# ECOREGIONS OF THE UPPER MIDWEST STATES

by

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# ABSTRACT

A map of ecoregions of the Upper Midwest States was compiled to give managers of aquatic and terrestrial resources a better understanding of the regional patterns of attainable quality of these resources. The ecoregions represent areas that are relatively homogeneous in patterns of combinations of factors including land use, land-surface form, potential natural vegetation, and soils. Descriptions and photographs provide a synopsis of the major characteristics affecting and distinguishing each ecoregion. A synoptic approach, similar to that used in defining the ecoregions, is also useful for applications of the map. Initial efforts to use the framework are at the State level of aquatic resource management and center on identifying attainable ranges in chemical quality, biotic assemblages, and lake trophic condition.

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## ACKNOWLEDGEMENT

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## BACKGROUND

Some of the most difficult problems facing a resource manager center on "representativeness" of data and research results, and "attainable" ecosystem conditions or quality. Processes and relationships that are dominant in one part of the country are often less important, even nonexistent, in other places. Interrelationships among natural and anthropogenic factors vary, both spatially and temporally, in such a complex way that models developed to predict land use-resource quality relationships are of questionable value when applied outside the specific area for which they were developed. This complexity precludes formulation of quantitative predictions without a prior qualitative understanding of the regional patterns of ecosystems.

Ecoregions[1] of the United States were delineated (Omernik 1987) to alleviate these problems and to provide a geographic framework for more efficient management of ecosystems and their components. Most important, this spatial framework can establish a logical basis for characterizing ranges of ecosystem conditions or qualities that are realistically attainable. For example, in regions of cultivated cropland, it is unrealistic to expect the present quality of water and land resources to be the same as existed before major human settlement. "Realistically attainable" depends on economically, culturally, and politically acceptable protective measures and their compatibility with regional patterns of natural and anthropogenic characteristics.

Our approach for defining ecoregions is based on the hypothesis that ecosystems and their components display regional patterns that are reflected in spatially variable combinations of causal and integrative environmental factors. Various combinations of climate, mineral availability (soils and geology), vegetation, physiography, and land use dictate various associated biological community structures. Although these factors interact, their relative importance in determining the character of ecosystems varies from one place to another. We believe that distinct regional patterns of ecosystems can be distinguished through analysis of a combination of small-scale maps depicting the important factors.

Neither the concept of ecological regions nor the attempt to delineate them is new. The development of regional classifications that incorporate spatial patterns from several ecological factors has been an evolutionary process.` One of the earliest efforts, by Herbertson (1905), was on a global scale. Herbertson considered the distribution of a combination of characteristics in defining his "major natural regions" (an unpopular approach at the time) and also recognized the need to consider distribution of human development (land use).

There are two notable examples of regional classification schemes that have been developed for the United States: 1) Land Resource Regions and Major Land Resource Areas of the United States (Austin 1965; U.S. Department of Agriculture, Soil Conservation Service 1981), developed to help make decisions about national and regional agricultural concerns, and 2) Ecoregions of the United States (Bailey 1976), developed for use by the U.S. Department of Agriculture, Forest

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[1]The term ecoregions was coined by J.M. Crowley (1967) and popularized by Robert G. Bailey (1976) to define a mapped classification of ecosystem regions of the United States. Unlike many coined words or words used to express special new meanings, such as "landscape" or "stream order," there is little disagreement, misunderstanding, or difference of opinion about the meaning of "ecoregion." Ecoregions are generally considered to be regions of relative homogeneity in ecological systems or in relationships between organisms and their environments.

Service. The former is a hierarchical classification based primarily upon soil survey information; the latter is a hierarchical classification which relies upon a different environmental parameter to delineate units at each level of resolution (e.g., Ecoregion Divisions are based on a climate map [Trewartha 1943], Ecoregion Sections, two steps finer in resolution, are based on units, or groups of units, from Kuchler's map of potential natural vegetation [Kuchler 1970]).

Our approach to defining ecoregions grew out of an effort to use existing spatial frameworks to classify streams for more effective water quality management (Hughes and Omernik 1981; Omernik, Shirazi, and Hughes 1982). Because these frameworks were not developed to sort environmental characteristics relating to aquatic ecosystems, they did not correspond to observed regional patterns in water quality. Least helpful were classifications based on a single mapped environmental feature, and/or based on features not well related to causal characteristics that affect regional patterns in ecosystem quality [such as Hydrologic Units (U.S. Geological Survey 1982)]. Additionally, none of the available classifications afforded a means to evaluate the "typicalness" of entire watersheds. Such an evaluation is necessary to assess utility of existing data, design sampling schemes to address regional representativeness, and determine regional patterns of attainable ecosystem quality.

Recognizing that different parameters (or sets of parameters) will have a predominating effect on water quality in different areas, we developed a more satisfactory scheme for defining aquatic ecoregions, based on synoptic assessment of patterns of terrestrial and climatic characteristics. The resulting regions are not exclusive to aquatic ecosystems but, because they have been developed using mapped terrestrial features, are useful for assessing terrestrial ecosystems as well.

## ECOREGION DELINEATION

To define ecoregions of the Upper Midwest States[2], we examined factors that either cause regional variations in ecosystems, or integrate causal factors. In general, many of the factors are interrelated; patterns depicted by a map of one factor also appeared in other maps. These congruent patterns help in the definition of ecoregions by reinforcing the relative homogeneity of particular areas. The following combination of maps was found to be most useful: Land Use (Anderson 1970); Potential Natural Vegetation (Kuchler 1970); Land-Surface Form (Hammond 1970); and Soils (Ohio Department of Natural Resources, Division of Lands and Soil 1973; U.S. Department of Agriculture, Soil Surveys of the States of the North Central Region 1957). We refer to these as the "component maps." Other important environmental parameters such as climate and length of growing season have already been integrated into the patterns depicted on the component maps.

The land use map is a strong integrative tool for revealing ecosystem patterns in most of the United States, reflecting spatial patterns in potentials and capacities of the land. Potential natural vegetation (PNV) is also integrative because it synthesizes a variety of natural and imposed land features. Hammond combined regional patterns of slope and local relief to produce a map of relatively homogeneous classes of land-surface form. The classification scheme of the soils taxonomy map (US Department of Agriculture, Soil Conservation Service 1970) was most appropriate for our purposes but, because of its inaccuracies (resulting from a poor data base and inappropriate cartographic techniques [Gersmehl 1977]), we relied on larger-scale soil maps (as referenced above).

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[2]We define "Upper Midwest" as including the States of Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, and Wisconsin.

Other maps were consulted to verify the regional accuracy of component maps and to reinforce patterns indicating ecoregions. Most helpful were Surficial Geology (Hunt 1979), Physical Divisions (Fenneman 1946), and Land Resource Regions and Major Land Resource Areas of the United States (U.S. Department of Agriculture, Soil Conservation Service 1981). Maps in Climates of the United States (Baldwin 1973) and the Census of Agriculture, Graphic Summary (U.S. Department of Commerce, Bureau of Census 1973, 1978, 1982, and 1985) also were useful.

The four most important component maps were analyzed together to sketch regions exhibiting spatial homogeneity with regard to soils, land use, land-surface form, and potential natural vegetation. Identifying classes of each characteristic were tabulated, as shown on the reverse side of the enclosed ecoregion map. We attempted to delineate ecoregions at a functional level of resolution for regional and State resource management. For instance, an ecoregion should not include highly contrasting areas containing topographic watersheds of greater than 200 square miles[3]. However, some ecoregions exhibit a mosaic of conditions common throughout the region that essentially constitutes an overall homogeneous pattern. In the "most typical" portions of the North Central Hardwood Forests Ecoregion, for example, most 200 square-mile watersheds contain cropland, woodland, and wetland. Some watersheds contain many lakes; in others, there are few or no lakes. Thus, the ecoregion is typified by a degree of contrast uncharacteristic of other adjacent ecoregions.

Subsequent steps for determining ecoregions included delineating ecoregion boundaries and defining the most typical portions of each ecoregion. The <u>most typical</u> portions of each ecoregion are those areas sharing all of the characteristics that typify that ecoregion. The remainder, or <u>generally typical</u> portions of each ecoregion, share most, but not all of these same characteristics.

The final step was to color-code each ecoregion to convey a sense of the broader, multi-regional patterns. Regions predominantly of cropland were assigned shades from yellow to brown and those characterized by forests were assigned shades of green or blue. Within each ecoregion, darker color tones denote the <u>most typical</u> areas, while lighter tones represent the <u>generally typical</u> areas.

## ECOREGION DESCRIPTIONS

Descriptions of the Upper Midwest ecoregions summarize the significant natural characteristics and land use conditions affecting aquatic ecosystems. Discussions of ecoregions are limited to those having "most typical" portions within the boundaries of the Upper Midwest map (i.e., the Central Irregular Plains and Mississippi Alluvial Plain Ecoregions are excluded). Each ecoregion synopsis includes a description of regional landscape features, stream and watershed drainage characteristics[4], major vegetation types, major soil taxa, and predominant land uses. Significant disturbances contributing to stream quality degradation are also listed.

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[3]Most references used in this research presented information in English units of measure. We have presented our measurements accordingly for ease of checking information.

[4]Because of the interest in applying this regional approach toward aquatic resource management, we have included information about "within-region" watershed size and stream density. Knowledge of within-region watershed size is important for determining the largest stream sizes of regionally representative (reference) stream sites. Estimates of stream density can provide a picture of the spatial distribution of the resource being managed.

Ecoregion photographs generally show most typical characteristics rather than extremes or anomalous examples. The high oblique views are taken from approximately 5,000 feet above mean terrain. Low oblique aerial photos (taken about 2,000 feet above the streams) have been paired with ground photos of the same, relatively undisturbed streams.

The ecoregion descriptions include information from a variety of sources (Anderson 1970; Braun 1974; Hammond 1970; Kuchler 1964, 1970; National Oceanic and Atmospheric Administration 1974; Society of American Foresters 1980; US Department of Agriculture, Forest Service 1970, 1977; US Department of Agriculture, Soil Conservation Service 1970, 1975, 1981; US Department of Agriculture, Soil Surveys of the States of the North Central Region 1957; U.S. Department of Commerce, Bureau of Census 1982, 1985; U.S. Geological Survey 1970; Weeks 1970). Stream density was determined from U.S. Geological Survey 7.5-minute topographic maps.

Northern Glaciated Plains (map unit #46[5])

The irregular, glacially formed topography, low to moderate annual precipitation, and relatively short growing (frost-free) season of the Northern Glaciated Plains Ecoregion promote a land use emphasis on dry-farming and livestock production (Photos 1-3). Approximately 7600 square miles, or a little more than 10 percent, of this ecoregion occurs within the Upper Midwest States. Here glacial lake plains and nearly level to rolling glacial till plains are punctuated by kettle holes, kames, and moraines. Elevations range from 1,000 to 1,800 feet

Photo 1. The Northern Glaciated Plains Ecoregion is a natural grassland. Dryland farming and livestock production are the principal land uses.

[5]Numbers correspond to numerical labels used on the Upper Midwest and national ecoregion (Omernik 1987) maps.

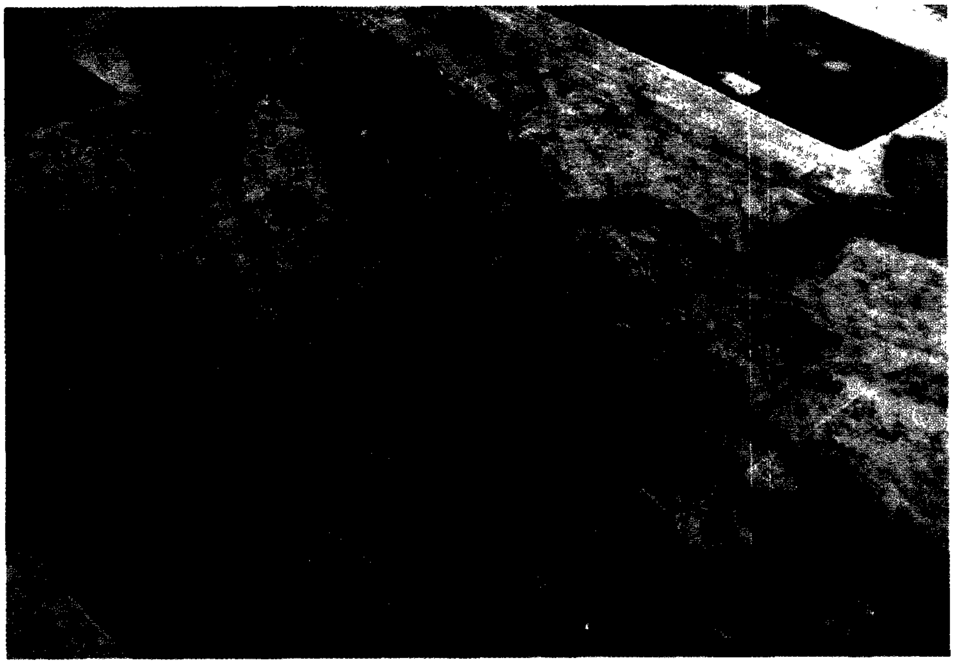

Photo 2

Photos 2 and 3. Most of the streams in the Northern Glaciated Plains Ecoregion are intermittent. Water withdrawal is a management concern in streams with enough water for irrigation.

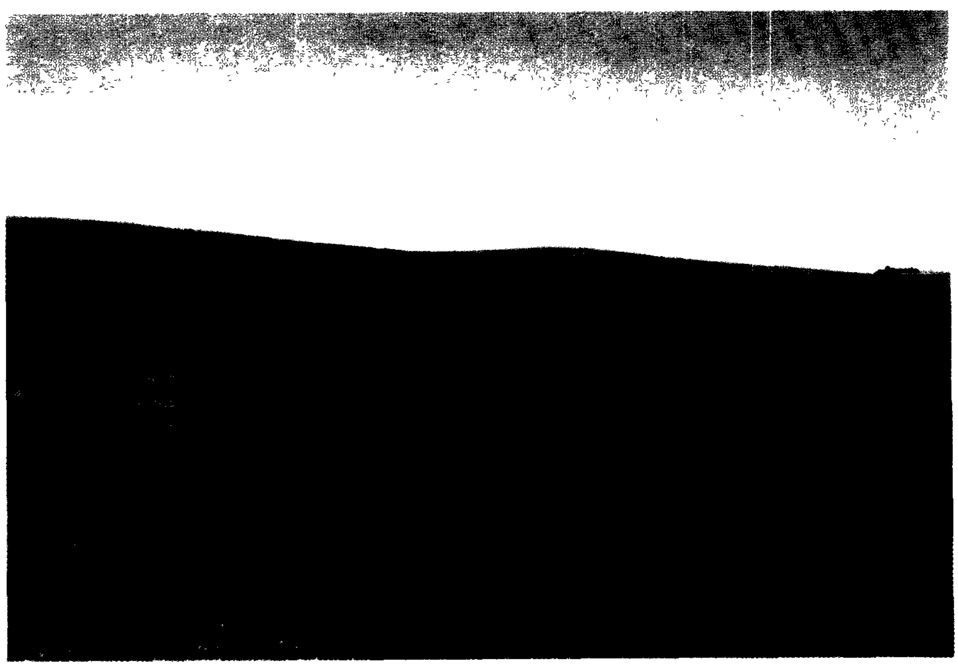

Photo 3.

above sea level. Topographic relief varies from a few feet on the till plains to greater than 150 feet in steep-walled stream valleys. The terrain is higher in elevation and more irregular than in the nearby Red River Valley Ecoregion. Average annual precipitation varies from 22 to 26 inches. Although more than half of the annual precipitation occurs during the growing season, it usually limits maximum crop production.

Large watersheds in this ecoregion[6] cover more than one thousand square miles; however, most watersheds are 100 square miles or less. Except for the large rivers, almost all of the streams (85 to 90 percent) in this ecoregion are intermittent. Drainage density of perennial streams is very low, approximately one-tenth mile per square mile. Numerous lakes and reservoirs are scattered throughout the ecoregion, but many of the smaller lakes are intermittent. Marshes occur in depressions and poorly drained flat areas.

Grasses such as big and little bluestem, green needlegrass, and porcupine grass predominate over most of the Minnesota and Iowa portion of this ecoregion. Prairie dropseed and needle-and-thread grow on steep slopes. Prairie cordgrass occurs on wet soils.

Chief crops in the Northern Glaciated Plains are corn and soybeans. The rest of the ecoregion is dry-farmed oats and other feed grains for livestock. The intensity of farming is somewhat less than in the adjacent Red River Valley and Western Corn Belt Plains Ecoregions. Swine are the predominant livestock in the "Upper Midwest portion" of the ecoregion (beef cattle predominate throughout the rest of the Northern Glaciated Plains). Beef cattle, dairy cattle, and sheep are also raised.

The soils of the Northern Glaciated Plains have been derived from parent materials similar to the soils of adjacent ecoregions. Some soils have formed from glacial lacustrine deposits and calcareous loam till, similar to the Red River Valley; however, the glaciated plains soils are drier and typically contain a horizon of carbonate accumulation. Other soils resemble those of the Western Corn Belt Plains and are derived from glacial till discontinuously mantled by loess. Haploborolls are dominant on well drained sites. Calciborolls are found primarily on calcareous loam till. Natriborolls and Psamments occur on some fluvial and aeolian materials. Calciaquolls and Haplaquolls in depressions are often drained for crop production.

Livestock production and dryland farming are the land use practices most affecting stream water quality in the Northern Glaciated Plains. Trampling of stream banks and stream beds is particularly severe in this region because livestock tend to travel in dry water courses. Washing of manure from feed lots and stock yards into streams has a dramatic effect on stream water chemistry. Rainstorms in this ecoregion tend to be of short duration and high intensity; severe erosion of cropland soils during runoff increases water turbidity and sedimentation in many streams. Fertilizers and herbicides, applied over extensive acreage, are carried to streams during runoff. In flat areas, many stream courses have been plowed for cultivation.

