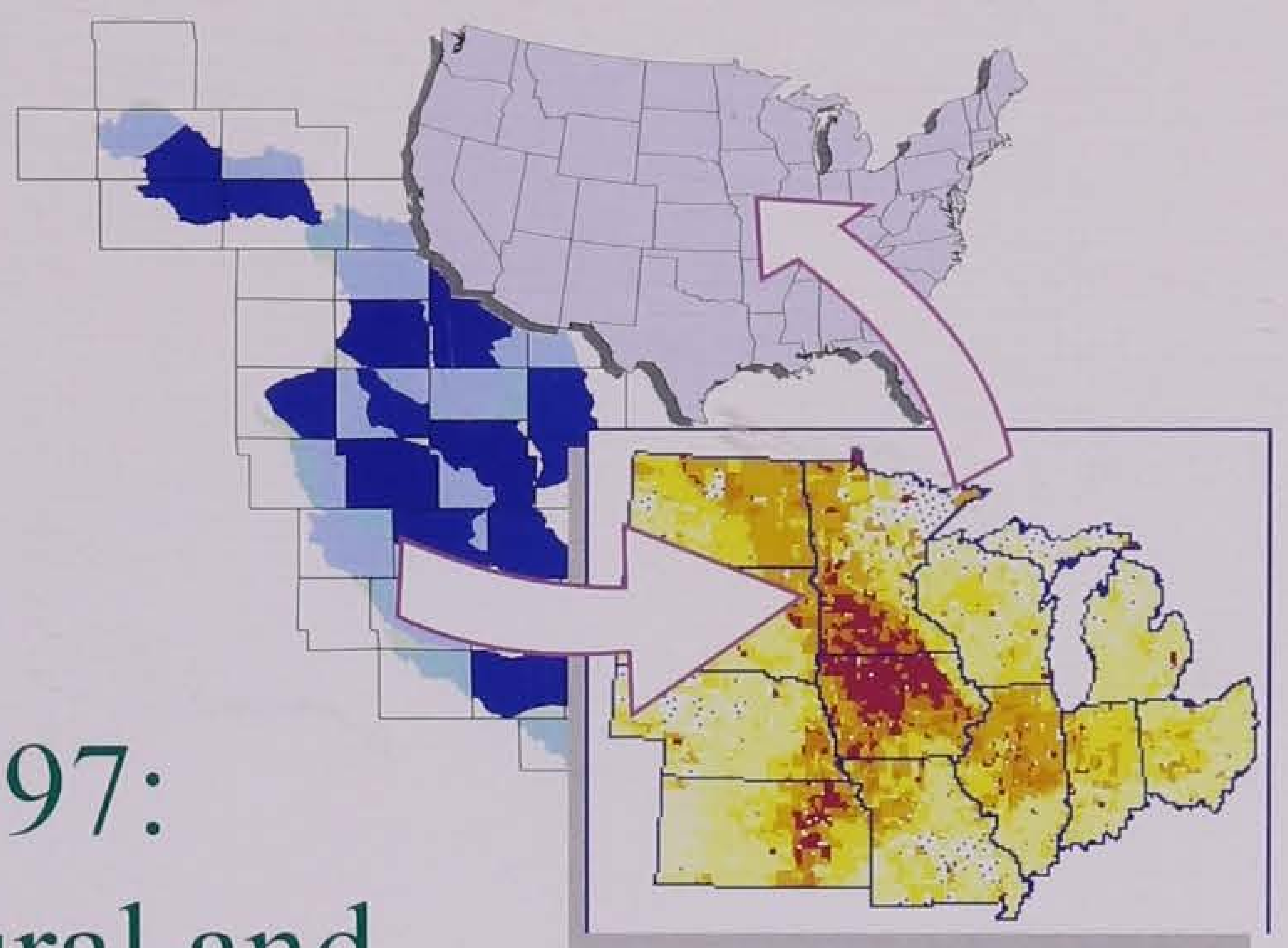

RAPS 1997: Agricultural and Environmental Outlook

RAPS
Resource and Agricultural Policy Systems

Center for Agricultural and Rural Development
Ames, Iowa 50011

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

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LIST OF ABBREVIATIONS

ARMS	Acreage Response Modeling System
AWC	Available Water-holding Capacity
CO_2	Carbon Dioxide
CRP	Conservation Reserve Program
CTIC	Conservation Tillage Information Center
EPA	U.S. Environmental Projection Agency
EPIC	Erosion Productivity Impact Calculator (version 5300)
EQIP	Environmental Quality Incentives Program
ERS	Economic Research Service of the U.S. Department of Agriculture
FAIR Act	Federal Agriculture Improvement and Reform ACT of 1996
GIS	Geographic Information System
HUC	Eight-digit Hydrologic Unit Code
LCC	Land Capability Class
MLRA	Major Land Resource Area
NASS	National Agricultural Statistic Service
NCDC	National Climate Data Center
NRCS	National Resource Conservation Service
NRI	National Resource Inventory
NWQAP	National Water Quality Assessment Program
PRZM	Pesticide Root Zone Model 2.0
RAPS	Resource and Agricultural Policy Systems
SIPP	Site-Specific Pollution Production modeling system
SOC	Soil Organic Carbon
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

1. INTRODUCTION

The Resource and Agricultural Policy System's 1997 Agricultural and Environmental Outlook presents current trends in crop and livestock production and indicators of how these trends affect environmental quality in the central United States. The Resource and Environmental Policy Division of the Center for Agricultural and Rural Development at Iowa State University in Ames, Iowa, produces this report for use by agriculturists, environmentalists, government agencies, and others interested in the interaction between agriculture and the environment.

What Is RAPS?

The Resource and Agricultural Policy Systems (RAPS) is a spatial modeling and accounting tool that provides an ongoing assessment of agriculture's impact on the Midwest's environmental health. In addition, RAPS analyzes the potential agricultural and environmental consequences of alternative agricultural and resource policies. Geographic Information System (GIS) maps show what and where crops and livestock are produced, as well as the spatial distribution of farming and its effect on the environment.

What's New in 1997?

RAPS has been completely remodeled since the publication of the 1996 report. The most important change is that a site-specific econometric model based on USDA's National Resource Inventory (NRI) database replaces the former regional linear programming model. For over 160,000 NRI locations in the Midwest, this model predicts farmers' crop choices and production practices based on input and crop prices, government commodity program provisions, cropping history, soil properties, and climatic conditions.

Four other major changes have also been made since the 1996 publication. First, RAPS now estimates expected county-level yields to help show why farmers choose particular crops. Second, the environmental models have been re-estimated and re-calibrated. And RAPS now includes an indicator for atrazine runoff, leaching, and volatilization. Third, National Agricultural Statistic Service (NASS) and Agricultural Census data expand the list of environmental indicators to include nutrients from livestock waste. Finally, an automated personal computer-based system integrates the crop production and environmental models. This integration enhances the ability of RAPS to conduct timely, comprehensive policy analysis.

What Does the 1997 RAPS Report Contain?

This report contains 1997 environmental baseline projections. The projections reflect the environmental effect of the Federal Agriculture Improvement and Reform Act (FAIR) of 1996. The FAIR Act brings an end to more than 60 years of planting restrictions and commodity subsidies that are tied to market prices. It allows farmers to plant almost any crop, while remaining eligible for fixed government payments. Eligible farmers include those who planted barley, corn, upland cotton, oats, rice, sorghum, and/or wheat and who participated in the corresponding government commodity programs at least one year during the period from 1991 to 1995.

The 1996 Act continues the Conservation Compliance provisions on highly erodible land and a revamped Conservation Reserve Program (CRP), which retires environmentally fragile farmland. However, most of the original CRP contracts have expired. Many farmers do not want to re-enroll their land because of favorable crop prices. In addition, significant portions of the original CRP land may not offer sufficient environmental benefits to be selected for enrollment. Thus, even though CRP has been renewed, the new CRP will contain a far different mix of land than the original program. The RAPS baseline accounts for the CRP changes that took place early in the summer of 1997.

Farmers benefit from the new legislation by gaining increased planting flexibility along with continued government subsidies. But the environmental impacts of the 1996 Act are uncertain. Certainly, continuation of CRP, Conservation Compliance, and swampbuster, along with new initiatives such as the Environmental Quality Incentives Program (EQIP) and whole-farm conservation plans, will yield important environmental benefits. In addition, the focus on obtaining the greatest environmental benefits per dollar and geographic targeting emphasized in the 1996 Farm Bill has created opportunities to improve the environmental performance of farm programs (Kuch and Ogg 1997). But the elimination of acreage set-asides and the change in economic conditions that have induced farmers to take land out of the CRP means increased production levels and increased chemical use. In addition, current high commodity prices increase pressure on the natural resource base by increasing the incentive for farmers to plant on marginal land that is currently providing important wildlife habitat and other environmental attributes. Planted acreage in the RAPS study region for both corn and soybeans increased significantly in 1997, reaching the highest level since the early 1980s. In this era of rapid change in the agricultural sector, it is especially important for policymakers and other interest groups to have objective, useful, and timely information about how these changes are likely to affect the environment. This second annual RAPS report continues to help fill this need.

Summary of Results

Greater planting flexibility and high commodity prices increased soybean production by 22.9 percent, over 10 million acres, in the central United States between 1992 and 1997. The new soybean acreage was taken from land previously planted to program crops or enrolled in the CRP. While corn acreage showed a slight increase for the region as a whole, traditional corn growing states tended to decrease corn acreage. Over the study region wheat acreage decreased by 7 percent, sorghum acreage by 15.6 percent, hay acreage by 5.5 percent, and CRP acreage by 4.7 percent.

While farmers planted additional marginal land and shifted to generally more erosive crops with a higher potential for chemical leaching and runoff between 1992 and 1997, they also increased their use of conservation practices to fulfill Conservation Compliance requirements and remain eligible for federal subsidies. Increased conservation led to a 14.8 percent increase, 10 million acres, in land cultivated using conservation tillage. This increase in conservation tillage had significant positive environmental consequences that alleviated much of the negative impacts of increased farming intensity.

The negative environmental impact of agricultural production throughout the central United States generally declined between 1992 and 1997 even though farming intensity increased. Soil erosion declined by 3.7 percent, 52 million tons. The rate of loss of soil organic carbon from fertile cropland decreased by 2.9 percent, more than 1 million tons, and atrazine lost from cropland decreased 12.4 percent, just under 24 thousand tons. The only exception was nitrogen lost from cropland, which increased by 1.6 percent or nearly 23 thousand tons.

Changes in crop production between 1992 and 1997 have generally improved the environmental health of the central United States. While planting flexibility introduced by the FAIR Act and higher commodity prices have increased farming intensity and placed greater demands on the environment and natural resource base, Conservation Compliance and its incentives have encouraged greater conservation. The net result was a decrease in the loss of fertile topsoil, organic carbon, and atrazine from croplands to the environment where they can adversely affect water resources, wildlife habitat, and human health.

2. DATA AND ANALYSIS

RAPS uses information from the National Resource Inventory and the USDA's Census of Agriculture, Cropping Practices Survey, and Crops County Data to perform two distinct functions. First, RAPS summarizes the spatial distribution of the natural resource characteristics and climatic conditions that influence agricultural production throughout the central United States, and shows the current trends and the spatial distribution of crop and livestock production. Second, RAPS integrates two separate modeling components to predict both production practices and the environmental consequences of these practices. The Acreage Response Modeling System (ARMS) projects crop choices, crop rotation, and conservation practices given the natural resource base, climatic conditions, commodity prices, and government policy at more than 160,000 points in the central United States. The Site-Specific Pollution Production modeling system (SIPP) then estimates the environmental effects of the projected management practices. The results show the effect of agricultural production on the environment in 1997 and how the environmental health of the central United States has changed since 1992 due to changes in agricultural policy and economic conditions faced by farmers.

Primary Data Sources

The USDA's National Resource Conservation Service (NRCS) every five years conducts the NRI survey for more than one million sites nationwide. Appropriate statistical sampling techniques ensure sample sites are representative of specific landscape areas. For each sample point, the NRI collects information on the natural resource characteristics of the land, as well as the farming practices used by the landowner. The NRI uses a link to the nearest wind and weather station to provide climatic information from the National Climate Data Center (NCDC). State, county, eight-digit hydrologic unit code (HUC), and major land resource area (MLRA) information allows each NRI point to be assigned to polygons defined by the intersection of the state, county, HUC, and MLRA boundaries. Each NRI point also has an expansion factor indicating the proportion of the landscape it represents within its polygon, which allows the aggregation of points to various levels (i.e., a polygon, county, state, or region).

Every five years the USDA's National Agricultural Statistics Service (NASS) conducts the Census of Agriculture. The census collects information on land use and ownership, agricultural production practices, farm labor, operator characteristics, and federal program participation. The census surveys all operators with more than $1,000 in agricultural sales during the survey year and operators who normally have more than $1,000 in agricultural sales.

NASS began surveying cropping practices and chemical use in 1990 as part of a multiagency Water Quality Initiative. Each year NASS surveys farmers producing a variety of field crops. Farmers are selected randomly according to the proportion of acres they cultivate. The survey collects information on crop choice, planting methods, irrigation, conservation practices, fertilizer and pesticide use, and targeted pests. For fertilizers, fungicides, herbicides, and insecticides, the survey collects information on acres treated, the number of applications, and the application rates. NASS aggregates the survey information and provides estimates of state-level application acres and pounds of active ingredient. NASS also provides the state-level average applications per acre, average application rates per acre, and average pounds of active ingredient per acre.

NASS collects annual crop information on crop planting, harvesting, and yields and uses this information to produces county-level estimates of planted acres, harvested acres, and the average yield per acre for most agricultural crops.

Analytical Methods

The primary determinant of an individual farm's effect on the environment is the interaction among the type of crop grown on the farm, the management practices used to grow the crop, and location-specific resource factors, such as soil type, and proximity to water. Most farmers base their choice of which crop to grow on profit considerations. Profits from growing a particular crop depend on crop prices, crop yield, and the cost of production. Farmers are more likely to grow a crop that has a higher price, a higher yield, and/or a lower cost of production than an alternative crop.

Yields and costs are affected by local factors such as soil type and climate. For example, farmers in northern Iowa grow corn and soybeans almost exclusively, whereas farmers in central North Dakota grow mostly wheat. Iowa farmers could grow wheat, and have higher average yields than North Dakota farmers, but the soil and climate of northern Iowa are ideally suited for corn and soybean production. Iowa crops typically are not irrigated because of generally plentiful moisture and moderate summer temperatures, so production costs are low. When summer dry spells hit, the high organic content of Iowa soil buffers crops from the shock. The growing season in North Dakota is too short for corn and soybean production, whereas wheat is better suited to the relatively cool and dry summers.

Under current farm programs, farmers can plant any crop they choose. This planting flexibility makes it difficult to predict which crops will be grown at particular locations. RAPS needs a systematic way of predicting the probabilities that particular crops are grown at particular sites in the study region, and the probabilities that certain conservation practices are utilized. ARMS fills this need.

ARMS consists of two "discrete choice" models that predict farmers' choices of crops and tillage system. The models are discrete choice because farmers grow only one crop and use only one tillage system on a field during the growing season. Because nobody can predict farmers' choices with certainty, ARMS estimates the probabilities that a particular site is planted to corn, soybeans, wheat, sorghum, hay, or some other crop. In addition, ARMS estimates the probability that a particular site is planted under a no-till, reduced-till, or conventional tillage system. These crop and tillage probabilities were estimated using the site-specific data on cropping history, tillage practices, and resource settings reported in the NRI, as well as climatic information from the NCDC.

After ARMS predicts probabilities for each NRI point, points are assigned to one of the six crops or the CRP, and to a tillage system. First, points are assigned to CRP using the 1992 NRI CRP designations as a baseline. ARMS uses Economic

Research Service (ERS) state-level CRP acreage reports to determine whether to add or remove NRI points from the 1992 baseline allocation on the basis of predicted probabilities for crop choice. Once state-level CRP acreage assignments agree with the ERS summary reports, ARMS assigns the remaining points to one of the six crop choices using the predicted probabilities and state-level acreage estimates from the Crops County Data. ARMS then assigns each point to one of 15 possible rotations using its own crop assignment and the crop history from the 1992 NRI. ARMS assigns each NRI point to one of the three tillage systems using the tillage probabilities and crop acreage estimates for conservation tillage in each state from the Conservation Tillage Information Center (CTIC). Finally, to predict the environmental effects of crop production, ARMS maintains the 1992 NRI assignments for irrigation and conservation practices (contouring, strip cropping, and terracing) for each NRI point.

SIPP uses eight environmental production functions to predict the local generation of water erosion, wind erosion, soil organic carbon changes, nitrogen runoff, nitrogen leaching, atrazine runoff, atrazine leaching, and atrazine volatilization. Levels of these pollutants serve as environmental indicators, measures of the site-specific environmental effects of crop production. When crop production and management practices change, the local environmental impacts change as well. These indicators quantify the environmental consequences of these changes.

SIPP uses the Erosion Productivity Impact Calculator version 5300 (EPIC) and the Pesticide Root Zone Model 2.0 (PRZM) to develop its environmental production functions. EPIC is a widely used model developed by USDA staff at the Texas Blacklands Research Center (Sharpley and Williams 1988). EPA researchers at the Environmental Research Laboratory in Athens, Georgia, developed PRZM (Mullins et al. 1993). Since running EPIC and PRZM simulations for every NRI point and all possible management practices is prohibitive, SIPP makes regional coverage possible by using a subsample of 11,000 NRI points to estimate environmental production functions. EPIC and PRZM simulate the environmental effects of crop management practices for this NRI subsample, using resource and management data from the NRI, climatic information from the NCDC, and fertilizer and atrazine application rates from the USDA's Cropping Practices Survey. The resulting environmental production functions predict site-specific pollution generation as a function of the local soil characteristics, climatic factors, and crop management practices. Mitchell et al. (1997) describes this technique and its use in developing an environmental production function for soil CO_2 emission.

To apply these environmental production functions, the NRI provides soil and climatic data and ARMS assigns the crop management practices (crop rotation, tillage system, conservation practices, and irrigation system) used at each NRI point. SIPP then uses this information to calculate the potential environmental impacts of crop production at each NRI point.

Profit considerations are a crucial determinant of what crops are grown. As an indicator of the profit potential for different crops, RAPS uses county-level yield functions, estimated with the Crops County Data, to calculate expected yields for corn, soybean, wheat, sorghum, and hay production throughout the study region. Maps illustrate the spatial distribution of expected yields for 1997.

RAPS uses the Census of Agriculture livestock inventories and information from agricultural engineers at Iowa State University to estimate the amount of manure, nitrogen, and phosphate waste generated by cattle, hogs, and poultry at the county level. First, livestock populations are separated into subgroups that vary by average weight and waste production. The population in each subgroup is converted to a standard 1,000 pound animal unit (AU) using average animal weights. Next, multiplying the population in each subgroup by the average pounds of waste produced per animal in that subgroup gives an estimate of waste generation. RAPS then aggregates to produce standardized inventories and waste generation for cattle, hogs, poultry, and livestock as a whole.

3. LAND RESOURCES AND CLIMATE

Land Resources

RAPS uses land resource information from the 1992 NRI to determine agricultural production practices and the environmental consequences of production. Various soil and landscape characteristics are important determinants of which crops will be grown and how they will be grown. These characteristics determine cultivation methods, fertilizer applications, and conservation practices because they determine soil fertility and the potential for soil erosion. Land resources are also important determinants of what happens to the fertilizers and pesticides applied by farmers. Understanding the resource base is essential to understanding crop production and its environmental consequences.

Soil organic carbon (SOC) measures the organic matter in soil. Organic matter exerts a profound influence on soil structure and properties such as available water-holding capacity, permeability, bulk density, and pH. High levels of SOC generally coincide with good soil quality. Figure 3.1 shows the high organic carbon content of the fertile belt stretching from central Illinois, through Iowa, southern Minnesota and to the Red River Valley in the north and to eastern Kansas in the south. This land encompasses some of the most productive soils in the world. The soils of northern Minnesota and Wisconsin also have high SOC levels, but are not farmed intensively because of excess moisture.

Clay in soil and organic matter provides the essential materials needed to form soil aggregates that create good soil structure necessary for aeration, erosion resistance, water retention and infiltration, and plant nutrient storage. However, too much clay makes heavy compacted soil with poor aeration, especially when little organic matter is present. Also, high clay content reduces the ability of water to infiltrate the soil, thereby increasing the potential for runoff while decreasing the potential for leaching. Figure 3.2 shows the high clay content in the soils of southern and eastern Missouri, northwestern Ohio, and central South Dakota. The Nebraska Sand Hills lack adequate clay, as do many soils around the Great Lakes.

