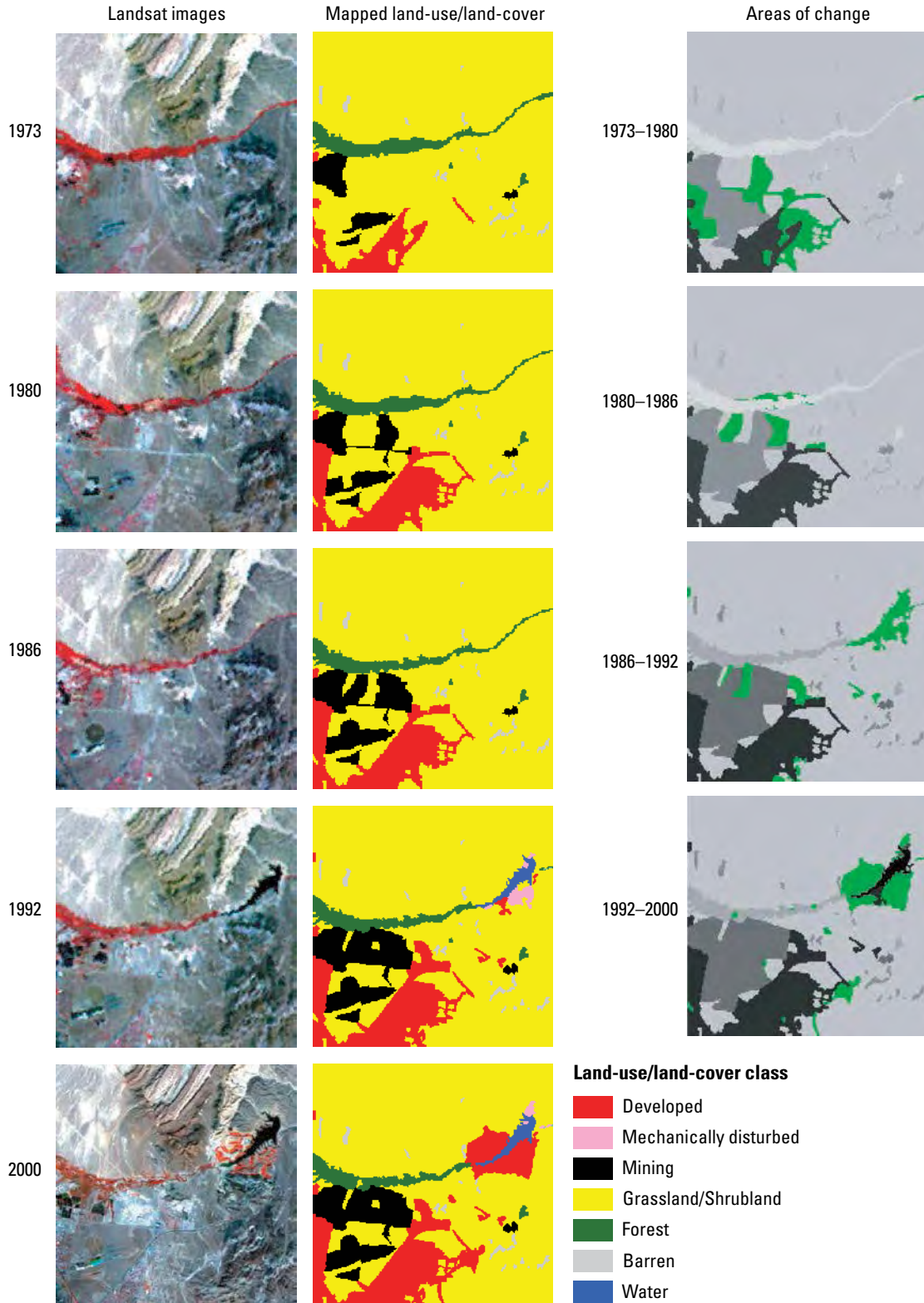
Figure 4.2. Example of data compiled for each sample block, showing sample block 14-0555 (located near Henderson, Nevada, in Mojave Basin and Range Ecoregion, one of Western United States ecoregions). Left column is satellite imagery collected for each of five years analyzed in study (imagery sources 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.

References Cited

Anderson, J.R., Hardy, E.E., Roach, J.T., and Witmer, R.E., 1976, A Land Use and Land Cover Classification System for Use with Remote Sensor Data: U.S. Geological Survey Professional Paper 964, 28 p., available at http://pubs.usgs.gov/pp/0964/report.pdf.

Kish, L., 1987, Statistical Design for Research: New York, John Wiley & Sons, Inc., 296 p.

Loveland, T.R., and Shaw, D.M., 1996, Multiresolution land characterization—Building collaborative partnerships, *in* Scott, J.M., Tear, T.H., and Davis, F.W., eds., Gap Analysis—A landscape approach to biodiversity planning: Bethesda, Maryland, American Society for Photogrammetry and Remote Sensing, p. 17–25.

Loveland, T.R., Sohl, T.L., Stehman, S.V., Gallant, A.L., Sayler, K.L., and Napton, D.E., 2002, A strategy for estimating the rates of recent United States land cover changes: Photogrammetric Engineering and Remote Sensing, v. 68, no. 10, p. 1,091–1,099.

Lunetta, R.S., Lyon, J.G., Guindon, B., and Elvidge, C.D., 1998, North American landscape characterization dataset development and data fusion issues: Photogrammetric Engineering and Remote Sensing, v. 64, no. 8, p. 821–829.

Omernik, J.M., 1987, Ecoregions of the conterminous United States: Annals of the Association of American Geographers, v. 77, no. 1, p. 118–125.

Turner, B.L., II, and Meyer, W.B., 1991, Land use and land cover in global environmental change—Considerations for study: International Social Science Journal, v. 130, p. 669–677.

U.S. Environmental Protection Agency, 1999, Level III Ecoregions of the continental United States: U.S. Environmental Protection Agency National Health and Environmental Effects Research Laboratory, scale 1:7,500,000, available at ftp://ftp.epa.gov/wed/ecoregions/usgs/useco_March1999_v5.pdf.

Vogelmann, J.E., Howard, S.M., Yang, L., Larson, C.R., Wylie, B.K., and van Driel, N., 2001, Completion of the 1990s National Land Cover Data Set for the conterminous United States from Landsat Thematic Mapper data and ancillary data sources: Photogrammetric Engineering & Remote Sensing, v. 67, p. 650–662.