Western Corn Belt Plains (map unit #47)

About eighty percent, or 68,000 square miles, of the Western Corn Belt Plains Ecoregion occurs in the Upper Midwest States. The regional landscape includes extensive cropland on nearly level to gently rolling dissected glacial till plains (Photos 4-6), hilly loess plains, and

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[6]Information concerning large watersheds refers to the largest topographic watersheds which originate, and are completely contained, within the ecoregion.

morainal hills with broad, smooth ridgetops. Streams generally have narrow, shallow valleys, and local relief is typically less than 100 feet, approaching 250 feet along stream valleys in the hilly portions of the ecoregion. Elevation ranges from less than 600 feet along the Mississippi River to about 1,700 feet in the northwest portion of the ecoregion, but most of the central portion of the ecoregion is between 900 and 1,200 feet above sea level. Average annual precipitation ranges from 25 to 35 inches across the ecoregion and occurs mainly during the growing season.

Larger watersheds cover as much as 4,000 square miles. The Des Moines River, draining more than 12,000 square miles, is a striking exception. Perennial and intermittent streams are equally characteristic of the ecoregion. Density of perennial streams is low, from virtually no streams to about three-fourths of a mile per square mile. Some streams are channelized for soil drainage and to improve field shape for crop production; however, the proportion of streams that are channelized is much lower than in the adjacent Central Corn Belt Plains Ecoregion. Lakes and reservoirs are scattered over portions of the region and groundwater is available under much of the area.

The most distinctive feature of the Western Corn Belt Plains Ecoregion is the extensive acreage in corn, soybeans, feed grains, and forage for livestock. Approximately three-fourths of the ecoregion is cropland, with most of the remainder serving as pasture vegetated with native and introduced grasses and legumes. The irregular topography of the Western Corn Belt Plains promotes a stronger emphasis on livestock production than in the neighboring Central Corn Belt Plains. Swine are the major livestock raised, but beef cattle, poultry, and sheep are also economically important. Deciduous woodland exists on some wet bottomlands and on steep slopes bordering stream valleys.

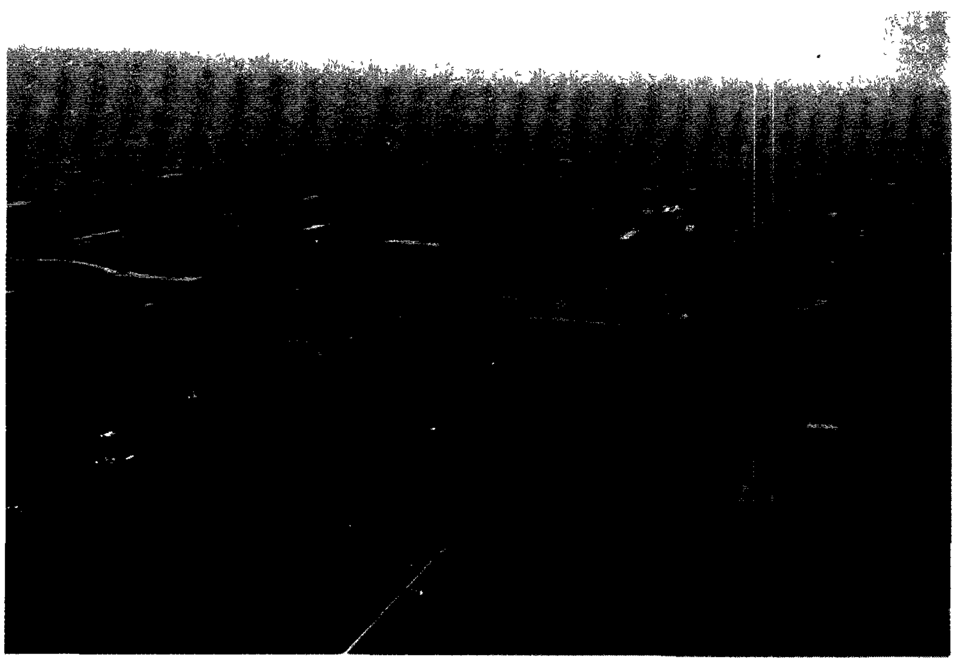


Photo 4. Livestock production of hogs, pigs, and beef cattle, and cultivation of corn, soybeans, feed grain and hay are major land use practices in the Western Corn Belt Plains Ecoregion.

Photo 5

Photos 5 and 6. Many streams are denuded of riparian vegetation and/or channelized to increase area available for cultivation. This portion of Elm Creek provides an example of a less-impacted stream, though the sediment bars are typical of streams in areas of upland erosion.

Photo 6

The dominant vegetation in the Western Corn Belt Plains is tall-grass prairie. In areas of sandy, droughty soils, native grasses include little bluestem, indiangrass, needlegrass, porcupine grass, and sand lovegrass. Big bluestem grows on well drained soils. Shallow soils support sideoats grama, blue grama, and little bluestem. Prairie forbs include roundhead lespedeza, spiderwort, and flowering spurge. Clover, phlox, sunflower, bayfeather, and goldenrod occur on the better developed soils.

Soils in the Western Corn Belt Plains are generally deep and fertile, formed from loess and glacial till under grasses. Upland soils are Hapludolls, Argiudolls, and Udorthents, with Haplaquolls in depressions and Hapludalfs on wooded slopes. Soils of stream terraces include Hapludolls and Haplaquolls. Haplaquolls, Udifluvents, and Fluvaquents are derived from alluvium on bottomlands.

Stream water quality is altered by crop and livestock production practices. In areas of low topographic relief, many streams are plowed to increase crop acreage. A major concern in steeper areas, especially in loess soils, is erosion. Fertilizers, herbicides, and insecticides, used extensively for crop production in this region, are washed and leached during runoff, altering stream chemistry. This process may be accelerated in areas with artificial drainage. Stream quality is greatly affected by manure dispersal in areas where livestock congregate. Livestock grazing in and near streams trample and denude riparian vegetation, thereby, reducing stream bank and stream bed stability.

Red River Valley (map unit #48)

The 16,500 square-mile Red River Valley Ecoregion occupies the nearly level basin of ancient Glacial Lake Agassiz (Photos 7-9). More than half of this ecoregion lies in the Upper

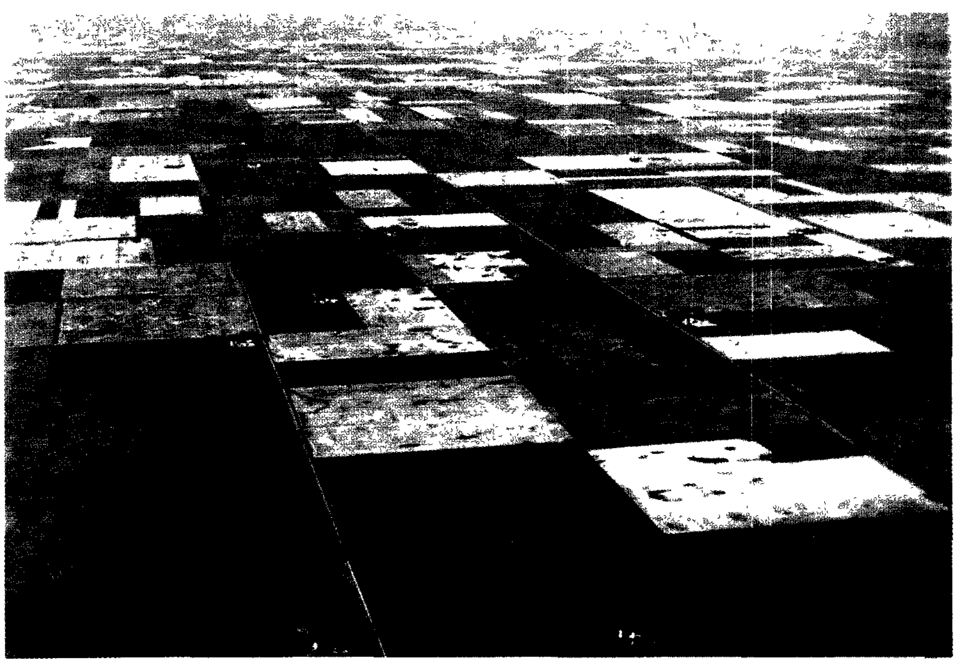


Photo 7. The Red River Valley Ecoregion occupies the nearly flat basin of former Glacial Lake Agassiz. Though the ecoregion includes very little standing water, a high water table has a significant influence on soil and vegetation.

Photo 8

Photos 8 and 9. Most streams in the Red River Valley Ecoregion are intermittent. An exception is Antelope Creek, draining approximately 280 square miles at this photo point. Its meandering course reflects the flatness of the terrain.

Photo 9.

Midwest States, generally at an elevation of about 800 to 1,100 feet. Local relief is minimal except around the margins of the ecoregion, where relief varies from 50 to 100 feet. Unlike the adjoining Northern Minnesota Wetlands Ecoregion, the Red River Valley has very little standing water. Lakes in this ecoregion occur mainly where glacial till and glacial moraine mark the transition to adjacent ecoregions. Most streams originating from within the ecoregion are intermittent and drain watersheds ranging up to a few hundred square miles. Perennial streams in the valley typically originate in adjacent ecoregions. Stream density averages less than one mile per square mile. Average annual precipitation is from 20 to 22 inches, approximately half of which occurs during the growing season.

Land use and vegetation in the Red River Valley resemble that of the nearby Northern Great Plains Ecoregion; however, the valley soils are distinctive because of the presence of a seasonally or permanently high water table (see mottling in Photos 7 and 8). Soils of the Red River Valley formed from lacustrine sediments and sandy, gravelly beach deposits. In some areas, the soils are calcareous. Soils have poor to imperfect drainage in areas of silt loam and clay, and poor to excessive drainage in areas of sandy loam or loamy sand. Principal soils on level sites are Calciaquolls and Haplaquolls. Haploborolls and Udipsamments occur on beach ridges and outwash plains.

Natural vegetation in the Red River Valley is primarily tall-grass prairie, dominated by big and little bluestem, switchgrass, and indiangrass. Bur oak, American basswood, American elm, eastern cottonwood, green ash, and willow grow in some riparian areas.

The ecoregion is dry-farmed for spring wheat, barley, sunflower seeds, sugar beets, potatoes, corn, rye, red clover, soybeans, and flax. Though most of the ecoregion is cropland, some farmers also raise beef and dairy cattle, and swine. Poultry farms are concentrated in some areas.

The main land use impacts on stream water quality in this region are related to dry-farming practices. Because of the flat topography of the region, many smaller headwater stream courses have been denuded and plowed for cropland. Runoff delivery of fertilizers, insecticides, and other farm chemicals, employed extensively in this ecoregion, alters water chemistry in many streams. This process is generally accelerated where drainage tiles assist in areas of naturally poor soil drainage.

Northern Minnesota Wetlands (map unit #49)

Much of the Northern Minnesota Wetlands Ecoregion is a vast and nearly level, sparsely (human) populated marsh. Formerly occupied by broad glacial lakes, most of the flat terrain is still covered by standing water (Photos 10-12). Elevation for most of this 7,700 square-mile ecoregion is around 1,200 feet, and average annual precipitation ranges from 20 to 25 inches across the ecoregion. There are few lakes; the three largest are Upper and Lower Red Lake and Lake of the Woods. An area directly south of Lower Red Lake contains many small lakes; however, the area is transitional between the Northern Minnesota Wetlands and Northern Lakes and Forests Ecoregions.

Watersheds are difficult to define in this region because of the flat terrain and numerous drainage ditches that have been constructed. Most watersheds within the ecoregion occupy less than 200 square miles, though a few are as large as 500 to 700 square miles. Natural streams account for approximately one-fourth of the total drainages in the ecoregion; their density is generally less than 0.3 miles per square mile. Streams are typically stained yellow-brown from

Photo 10. The Northern Minnesota Wetlands Ecoregion is characterized by swamp and marshland. Ditches along roadsides augment the otherwise naturally poor drainage.

dissolved organic material.

Soils of the Northern Minnesota Wetlands are affected mainly by poor drainage. Ochraqualfs formed in poorly drained lacustrine materials and Eutroboralfs formed in better drained areas. Organic soils such as Sphagnofibrists and Borosaprists formed from organic residues in depressional areas.

Most of the ecoregion is covered by swamp and boreal forest vegetation. Dominant tree species are tamarack, black spruce, northern white-cedar, and black ash. Other prominent forest components are balsam fir, red maple, mountain maple, glossy buckthorn, several shrub and herbaceous species, and sphagnum mosses.

The forested portions of the ecoregion are used primarily for lumber and recreation. Land is severely limited for agricultural use because of the locally poor soil drainage and short growing season. Wild rice, however, is grown in some wet soils, and feed grains and forage are cultivated locally for beef and dairy cattle.

Land use effects on stream quality are mainly from channelization of streams to improve soil drainage. Channelization alters the physical habitat for stream biota and affects biotic community structure.

Photo 11.

Photos 11 and 12. Stream water in the Northern Minnesota Wetlands Ecoregion is typically transparent, but coffee colored from dissolved organic material. Land use in this ecoregion is limited by poor soil drainage and adverse climate.

Photo 12.

Northern Lakes and Forests (map unit #50)

Forests of conifers and northern hardwoods blanket the undulating till plains, morainal hills, broad lacustrine basins, and extensive sandy outwash plains of the 69,700 square-mile Northern Lakes and Forests Ecoregion (Photos 13-15). Rock outcrops are common in some areas. Elevations across the ecoregion range from 600 feet, along the shorelines of the Great Lakes, to greater than 2,000 feet, on hills of the Superior National Forest in northeastern Minnesota. Most of the ecoregion is between 1,200 and 1,600 feet above sea level. Local relief is minimal on the plains, about 200 to 500 feet in most of the hills, and 600 to 1,200 feet in the hills and cliffs bordering the western part of Lake Superior. Numerous lakes dot the landscape. Average annual precipitation ranges from 26 to 36 inches across the ecoregion. Snowfall in this ecoregion is considerably greater than in the rest of the Upper Midwest (where average annual snowfall ranges from 12 to 50 inches) and averages 50 to 80 inches over most of the ecoregion, exceeding 100 inches along the southern shores of Lake Superior.

Most streams in the ecoregion are perennial, commonly originating in lakes or wetlands. Stream density, however, is relatively low, generally less than one mile per square mile. Although relatively free of sediment, surface waters have a characteristic brownish cast because of high concentrations of dissolved organic material. Many streams originating within this ecoregion drain watersheds of more than 1,000 square miles; a few drain watersheds on the order of 4,000 square miles. Extensive wetlands cover flat and/or low-lying areas.

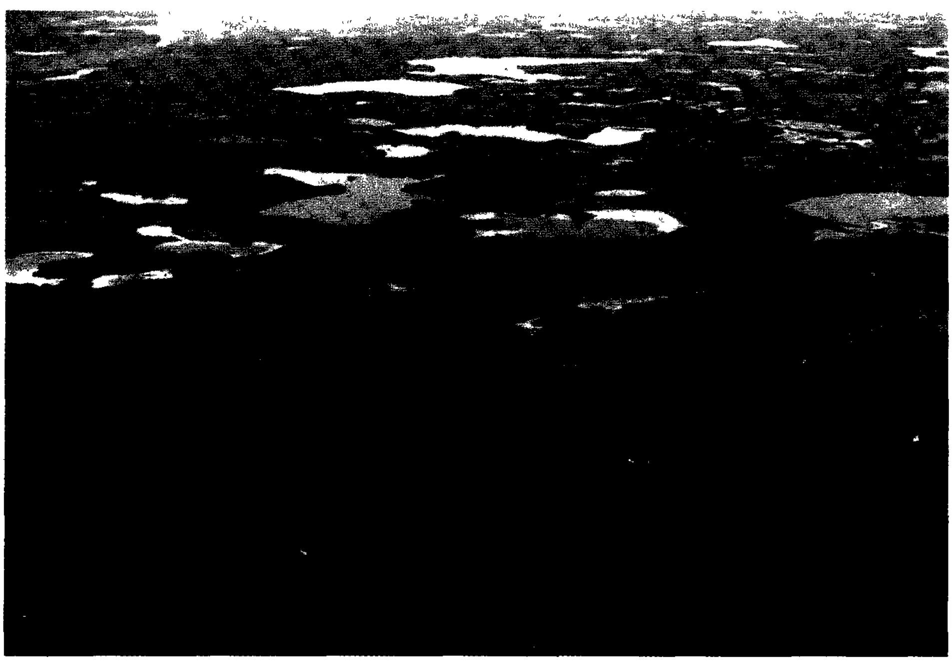
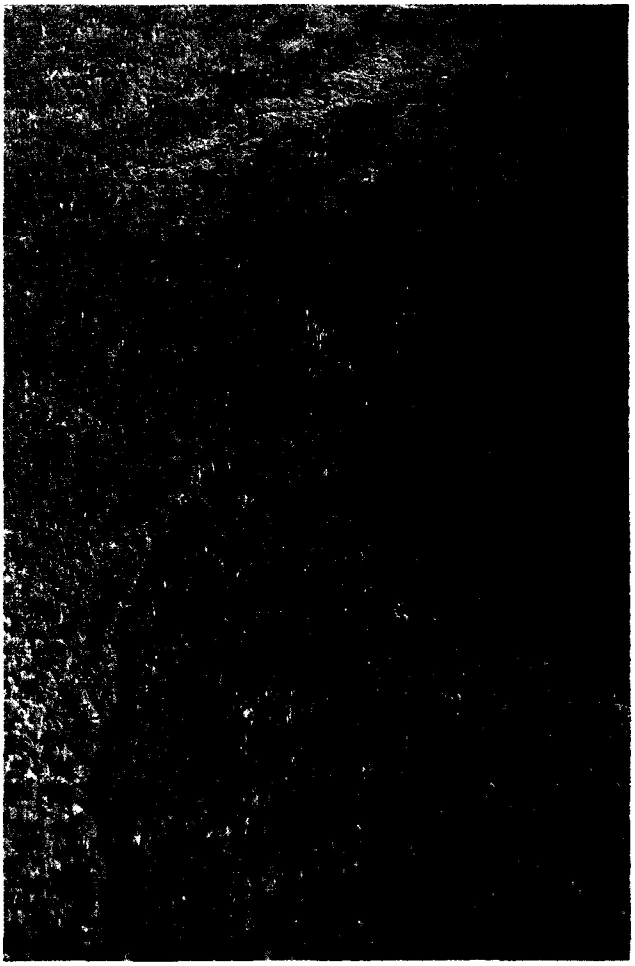


Photo 13. The Northern Lakes and Forests Ecoregion has numerous lakes and extensive wetlands.