Maintaining a soil pH around 7 by using soil amendments and appropriate management improves productivity, since crops can maximize their use of soil nutrients. Forested soils tend to be acidic (low pH), as seen in Figure 3.3 in the coniferous forests of northern Minnesota and Wisconsin, the Ozarks of southern Missouri, and along the Ohio River Valley. The semi-arid grasslands of the Plains states tend to be alkaline (high pH). Applying fertilizer, especially ammonia and organic nitrogen, acidifies soil, and farmers regularly apply lime to increase pH. Applications of gypsum and/or sulfur reduce the pH of alkaline soils, but often improving drainage is sufficient to leach soils and reduce their pH, especially for irrigated soils.

Dry bulk density measures the density of soil and indicates the amount of pore space. Soils with low bulk density have lots of pore space for water storage and root growth, making the soil more productive. However, these soils can be susceptible to wind erosion, especially in dry, windy areas. Heavy, compacted soils with poor structure have high bulk densities (above 1.4) that inhibit root growth and water penetration, increasing the potential for runoff while decreasing the potential for leaching. In addition, tilling heavier soil requires more fuel and increases production costs. The dense clay soils of Ohio and Indiana, and the dense sandy soils in Michigan, Wisconsin, central Minnesota, and the Nebraska Sand Hills are apparent in Figure 3.4.

The available water-holding capacity (AWC) measures the maximum amount of water a soil can store for use by crops. Several soil properties jointly determine the AWC, particularly clay content, organic matter, soil structure, and profile thickness. Figure 3.5 shows the productive soils of Illinois, Iowa, and southern Minnesota have high AWC, giving them better dry weather tolerance than the soils of Ohio or Indiana. Soils with a high AWC in the Great Plains make wheat production possible by storing winter and spring moisture for crop use. For irrigated land, the AWC affects how often and how much water must be applied. In Nebraska, where irrigation is widely used, this dictates different irrigation methods for different areas.

Land with steeper slopes is prone to erosion. In addition, soil on steeper slopes tends to be thinner and drier and contains less organic matter. Farming in these areas requires conservation practices to control erosion. Land with too little slope is typically poorly drained and requires artificial drainage (tiling) to be suitable for crop production. While tiling prevents chemicals from leaching to groundwater supplies, these chemicals are instead diverted to surface water supplies. The hilly regions along the Missouri, Mississippi, and Ohio River Valleys are particularly prominent in Figure 3.6. Southern Iowa and northern Missouri are also hilly. Conversely, the Red River Valley along the North Dakota-Minnesota border, Indiana, and Illinois are particularly flat.

Land capability classes (LCCs) were developed by the USDA to indicate the potential limitations posed by the resource base on crop production. The NRCS uses this classification system when preparing conservation plans for farmers. There are eight LCCs, with subclasses indicating additional soil hazards and limitations. Class I land has no limitations for crop production, while II indicates land requiring suitable conservation practices such as erosion control or drainage. Class III land has strong limitations that restrict use for some crops and requires intensive conservation practices. Class IV land has severe limitations that permit only occasional cropping and the use of very intensive conservation practices. Classes V through VIII are for land that is not suitable for cultivation. Figure 3.7 shows the high percentage of land granted a favorable rating, Class I or II, stretching down from the Red River Valley, through Iowa and into Illinois, Indiana, and Ohio. Western parts of Kansas and southern Nebraska also generally fall in Class I or II.

Climate

Climate is as important as land resources for determining the suitability of land for crop production and the environmental consequences of production. Moderate temperatures, adequate rainfall, and low winds allow commodity crops to thrive and produce high yields. Alternatively, temperature and rainfall extremes and high wind can thwart crop growth, reducing yields while also increasing erosion, chemical runoff, leaching, and volatilization. High climatic variability also stresses crops and increases the risks of production for farmers.

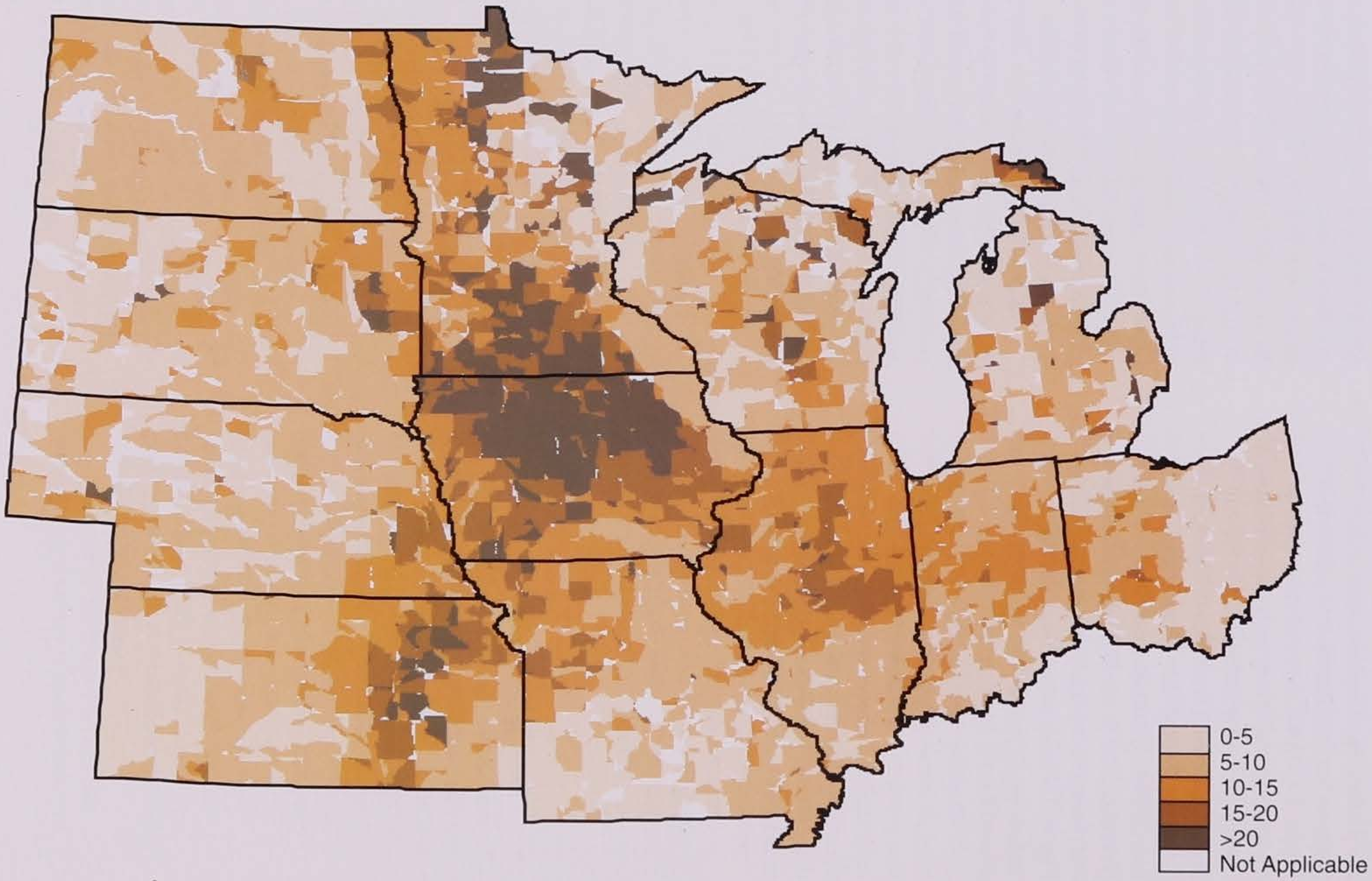
Climates with lower average temperatures have slower crop development.

Climates with higher average temperatures rob plants of precious moisture and promote the volatilization of pesticides. Figure 3.8 shows the moderate range of the average maximum daily temperature during the corn growing season for the region stretching from South Dakota and Nebraska through Iowa, northern Missouri, Illinois, Indiana, and Ohio. While Nebraska and South Dakota have moderate average maximum daily temperatures, Figure 3.9 indicates that temperature variability is higher than in Iowa, Missouri, Illinois, Indiana, and Ohio.

Climates with too little or too much rainfall stress crops. Too little rainfall also promotes wind erosion, while too much rainfall encourages water erosion, chemical leaching, and runoff. Average daily precipitation during the corn growing season, as seen in Figure 3.10, is high throughout Iowa, Missouri, and eastern Kansas and Nebraska. Conversely, North and South Dakota and western Nebraska and Kansas are dry. Figure 3.11 shows the remarkably low variability of rainfall during the corn growing season in Iowa, typically the highest corn producing state in the country. Variability is also low in Ohio where crop production is intensive, and in northern Minnesota, Wisconsin, and the peninsula of Michigan where crops are not produced extensively.

Climates with excessive wind speed rob plants of moisture, erode valuable topsoil, and encourage the volatilization of pesticides. Figure 3.12 shows that higher average annual wind speeds occur in North Dakota, parts of South Dakota, western Kansas, central Nebraska, eastern and south central Minnesota, and north central Iowa.

Figure 3.1. Average total organic carbon in the soil profile, kg/m²



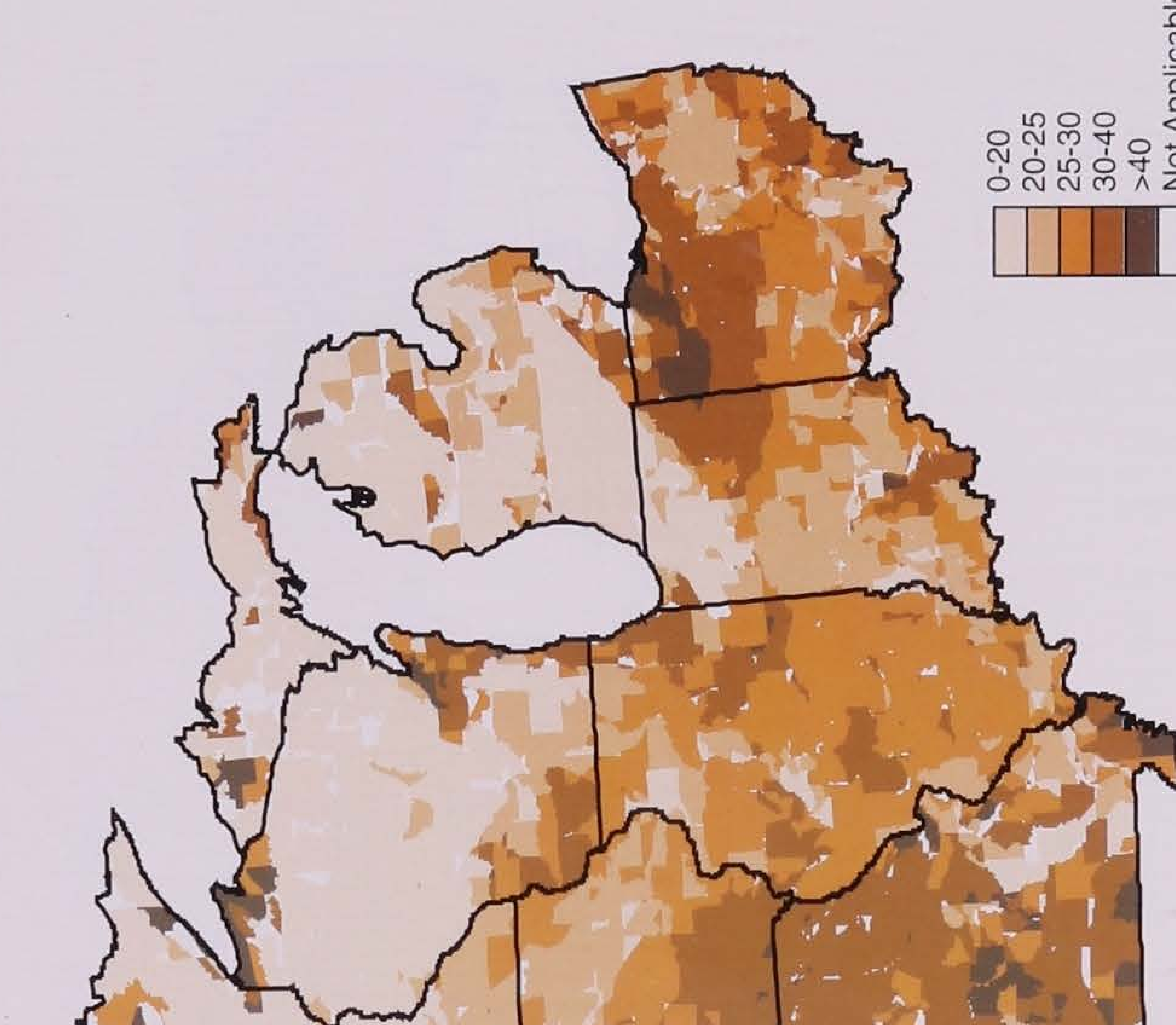


Figure 3.2. Average percentage of clay in the soil profile

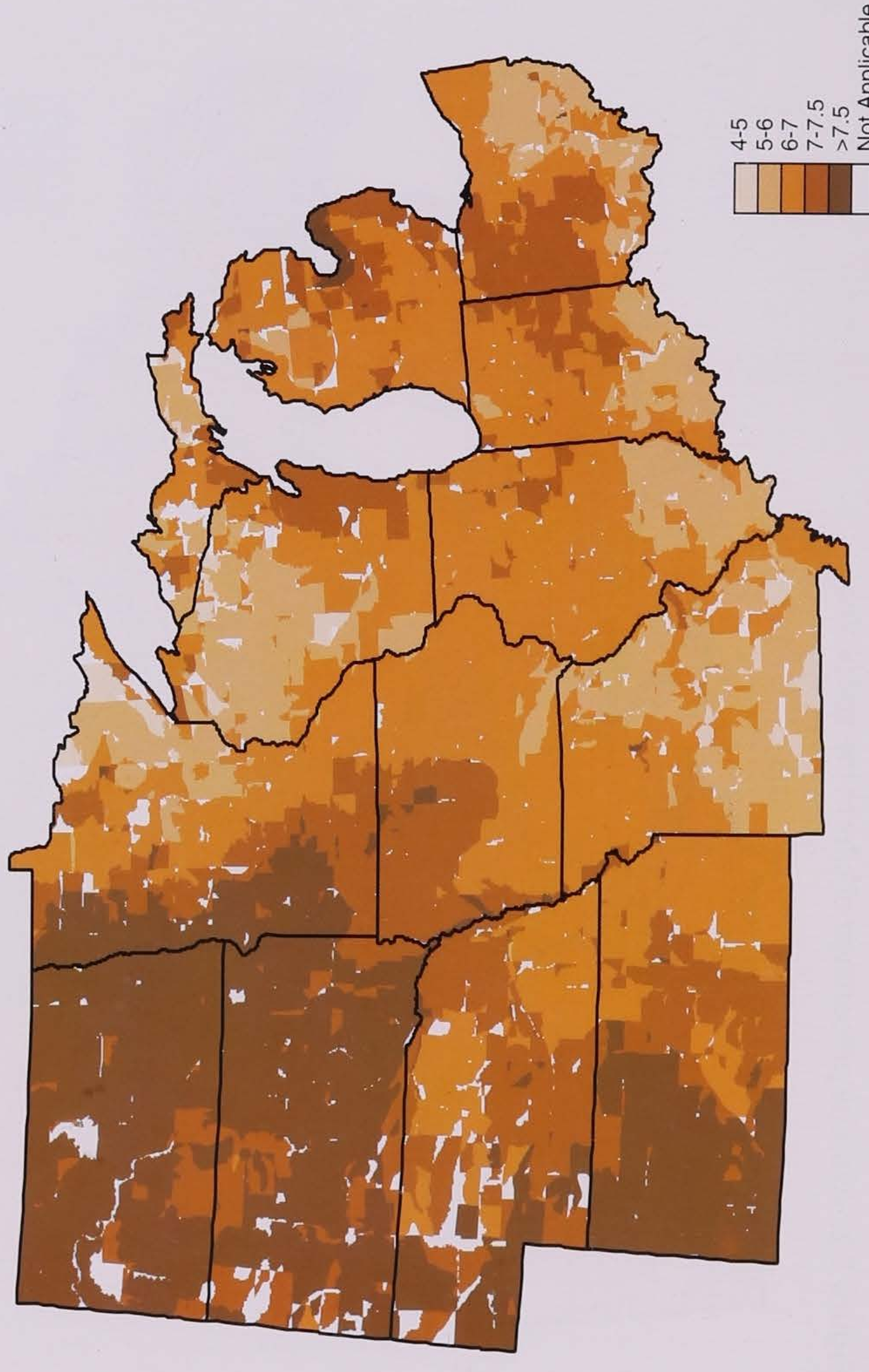


Figure 3.3. Average soil pH

Figure 3.4. Average dry bulk density of the soil profile, g/cm^3

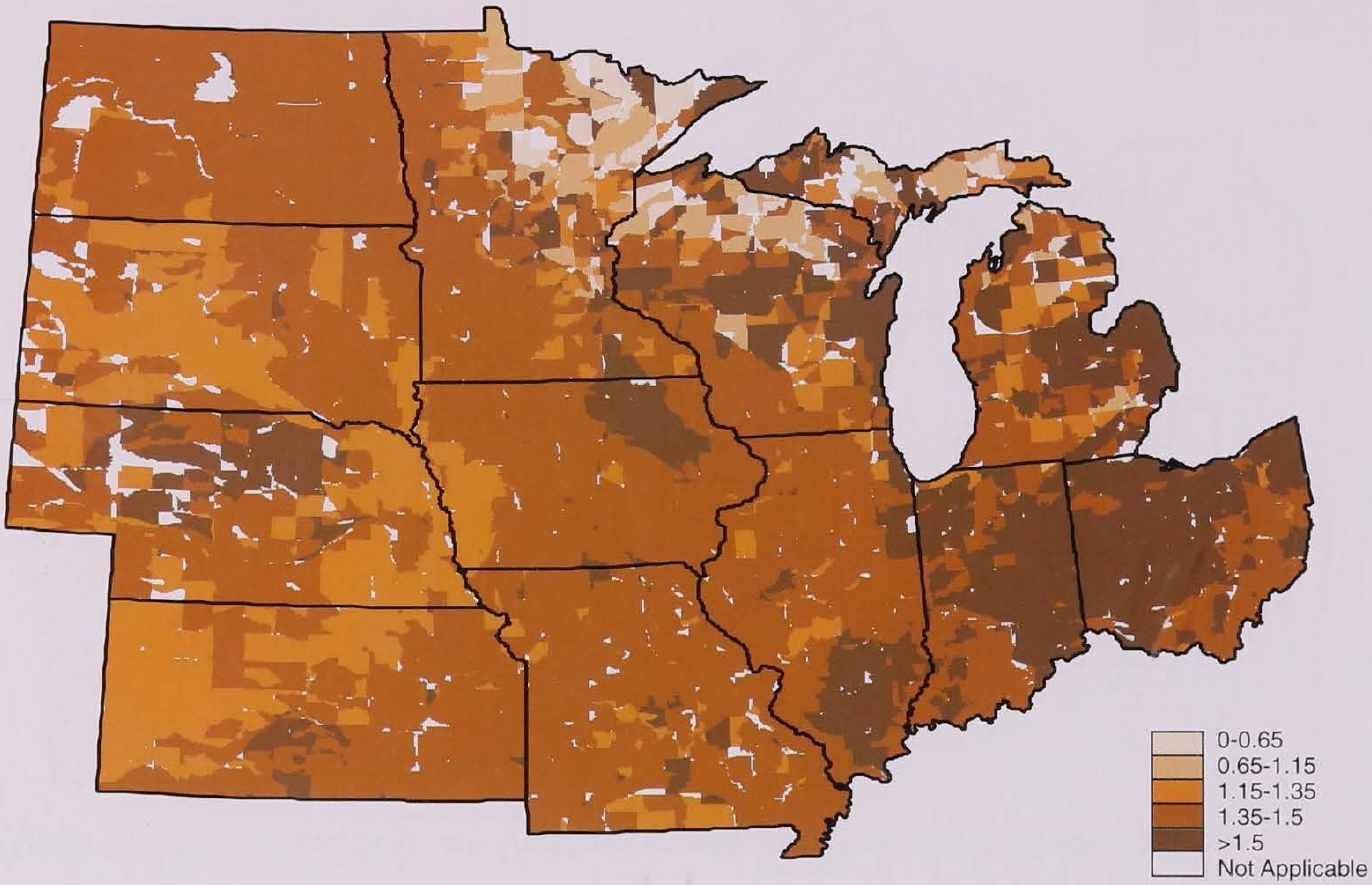
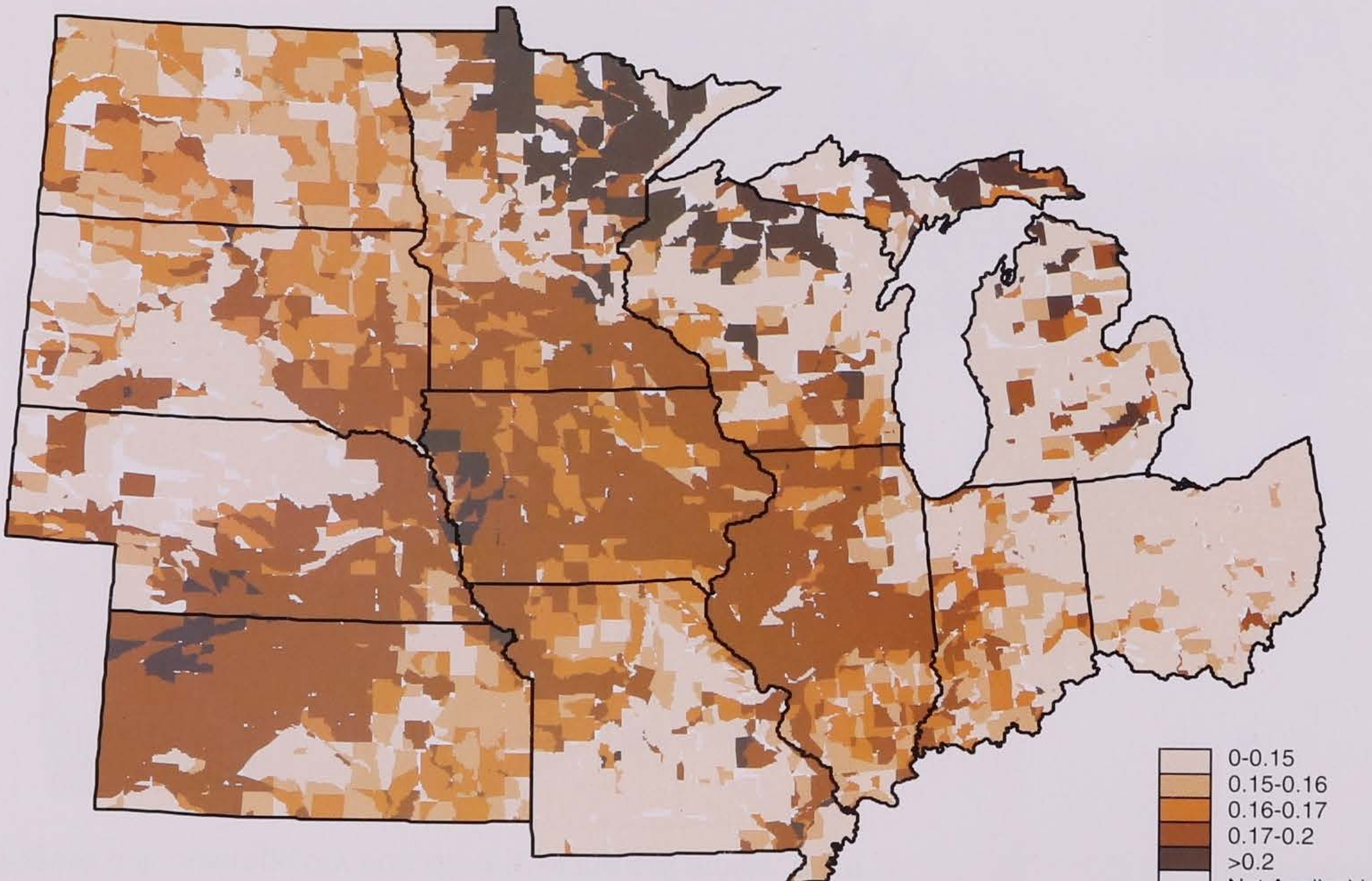