Photo 14.



Photos 14 and 15. The natural vegetation in the Northern Lakes and Forests Ecoregion consists of mixed northern hardwoods and pine. Stream water is usually stained brown by dissolved organic material.

Photo 15.

Soils in the Northern Lakes and Forests Ecoregion formed primarily from sandy and loamy glacial drift materials; the variety of parent materials is evident in the complexity of the soil pattern. Haplorthods and Dystrochrepts dominate on uplands and outwash plains. Udipsamments occur on sandy outwash plains. Glossoboralfs, Glossaqualfs, and Ochraqualfs can be found on loess-mantled drift on outwash and till plains. Haplaquepts and Ochraqualfs occur on low till plains and lake plains. Borosaprists and other organic soils are common in depressions.

Like the North Central Hardwood Forests Ecoregion, the Northern Lakes and Forests region supports mixed northern hardwoods forest vegetation, but additionally includes some extensive stands of coniferous forest. Sandy soils support forests of white pine, red pine, jack pine, bigtooth aspen, and bur oak. Sugar maple, mountain maple, balsam fir, yellow birch, hemlock, and American beech grow on more moist sites. Swampy lowlands support tamarack, black spruce, black ash, and northern white cedar; sphagnum bogs occur in the wettest sites.

Similar in many respects to the North Central Hardwood Forests Ecoregion, the Northern Lakes and Forests Ecoregion is markedly different in agricultural potential. Farming is all but precluded by a combination of interrelated factors, including relatively nutrient-poor soils and a short growing season. Most of this ecoregion remains as ungrazed forest and woodland, some of which is used for timber production and recreation. In the few cultivated areas, crops mainly provide forage and feed grains for dairy and beef cattle and other livestock. A small acreage is in permanent pasture. Though mining is not widespread in this ecoregion, the belt of hills comprising the Mesabi Range in Minnesota has been heavily strip-mined for iron.

Historic logging, followed by extensive fires, have greatly altered forest vegetation and stream quality in the Northern Lakes and Forests Ecoregion. Cut-over pine/spruce forests have been replaced by aspen and birch. Layers of charcoal in lake sediments and an entirely altered litter chemistry in streams are evidence of the effects on water quality from these early land use practices. Effects on stream water quality from present land use practices are minimal.

North Central Hardwood Forests (map unit #51)

The North Central Hardwood Forests Ecoregion is transitional between the predominantly forested Northern Lakes and Forests Ecoregion and the agricultural ecoregions to the south (Photos 16-18). This 36,000 square-mile ecoregion consists of nearly level to rolling glacial till plains, lacustrine basins, outwash plains, and rolling to hilly moraines and beach ridges. Clusters of lakes dominate the landscape in many parts of the region, particularly the western half. Local topographic relief is minimal in the plains, and generally 100 to 200 feet in morainal areas. Elevation ranges from approximately 600 feet above sea level, along the Lake Michigan shoreline, to over 2,000 feet in the extreme western portion of the ecoregion. The region averages 24 to 32 inches of annual precipitation, occurring primarily during the growing season.

Stream density and stream flow are highly variable throughout the ecoregion. Density ranges from virtually no streams, as in kettle/wetland terrain, to more than two miles of perennial streams per square mile. Stream flow, while entirely intermittent in some portions of the ecoregion, is entirely perennial in others. Streams with watersheds contained completely within the ecoregion generally drain less than 600 square miles. Two larger exceptions are the Long Prairie River and the North Fork of the Crow River in Minnesota, each draining more than 1,500 square miles.

This ecoregion has mixed land use potential. Almost one-third of the land is cultivated primarily to feed dairy cattle. Poultry farms are concentrated in some areas. Truck crops and

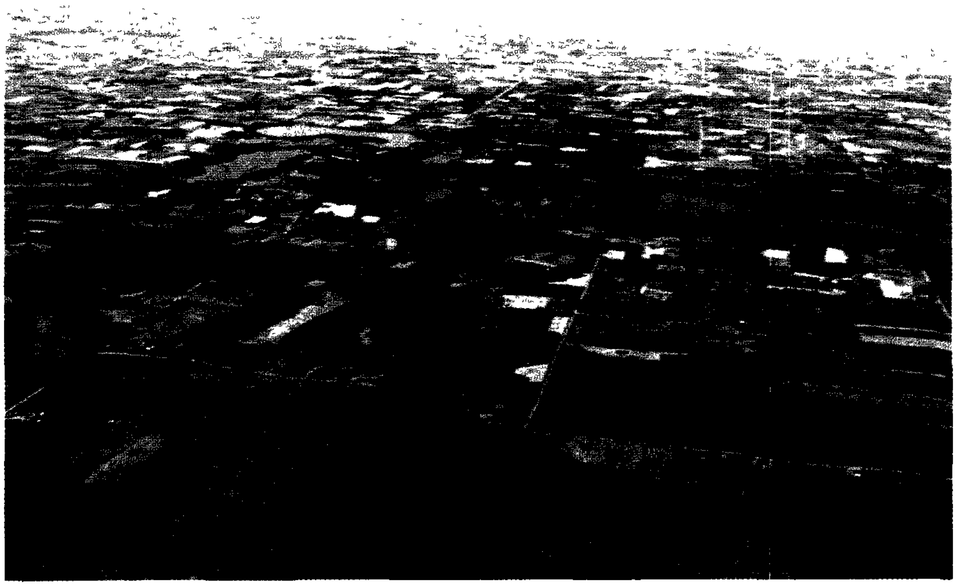


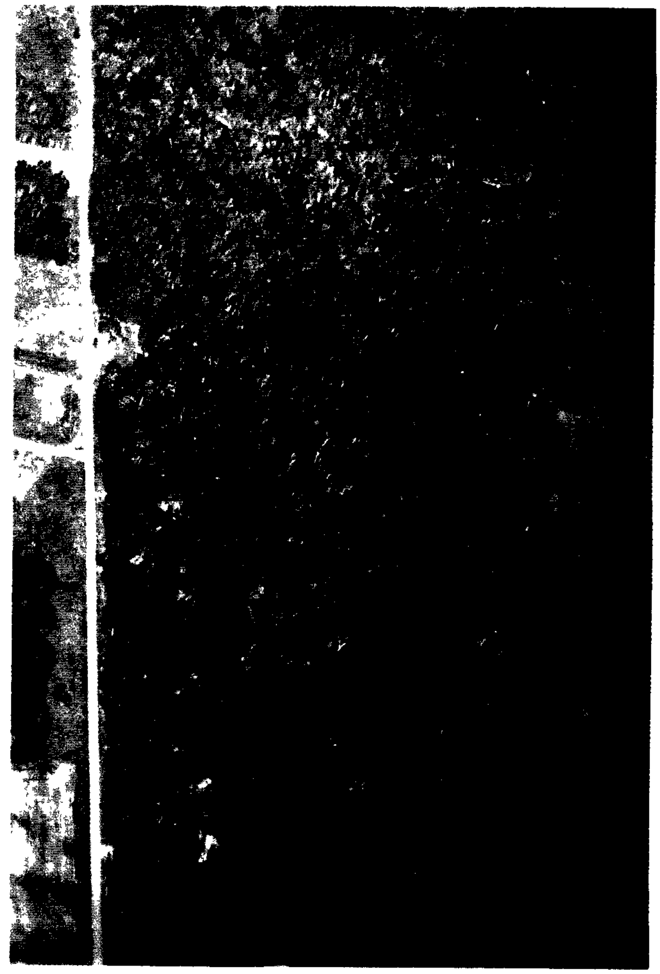
Photo 16. The varied terrain of the North Central Hardwood Forests Ecoregion supports forest and woodland, cropland, dairy farming and poultry production. Numerous lakes and wetlands provide habitat for wildlife and recreation.

cash crops are also important. Potatoes, snap beans, peas, corn, and other canning crops are commonly grown under irrigation, and cranberries are grown in some of the wetter areas. Fruits (especially cherries) and specialty crops are important on the Door Peninsula in Wisconsin. Ten to 15 percent of the farmland is in permanent pasture. Wet bottomlands, steep slopes of stream valleys and moraines, and extensive sandy areas remain forested and are used for woodlots and pulp and timber production.

The North Central Hardwood Forests Ecoregion is named for its dominant forest species, although the region is a mosaic with patches of many vegetation types that are more common in some surrounding ecoregions. Some areas of wet soils have tamarack, white cedar, and other conifers, similar to those found in the adjacent Northern Lakes and Forests Ecoregion. Prairie openings resemble those of the Driftless Area; both regions contain species also found in the Western Corn Belt Plains. The overstory in the hardwood lowlands resembles the maple/basswood forests in the Southeastern Wisconsin Till Plains and Driftless Area Ecoregions, typically including some combination of sugar maple, yellow birch, American beech, American basswood, oak, white ash, and hemlock.

Soils have been derived from glacial materials of many different particle sizes. A few areas are covered by sandy outwash or capped by silty loess. Peat bogs are sometimes numerous. Hapludalfs are the dominant soils on well drained uplands, though Eutroboralfs, Hapludolls, and Haplorthods are locally common. Glossoboralfs, Glossaqualfs, Ochraqualfs, Haplaquolls, and Haplaquods occur where drainage is somewhat poorer. Wet organic soils, such as Borofibrists, Sphagnofibrists, Borosaprists, Borohemists, and Humaquepts formed from plant residues in wet areas and depressions. Fluvaquents and Udifluvents occur on floodplains of rivers and streams. Udipsamments and Psammaquents are common on sandy outwash plains.

Photo 17.



Photos 17 and 18. Density of streams draining the North Central Hardwood Forests Ecoregion is widely variable. Some areas support only perennial streams while other areas support only intermittent streams.

Photo 18.

Land use practices affecting stream water quality in the North Central Hardwood Forests center around dairy farming. Cattle affect stream bank stability by trampling and destroying riparian vegetation. Manure from livestock or poultry alters stream water chemistry. Water quality is also affected by erosion of topsoil and runoff of farm chemicals from cropland.

Driftless Area (map unit #52)

The hilly uplands of the Driftless Area Ecoregion easily distinguish it from the surrounding ecoregions. Much of the area consists of a loess-capped plateau, deeply dissected by streams (Photos 19-21). Some lower areas are covered by glacial outwash or lake and stream sediments. Unlike adjacent ecoregions, the "Driftless" Area escaped the most recent glacial advance, and, in fact, much of the region was apparently free of ice during the Pleistocene Epoch.

Elevations across the 13,500 square-mile ecoregion vary from about 600 to 1,400 feet. Local relief is generally between 200 and 500 feet. Occurring mainly during the growing season, average annual precipitation ranges from 30 to 33 inches throughout the ecoregion.

Large streams in the Driftless Area drain 300 to 400 square miles; a few streams have watersheds in excess of 700 square miles. Intermittent streams account for somewhat more than half of the total stream miles in this ecoregion. Density of perennial streams is around one-half mile per square mile. Wetlands border some of the streams, especially in headwater stretches and where natural or constructed dams have altered water levels.

Livestock and dairy farming are major land uses. Level and gently sloping areas are used

Photos 19. Dairy farming is the principal land use in the hilly Driftless Area Ecoregion. The less sloping terrain is cultivated for feed grains and forage for cattle.

Photo 20.

Photos 20 and 21. Streams in the larger watersheds of the Driftless Area Ecoregion are perennial. High flow is usually accompanied by suspended sediments from erosive loessal soils.

Photo 21.

as cropland, primarily for corn and feed grains. Permanent pasture and forests cover most of the steeper slopes, and woodlots are sufficiently extensive to allow some production of lumber and firewood.

The vegetation of the Driftless Area is transitional between the mixed forests of North Central Wisconsin and the oak savannas of Iowa. Upland hardwood forests consist primarily of red oak, white oak, bitternut hickory, shellbark hickory, sugar maple, and/or wild cherry. Low areas support forests dominated by elm, cottonwood, river birch, ash, silver maple, and willow. Savanna communities of bur oak and bluestem grasses grow in some areas, particularly on sandy soils; however, the grasslands have largely been converted for cropland or invaded by forests.

The soils of the Driftless Area are derived mainly from variously thick layers of loess over sedimentary bedrock. The major soils on well drained uplands are Hapludalfs. Argiudolls and Hapludolls occur on some benches and broad ridgetops. Quartzipsamments are derived from sandstone on steep slopes. Udipsamments, Udifluvents, and Haplaquolls are found on stream terraces and bottomlands.

Agricultural activities have a major impact on stream quality in the Driftless Area. Unless carefully managed, the loessal soils are extremely vulnerable to sheet and rill erosion. Sediments delivered to streams during runoff increase stream turbidity. Livestock affect stream quality when they remove riparian vegetation and trample stream banks and stream beds. Direct deposit of animal wastes has altered the chemistry of many streams. Quarries and gravel pits affect the physical habitat quality of nearby streams.

Southeastern Wisconsin Till Plains (map unit #53)

The Southeastern Wisconsin Till Plains Ecoregion is primarily oriented toward livestock and dairy farming and secondarily oriented toward production of canning and truck crops (Photos 22-24). Terrain features include outwash plains, lacustrine basins, and nearly level to rolling till plains locally mantled with silt. The plains are interrupted by drumlins and morainal belts, adding as much as 200 to 250 feet of topographic relief. Elevation is about 600 feet along the Lake Michigan shoreline and over 1,000 to 1,200 feet on some of the hills. Lakes and basin bogs are common in many parts of this 12,000 square-mile ecoregion. Average annual precipitation is from 28 to 33 inches across the ecoregion. Most precipitation occurs during the growing season.

Large watersheds in this ecoregion typically cover 400 to 1,000 square miles. The Rock River, draining 4,000 square miles, is exceptionally large. Approximately 25 to 30 percent of the streams in this region are intermittent. Density of perennial streams averages around one-half mile per square mile. Many streams are channelized to facilitate the drainage of wetland areas. Constructed channels supply additional drainage for wet sites. Numerous perennial and intermittent lakes occur in depressions throughout the ecoregion.

The Southeastern Wisconsin Till Plains have a noticeably larger percentage of cropland than the nearby North Central Hardwood Forests, Northern Lakes and Forests, and Southern Michigan/Northern Indiana Till Plains Ecoregions. The Central Corn Belt Plains is the only neighboring ecoregion with an equally strong emphasis on cropland; however, the mosaic of crops in the two regions is entirely different. Dairy and livestock farming predominate in the Southeastern Wisconsin Till Plains, and most of the cropland is dedicated to the cultivation of forage and feed grains. Canning and truck crops are also important. Large areas of organic soils are cultivated for onions, mint, corn, potatoes, beans, peas, and other vegetables. Sandier soils produce fruits such as berries, strawberries, and some orchard crops. The remaining cropland is in pasture and farm woodlots.

The agricultural soils of the Southeastern Wisconsin Till Plains formed in a humid temperate climate under hardwood forest vegetation. They are lighter in color and more acid than the prairie soils of the adjoining Central Corn Belt Plains Ecoregion. Hapludalfs are the dominant soils on the silt-covered till plains. Argiudolls are found on grassy parts of the same landscape. Haplaquolls and Argiaquolls are common in depressions, while Udipsamments occur on some sandy sites. Udifluvents and Hapludolls are found in silty sediments on floodplains.

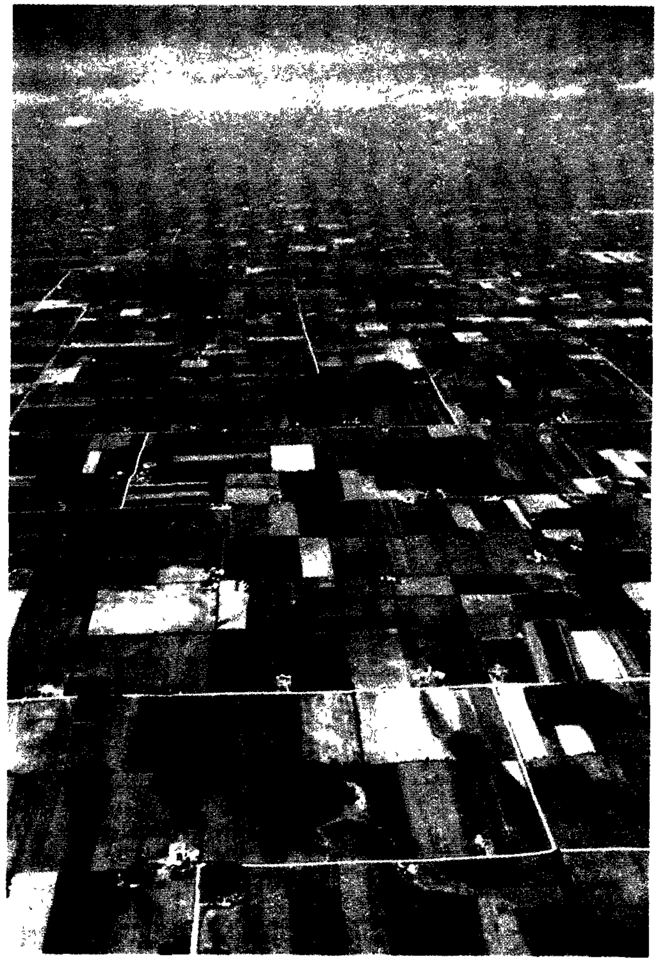


Photo 22. Dairy farming is the major land use in the Southeastern Wisconsin Till Plains Ecoregion. Feed grains and hay dominate on upland fields. Some organic soils are cultivated for onions, mint, corn, and truck crops.