Figure 3.5. Average available water-holding capacity, inch of water/inch of soil



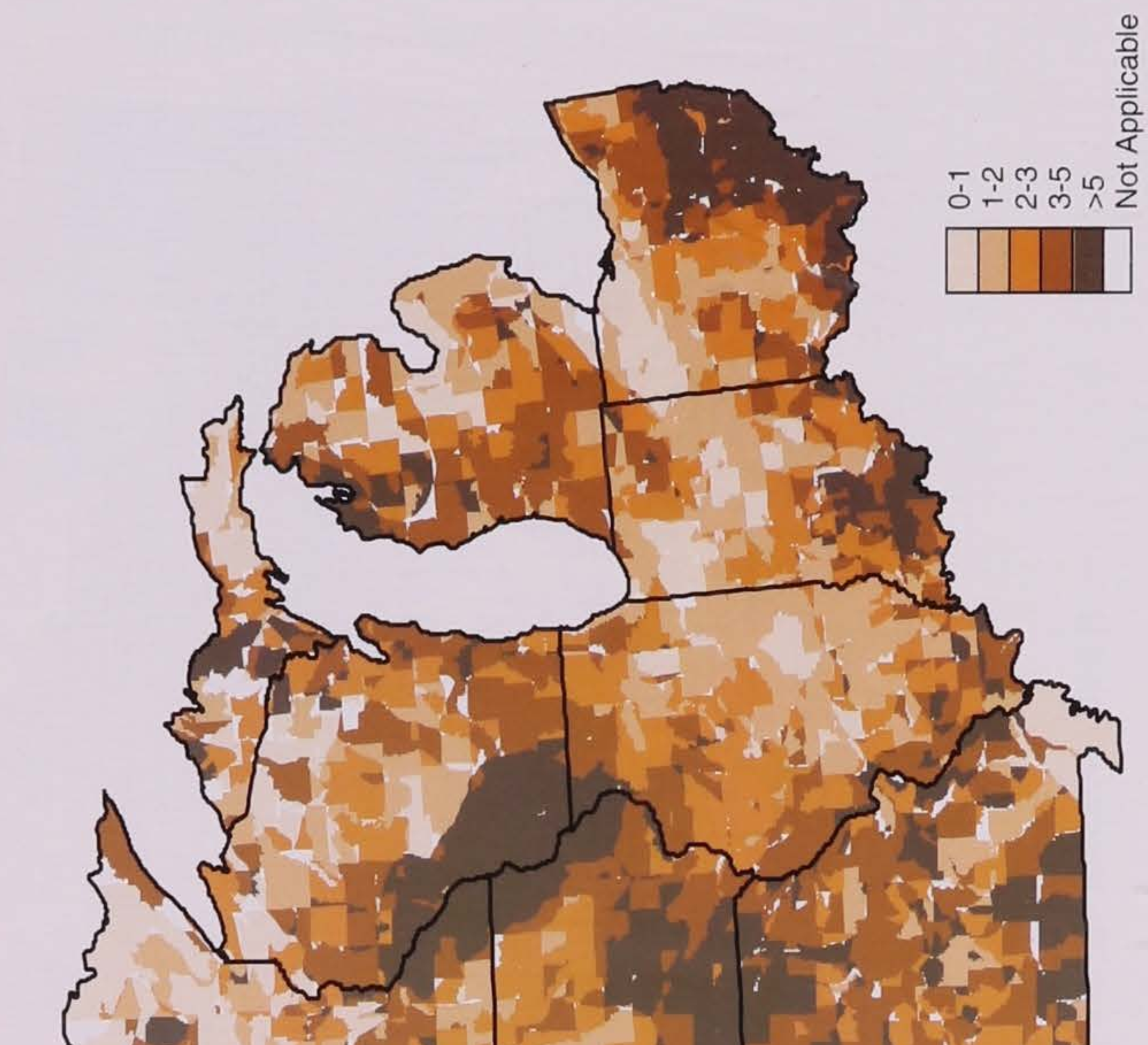


Figure 3.6. Average percentage slope of the land

Figure 3.7. Percentage of land in land capability classes I and II

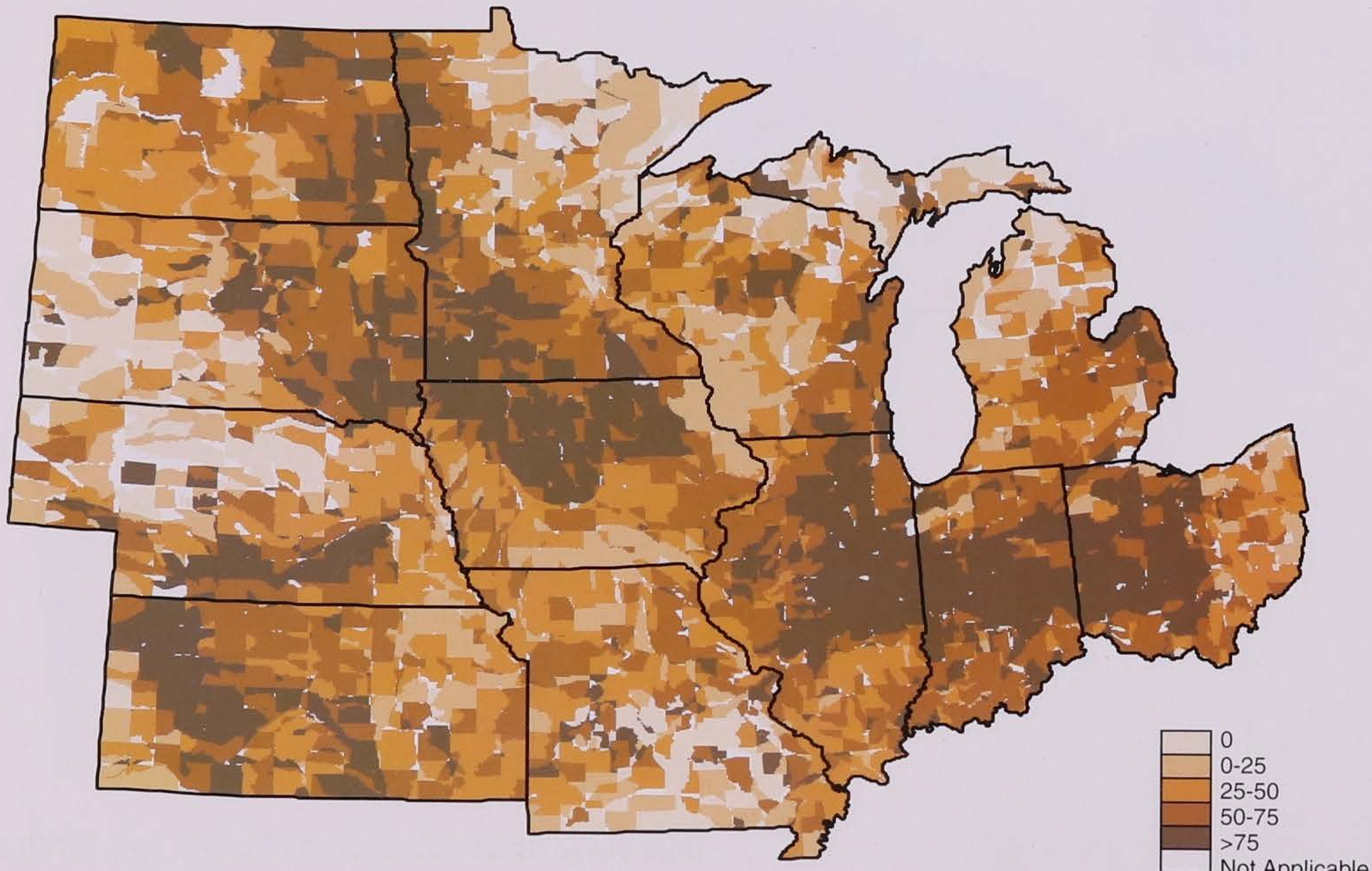


Figure 3.8. Average maximum daily temperature during the corn growing season

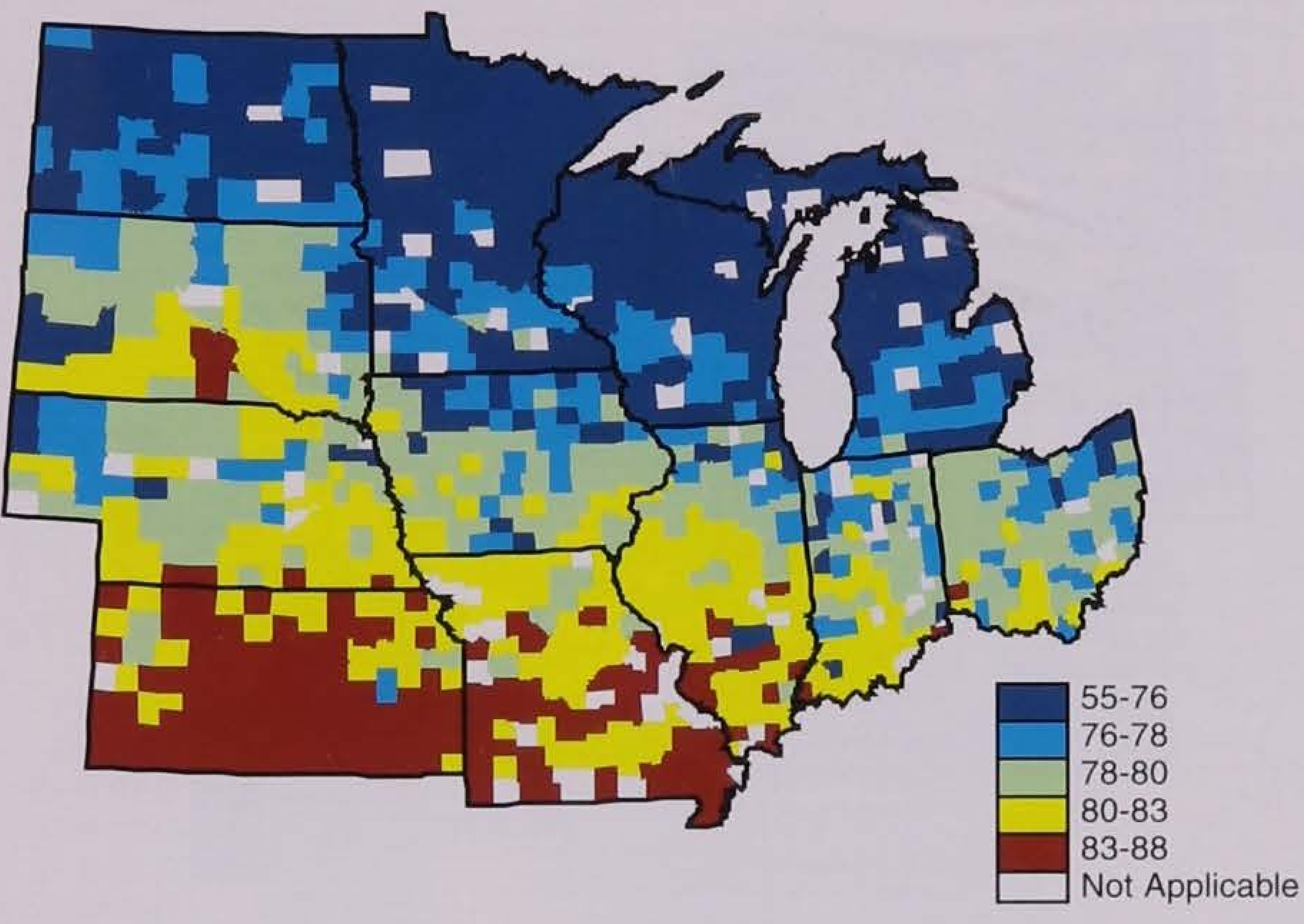


Figure 3.9. Coefficient of variation for the maximum daily temperature during the corn growing season

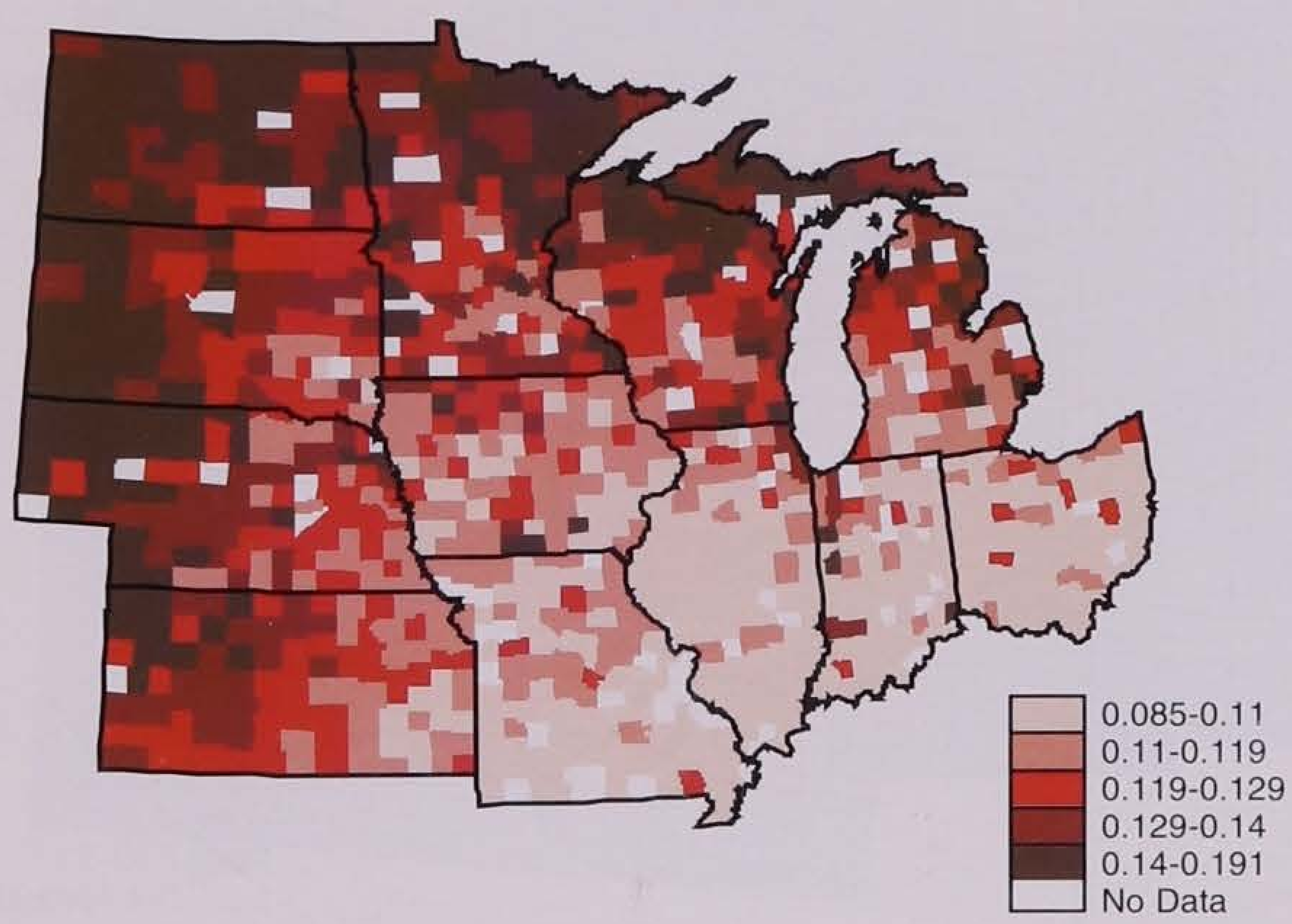


Figure 3.10. Average daily precipitation during the corn growing season in inches