The Southeastern Wisconsin Till Plains supports a mosaic of vegetation types, representing a transition between the hardwood forests of the North Central Hardwood Forests Ecoregion, the oak savannas of the Driftless Area, and the tall-grass prairies of the Central Corn Belt Plains. Upland soils support stands of oak, sugar maple, and hickory, as well as natural prairie characterized by big and little bluestem. Oak and hickory trees are scattered throughout many of the prairies. Uplands in the northern portion of the ecoregion support forests of mixed hardwood and pine species including sugar maple, oak, white ash, elm, yellow birch, white pine, red pine, and American beech. Lowland soils support sedge and grass meadows and mixed stands of hardwoods and conifers, including elm, ash, cottonwood, soft maple, and white cedar.

Primary land use impact to stream quality is related to dairy farming. Livestock in and near streams reduce stream bank and stream bed stability. Manure deposited in streams has a major impact on stream water chemistry. Runoff of agricultural fertilizers and insecticides also alters stream chemistry in this ecoregion. In wet, marshy areas, channelization of streams to increase drainage causes loss of stream habitat for biota. The numerous gravel pits in this ecoregion affect habitat quality of nearby streams.

Photo 23.

Photos 23 and 24. Cultivating wet soils and allowing livestock near streams can affect stream habitat quality in the Southeastern Wisconsin Till Plains Ecoregion.

Photo 24.

Central Corn Belt Plains (map unit #54)

The Central Corn Belt Plains Ecoregion is strongly oriented toward production of feed crops for livestock (Photos 25-27). It has less topographic relief and more rainfall than the adjacent Western Corn Belt Plains Ecoregion. For these reasons, almost all of the Central Corn Belt Plains Ecoregion is in cropland, and there is less emphasis on raising of livestock. Much of the ecoregion consists of a dissected glacial till plain mantled with loess. The till plain has mostly low relief, but the northern portion of the ecoregion includes some morainal hills with local relief approaching 200 feet. Stream valleys are generally shallow throughout the 46,400 square-mile ecoregion. Small streams have narrow valley floors; larger streams have broad valley floors. Elevation varies from about 400 feet, in the southern portion of the ecoregion, to over 1,000 feet on a few of the hills in the north. Precipitation occurs mainly during the growing season and averages from 32 to 44 inches annually. Except near Lake Michigan, and in the meander corridors along major rivers, few natural lakes occur in the ecoregion. Several reservoirs have been constructed for flood control, water supply, low-flow augmentation, and hydroelectric power generation.

Large watersheds in the ecoregion generally cover 1,000 square miles. Exceptional watersheds include those of the Embarras River (2,000 square miles) and the Sangamon River (5,000 square miles). Other large rivers, such as the Rock and Illinois, originate in adjacent ecoregions and flow through the Central Corn Belt Plains. Both perennial and intermittent streams are common in this ecoregion. Constructed drainage ditches and channelized streams further assist in soil drainage in flat, poorly drained areas (e.g., claypans). Stream density is approximately one mile per square mile in the "most typical" portions of the ecoregion, but ranges from one to two miles per square mile in the "generally typical" portions of the ecoregion.

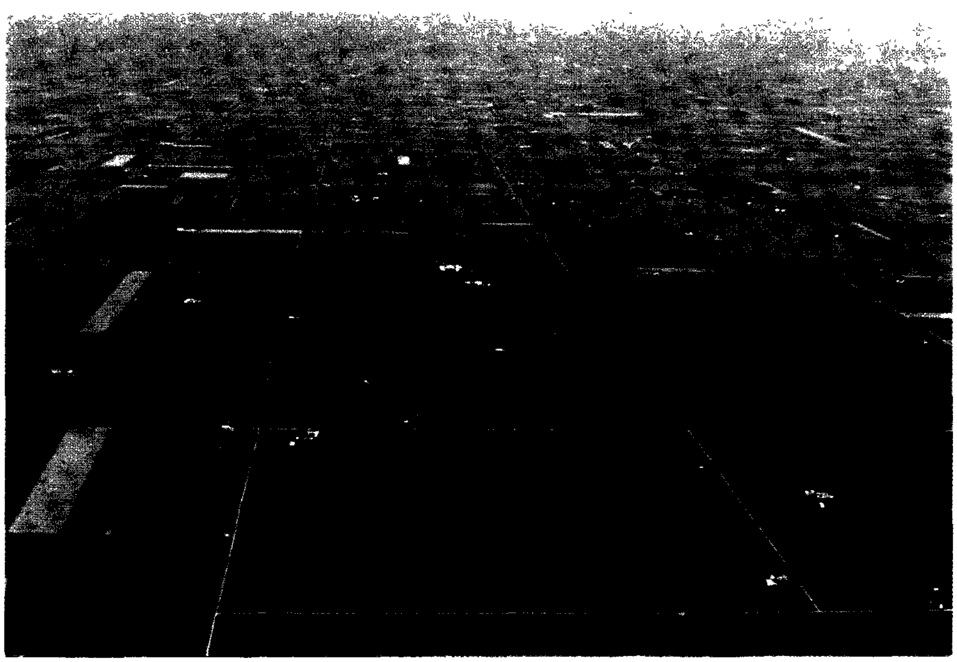


Photo 25. Land use in the Central Corn Belt Plains Ecoregion is strongly oriented toward cultivation of corn, soybeans, feed grains, and hay. Drainage ditches and channelized streams aid soil drainage where claypans occur.

Photos 26 and 27. Land in the Central Corn Belt Plains Ecoregion is commonly plowed right up to streams banks to maximize cropland acreage. This vegetated, unchannelized section of Rooks Creek is an example of a stream having relatively little impact.

Photo 26.

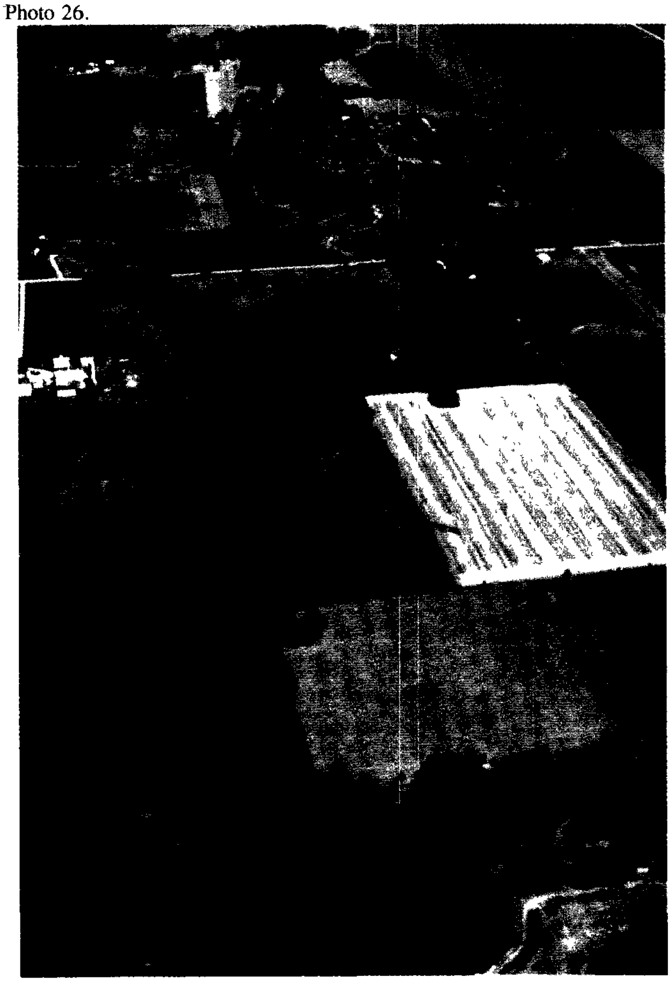


Photo 27.

Crops cultivated in the Central Corn Belt Plains are mainly corn, soybeans, feed grains, and some forage for livestock. Hogs and pigs are of primary economic importance; beef cattle, sheep, poultry, and some dairy cattle are also produced. Emphasis on livestock production is not as great as in the Eastern and Western Corn Belt Plains Ecoregions. Approximately five percent of the Central Corn Belt Plains remains as woodland, primarily on wet floodplains, steeply sloping valley sides, and morainal ridges. Numerous oil fields occur in the southeastern quarter of the ecoregion, and several areas of the ecoregion (particularly in western Illinois) have been strip-mined for coal.

Most of the soils of the Central Corn Belt Plains developed under tall-grass prairie. They are darker and more fertile than soils in the formerly wooded Eastern Corn Belt Plains. Hapludolls and Argiudolls are the most common soils on loess-covered till. Argiaquolls, Haplaquolls, and Ochraqualfs occur on broad, flat uplands, especially in the claypan region of south central Illinois. Fragiaqualfs and Hapludalfs are locally common on forested slopes and loessal ridges. Hapludolls, Haplaquolls, Udifluvents, and Fluvaquents are found on poorly drained silty or clayey alluvium on floodplains. A few Haplaquolls and Medisaprists have formed in poorly drained flats and wet depressions.

The Central Corn Belt Plains historically supported a mosaic of bluestem prairie and oak/hickory forest. Most of the level uplands and broad floodplains were covered by tall grasses: big and little bluestem, indiangrass, prairie dropseed, and switchgrass. Hardwood forest originally occupied the irregular topography of stream valleys and moraines. The woodlands were mainly a mixture of oak and hickory species: black oak, white oak, bur oak, red oak, shingle oak, shagbark hickory, and bitternut hickory, with an occasional black walnut, yellow poplar, white ash, sugar maple, basswood, elm, and beech. Riparian areas at present support pin oak, silver maple, elm, ash, cottonwood, willow, sycamore, and sweetgum. Cattails, bulrushes, and common reed grow in organic soils in marshes.

Nonpoint source pollution in the Central Corn Belt Plains is derived mainly from crop and livestock production. Erosion of soils from cultivated slopes, particularly a problem in loessal soils, increases stream turbidity and sedimentation. Likewise, runoff of the fertilizers, herbicides, and insecticides used extensively in this region alter water chemistry in many streams. Channelization of streams and construction of drainage ditches in cropland, particularly where claypans exist, reduce habitat for stream biota. Decreased stream bank and stream bed stability result from livestock trampling and grazing of riparian vegetation in and near streams. Where livestock congregate, manure dispersal can strongly affect stream water chemistry. Strip mining for coal has long-term effects on stream water chemistry and habitat over many stream miles.

Eastern Corn Belt Plains (map unit #55)

The Eastern Corn Belt Plains Ecoregion is a region of extensive cropland agriculture (Photos 28-30). It is distinguished from similar corn belt regions to the west primarily by its natural forest cover and associated soils. The gently rolling glacial till plain comprising the Eastern Corn Belt Plains Ecoregion is broken by moraines, kames, and outwash plains. Elevations throughout the ecoregion range from about 600 feet, near Lake Erie, to greater than 1,200 feet. Local relief is generally less than 50 feet; however, in some of the north central moraines, relief reaches 200 feet, and along some streams in the southern portion of the ecoregion, there are elevation differences of up to 400 feet. Valleys are typically narrow and shallow.

Larger watersheds in the ecoregion cover thousands of square miles. For example, the

White River (Indiana) drains some 2,500 square miles; the Great Miami River (Ohio) drains 3,500 square miles; and the Wabash River (Indiana) drains 4,000 square miles. About half the streams in this 31,800 square-mile ecoregion are perennial, and many have been channelized to assist soil drainage. Larger streams are regulated to inhibit flooding. Density of perennial streams is approximately one-half mile per square mile. The ecoregion has few reservoirs or natural lakes. Of these, many are in steeper river valleys and are long and sinuous. Average annual precipitation ranges from 35 inches in the north, to 40 inches in the south. Much of the precipitation occurs during the growing season and is generally adequate for crop production.

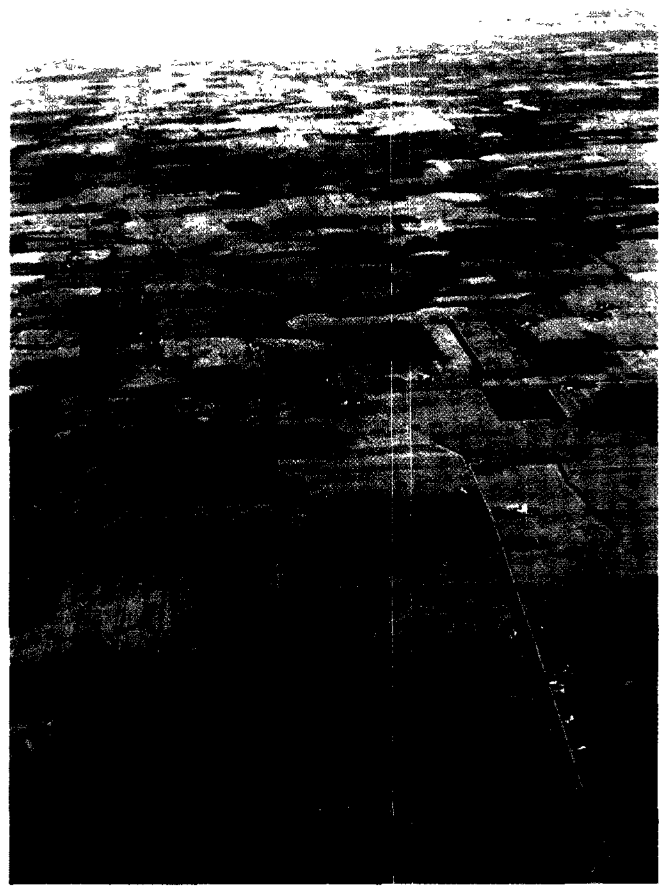


Photo 28. Approximately three-fourths of the Eastern Corn Belt Plains Ecoregion is in cropland, primarily for corn and soybeans.

The Eastern Corn Belt Plains support a diverse hardwood forest; American beech and sugar maple predominate, but a significant amount of white oak, black oak, northern red oak, yellow poplar, hickory, white ash, and black walnut is also found. Many of the same tree species occur in adjacent ecoregions, but most of those ecoregions are characterized by a predominance of oak and hickory. On wetter sites in the Eastern Corn Belt Plains, the forest includes white oak, pin oak, northern red oak, yellow poplar, ash, and sweetgum as major constituents; shingle oak, black oak, and hickory may also occur. Silver maple, cottonwood, sycamore, pin oak, elm, and sweetgum grow along rivers and streams.

Soils of the Eastern Corn Belt Plains reflect the influence of deciduous forest vegetation. The parent material is mainly a loamy calcareous glacial till, overlain by loess deposits in some southern parts of the ecoregion. Though derived from similar parent materials, these soils are lighter in color and more acid than those of the adjacent Central Corn Belt Plains, which formed under tall grasses. Hapludalfs and Ochraqualfs are the dominant soil groups on drier and wetter upland sites, respectively. Argiaquolls, Haplaquolls, and Medisaprists have developed in flats and depressions. Hapludalfs and Fragiudalfs are common on well drained slopes of valleys. Shallow Hapludolls occur on some valley sides where erosion has removed the glacial material and exposed the underlying shaly limestone. Udifluvents and Fluvaquents have derived from

Photo 29.

Photos 29 and 30. Many streams in the Eastern Corn Belt Plains Ecoregion have been channelized or regulated to inhibit flooding. This portion of the Stillwater River provides an example of a less impacted stream.

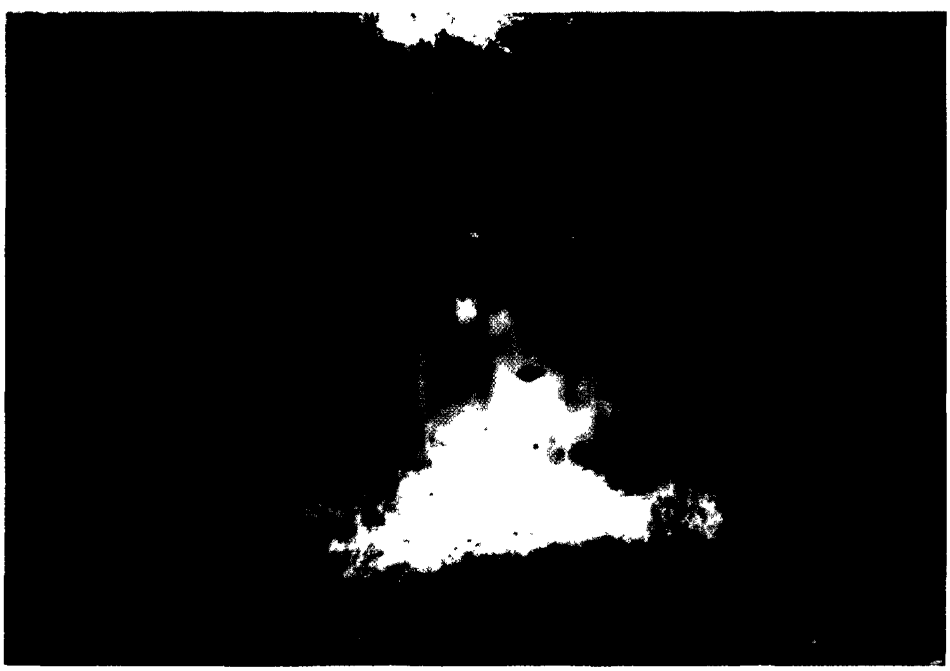


Photo 30.

silty alluvium in relatively narrow floodplains.

The ecoregion is almost entirely farmland. Three-fourths of the area is in cropland; the rest is permanent pasture, small woodlots, or urban. Corn and soybeans are the principal crops; other feed grains and hay for livestock are also grown. Truck and canning crops are locally important, and some farms grow tobacco as a cash crop. Swine, beef and dairy cattle, chickens, and turkeys are raised throughout the ecoregion. Oil fields augment the economy in some areas.

Stream quality in the Eastern Corn Belt Plains is influenced by the agricultural economy. Runoff of fertilizers, herbicides, and insecticides, used extensively for crop production in this ecoregion, can alter stream chemistry. Where natural soil drainage is poor, artificial drainage systems accelerate the rate of delivery of these farm chemicals to streams. Extensive stream channelization reduces habitat diversity for stream biota. In livestock areas, manure disposal can pollute streams. Cattle in and near streams can contribute to stream bank and stream bed erosion. Seepage of sludge near drilling sites in oil fields may increase stream turbidity. A moderate number of quarries and instream mining of gravel occur in this ecoregion and may impose local effects on stream habitats.

<u>Southern Michigan/Northern Indiana Till Plains</u> (map unit #56)

Land use in the Southern Michigan/Northern Indiana Till Plains Ecoregion is more varied than in the adjacent Northern Lakes and Forests, Huron/Erie Lake Plain, Eastern Corn Belt Plains, and Central Corn Belt Plains Ecoregions. Land use in this transitional region (Photos 31-33) encompasses crop and livestock production, forests and woodland, a high degree of

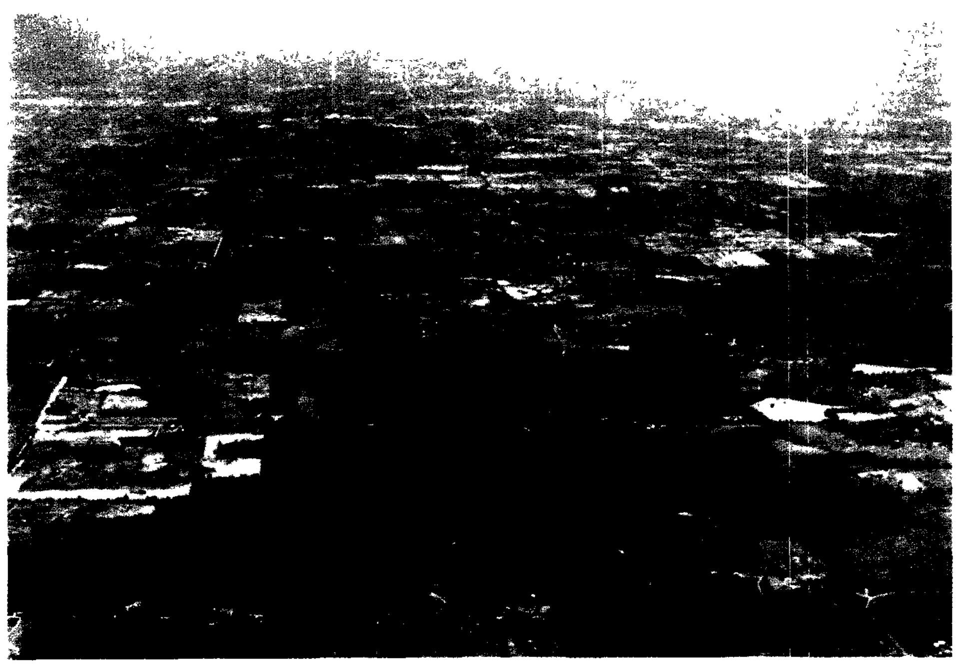


Photo 31. Land use is varied in the Southern Michigan/Northern Indiana Till Plains Ecoregion. Cropland is mainly in corn, other feed grains, and hay for dairy cattle. Pasture, forest, and woodland occupy sloping sites.

Photo 32.

Photos 32 and 33. Streams in the Southern Michigan/Northern Indiana Till Plains Ecoregion are typically sluggish and often bordered by swampy tracts.

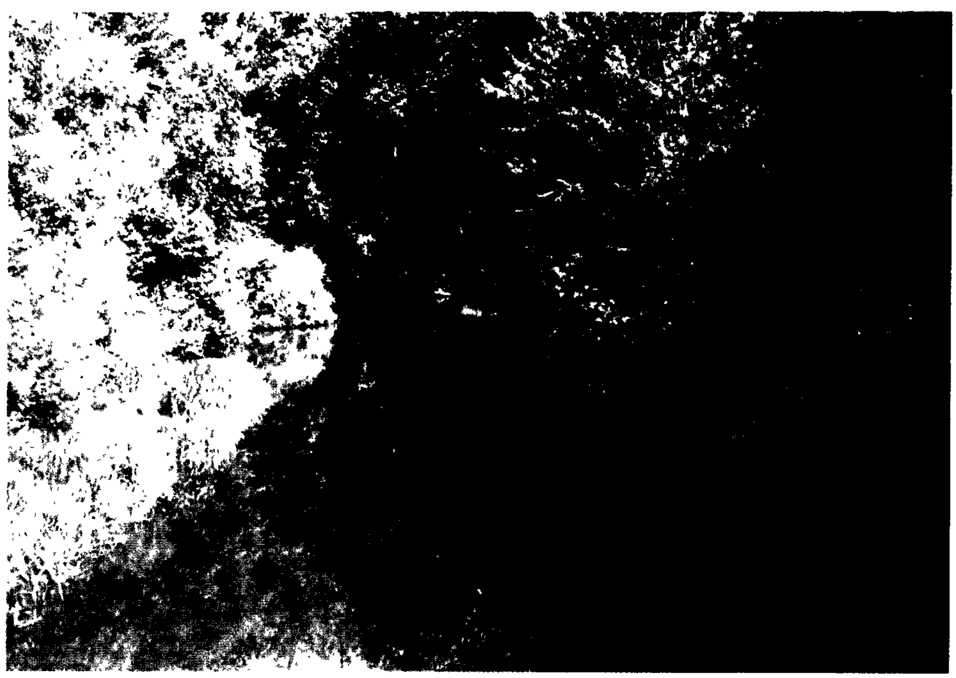


Photo 33.

urbanization (particularly near the Great Lakes and along major rivers), and extensive quarrying. The ecoregion includes a broad, nearly flat to rolling glaciated plain, deeply mantled by glacial till and outwash, sandy and gravelly beach ridges and flats, belts of morainal hills (including drumlins and kames), and boggy kettle depressions. The terrain is more irregular than in the adjacent Huron/Erie Lake Plain, Central Corn Belt Plains, and Eastern Corn Belt Plains Ecoregions, but not as hilly as the Northern Lakes and Forests Ecoregion. Local topographic relief is only a few feet in the flatter portions of the Southern Michigan/Northern Indiana Till Plains, and several hundred feet on the more irregular features. Elevation ranges from about 600 feet along the shores of the Great Lakes, to over 1,000 feet on some moraines. Average annual precipitation is from 35 to 46 inches, generally increasing from north to south across the ecoregion. Most of the precipitation occurs during the freeze-free period.

The 25,800 square-mile ecoregion is drained predominantly by perennial streams. Density of perennial streams is approximately one-half mile per square mile. Only 10 to 15 percent of the streams are intermittent. Streams are typically sluggish and are bordered, often extensively, by swampy tracts. Drainage ditches and channelized streams commonly assist drainage of wetter areas. The larger streams originating from within the ecoregion drain watersheds of 500 to 2,000 square miles. Lakes are common in some areas; however, many depressions are filled with peat deposits or dark mineral soils.

Land is managed for cropland, livestock, forest and woodland, and urban use. Cropland is mainly in corn, other feed grains, soybeans, and hay for livestock. Soft winter wheat and dry edible beans are important cash crops. Other cash and truck crops, especially on outwash areas near the Great Lakes include berries, strawberries, apples, peaches, plums, grapes, Irish potatoes, asparagus, cucumbers, onions, cabbage, sweet corn, and red clover seed. Livestock emphasis is on dairy cattle, but beef cattle, swine, sheep, and poultry are also important. Approximately one-fourth of the ecoregion is urbanized. Gravel quarries are common across the entire region.

Oak/hickory forests are the natural vegetation throughout most of the Southern Michigan/Northern Indiana Till Plains. Major tree species include white oak, red oak, black oak, bitternut hickory, shagbark hickory, sugar maple, and beech. This vegetation is not common in the mixed forest to the north or on the poorly drained lake plains to the south and east. Red maple, white oak, American elm and basswood are common on somewhat wetter soils in the Southern Michigan/Northern Indiana Till Plains. Wet sites support swamp forests of white ash, red maple, quaking aspen, and black cherry.

Soils of the Southern Michigan/Northern Indiana Till Plains have been derived from a variety of parent materials under the influence of forest vegetation cover. Hapludalfs and Ochraqualfs developed in loamy glacial drift and till. Soils derived from finer materials and areas of poor drainage include Argiaquolls, Haplaquolls, Haplaquepts, and Psammaquents. Udipsamments formed on better drained outwash plains. Medisaprists and other organic soils can be found in depressions throughout the ecoregion.

Farming practices and urban needs impose the greatest land use impacts on water quality in the Southern Michigan/Northern Indiana Till Plains Ecoregion. Stream channelization reduces habitat for biota. Runoff carries fertilizers and other chemical compounds to streams, altering water chemistry. Where livestock have access to streams, grazing and trampling along stream banks and stream beds reduces stability of the physical stream habitat. Animal wastes alter stream water chemistry. Urbanization occurs mainly along the shores of the Great Lakes and the major rivers. Water courses are physically and chemically altered through a variety of municipal and industrial practices (winter road-salting is one significant example). Numerous gravel pits in this ecoregion have local impacts on stream water quality where hillslope erosion is accelerated or stream substrate is disturbed by quarrying activities.

Huron/Erie Lake Plain (map unit #57)

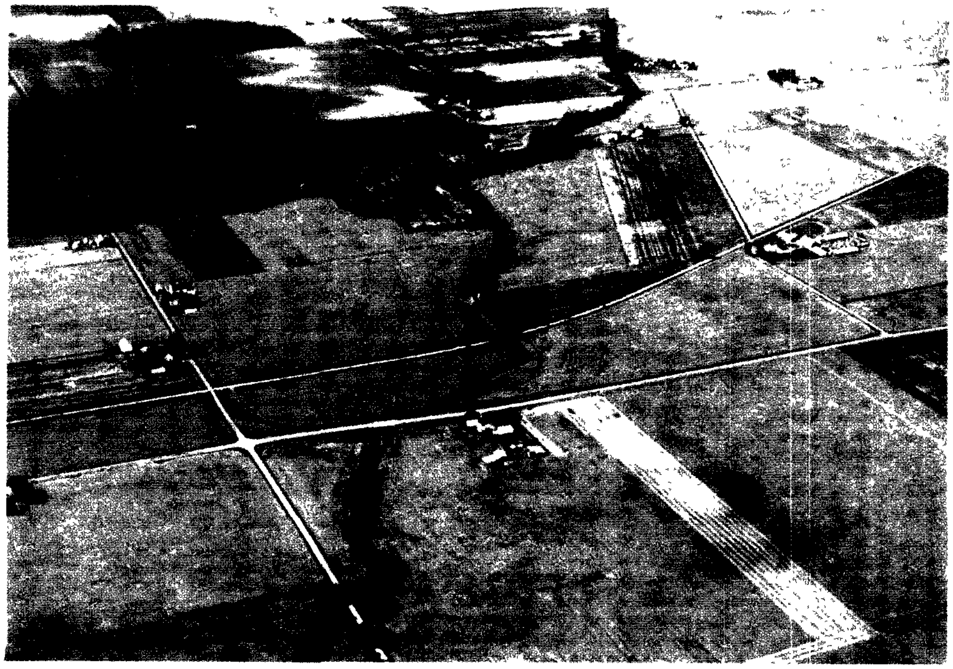
The discontinuous Huron/Erie Lake Plain Ecoregion is distinguished from surrounding ecoregions primarily by features related to poor soil drainage. The ecoregion consists of a broad, nearly level lake plain crossed by beach ridges and low moraines. Most of the area was once covered by forested wetlands. Many wetlands still dot the landscape, but much of the region has been drained and cleared for cropland (Photos 34-36). The elevation across most of the ecoregion is around 600 feet, rising to 800 feet on some of the moraines. Local relief is generally only a few feet.

Photo 34. Extensive plains and numerous depressions have led to the formation of poorly to very poorly drained soils in the Huron/Erie Lake Plain Ecoregion.

More than half of the streams draining the 11,000 square-mile Huron/Erie Lake Plain are intermittent, though density of perennial streams accounts for approximately one-half mile per square mile. In the northern section of the ecoregion, streams draining larger watersheds (contained completely within the ecoregion) drain 100 to 200 square miles. In the southern section of the ecoregion, large streams drain as much as 400 to 500 square miles. However, the majority of streams in the ecoregion drain less than 100 square miles (because larger streams generally originate in adjacent ecoregions). In addition to the construction of numerous drainage ditches, many streams are extensively channelized for quicker drainage. The few lakes and reservoirs in this ecoregion (mainly in Ohio) are small, with surface areas of less than one-fourth of a square mile. Average annual precipitation ranges from 31 to 35 inches across the ecoregion. Precipitation is fairly evenly distributed throughout the year and generally adequate for crop production.

The extensive, nearly level plains and numerous depressions in morainal areas are responsible for the formation of poorly and very poorly drained soils. Ochraqualfs and Haplaquepts have formed in lacustrine and glacial drift. Udipsamments and Hapludalfs can be

Photo 35.



Photos 35 and 36. A majority of the Huron/Erie Lake Plain Ecoregion is in cropland, most of which requires artificial drainage. Portions of this stream have been channelized to improve field shape.

Photo 36.

found on beach ridges and other well drained sites.

The poorly drained soils of the Huron/Erie Lake Plain support swamp forests. Major species are American elm, red maple, and black ash (replaced by white ash where soil drainage is slightly better, as in northern Ohio). Accompanying the major forest species in the northern part of the ecoregion are balsam poplar, balsam fir, yellow birch, and, less commonly, eastern white pine, tamarack, black spruce, northern white cedar, white spruce, quaking aspen, slippery elm, paper birch, and American basswood. In parts of northern Ohio, the forest also includes silver maple, swamp white oak, sycamore, pin oak, blackgum, and eastern cottonwood.

Cash crop farming is the primary land use in the Huron/Erie Lake Plain. Corn, winter wheat, soybeans, and hay are the principal crops, but sugar beets, field and seed beans, and a variety of canning crops are also important. Fruit and truck crops are grown on some coarse-textured soils. Some farmland is in pasture and small woodlots. Principal livestock include swine, dairy cattle, and chickens. Approximately one-tenth of the area is urbanized.

Land use impacts on stream water quality in the Huron/Erie Lake Plain are primarily from crop and livestock production and the exploration and drilling activities associated with numerous oil fields. Channelization of streams and construction of ditches to improve soil drainage reduce habitat for stream biota. Additionally, delivery of farm chemicals to streams is expedited by the use of artificial drainage. Livestock can disrupt stretches of stream by trampling and grazing in and near streams, and through deposition of animal wastes (either directly by instream livestock, or indirectly by manure dispersal).

<u>Erie/Ontario Lake Plain</u> (map unit #61)

The nearly level to strongly rolling terrain of the Erie/Ontario Lake Plain Ecoregion exhibits a mosaic of cropland, pasture, livestock and poultry production, and woodland and forest (Photos 37-39). The 8,000 square miles shown on the map of the Upper Midwest, and addressed in this description, represent one-third of the total area of this ecoregion. The glacial plain is interspersed with higher remnant beach ridges, drumlins, glacial till ridges, till plains, and outwash terraces. Local relief is greater in the Erie/Ontario Lake Plain Ecoregion than in the neighboring Huron/Erie Lake Plain and Eastern Corn Belt Plains Ecoregions, but less than in the steep, rugged terrain of the Western Allegheny Plateau. The elevation of the Erie/Ontario Lake Plain ranges from about 600 feet near Lake Erie, to 1,200 feet on the uplands. Local relief of the plain is generally minimal, but glacial till ridges and outwash terraces may rise 100 feet above adjacent valley floors, and larger drumlins may have as much as 300 feet of elevation change.

The majority of streams in the Ohio portion of the Erie/Ontario Lake Plain ecoregion are perennial; however, there is great local variation in the concentration of streams. Density of perennial streams, for example, varies from one-half mile to two miles per square mile. Many streams have been channelized to control adjacent marshy areas.

Large watersheds in this ecoregion typically cover 500 square miles. Two larger examples are French Creek, draining more than 1,000 square miles, and Beaver River, draining more than 2,000 square miles. Average annual precipitation ranges from 35 to 45 inches. Precipitation is generally adequate for good crop production, although some high value fruit and vegetable crops receive supplemental irrigation. The ecoregion includes many lakes and reservoirs.