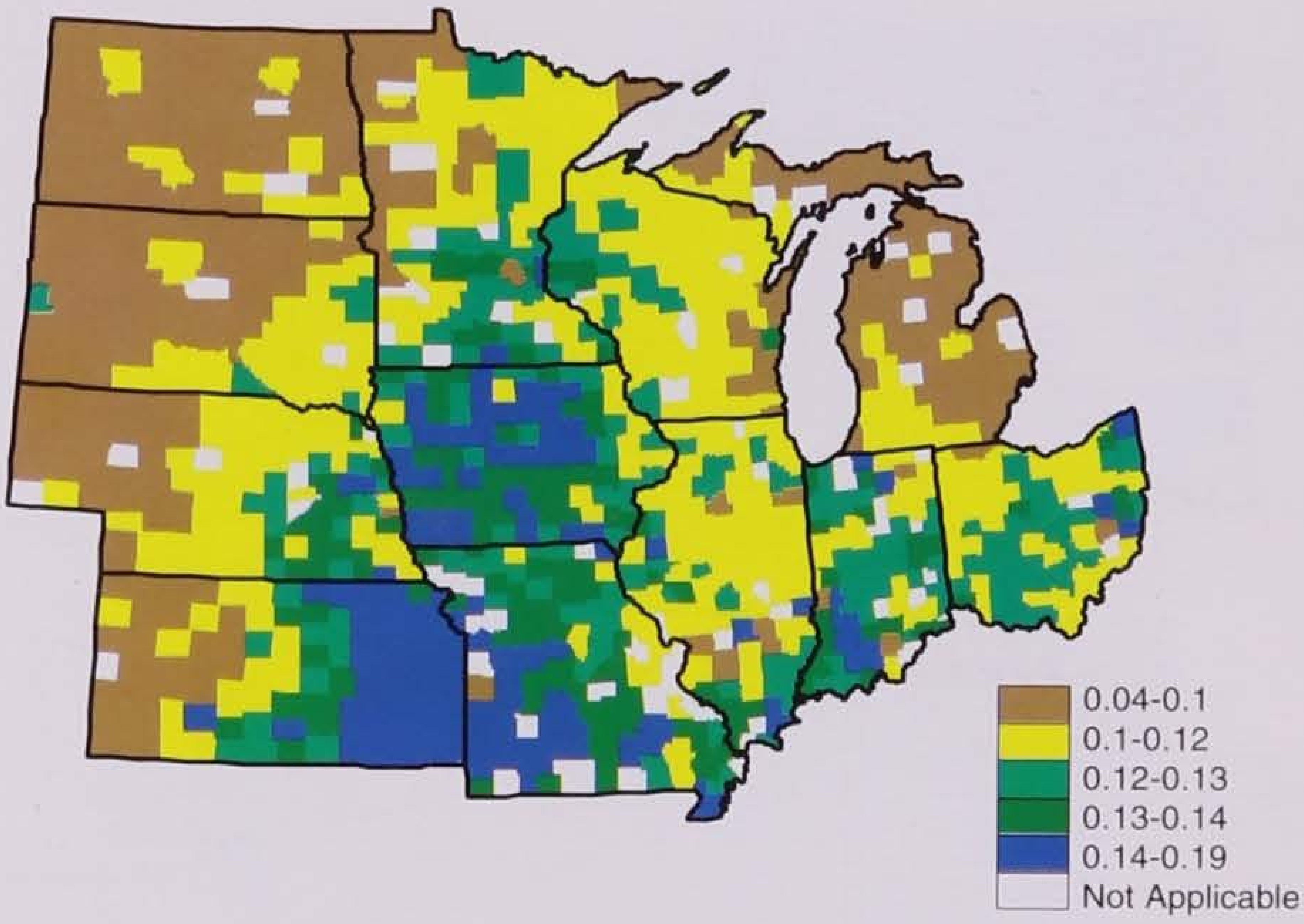
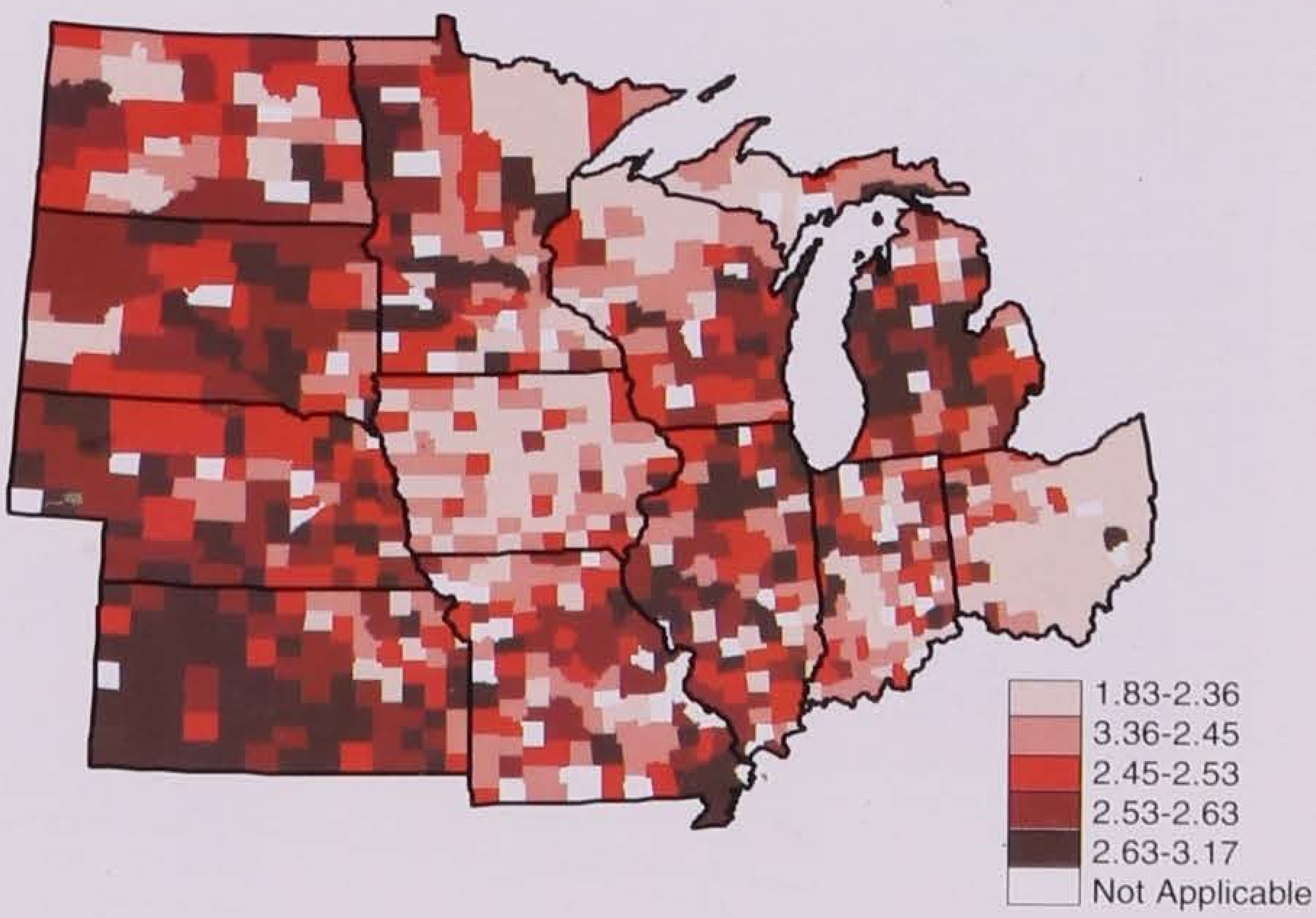


Figure 3.11. Coefficient of variation for daily precipitation during the corn growing season



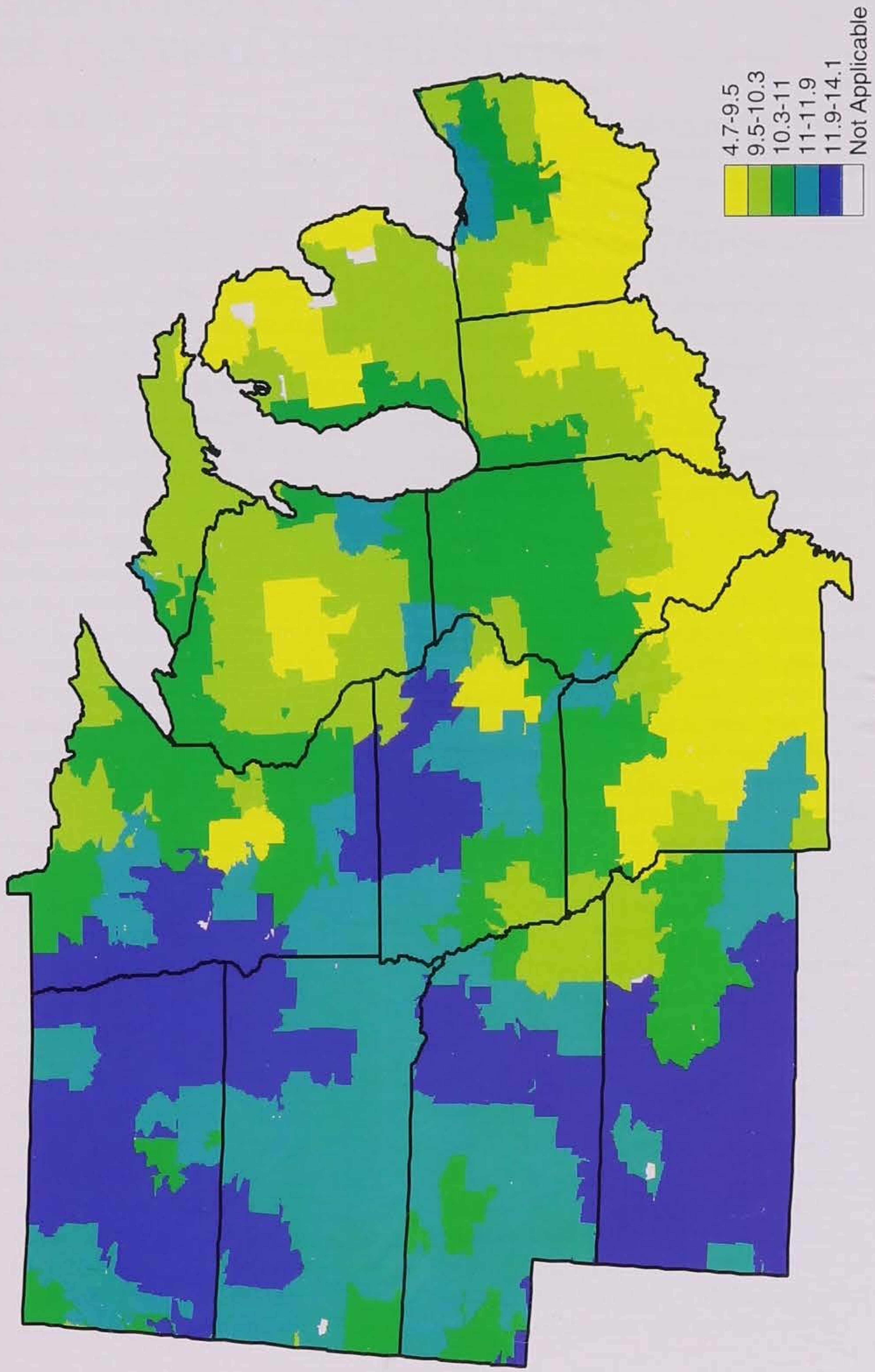


Figure 3.12. Average annual wind speed, mph

4. AGRICULTURAL PRODUCTION IN THE CENTRAL UNITED STATES

Crop Production

The RAPS study region includes the most important grain- and oilseed-producing states in the United States. Figures 4.1 through 4.5 show the percentage of land by county devoted to corn, soybeans, wheat, sorghum, and hay in the study region. As can be easily seen in Figure 4.1, corn is the dominant crop in the Corn Belt that includes southern Minnesota, Iowa, Illinois, and Indiana. In addition, corn is planted heavily in the Platte River Valley of central Nebraska, and in areas adjacent to the central Corn Belt in southeastern South Dakota, eastern Nebraska, and southern Wisconsin.

Figure 4.2 shows that soybeans are grown in many of the same locations as corn. In addition, large concentrations of soybeans are also grown in western Ohio, western Kansas, and parts of Missouri.

Figure 4.3 shows that the major wheat producing areas can be found where corn and soybeans are not grown. The reason for this is that corn and soybeans are more profitable than wheat. So corn and soybeans are the crops farmers prefer to grow in locations where the growing season is long enough, summer rainfall is usually adequate, and summer heat is not too extreme. Wheat is grown in areas that do not meet these conditions. The major wheat growing areas are North Dakota, central South Dakota, and the western two-thirds of Kansas. In addition, significant wheat acreage can be found in southern Illinois and northwestern Ohio.

Figure 4.4 shows that sorghum production is important in a limited number of counties in Kansas and southwest Nebraska. Sorghum is often planted as a rotation crop by wheat farmers or as a substitute for corn where there is not adequate rainfall.

Figure 4.5 shows that every state in the study region has some heavy concentrations of hay land. Not surprisingly, these heavy concentrations are located where higher value land uses are not feasible, such as western South Dakota or southern Iowa, or where heavy livestock concentrations exist, such as dairy cattle in southwestern Wisconsin and eastern Ohio.

Crop Yields

As a general rule, farmers will choose crops that result in the highest profits. Profits depend on market prices, per acre yields, and the cost of production. In the RAPS study region, soils and climate primarily drive crop yields. In parts of Nebraska and Kansas, yields are increased by irrigation, which significantly increases the cost of production. Figures 4.6 to 4.10 show expected county yields of corn, soybeans, wheat, sorghum, and hay in the study region. These estimates give a partial explanation of the existing spatial patterns of crops shown in Figures 4.1 to 4.5. A full explanation would also account for production costs and prices.

Figure 4.6 shows that corn yields are generally highest in southern Minnesota, north central Iowa, central Illinois, and central Indiana. Why is this so? Referring back to the resource maps in section 3, Figures 3.1 and 3.2 show that high corn yields in Iowa and Minnesota are in counties that have high soil organic carbon and a relatively low clay content. Figure

3.3 shows that soil pH is also at an optimal range in much of the Corn Belt. Figures 3.5 and 3.6 show that high corn yields in Iowa and Illinois also occur on soils with high water-holding capacity and where land is relatively flat. None of these factors by themselves explains corn yields. But areas that have many favorable conditions will tend to have the highest yields.

But good soil is not a sufficient condition for high corn yields. Corn needs rain and adequate, but not excessive heat. Figures 3.8 through 3.11 show the areas meeting these conditions. It is generally too cool in the northern parts of the study region for high corn yields and too hot in southern portions. Rainfall amounts are inadequate in western portions of the study region but adequate rainfall is not sufficient for high corn yields. In eastern Kansas, for example, rainfall is plentiful, but heat is excessive. Also, plentiful rainfall is not necessary for high corn yields. Central Nebraska and western Kansas have high corn yields because irrigation makes up for inadequate rainfall. And in central Illinois, high corn yields are possible because of soil with high water holding capacity, which allows moisture during the fall, winter, and early spring to be available to the corn crop in the summer. Thus, it is a combination of the resource characteristics that allows an area to have consistently high corn yields.

Figure 4.7 illustrates that the conditions that are conducive to high corn yields are also, in general, conducive to high soybean yields. Exceptions to this tendency are in irrigated areas, and in Iowa, where the highest soybean yields are located a bit south of where the highest corn yields occur.

Figure 4.8 shows that wheat yields are highest in a central belt across Illinois, Indiana, and Ohio. Yet, with the exception of northwest Ohio, wheat is not a major crop in these areas. Wheat is not grown more in these areas because there is a comparative advantage growing corn and soybeans. Wheat is grown in the western parts of the study region because, even though yields are lower than in the Corn Belt, the profits from wheat in the west are greater than profits from corn and soybeans in these areas. It is the relative profitability that determines where crops are grown. As an indication of this principle, note that in western Kansas expected wheat yields fall between 30 and 40 bushels per acre, which generates about $120 per acre in revenue. Figure 4.6 shows that corn yields in these areas are about 130 bushels per acre, which generates about $280 per acre. But corn is not the dominant crop in the region because the cost of producing 130 bushels of corn is much higher than the cost of producing 35 bushels of wheat because corn must be irrigated. And the cost of producing 130 bushels of corn in western Kansas is much higher than producing 130 bushels in Iowa. Thus wheat, not corn, dominates the landscape in most parts of western Kansas.

Conservation

Conservation is important to maintaining the long-term viability of midwestern agriculture. Careful land management can prevent the erosion of precious topsoil, reduce sedimentation, preserve reservoir capacity, improve water quality, protect fragile wildlife habitats, and reduce the runoff and leaching of agricultural chemicals. Therefore, farmers must develop and implement conservation plans in order to maintain their eligibility for federal farm programs. In addition, the CRP offers farmers an opportunity to retire environmentally fragile land from crop production.

The CRP is a voluntary land retirement program that pays farmers an annual rental payment and one-half cost sharing for establishing natural cover (grass and trees) on traditionally farmed cropland. Farmers bid competitively for 10-year contracts, although in some instance contracts can be accepted for up to 15 years. In 1992, there were 17.6 million acres of CRP in the RAPS study region. Figure 4.11 shows that concentrations of CRP were typically higher in North and South Dakota, the western half of Kansas, southern Iowa, northern Missouri, western Minnesota, and along the Mississippi River stretching though southeastern Minnesota, southwestern Wisconsin, and northeastern Iowa. However, this distribution of CRP acreage is likely to change dramatically since the original contracts have already begun to expire and high commodity prices and the new environmental benefits indicator mandated by the FAIR Act will mean that many expiring contracts will not be renewed.

Conservation tillage typically leaves more than 30 percent crop residue on the field. This residue provides economic benefits by reducing the labor and machinery hours required for field preparation. Conservation tillage also provides environmental benefits by reducing soil erosion. However, conservation tillage can also increase pest pressure and result in the use of more pesticides. Figure 4.12 shows a higher proportion of conservation tillage in 1992 along the Missouri and Mississippi Rivers, central Iowa and Illinois, south central Nebraska, and western and southern Indiana.

Throughout much of the study region rainfall is adequate and irrigation is not cost effective. However, where irrigation is cost effective it can promote the leaching and runoff of chemicals and contribute to soil erosion. Figure 4.13 shows irrigation is prominent in most of Nebraska, eastern Kansas, and the Missouri panhandle where rainfall is typically lower and more varied.

Subsurface drainage systems (tiles) allow farmers to remove excess water from cropland and improve crop growth. Tiled cropland contains artificial channels that divert excess water from the root zone to nearby ditches, streams, rivers, and lakes. From an environmental perspective field tiles are precarious. While preventing agricultural chemicals from leaching into groundwater supplies, these chemicals are instead diverted to surface water. Additionally, these tiles serve to drain natural wetlands in order to create suitable cropland. Figure 4.14 indicates that tiled cropland is most extensive throughout eastern Indiana and western Ohio where annual rainfall is higher and fields are flatter. Tiling is also relatively common in southern Minnesota, Iowa, northern Illinois and Indiana, and central Michigan.

Grassed waterways use natural cover such as grass and trees along ditches, streams, rivers, and lakes to capture sediment, fertilizer, and pesticide runoff. These waterways protect water quality, prevent damage to sensitive aquatic ecosystems, preserve reservoir capacity, and reduce flooding. Grassed waterways are more common in western Kansas and southeast Nebraska (Figure 4.15). They are also relatively common across Iowa, northern Missouri, and Illinois, and to a lessor extent in Indiana, Ohio, and Wisconsin. Grassed waterways are popular because of relatively low establishment and maintenance costs.

Contour cropping plants across the slope of the landscape at similar elevations. This low-cost conservation practice slows the flow of water downhill reducing soil erosion, improving water quality, and increasing soil moisture. In Figure 4.16, contouring is more frequent in Kansas and along the Missouri River between Iowa and Nebraska due to greater field slopes. Contouring is also relatively common along the Mississippi River where field slopes are also steep.

Strip cropping combines crop rotation with contouring by alternating crops along the contour to further reduce water erosion, improve water quality, and increase soil moisture. Strip cropping can also effectively reduce wind erosion on cropland with flatter slopes. Strip cropping is low cost and most heavily practiced along the hilly regions of the Mississippi River between Iowa, Minnesota and Wisconsin, and in western parts of North and South Dakota, the panhandle of Nebraska, central Kansas, and eastern Ohio (Figure 4.17).

A terrace is constructed to form a plateau on steeper landscapes. Terraces reduce soil erosion and sedimentation in streams, rivers, and lakes to improve water quality, protect aquatic ecosystems, preserve reservoir capacity, and reduce flooding. Terraces are generally costly, so alternative conservation measures are usually preferred. Figure 4.18 shows terraces primarily in Kansas and along the Missouri River border of Iowa, Nebraska, and Missouri.

Livestock Production

Abundant feed and sufficient cropland available to assimilate animal waste makes livestock production an important industry for the Midwest. Figure 4.19 shows the high concentration of livestock inventories in 1992 throughout western South Dakota, Nebraska, southern Missouri, and along the Iowa and Wisconsin border. Figure 4.20 shows the high concentration of cattle extending from North Dakota down through South Dakota, Nebraska, Kansas, and Missouri. These are generally areas where crop production is less profitable, and there is sufficient land to support large cattle inventories. Large concentrations of dairy cattle in Wisconsin are also notable. Hog inventories are most concentrated in Iowa (Figure 4.21), with smaller concentrations west into South Dakota, Nebraska, and Kansas, south into Missouri, and east into Illinois, Indiana, Michigan, and Ohio where the relatively less demanding land requirements of hogs can help farmers reduce the risk of crop production.