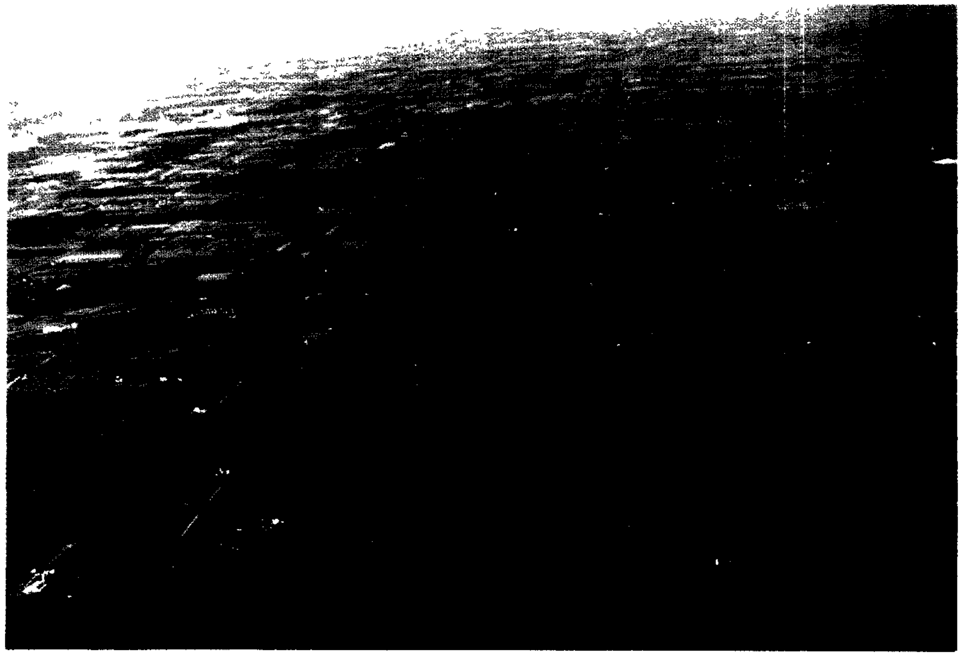


Photo 37. Dairy farming is the major enterprise in the Erie/Ontario Lake Plain Ecoregion. Cultivation of feed grains and forage is interspersed with pasture, woodland, and forest.

Dairy cattle are raised throughout the Erie/Ontario Lake Plain Ecoregion. In Ohio, approximately one-tenth of the region provides pasture for cattle. Poultry farms are found in some areas. Cropland covers about one-third of the area and is interspersed with pasture, woodland, and forest. Cropland emphasis is on feed grains and forage for dairy cattle. Hay is the principal crop; corn is common. Cash crops include canning and truck crops such as berries and some orchard varieties. Forests cover about one-fifth of the area and are used primarily as woodlots, saw logs, and pulpwood. Approximately 20 percent of the ecoregion is urbanized. There is some oil and gas drilling and strip mining for coal in the southern arm of the ecoregion.

The Erie/Ontario Lake Plain supports a northern hardwoods forest. Many of the tree species also occur in the Western Allegheny Plateau Ecoregion, but the simpler forest of the Erie/Ontario Lake Plain more closely resembles the Eastern Corn Belt Plains forests. On wetter soils, vegetation of the Erie/Ontario Lake Plain is similar to the swamp forest of the Huron/Erie Lake Plain. American beech, sugar maple, red oak, white ash, and white oak predominate over much of the region in Ohio. Associated trees are American basswood, shagbark hickory, black cherry, and cucumbertree. On wet sites in northern Ohio, forest constituents are silver maple, swamp white oak, sycamore, pin oak, blackgum, and eastern cottonwood.

Soil traits in the Erie/Ontario Lake Plain reflect the humid climate and forest cover. Soils tend to be light-colored and acid, and are mainly derived from glacial till and lacustrine sediments. Hapludalfs, Fragiudalfs, and Fragiudults formed on uplands. Ochraqualfs, Haplaquepts, and Eutrochrepts developed in lacustrine sediments and in depressions in glacial till plains. Eutrochrepts, Fluvaquents, and Haplaquepts developed from alluvial deposits along streams.

Photo 38.

Photos 38 and 39. Most streams in the Erie/Ontario Lake Plain Ecoregion are perennial. Stream habitat quality is most likely to be affected by in- and near-stream dairy cattle, and runoff of farm chemicals.

Photo 39.

Dairy farming is responsible for the major land use impacts on stream quality in the Erie/Ontario Lake Plain Ecoregion. Pastured cattle with access to streams cause stream bank erosion through trampling and grazing of riparian vegetation. Where cattle or poultry are concentrated near streams, manure dispersal greatly alters stream water chemistry. Some cropland areas require artificial drainage, which accelerates the rate of delivery of farm chemicals to streams. Streams are often channelized, regulated, and used for industrial purposes in urbanized areas. Numerous gravel pits, quarries, and oil and gas drilling have local effects on nearby streams.

Western Allegheny Plateau (map unit #70)

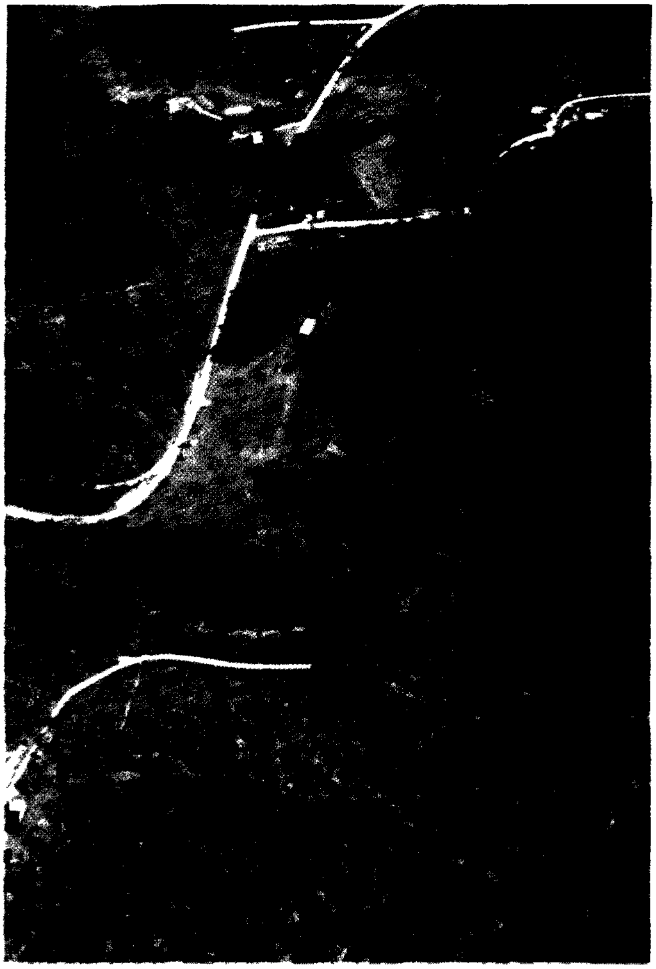
The Western Allegheny Plateau Ecoregion is a dissected plateau comprised of horizontally bedded sandstone, siltstone, shale, and limestone. The 12,000 square miles of the Ohio portion of this ecoregion, discussed here, represent somewhat more than one-third of the total extent of the region. This portion is characterized by steeper, more rugged terrain than neighboring ecoregions to the north and west (Photos 40-42). Consequently, most of the ecoregion remains in forest. Elevation ranges from about 600 feet along the Ohio River, to over 1,000 feet on some of the higher ridges. Local relief is between 300 to 500 feet.

Photo 40. Steep topography and erosive soils influence land use in the Western Allegheny Plateau Ecoregion. Streams are most heavily impacted from strip mining practices. Effects from mining are generally long-term.

Large watersheds in this ecoregion typically cover 200 to 400 square miles. Most streams are perennial; some, in smaller agricultural valleys, may be channelized. Density of streams is generally between one and two miles per square mile. The few natural lakes are small, usually less than half a square mile. Reservoirs, though few, outnumber natural lakes. Most reservoirs are smaller than five square miles.

Steep topography and high erosion potential are the chief land use limitations of the Western Allegheny Plateau. Most of the ecoregion is forested; timber harvest is an important land use over much of the area. A large portion of the ecoregion has

Photo 41.



Photos 41 and 42. Most of the Western Allegheny Plateau Ecoregion is forested. Cropland and pasture occur where local relief is minimal, primarily on valley floors.

Photo 42.

been strip-mined for coal. Less than one-fifth of the ecoregion is in cropland, which generally occurs on valley floors. Alfalfa and hay for beef and dairy cattle are the main crops. Fruit and vegetable crops are farmed on a small, local scale. Urban growth continually infringes on farmland area.

The Western Allegheny Plateau is an ecoregion of mixed mesophytic forest. Characteristically, canopy dominance is shared by more species than in the neighboring ecoregions to the north and west. Major forest species are white oak, black oak, northern red oak, scarlet oak, shagbark hickory, bitternut hickory, pignut hickory, mockernut hickory, basswood, American beech, yellow poplar, blackgum, sugar maple, red maple, white ash, green ash, American elm, red elm, cucumbertree, sweetgum, short leaf pine, pitch pine, Virginia pine, loblolly pine, linden, black walnut, black cherry, and eastern hemlock. The composition of the forest changes spatially with moisture availability and soil fertility. Oak/hickory communities, accompanied by pines, occur on drier sites, such as ridge tops or southwest-facing slopes. Mixed forests of maples and other hardwoods occur on sites with more moisture, such as in coves or on northeast-facing slopes.

Soils of the Western Allegheny Plateau are formed predominantly from unglaciated sedimentary rocks, with a capping of loess in some areas. Soils developed under forest cover are light in color, acidic, and likely to have a hardpan layer. On steep slopes, there is enough root throw activity to disrupt soil layering and inhibit soil profile development. Such activity explains the relatively large percentage of Inceptisols on the steeper terrain. Hapludalfs formed in residuum from shales and siltstones. Hapludults are found in the more acid siltstones, shales, and some sandstones. Shallow, acid Dystrochrepts are common on steep slopes and ridges. Fragiudults, occur in colluvium or residuum on side slopes. Eutrochrepts, Fluvaquents, and Haplaquolls have developed on floodplains.

Mining operations have a major impact on stream water quality in the Western Allegheny Plateau. Erosion of sediments from open pits, introduction of toxic compounds, and direct physical disruption of stream beds have degraded stream habitat and water quality in many areas. Sludge and seepage from numerous oil and gas fields add sediment and affect stream water chemistry on nearby streams. Though crop and livestock agriculture account for only a small percentage of land use in the Western Allegheny Plateau, their impact on water quality is significant because they occur predominantly in narrow stream valleys. Stream side vegetation has often been removed to expand cropland or pasture, causing erosion along denuded stream banks and adjacent cropland. This increases stream turbidity and sedimentation.

Interior Plateau (map unit #71)

Characteristics of the Interior Plateau Ecoregion are transitional between the adjacent Eastern Corn Belt Plains and Western Allegheny Plateau Ecoregions. The Interior Plateau includes a till plain of low topographic relief formed from Illinoian glacial drift materials, rolling to moderately dissected basin terrain, and rolling to deeply dissected plateaus (Photos 43-45). Layers of sandstone, siltstone, shale, and limestone underlie much of the Interior Plateau. Limestone outcrops are common, as are areas pitted with limestone sinks.

Approximately 15 percent, or 8,400 square miles, of the entire ecoregion is represented on the map of the Upper Midwest. Elevations within this area vary from about 500 feet near the Ohio River, to more than 1,000 feet on some of the higher hills. Local relief is commonly between 100 and 200 feet on the till plains and generally around 400 feet in the more hilly terrain, though relief may exceed 800 feet on some of the steeper hills. Average annual

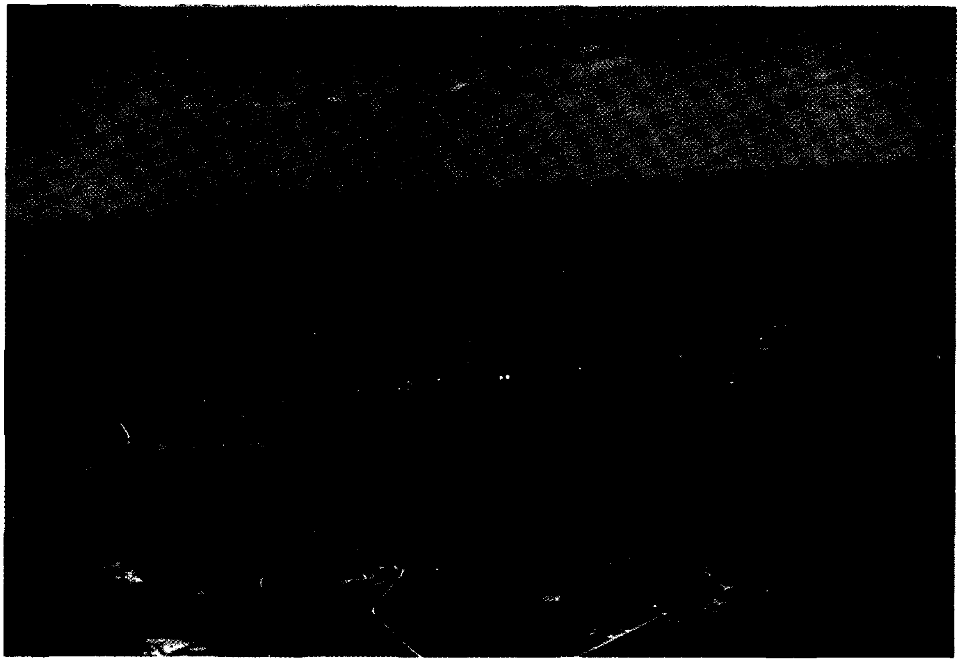


Photo 43. The Interior Plateau Ecoregion is transitional between the flat to rolling cropland of the corn belt and the hilly, forested uplands to the east. Stream density is high, except in areas of numerous limestone sinks.

precipitation in the Interior Plateau ranges from 40 to 45 inches. Precipitation is distributed fairly evenly throughout the growing season and is usually adequate for crop production.

The majority of the streams in this ecoregion are perennial. Stream density over much of the region is approximately two miles per square mile, except in areas containing numerous limestone sinks, where surface streams are much less common. Large watersheds cover 200 to 500 square miles. Natural lakes are few, and occur mainly in areas underlain by limestone (which may include many limestone sinks containing standing water).

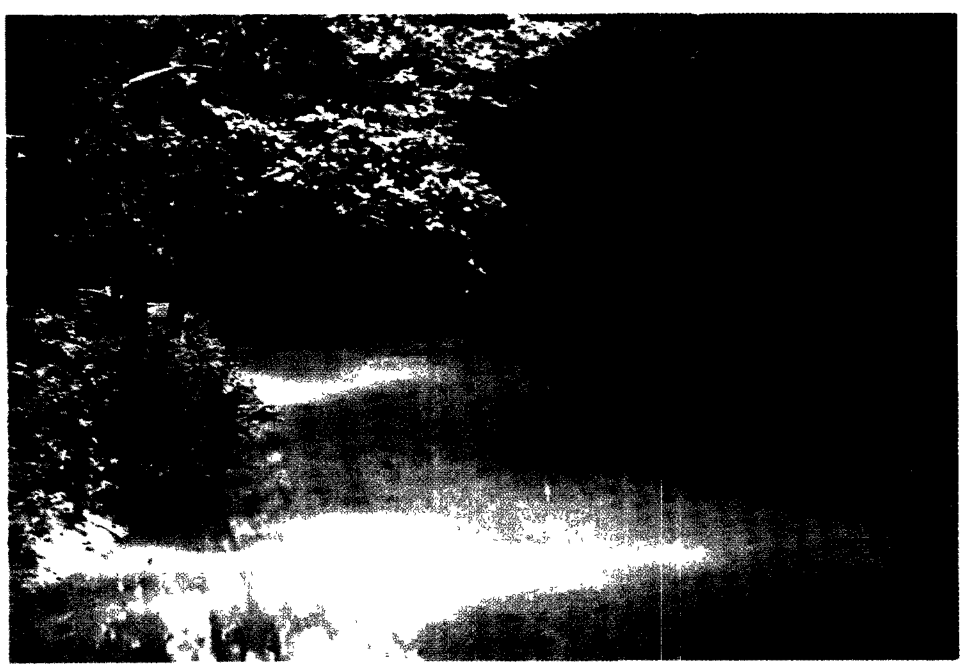
Land use in the Interior Plateau represents a transition between the Eastern Corn Belt Plains and the Western Allegheny Plateau. The Eastern Corn Belt Plains Ecoregion is well suited for cropland and livestock production while the Western Allegheny Plateau is managed mainly for timber and mining products. Acreage in the Interior Plateau is managed for cropland, livestock, pasture, woodland, and forest; the land use varies with local topography. Principal crops include hay, grains, and pasture for livestock. Corn, soybeans, wheat, and tobacco are cultivated to a lesser degree. Beef cattle are the predominant livestock throughout the ecoregion, with dairy cattle and swine well represented. Poultry is raised intensively in some locations. Numerous quarries and gravel pits occur throughout the ecoregion, and some areas are covered by gas and oil fields and coal strip mines.

As with soils of the Western Allegheny Plateau, many of the soils in the Interior Plateau formed in residuum from a variety of sedimentary rocks overlain by varying amounts of loess. Some soils of the Interior Plateau, like those of the Eastern Corn Belt Plains, are derived from calcareous loam till with localized mantlings of loess. Developed under predominantly forest vegetation, soils are lighter in color, more acid, and more likely to have a hardpan layer.

Photo 44.

Photos 44 and 45. This Interior Plateau stream flows through a forested lowland, but its sediment load reflects the intensity of cultivation on the sloping uplands.

Photo 45.