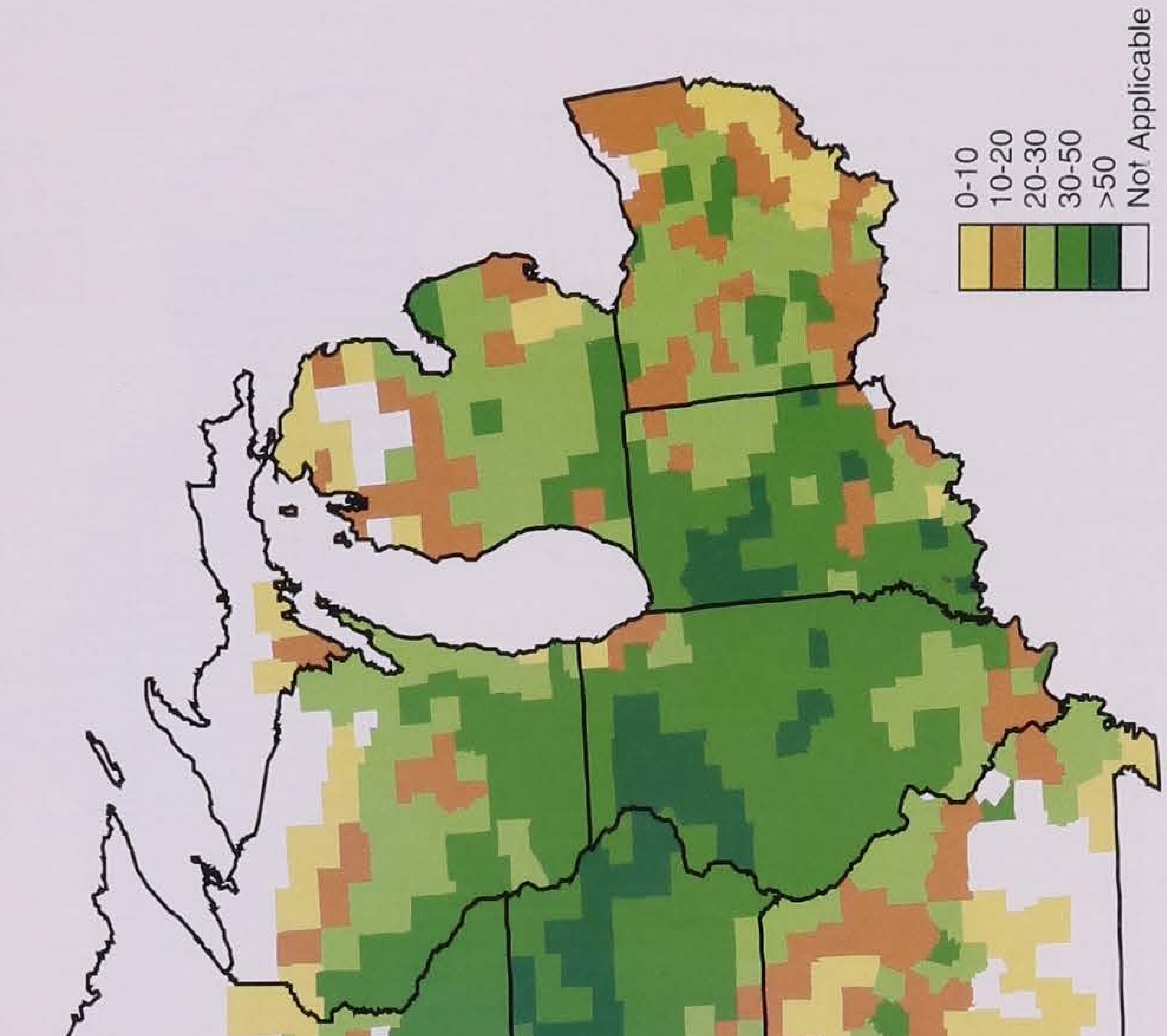
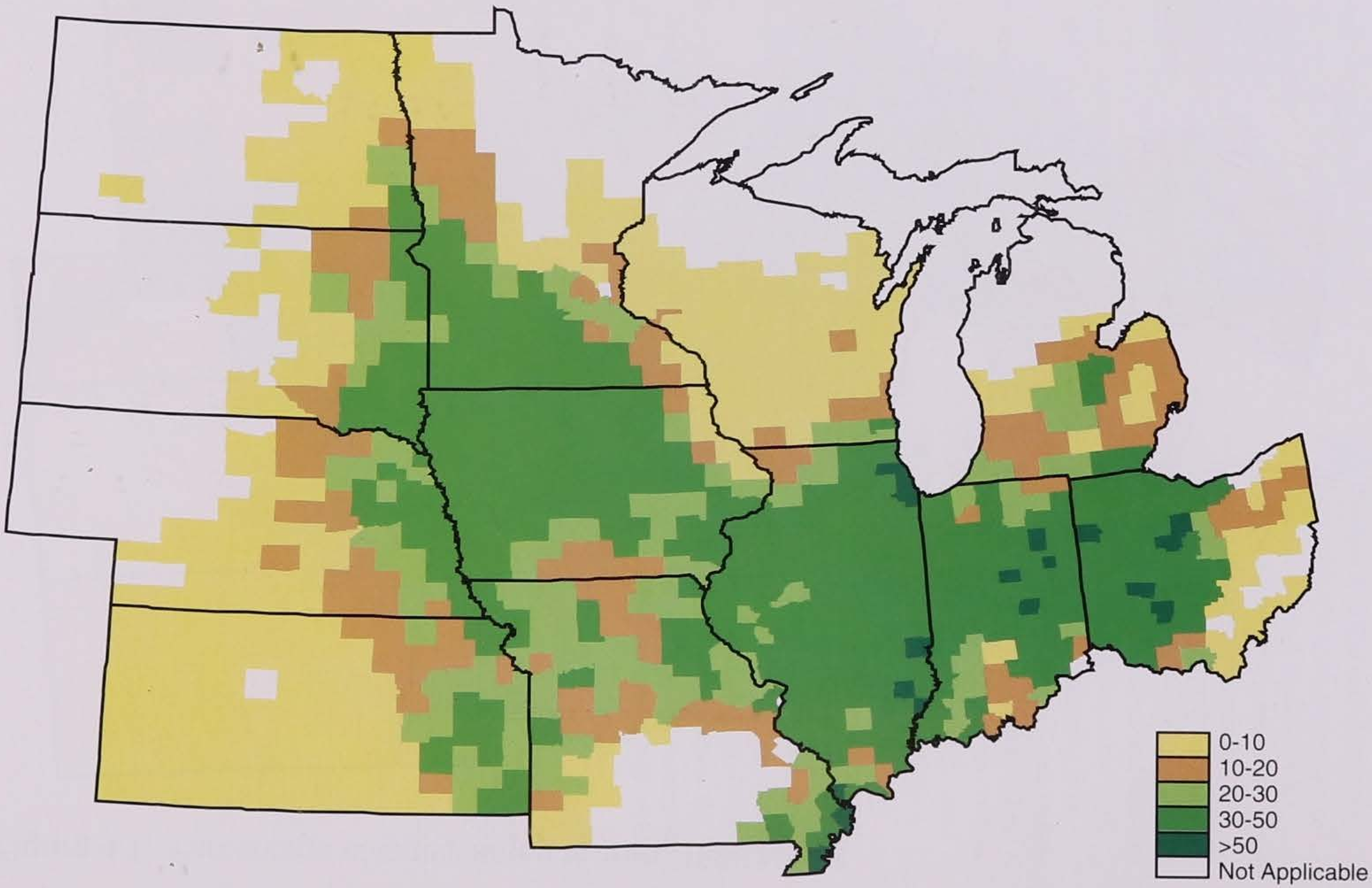


Figure 4.1. Percentage of land planted to corn, 1996 NASS

Figure 4.2. Percentage of land planted to soybeans, 1996 NASS



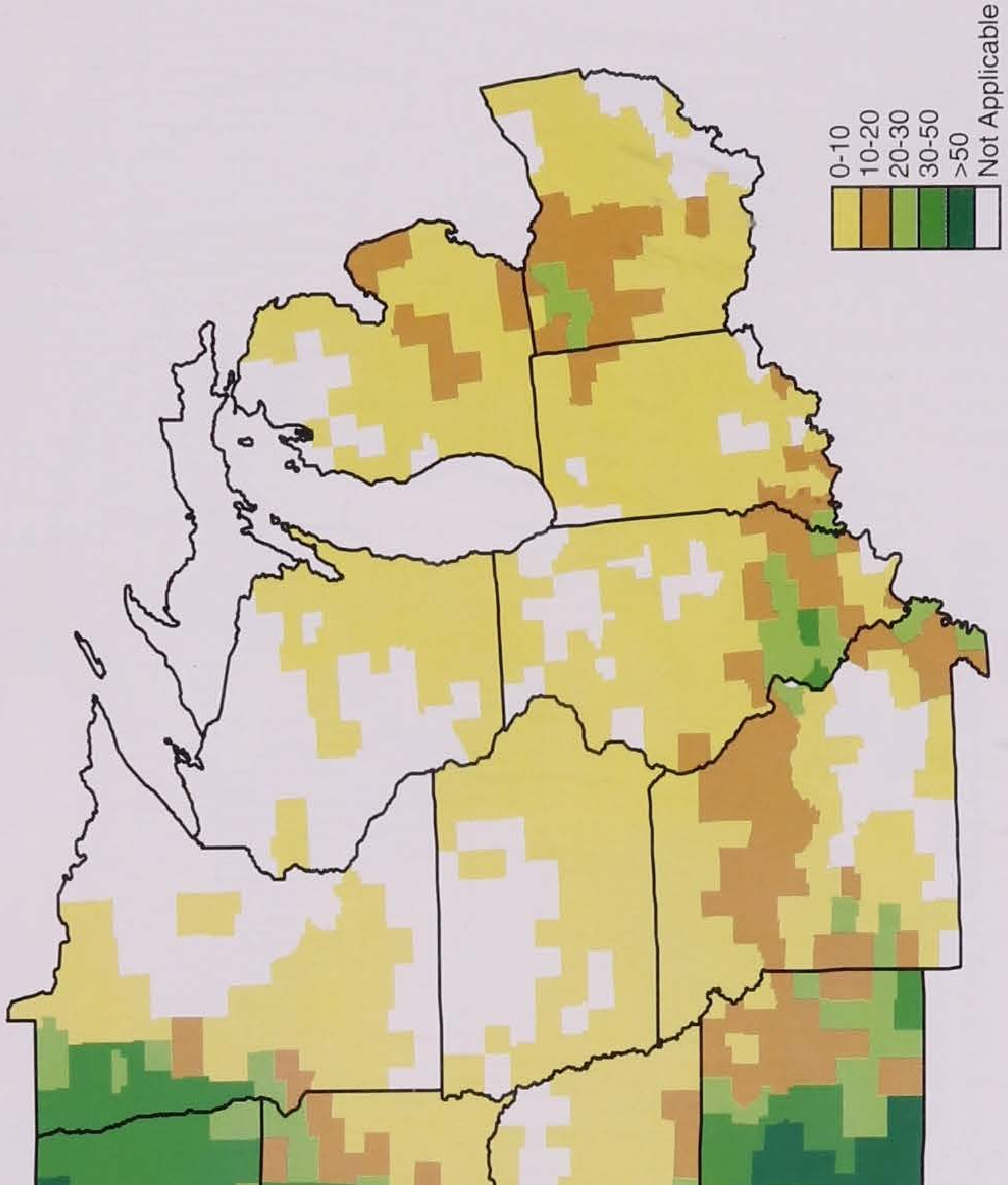
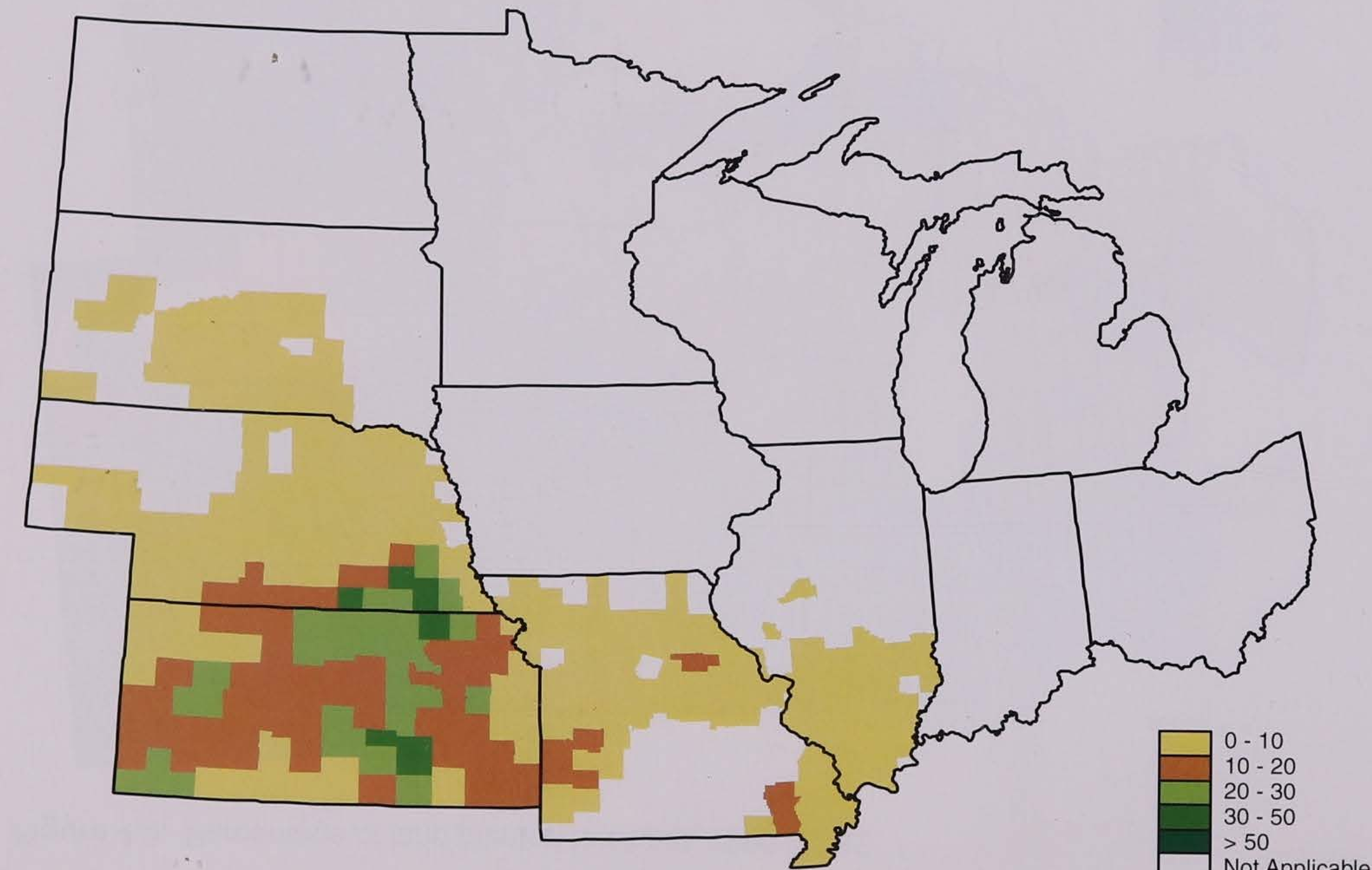


Figure 4.3. Percentage of land planted to wheat, 1996 NASS

Figure 4.4. Percentage of land planted to sorghum, 1996 NASS



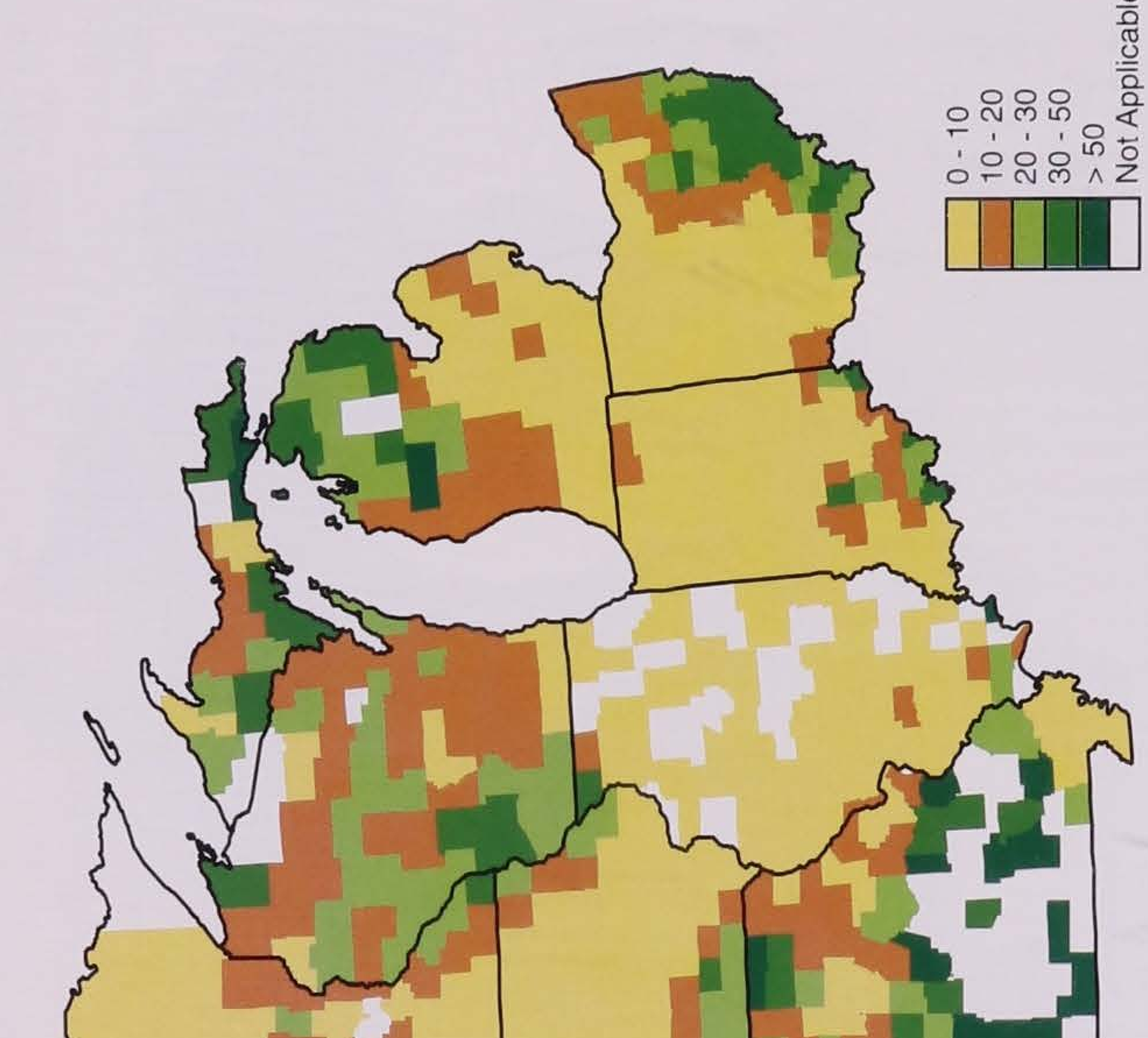
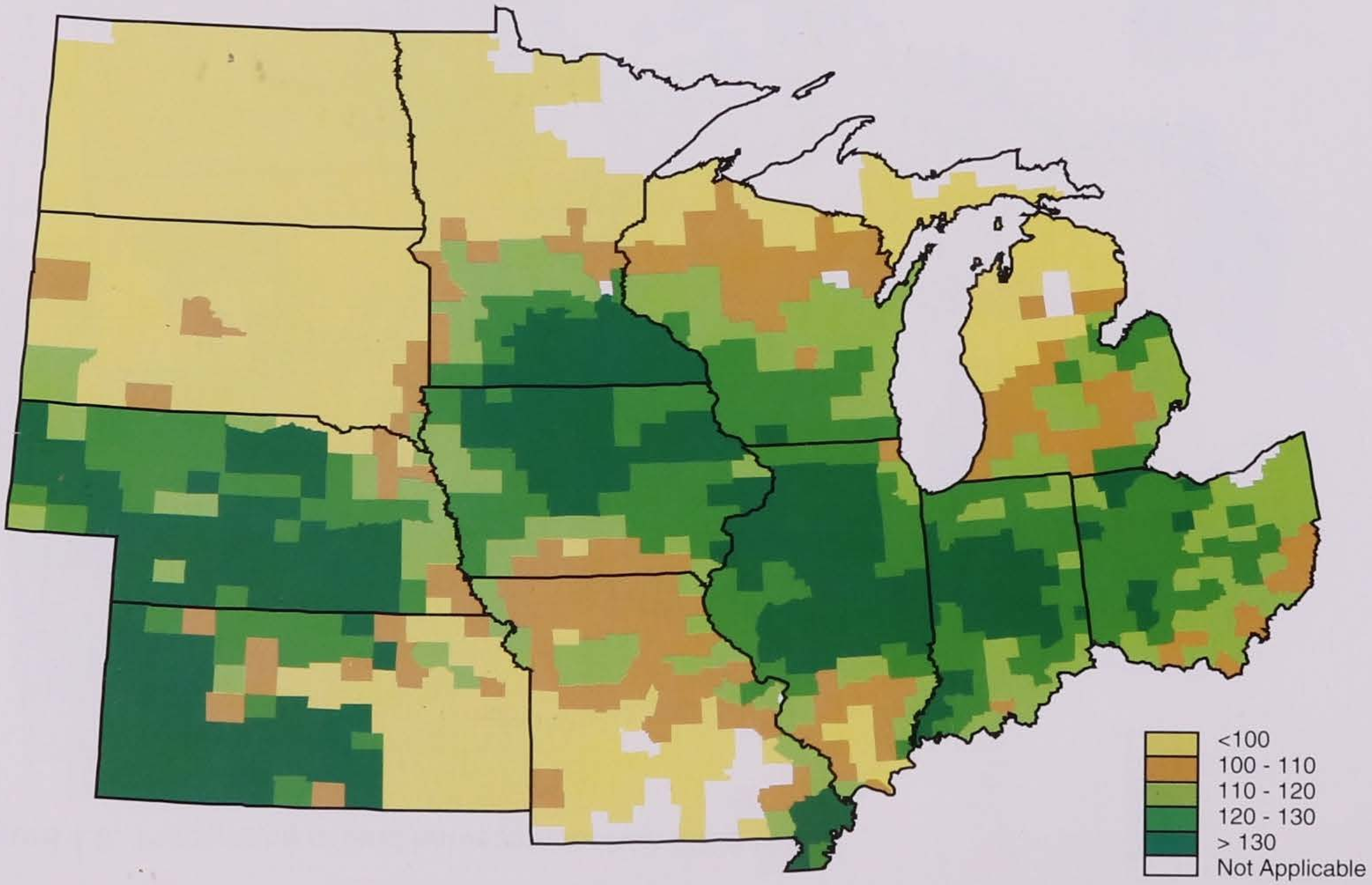


Figure 4.5. Percentage of land harvested for hay, 1996 NASS

Figure 4.6. Expected corn yields in 1997, bushels/acre



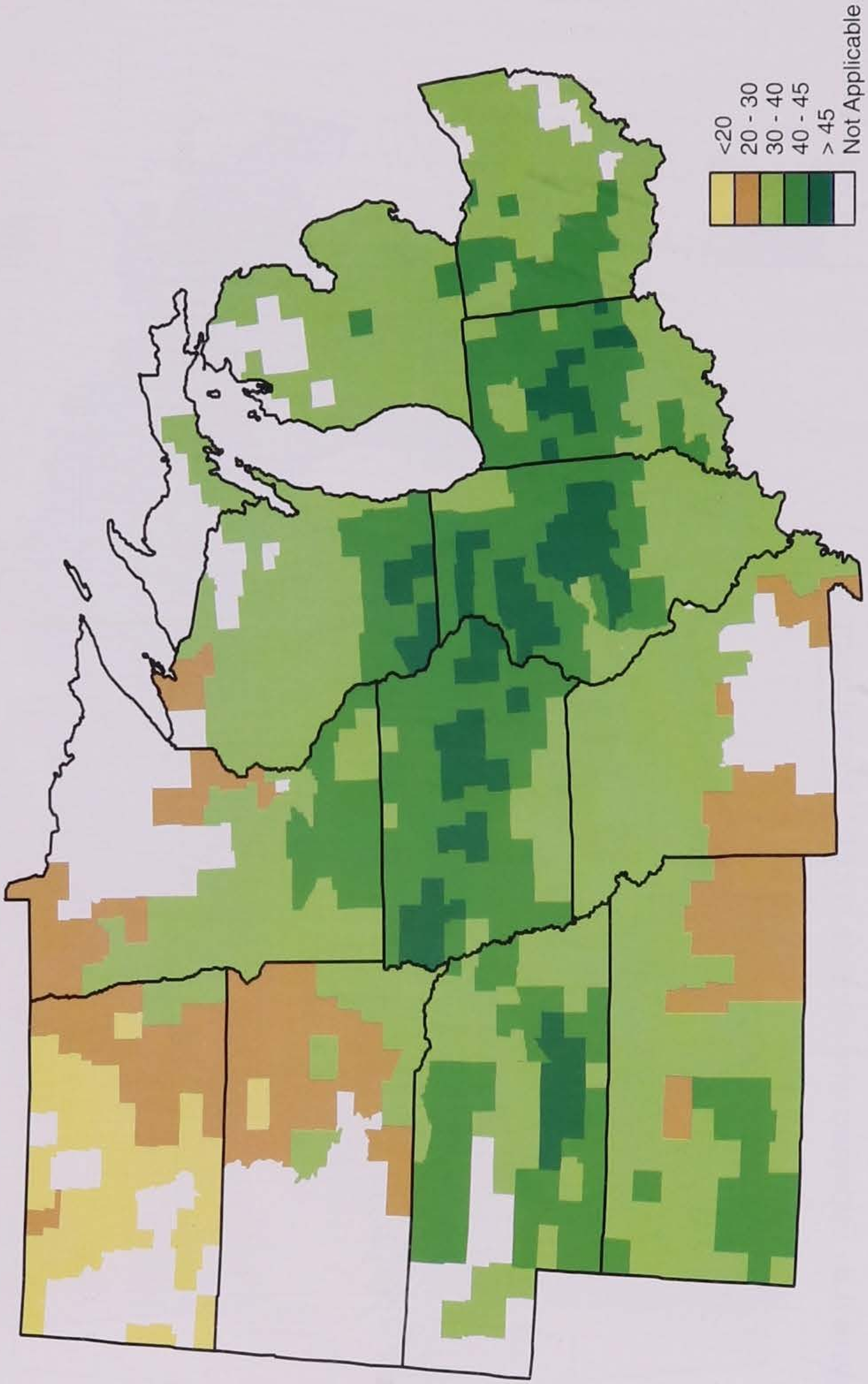
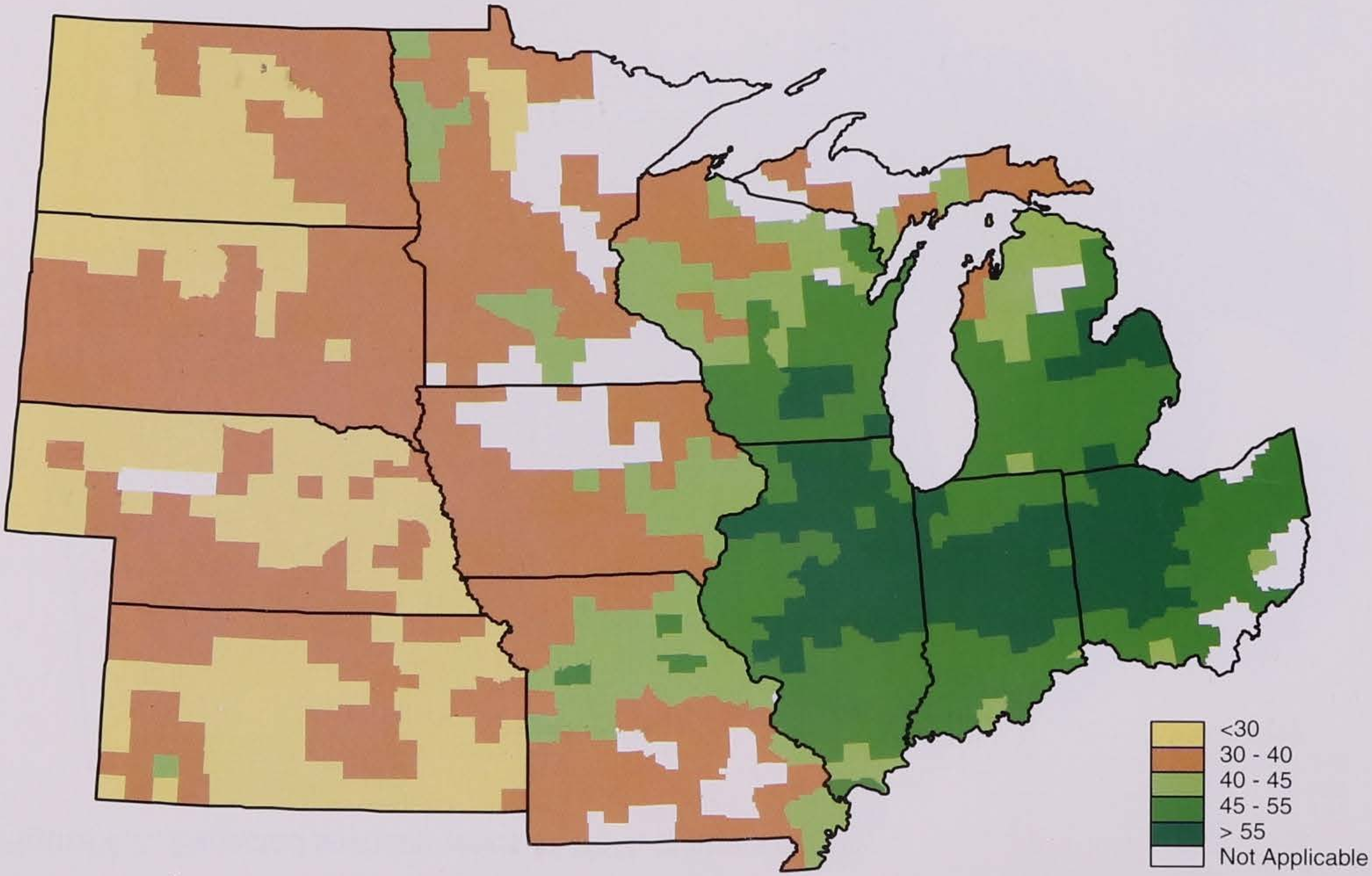