Fragiudalfs, Hapludalfs, Fragiudults, and Hapludults formed on ridge tops, side slopes, and flat areas of uplands. Dystrochrepts formed locally on upland ridge tops and side slopes. Hapludolls, Haplaquolls, Eutrochrepts, Dystrochrepts, Fluvaquents, and Udifluvents developed in association with floodplains. Fragiaquults evolved in some small basins and depressions, and Haplaquepts in slack water areas. Paleudults developed on old landscapes with broad, smooth slopes.

The vegetation of the Interior Plateau includes a variety of forest types which range from hardwood forests, like those in the Eastern Corn Belt Plains, to mixed mesophytic forest, like that of the Western Allegheny Plateau. The biotic complexity in the Interior Plateau can be attributed to the variety in topographic and edaphic factors. On drier slopes and uplands, forest communities include combinations of oak species (such as white, black, red, scarlet, chinkapin, post, bur, blackjack, and chestnut) and one or more species of hickory (bitternut, mockernut, pignut, and shagbark). Associated trees include yellow poplar, blackgum, sugar maple, red maple, white ash, green ash, American elm, red elm, basswood, sweetgum, and several pine species. Black walnut, black cherry, American beech, and eastern hemlock may also be present. In basins underlain by limestone, forests are comprised of blue ash, white ash, American elm, Ohio buckeye, and red mulberry. Flat areas with impervious soils support hydro-mesophytic forest communities of pin oak, Shumard oak, cherry bark oak, sweetgum, red maple, white elm, and associated species such as swamp white oak, sourgum, white oak, shellbark hickory, beech, and cottonwood.

Land use impacts on stream quality are mainly from production of livestock, poultry, and crops. Where pastured cattle have access to streams, stream banks become eroded through trampling and removal of riparian vegetation. Manure dispersal can have large effects on stream water chemistry. Many rivers have been channelized and/or dammed for flood control. Such alteration of seasonal hydrologic cycles decreases the array of stream habitats for biota. Strip mines can have long-term physical and chemical effects over many stream miles. Seepage of sludge from drilling sites in gas and oil fields can affect water turbidity and water chemistry.

Interior River Lowland (map unit #72)

Varied land use potential is typical of the Interior River Lowland Ecoregion and includes: forestry, diverse cropland agriculture, orcharding, production of livestock, and excavation for fossil fuels. The ecoregion is comprised of a dissected glacial till plain (a portion of which is covered by a moderately thick mantle of loess), rolling, narrow ridgetops, and hilly to steep ridge slopes and valley sides (Photos 46-48). About 19,000 square miles, or two-thirds, of this ecoregion occurs in the Upper Midwest. Most of this area ranges between 400 and 600 feet in elevation; however, elevation along the Mississippi River is around 300 feet, and a few hilltops in southern Illinois exceed 1,000 feet. Local relief varies from a few feet on the till plains, to 100 feet on rolling ridges, to nearly 600 feet on more prominent ridges. Average annual rainfall is between 35 and 46 inches, and most precipitation occurs during the freeze-free period. Lakes, reservoirs, and numerous ponds are scattered throughout the ecoregiogion

Large watersheds in the ecoregion cover as much as 350 square miles. A large exception is the Saline River in Illinois, draining more than 1,000 square miles. Streams in hills are often intermittent, becoming perennial when they reach valley floors. Density of streams is approximately two miles per square mile. Ditches and channelized streams are common in areas of poor natural soil drainage.

Patterns of land use in the Interior River Lowland are more varied than in the neighboring

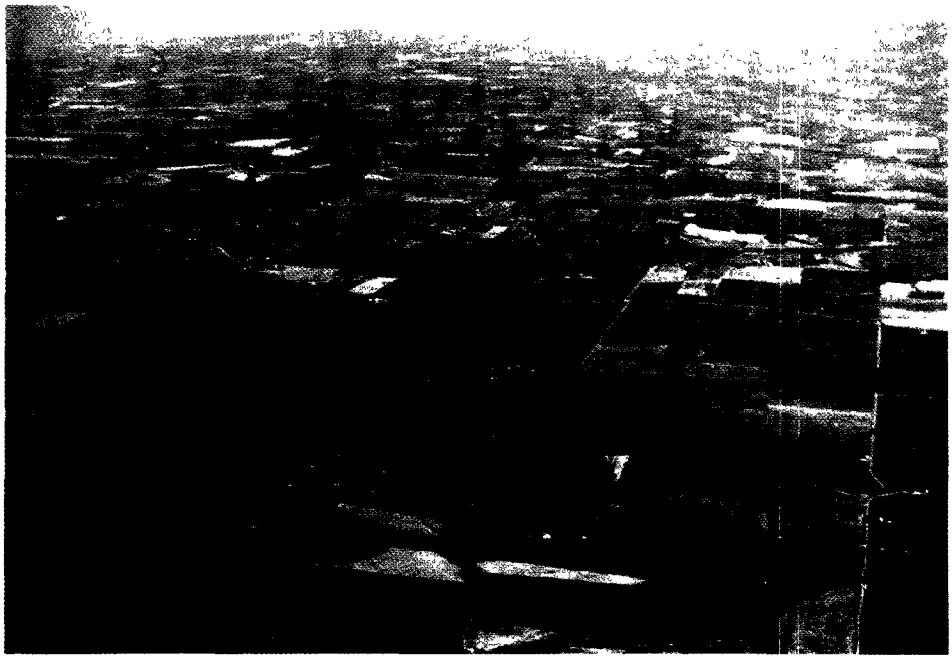


Photo 46. The Interior River Lowland Ecoregion has a mosaic of land use patterns because the soils and topography are more locally variable than in many other ecoregions.

Corn Belt Plains and Interior Plateau regions. Drained alluvial soils are farmed intensively for feed grains and hay for livestock, some corn, soybeans, and red clover seed. Undrained sites are used for forage crops (such as lespedeza), pasture, or timber (approximately one-third of the area is forested). Upland soils are used for mixed farming, livestock (mostly beef cattle, swine, and poultry), some orcharding (peaches and apples), and, on a more local scale, grape vineyards. Many square miles of this ecoregion have been strip-mined for coal. Oil and gas fields are scattered throughout the area.

The better drained soils of this forested ecoregion are generally light in color and moderately acid. Hapludalfs, dominate in silty loess, glacial till, and sandy aeolian materials. Fragiudalfs have formed on some silt-covered ridgetops. Paleudalfs are common on old cherty limestones. Shallow Hapludolls occur on steep slopes. Udifluvents, Fluvaquents, and Haplaquolls are found in poorly drained floodplains.

The Interior River Lowland is mainly a region of oak/hickory forest. White oak, black oak, red oak, bitternut hickory, shagbark hickory, yellow poplar, white ash, sugar maple, and black walnut occur on well drained sites. Pin oak, shingle oak, and sweetgum join on wetter sites. Riparian areas support pin oak, silver maple, cottonwood, willow, sycamore, elm, sweetgum, ash, and river birch.

The greatest land use impacts on stream water quality in the Interior River Lowland result from crop and livestock production and strip mining. Channelization of streams and construction of drainage ditches decrease stream habitat for biota in many streams. Soil erosion and

Photo 47.

Photos 47 and 48. Approximately one-third of the Interior River Lowland Ecoregion is forested, dominated mainly by oak and hickory species.

Photo 48.

sedimentation can be severe on cultivated slopes. Runoff delivery of farm chemicals, used extensively in some areas (as near the Wabash River), alters water chemistry in many streams. Where livestock have access to streams, trampling of stream banks and grazing of riparian vegetation reduce stream bank stability. Deposition of animal wastes into streams directly, or by manure dispersal mechanisms, strongly alters stream chemistry. Seepage of sludge from oil and gas fields has local effects on water quality of nearby streams. Strip mining activities have long-term effects on stream quality.

## APPLICATIONS

The primary function of the ecoregion map is to provide a geographic framework for organizing aquatic ecosystem resource information. This framework should improve the ability of managers, planners, and scientists to: (1) compare the similarities and differences of land/water relationships; (2) determine reasonably attainable water quality conditions consistent with regional patterns of tolerances and resilience to human impacts; (3) locate sites for monitoring, demonstration, or reference; (4) extrapolate from existing site-specific studies; and (5) predict the effects of changes in land use and pollution controls. Specific applications will vary among States and regions, as do the issues of concern such as nonpoint source pollution, eutrophication, and sensitivity of forest and water resources to acidification. In spite of (or perhaps because of) these differences, there is a significant need to understand the spatial patterns of realistically attainable conditions and quality of aquatic ecosystems.

Initial efforts to use this ecoregion framework are underway in Arkansas, Colorado, Minnesota, North Carolina, Ohio, Oregon, Pennsylvania, Texas, and Wisconsin. These statewide projects focus on the attainable ranges of chemical quality and biotic assemblages in aquatic systems. A typical application involves three steps:

1. Transfer boundaries of ecoregions and their most typical portions to State-level (normally 1:500,000-scale) maps.[7]

2. Select and sample streams, or lakes, or watersheds within the most typical portions of each ecoregion. Each selected stream/watershed should have a relative lack of human disturbance[8] and be reasonably typical in terms of overall land-surface form, vegetation, soil, and land use characteristics. For example, one would not expect a "typical" stream draining 125 square miles in the Western Corn Belt Plains to be void of cropland, or even with less than 75 percent cropland. However, there are streams of that size in that ecoregion that drain watersheds having a <u>relative</u> lack of

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[7]Caution must be used when transferring the ecoregion boundaries to larger scale maps. Ecoregions do not start and end at precise lines; there are transition areas along the boundaries. Correctly locating these boundaries at a larger scale requires concurrent analysis with the original information used to define the ecoregion.

[8]The selection of less impacted sites addresses the notion of "reasonably attainable quality". These sites represent the best quality of aquatic biotic habitat that can currently be found in an ecoregion. Thus, under present land use conditions, it is possible to attain such a level of aquatic habitat quality; to attain quality surpassing this level would require major alterations in land use practices, which may not be considered "reasonable" within the constraints imposed on resource managers.

of that size in that ecoregion that drain watersheds having a relative lack of population density and industrial impact, a relative abundance of woody riparian vegetation, and relatively little stream channelization.

3. Map and statistically analyze data to determine: the regional patterns of attainable aquatic ecosystem quality; the relationship between ecosystem quality and stream/watershed size; the variation of quality within and between ecoregions; and the regional properties that appear to be most helpful in explaining these variations and, thus, enabling more precise predictions of attainable quality.

Applications in Ohio

The Ohio Environmental Protection Agency (OEPA) has been interested in determining reasonably attainable water quality and biological integrity in streams. In previous monitoring programs, sampling was on a case-by-case basis, focused on highly disturbed stream systems. This approach was not suited for extrapolation of information from one stream system to another, so a regional ecological stratification was devised to address this need.

Streams that were regionally representative and least impacted by management practices were selected for sampling. Numerical data from these streams were analyzed to provide information on regionally attainable stream quality. Sampling included a variety of measurements relating to nutrient richness, ionic strength, concentration of metals, and biological characteristics (including fish assemblages) (Whittier et al. 1987). Examples of stream data analyses are described below.

Distinct regional differences are most apparent in two of Ohio's five ecoregions. The Huron/Erie Lake Plain Ecoregion of northwestern Ohio is characterized by nearly flat terrain, poor soil drainage, extensive farming, stream channelization, and a lack of woody riparian vegetation. In contrast, the Western Allegheny Plateau Ecoregion in southeastern Ohio is characterized by the mostly forested, steep, rugged terrain of a dissected plateau. The remaining ecoregions in Ohio consist of characteristics intermediate between those of the Huron/Erie Lake Plain and the Western Allegheny Plateau.

Regional differences in fish assemblages are most pronounced in the Huron/Erie Lake Plain and Western Allegheny Plateau Ecoregions. Regional species signatures (Figure 1) indicate that the dominant fish of the Huron/Erie Lake Plain Ecoregion are those considered tolerant of turbid conditions and low concentrations of dissolved oxygen (Becker 1983; Pflieger 1975; Smith 1979; Trautman 1981). The species signature of the contrasting Western Allegheny Plateau indicates dominance by a number of moderately intolerant and intolerant fish species. The species signatures of the other three Ohio ecoregions are transitional.

In a similar fashion, analyses of Ohio stream chemistry also shows the greatest degree of regional difference between the Huron/Erie Lake Plain and Western Allegheny Plateau Ecoregions (Figure 2). Using a principal component analysis (PCA), data for sites in different ecoregions cluster together, illustrating the degree of regional homogeneity (the data would be randomly distributed over the graph if there were no regional patterns in water quality). Because streams sampled were minimally impacted, as well as representative, circumscribed areas in Figure 2 indicate the range of attainable water quality (given current land use practices) within each ecoregion.

Streams in the intensively farmed Huron/Erie Lake Plain Ecoregion are characterized by

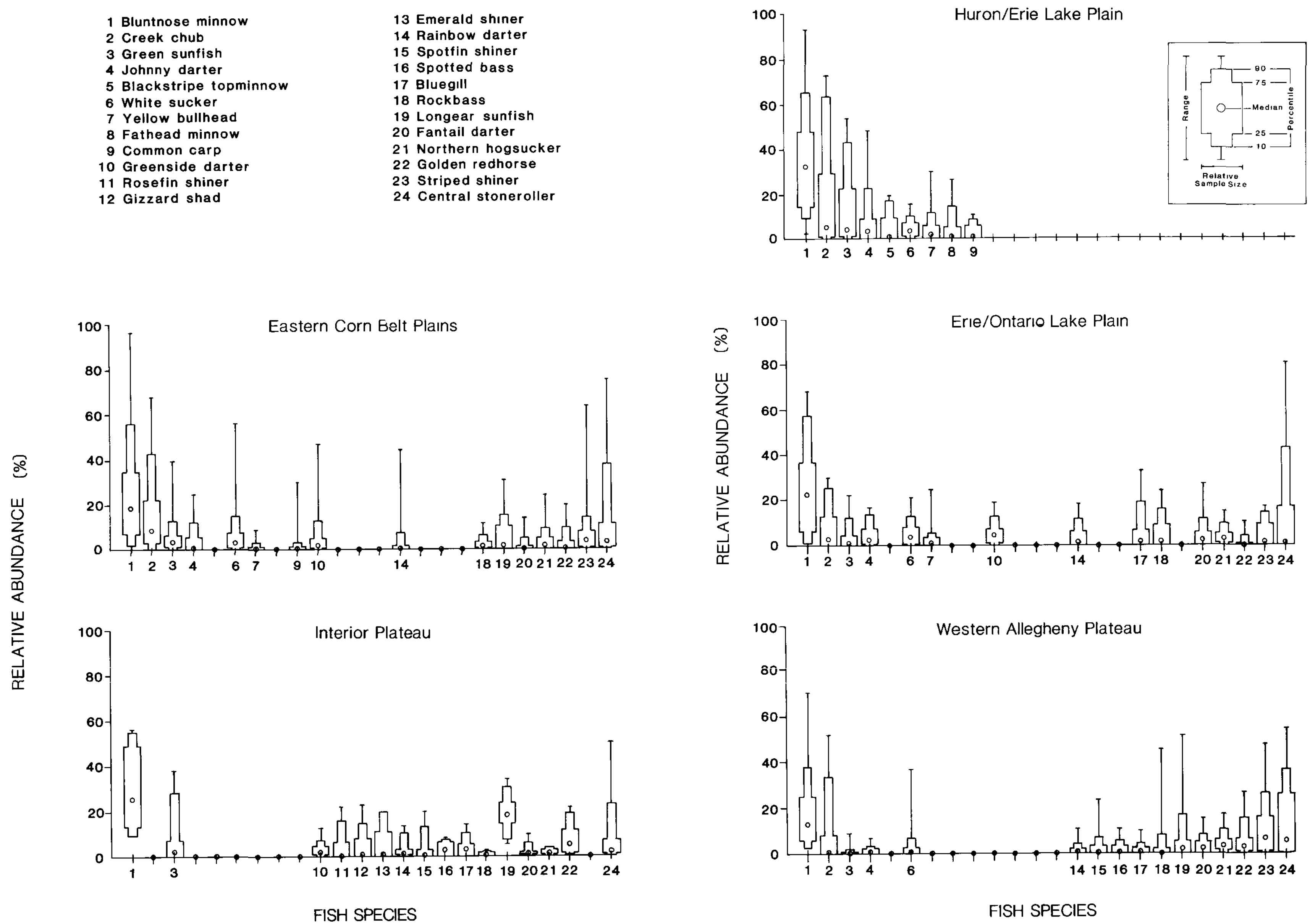


Figure 1. Regional signatures of dominant fish species in Ohio streams (from Whittier et al 1987). For each region, only those species found in at least 50% of the region's samples are plotted. For example, at half of all the sample sites in the Huron/Erie Lake Plain Ecoregion, the bluntnose minnow (species #1) comprised more than 30% of the total catch.