Figure 4.7. Expected soybean yields in 1997, bushels/acre

Figure 4.8. Expected wheat yields in 1997, bushels/acre



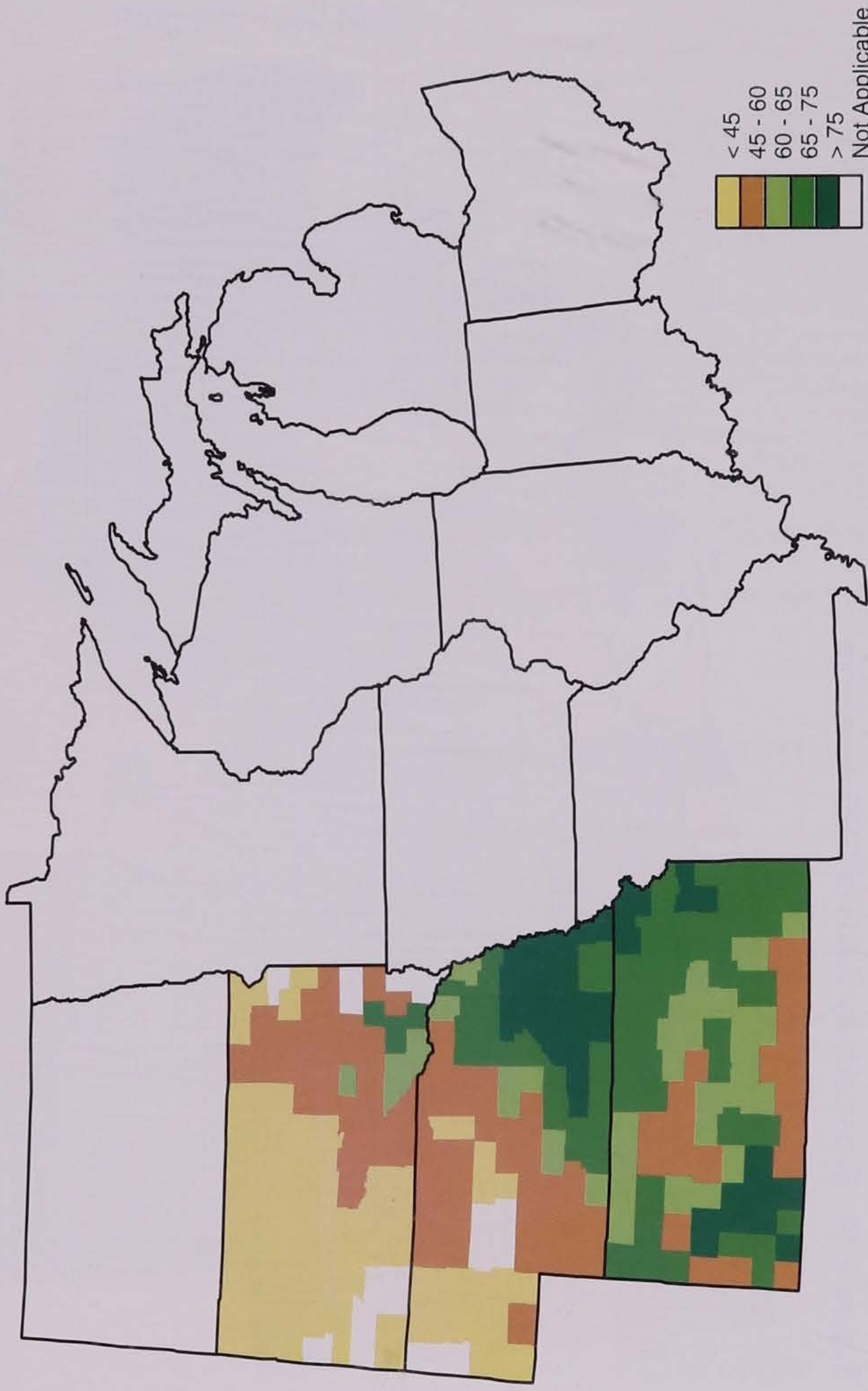


Figure 4.9. Expected sorghum yields in 1997, bushels/acre

Figure 4.10. Expected hay yields in 1997, tons/acre

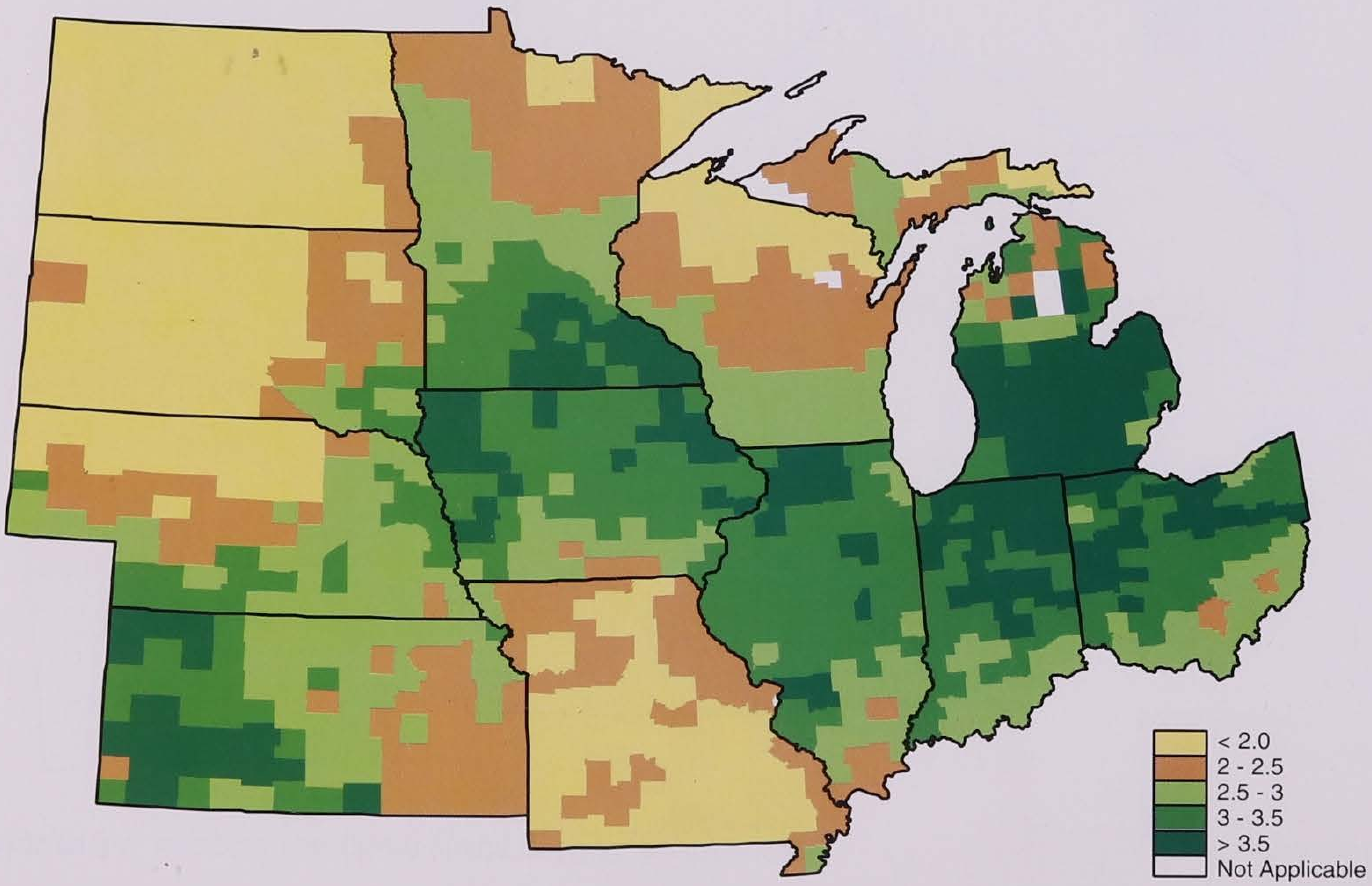


Figure 4.11. Percentage of land in the Conservation Reserve Program, 1992 NRI

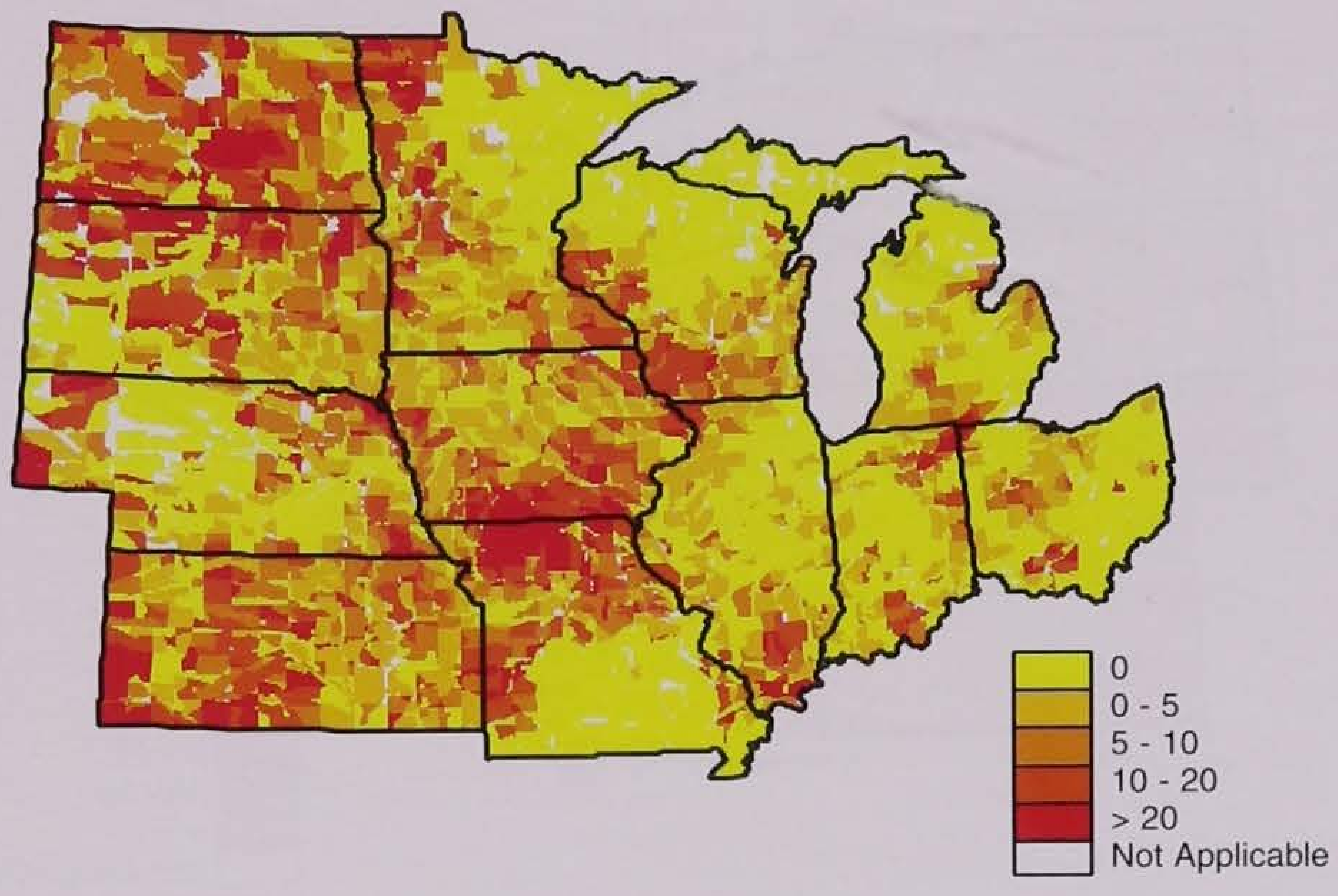


Figure 4.12. Percentage of land cultivated using conservation tillage, 1992 NRI

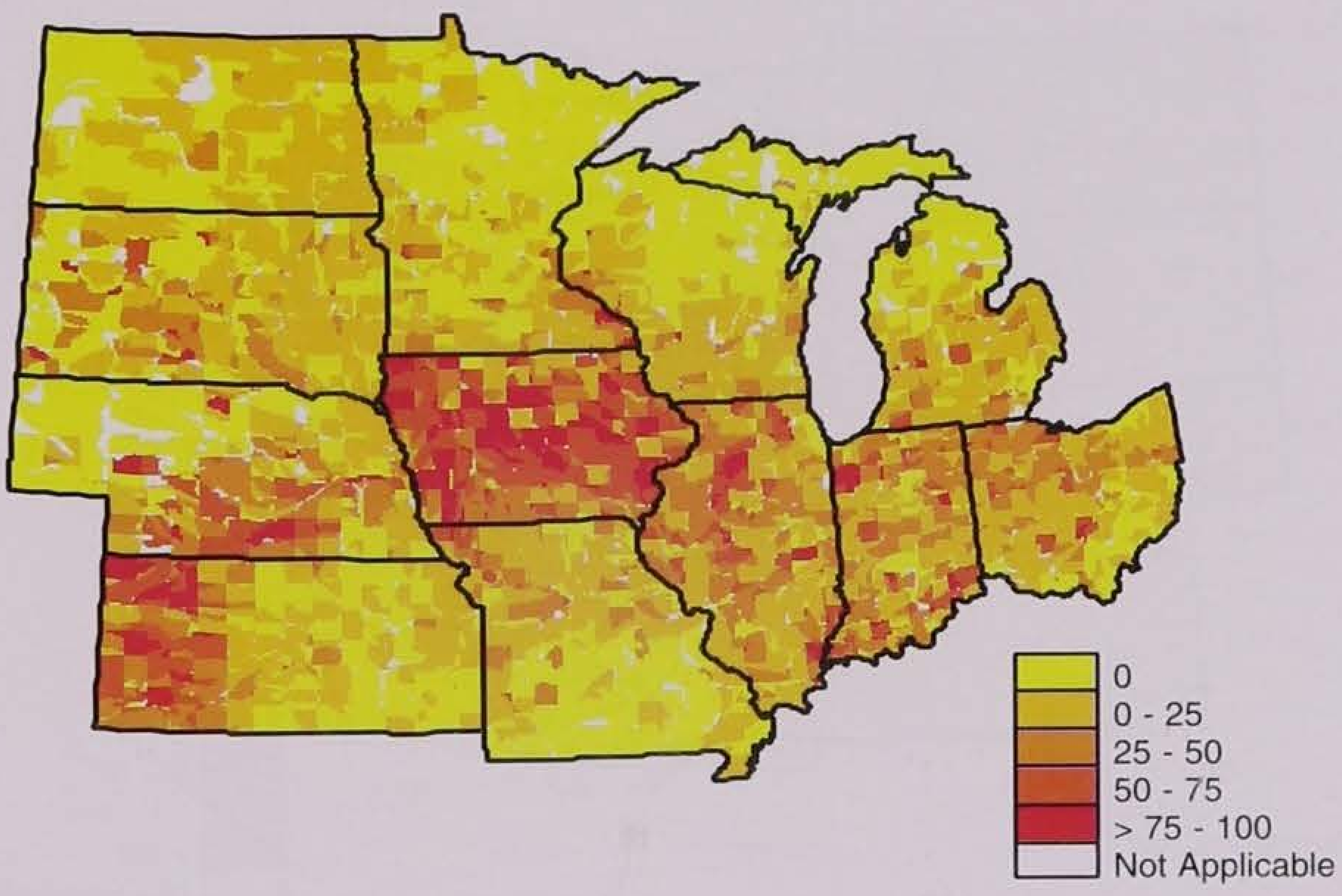


Figure 4.13. Percentage of irrigated land, 1992 NRI

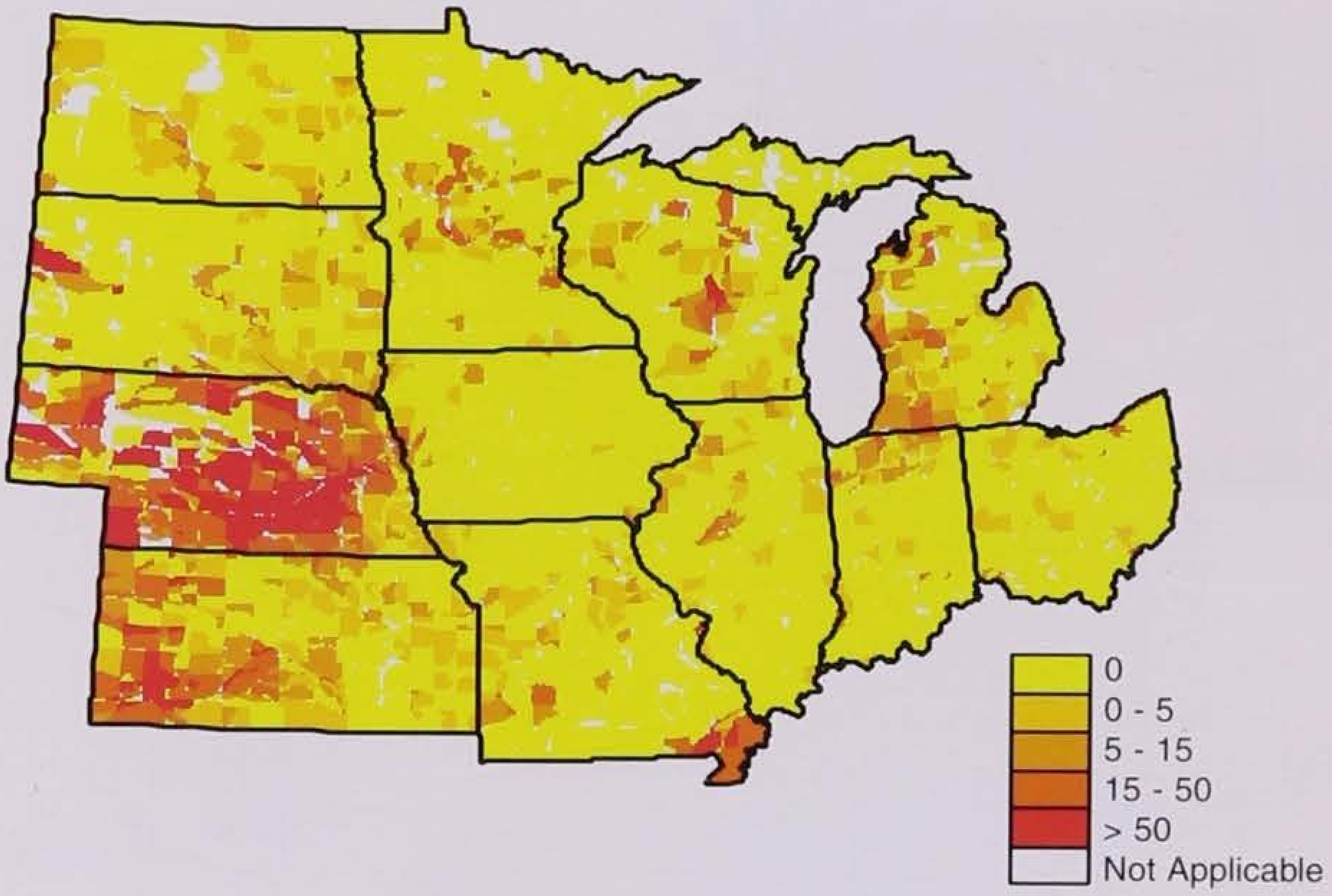


Figure 4.14. Percentage of tiled land, 1992 NRI

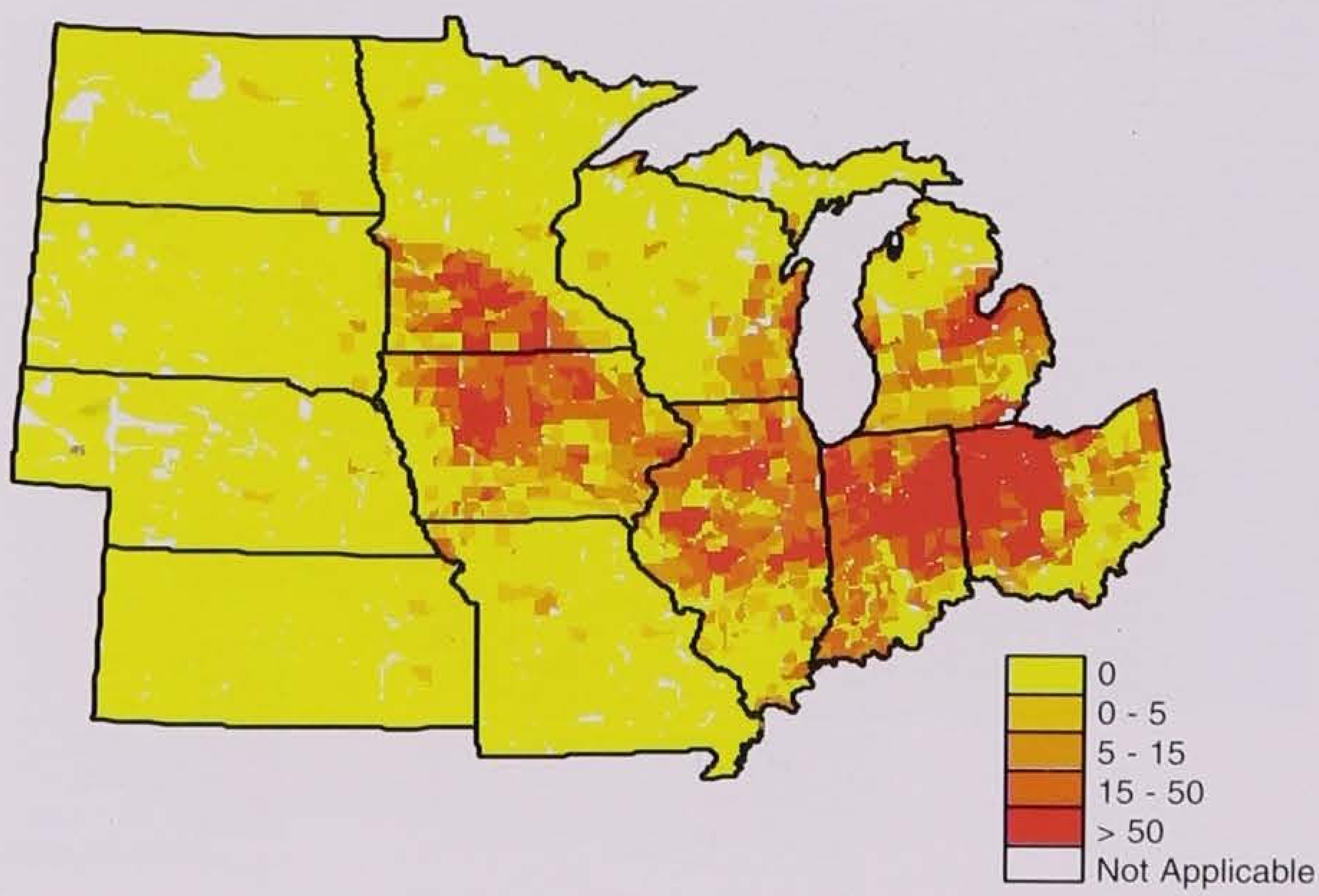


Figure 4.15. Percentage of land with grassed waterways, 1992 NRI

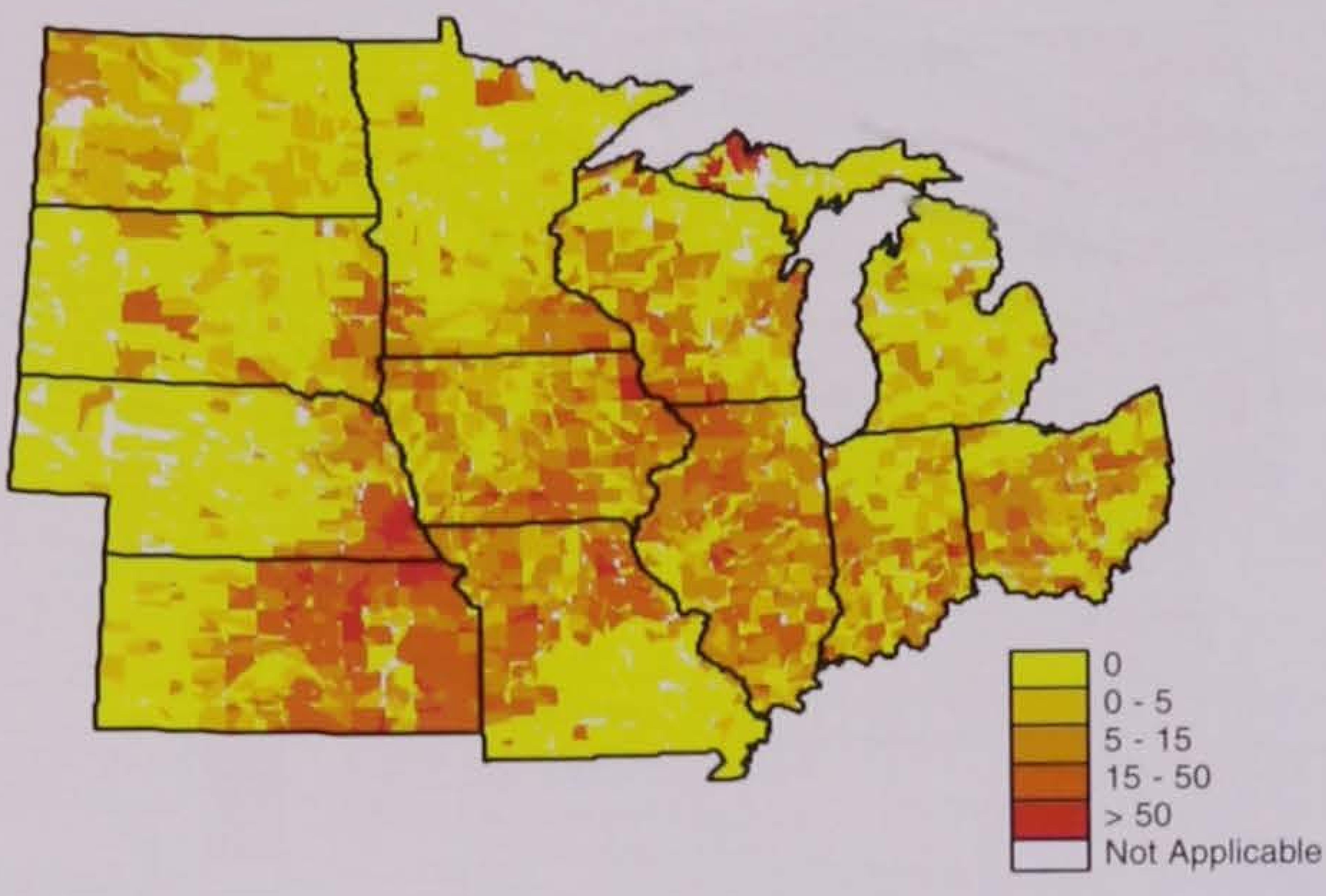


Figure 4.16. Percentage of land contour cropped, 1992 NRI

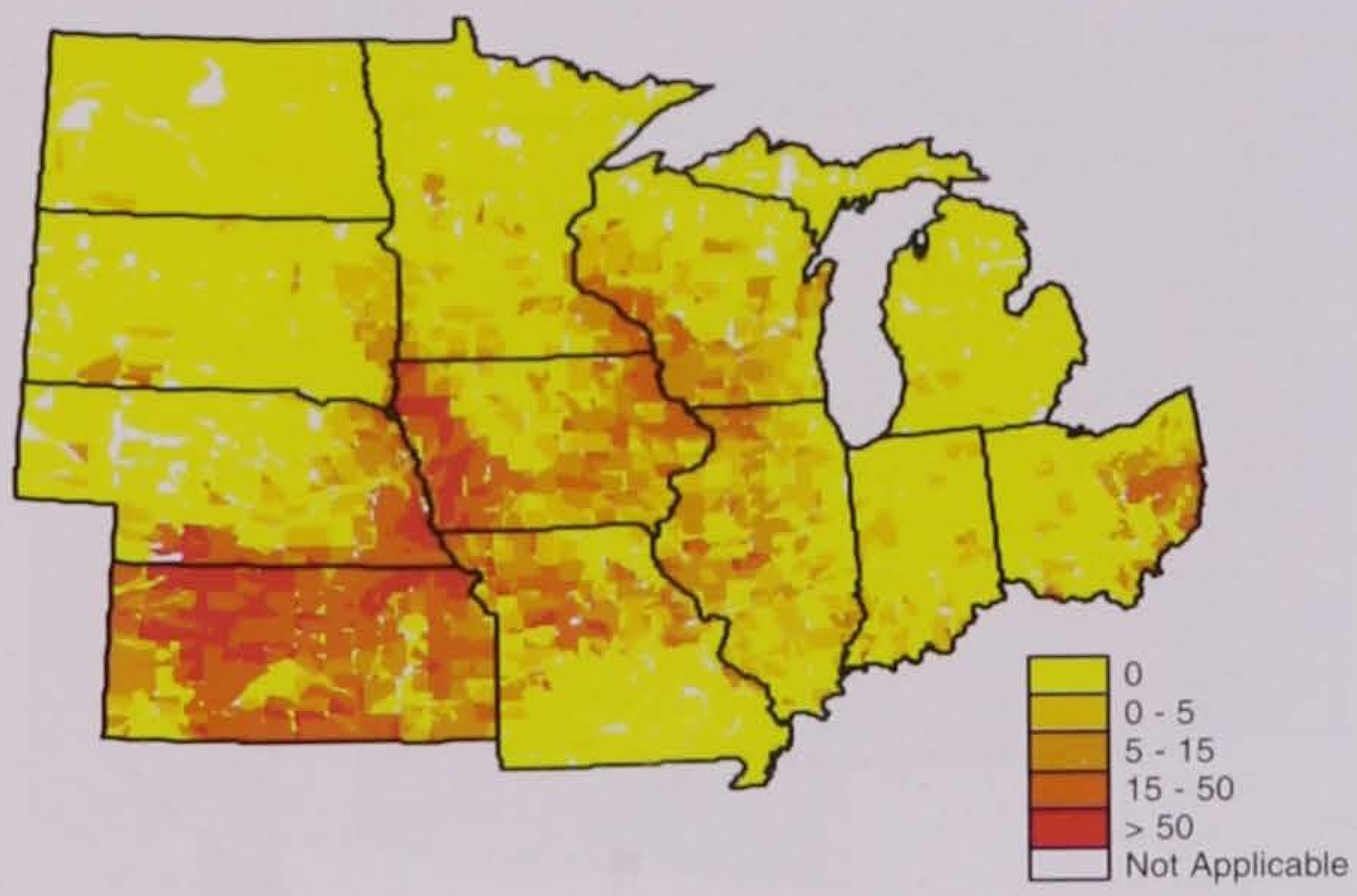


Figure 4.17. Percentage of land strip cropped, 1992 NRI

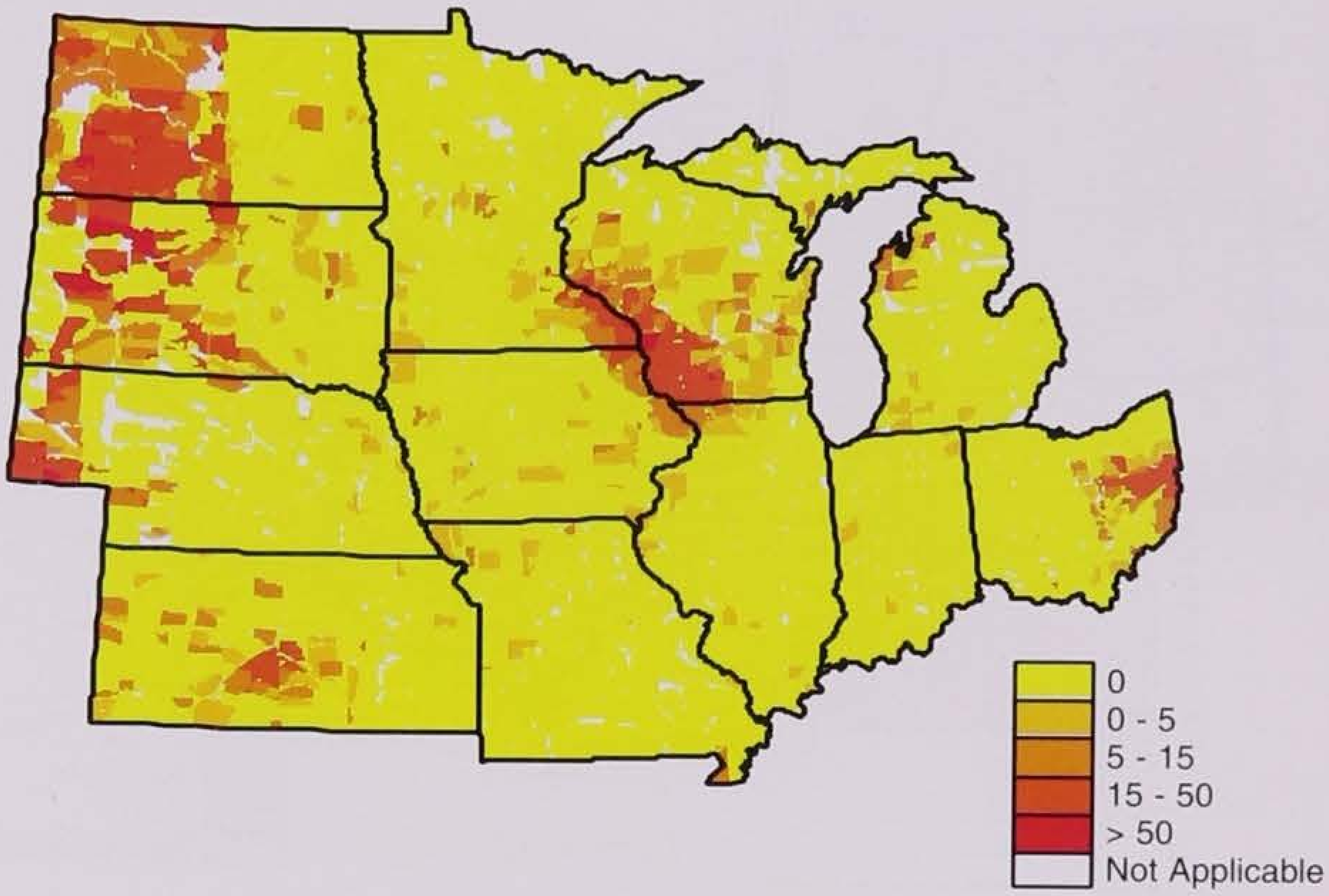
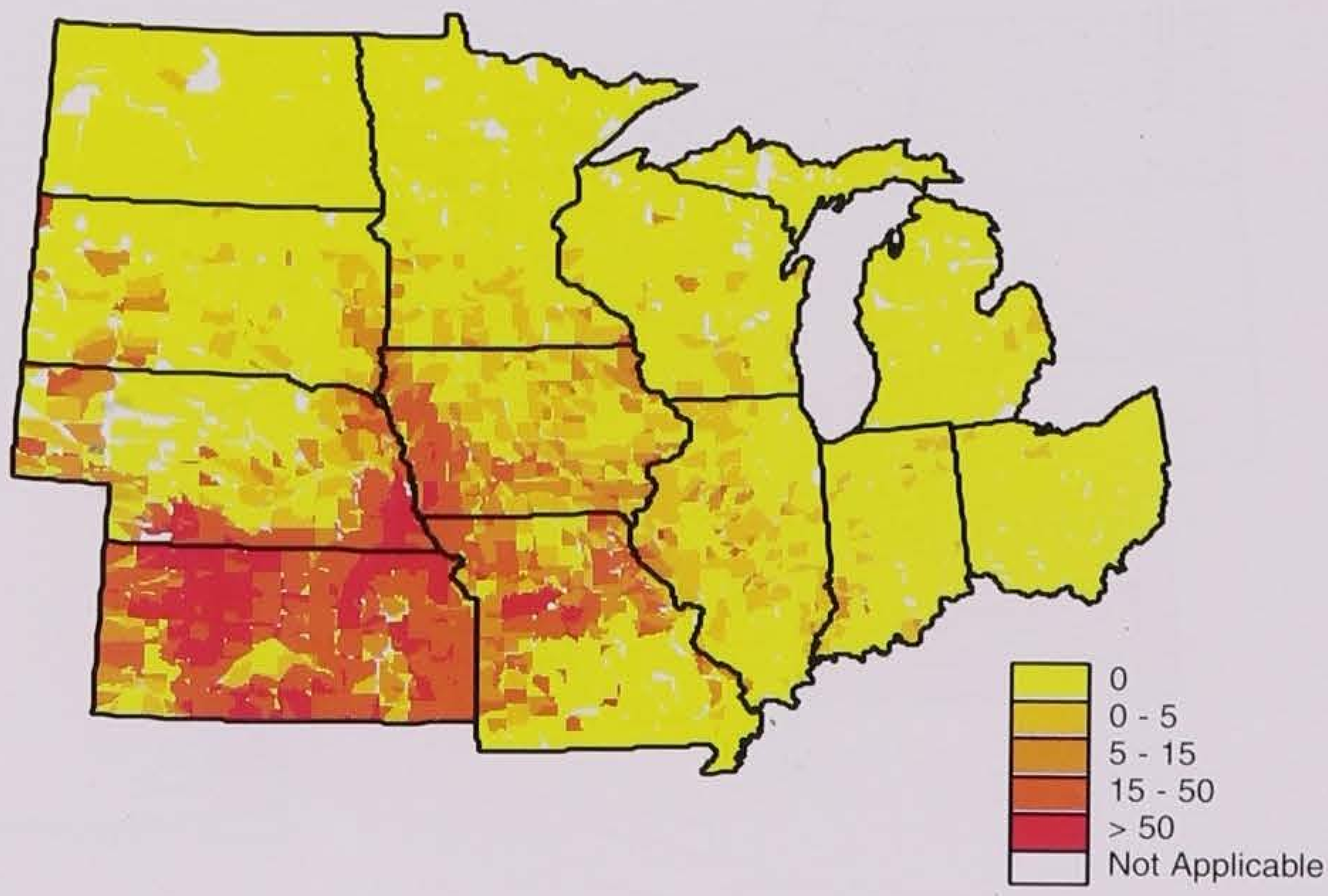


Figure 4.18. Percentage of land terraced, 1992 NRI



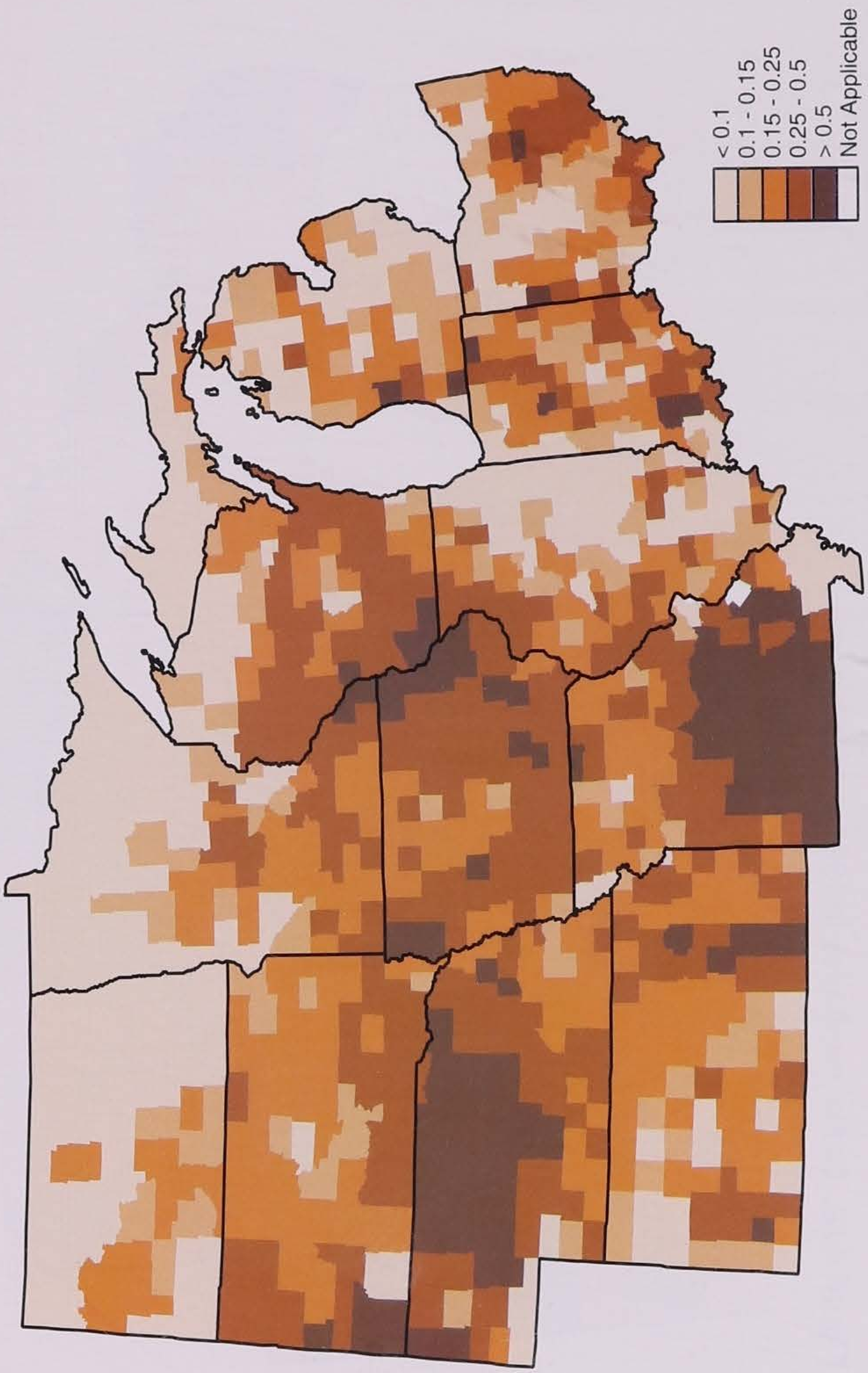
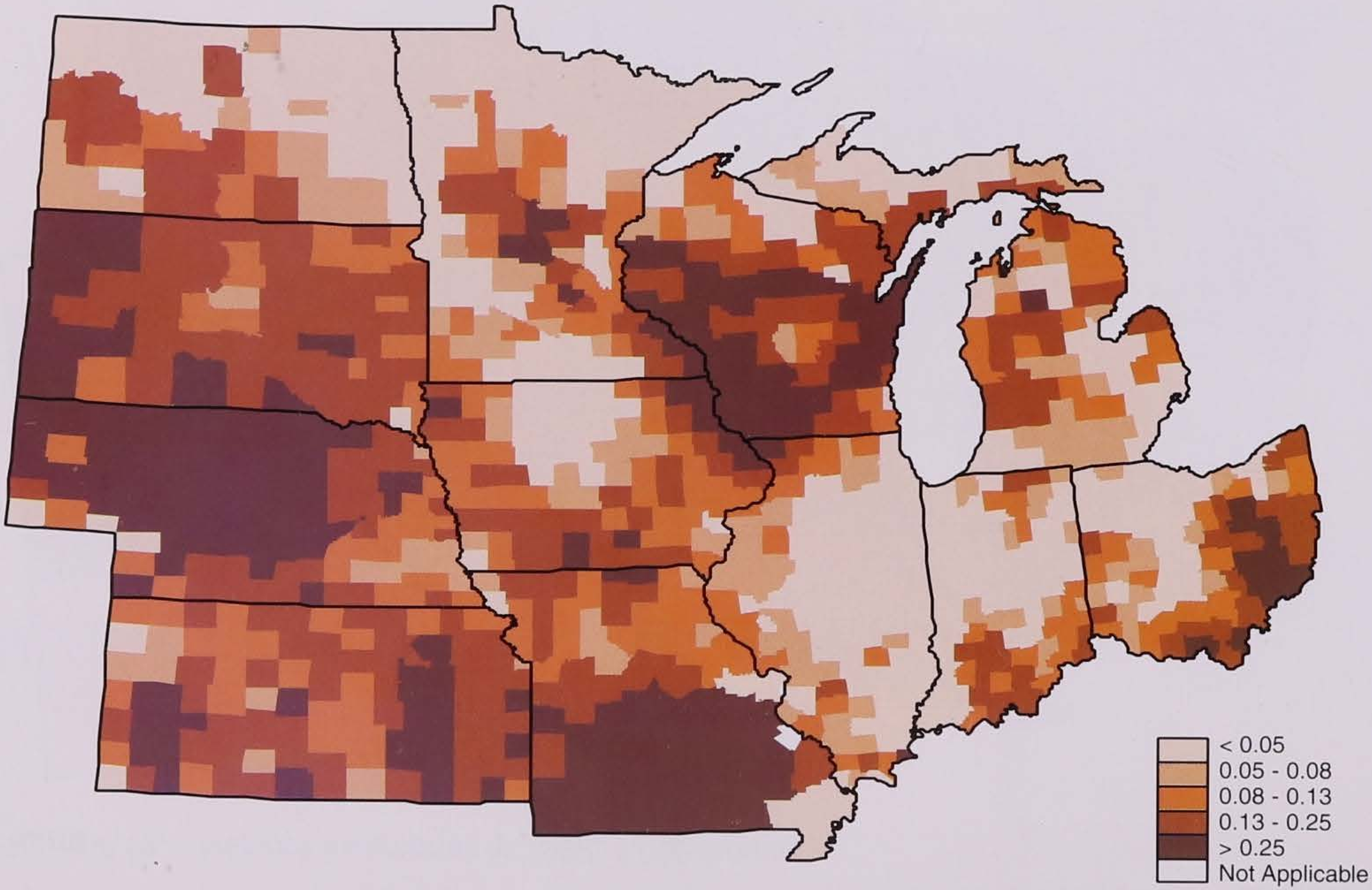


Figure 4.19. Livestock inventories in 1992, 1,000 lb/acre

Figure 4.20. Cattle inventories in 1992, 1,000 lb/acre



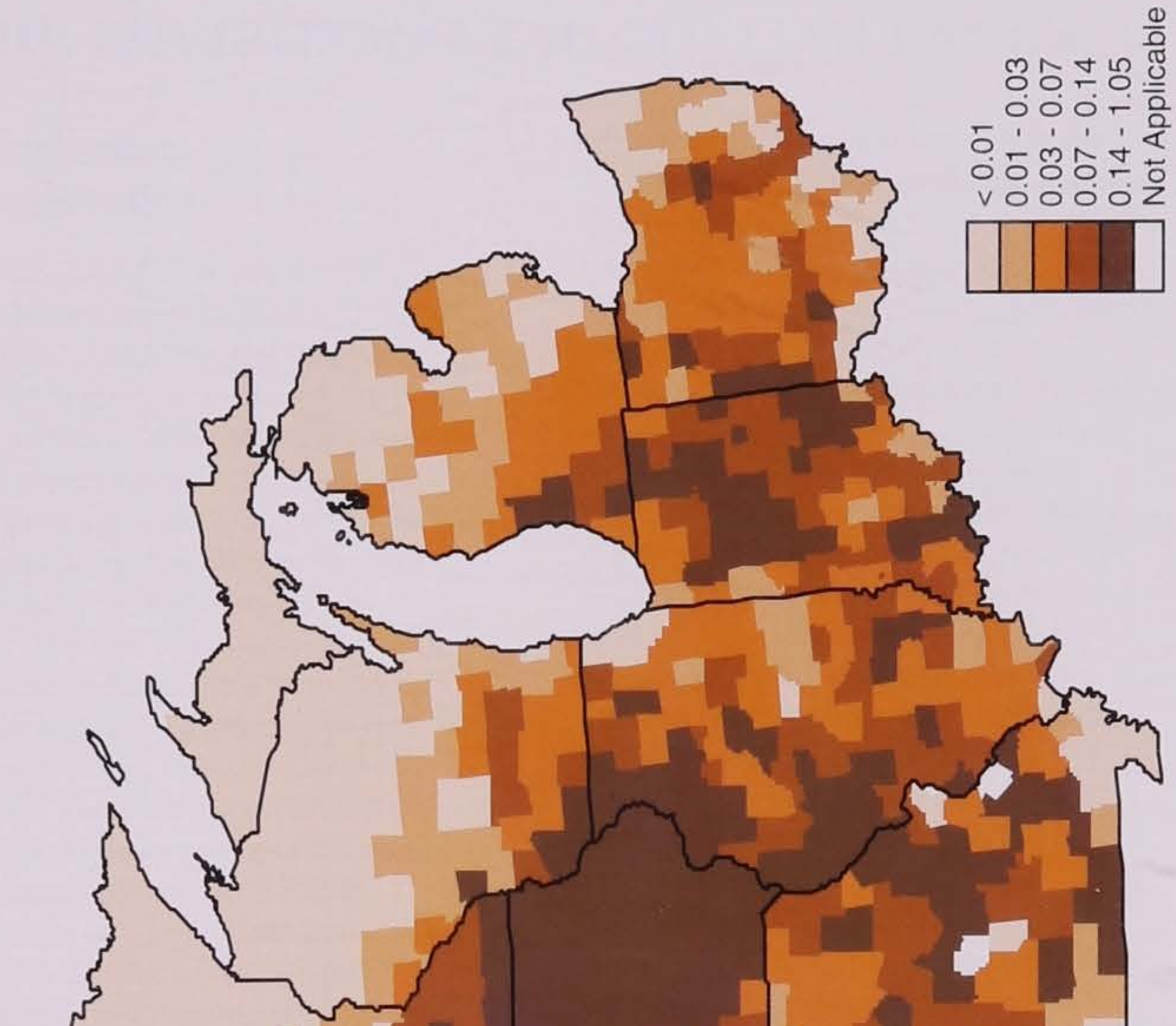


Figure 4.21. Hog inventories in 1992, 1,000 lb/acre

5. RECENT CHANGES IN PRODUCTION AND THE ENVIRONMENTAL CONSEQUENCES

Crop Production and Conservation

The FAIR Act of 1996 gives most U.S. farmers freedom to choose which crops to grow. Therefore, the relative profitability of crops is what now drives cropping patterns. In the past, government payments played a large role in driving cropping patterns. Under the old policy, farmers who wanted to plant more or less of certain crops risked losing federal subsidies. The loss of subsidies created a strong incentive for farmers to maintain production levels of program crops (barley, corn, upland cotton, oats, rice, sorghum, and wheat). Thus, the old program rules artificially held down production levels of nonprogram crops, such as oilseeds.

The first crop year when farmers had sufficient knowledge of the new program rules to adjust their planting decisions was 1997. The extent to which farmers devoted fewer acres to program crops and more acres to nonprogram crops under the new rules is shown in Table 5.1. This table shows 1992 and 1997 crop acres by state, USDA production region (Lake States, Corn Belt, and Northern Plains), and for the entire study region.