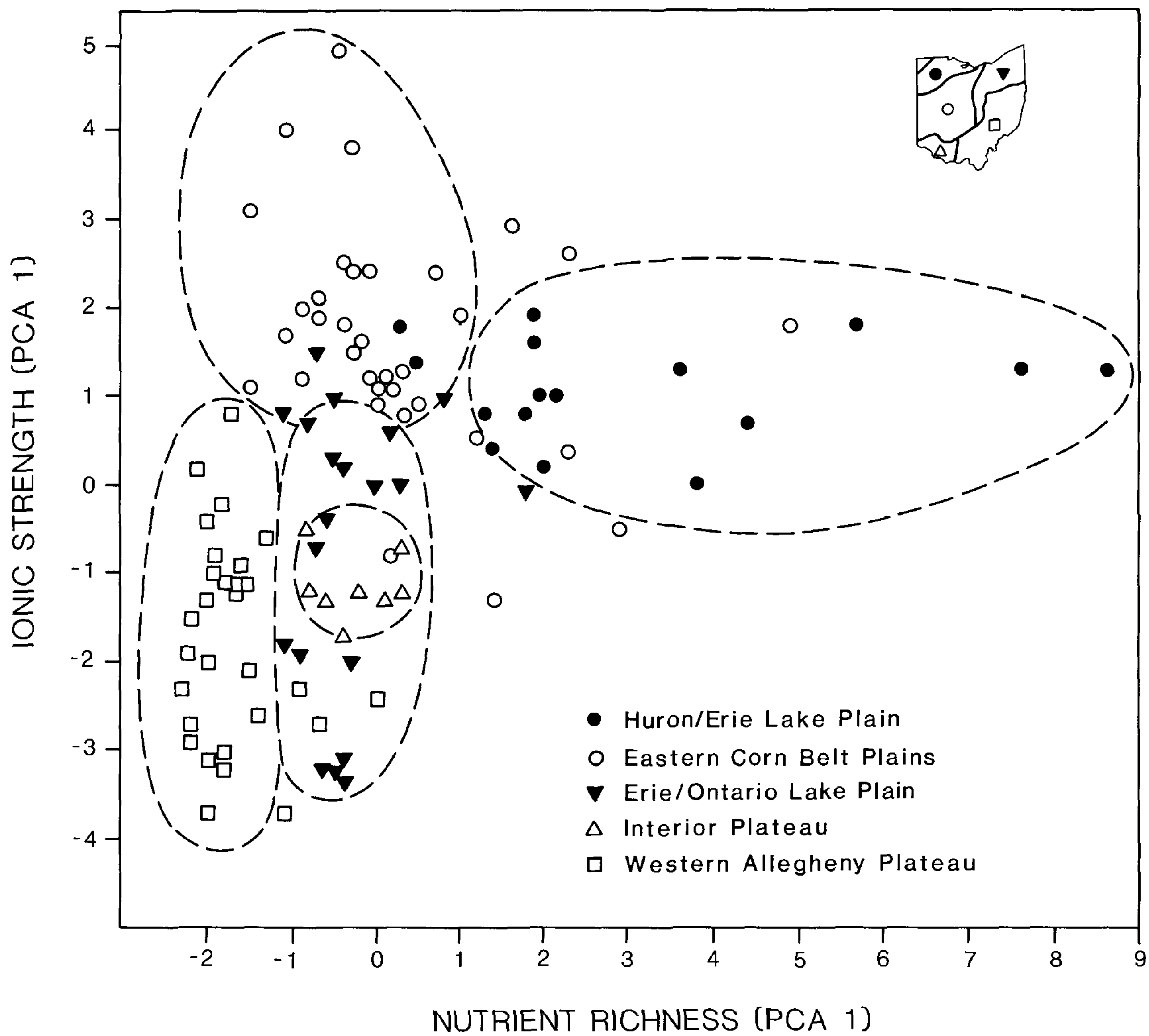


Figure 2. Principal component axis I scores for nutrient richness and ionic strength variables sampled for Ohio streams. Attainable water quality for each region is inferred from circumscribed areas (coded to correspond with ecoregions). Dashed enclosures have been estimated by eye to suggest range of attainable water quality for each region (Larsen, Dudley, and Hughes 1988).

nutrient-rich water with high ionic strength. By contrast, streams in the more forested Western Allegheny Plateau Ecoregion show lower levels of ionic strength (though a wider range than the Huron/Erie Lake Plain Ecoregion) and much lower concentrations of nutrients. Although there may be great overlap in one set of ecoregion characteristics (e.g., the range in ionic strength for the Western Allegheny Plateau and Erie/Ontario Lake Plain Ecoregions), there may be distinct separation between another set of characteristics (e.g., the range in nutrient richness for these two ecoregions). This illustrates the importance of assessing a suite of parameters (rather than a single parameter) in determining ecosystem regions.

Applications in Minnesota

The Minnesota Pollution Control Agency (MPCA) is responsible for assessment and management of pollution in the State's more than 12,000 lakes. Much of the focus of assessment and management is on trophic state of lakes and the role of phosphorus control. Lakes are routinely sampled for various trophic state indicators including phosphorus and Secchi depth. Regional patterns in productivity of Minnesota surface waters have been previously noted (e.g., Moyle 1956) and generally thought to be related to geology, hydrology, vegetation, and land use. These observations have influenced fishery and wildlife management in the State (Heiskary, Wilson, and Larsen 1987).

From 1980 to 1985, approximately nine percent of Minnesota's lakes were sampled. Although these lakes were not selected with an ecoregional framework in mind, (i.e., regionally representative and minimally impacted), Heiskary, Wilson, and Larsen (1987) used this framework to interpret the available data[9]. The lakes (about 30 percent of the State's total lake surface area) occur in four of Minnesota's seven ecoregions (only two percent of Minnesota's lakes are found outside these regions): the Northern Lakes and Forests, the North Central Hardwood Forests, the Northern Glaciated Plains, and the Western Corn Belt Plains. Following is a summary, by ecoregion, of the results and recommendations suggested by Heiskary, Wilson, and Larsen (1987) (Figure 3).

The Northern Lakes and Forests Ecoregion, dominated by forests, lakes, and marsh, had very low concentrations of total phosphorus, with a median of 23 ug/l. Median Secchi disk transparency was 2.7 meters. Lakes in this region tend to be small and deep and are sensitive to small changes in phosphorus levels.

The North Central Hardwood Forests Ecoregion is typified by a variety of land uses. Fifty percent of the region is cultivated, interspersed with pasture, cleared land, prairie, and forest. Regional data exhibit a large range in total phosphorus concentration, 2 to 454 ug/l. Although this range is wide, 90 percent of the lakes sampled were below 150 ug/l. Median phosphorus concentration was 50 ug/l. Lakes in this region are generally small and deep. Median Secchi disk transparency measured 1.5 meters. Phosphorus concentrations greater than 150 ug/l likely result from extensive urban or agricultural runoff.

The Western Corn Belt Plains Ecoregion is primarily under cultivation, but about 10 percent is pasture or cleared land (no longer under cultivation). Lakes in this region are typically large, but shallow. Median total phosphorus concentration was 121 ug/l. Median Secchi disk

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[9]Sources contributing available data included the MPCA (80%); the Metropolitan Council (9%); the U.S. Department of Agriculture, Forest Service (6%); and miscellaneous others (5%).

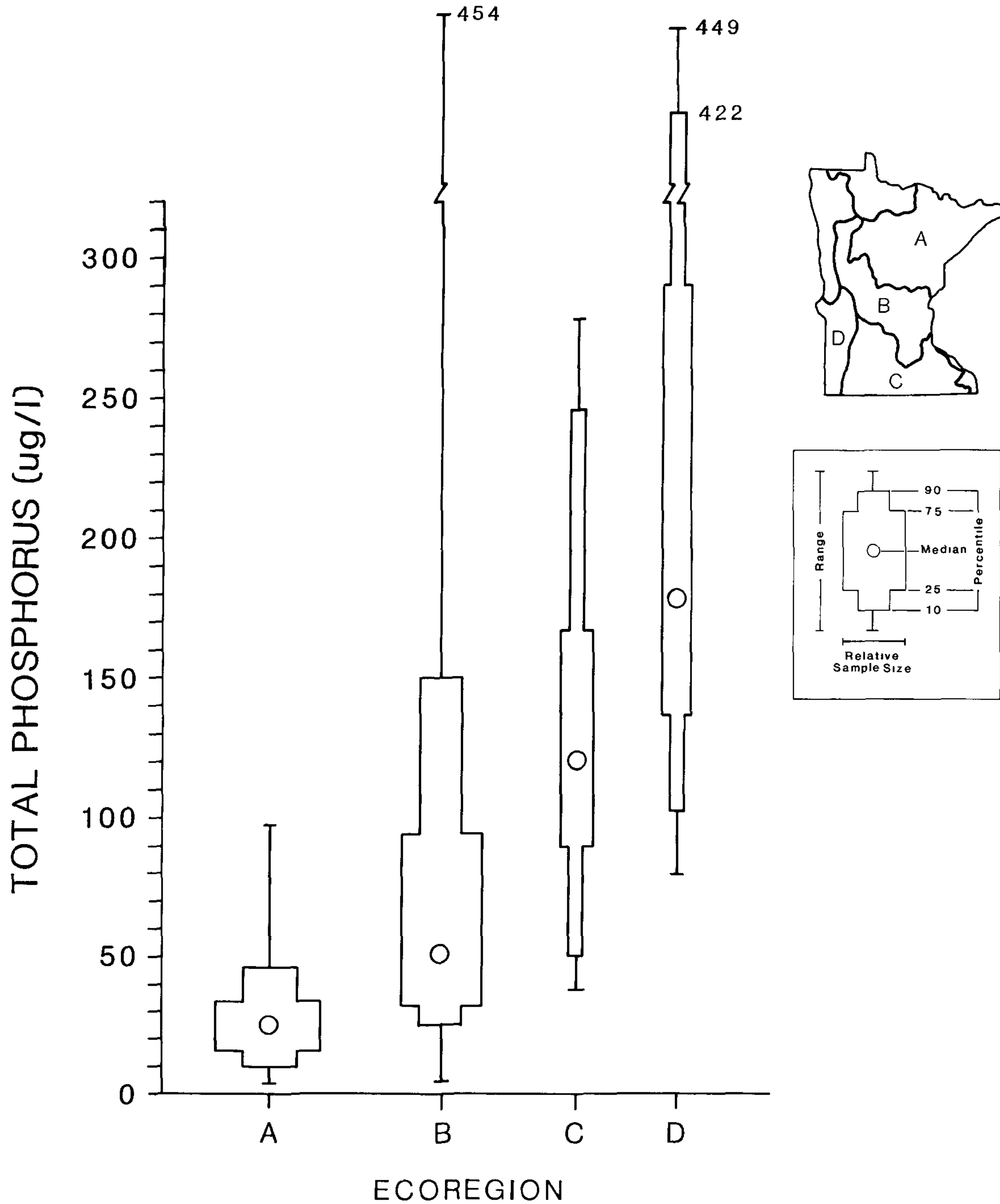


Figure 3. Total phosphorus values for Minnesota lakes, by ecoregion (adapted from Heiskary, Wilson, and Larsen 1987). A=Northern Lakes and Forests, B=North Central Hardwood Forests, C=Western Corn Belt Plains, D=Northern Glaciated Plains.

transparency was 0.5 meters.

Ninety percent of the Northern Glaciated Plains Ecoregion is cultivated; the rest is in pasture, cleared land, and prairie. The median total phosphorus concentration in these lakes was 176 ug/l. Median Secchi disk transparencies measured 0.8 meters.

Based on this regional analysis of total in-lake phosphorus, Heiskary, Wilson, and Larsen (1987) suggested the following management strategies:

- Northern Lakes and Forests. Management emphasis should be to protect the high quality lakes and reduce phosphorus concentrations in lakes with phosphorus levels above 20 ug/l exhibiting water quality problems. These levels appear regionally attainable.

- North Central Hardwood Forests. Frequency of summer algal blooms can probably be reduced if lake phosphorus concentrations are maintained at or below the median level of 50 ug/l. Implementation of "best management practices" to reduce total phosphorus export in the watersheds of these lakes should prove helpful in this region where nonpoint sources of phosphorus are important. In-lake remedial measures may also be necessary to attain total phosphorus concentration less than 50 ug/l in the shallower lakes.

- Western Corn Belt Plains. Lakes cannot be expected to attain the quality of those in the Northern Lakes and Forests or North Central Hardwood Forests Ecoregions. A reasonable goal for this naturally fertile region might be no more than 100 ug/l total phosphorus. Lakes which cannot attain this level are probably unsuitable for primary contact recreation during much of the open water season. For these lakes, management emphasis could be directed towards maintenance of a fishery or wildlife habitat.

- Northern Glaciated Plains. Like the Western Corn Belt Plains, this region is fertile, and attainable lake quality will be governed both by natural fertility and agricultural practices. Lakes have large surface areas, but are shallow. Although directives for the Northern Glaciated Plains should be similar to those of the Western Corn Belt Plains, it will be more difficult to attain lake phosphorus below levels promoting summer algal bloom.

Based on this evaluation of lake phosphorus and Secchi disk transparency, measurable regional differences are evident in the water quality of Minnesota's lakes.

In another application, the MPCA examined trends in stream water quality over time (Minnesota Pollution Control Agency 1986) using data collected from monitoring stations in all seven Minnesota ecoregions. Data for water quality attributes such as dissolved oxygen, un-ionized ammonia, nitrate-nitrite concentration, and total suspended solids were plotted for water years[10] 1975 to 1985 and trends were noted . As an example, data from nitrate-nitrite ($NO_3$-$NO_2$) concentrations are presented by ecoregion (Figure 4). Nitrates are found in agricultural

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[10]A water year is calculated over a twelve-month period beginning each October.

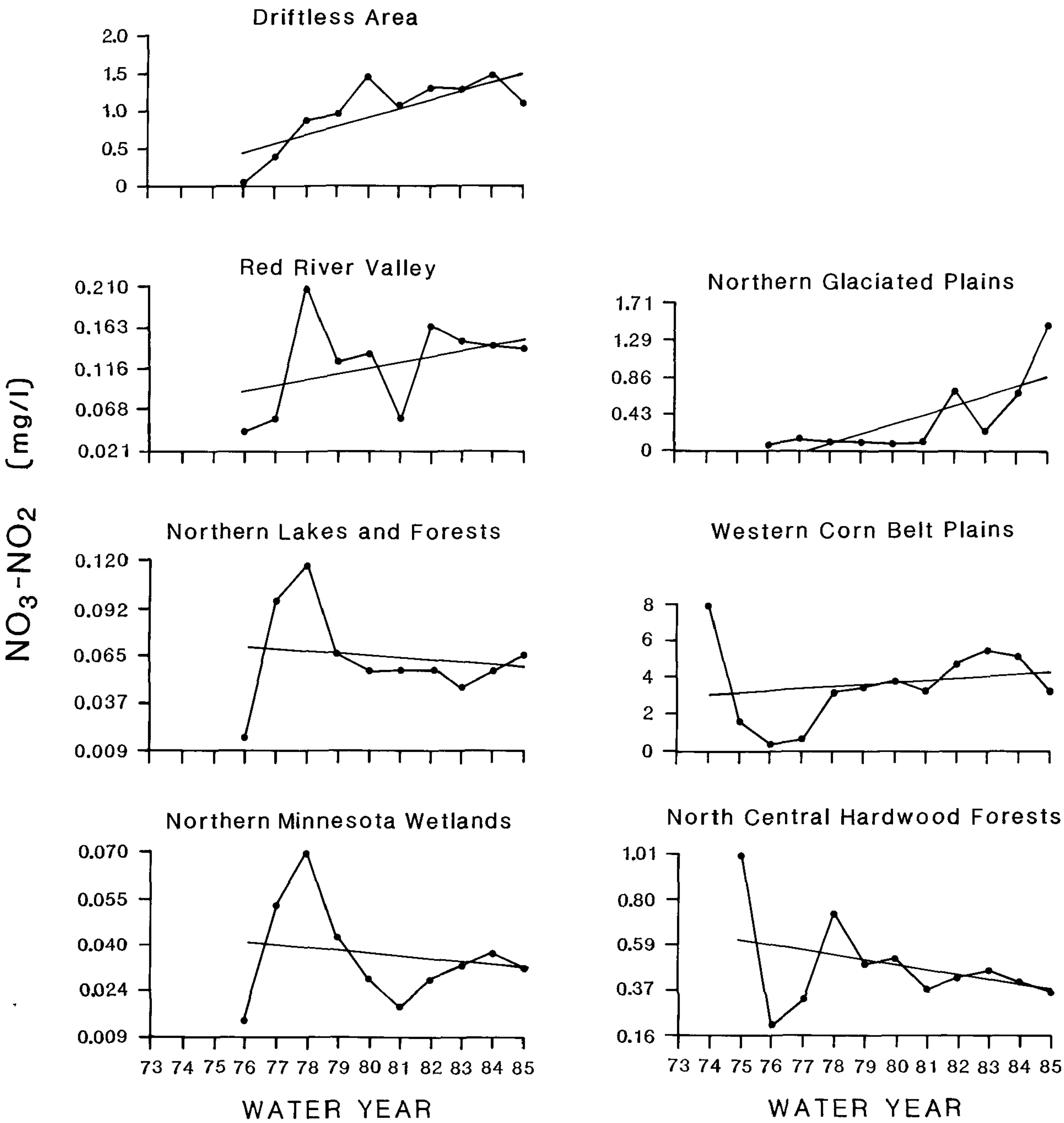


Figure 4. Nitrate-nitrite values for Minnesota streams, by ecoregion (adapted from Minnesota Pollution Control Agency 1986). Values are expressed as medians of all observations for each water year. Solid line indicates best fitting trend line. Note that scaling on Y-axis differs for each ecoregion.

fertilizers and often carried to streams via artificial drainages and surface runoff. Ambient levels of $NO_3$-$NO_2$ in Minnesota differ among regions. In the Western Corn Belt Plains, for example, median concentrations range from less than one, to eight milligrams per liter. In the Northern Minnesota Wetlands, yearly median concentrations are substantially lower, from 0.009 to 0.07 mg/l. Significant increases in $NO_3$-$NO_2$ concentrations over the 10-year sample period have occurred in the agricultural Driftless Area and Northern Glaciated Plains Ecoregions. Though nitrates, alone, at these levels may not be important stream pollutants, the increasing concentration in streams due to farm runoff may indicate that other, more detrimental water-soluble contaminants are leaking into streams. Thus, specific land use related pollutants may be regionally defined and monitored.

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