Over the entire study region, corn acreage increased by a scant 0.3 percent, wheat acreage dropped by 7.0 percent, and sorghum acreage dropped by almost 16.0 percent. Soybean acreage increased by almost 23 percent. Thus, at least for wheat, sorghum, and soybeans, the FAIR Act seems to have had the predicted effect of increasing nonprogram crops in favor of program crops. The small aggregate increase of corn acreage from 65.6 to 65.8 million acres hides large changes in the distribution of acreage across the study region. In Iowa, corn acreage dropped by 1 million acres (7.6 percent) whereas in Missouri, acreage increased by 450,000 acres (17.8 percent). Kansas corn acreage increased by more than 1 million acres (56.6 percent), but in North Dakota, corn acreage dropped by 21 percent.

What occurred was that farmers in Missouri and Kansas planted more corn because they found that their farm resources, combined with crop prices, made corn a relatively more attractive alternative than other crops. In Iowa and North Dakota, corn was relatively less attractive, so acreage decreased. The FAIR Act gave farmers the ability to adjust crop acreage in this manner. It just happened that the optimal adjustment across the study region resulted in little net change in corn acreage.

Why did soybean acreage increase so dramatically? First, soybean acreage had been artificially held down because, under the old farm program, soybeans did not receive subsidies. So putting soybeans on a "level playing field" with corn and wheat naturally resulted in relatively more soybean acres. Nationally, the ratio of corn to soybean acres fell from 1.44 in 1992 to 1.18 in 1997. In the Corn Belt, where most of the nation's corn and soybeans are grown, this ratio fell from 1.22 to 1.02. So even though total corn acreage did not fall in absolute terms, it fell dramatically relative to soybean acreage. The second reason soybean acreage increased so dramatically is that the price of soybeans relative to other crops is high. The new farm policy

Table 5.1. ARMS crop acres

Region	Corn Acres			Soybean Acres			Wheat Acres			Sorghum Acres			Hay Acres		
	1992	1997	Change	1992	1997	Change	1992	1997	Change	1992	1997	Change	1992	1997	Change
	1,000 acres		percent	1,000 acres		percent	1,000 acres		percent	1,000 acres		percent	1,000 acres		percent
Corn Belt															
Illinois	11,207	11,201	-0.1	9,514	10,004	5.1	1,450	1,202	-17.1	258	151	-41.6	1,071	1,021	-4.7
Indiana	6,102	6,002	-1.6	4,551	5,452	19.8	801	697	-13.0	0	0		631	750	19.0
Iowa	13,203	12,202	-7.6	8,153	10,501	28.8	69	25	-64.0	2	0	-100.0	1,951	1,700	-12.8
Missouri	2,504	2,951	17.8	4,309	4,901	13.7	1,498	1,101	-26.5	743	445	-40.1	3,600	3,481	-3.3
Ohio	3,801	3,601	-5.3	3,695	4,500	21.8	1,220	1,202	-1.5	1	0	-100.0	1,402	1,251	-10.8
Region Total	36,817	35,956	-2.3	30,223	35,357	17.0	5,038	4,227	-16.1	1,003	595	-40.7	8,654	8,203	-5.2
Lake States															
Michigan	2,698	2,602	-3.6	1,450	1,900	31.1	651	542	-16.6	0	0		1,369	1,251	-8.7
Minnesota	7,227	7,001	-3.1	5,507	6,802	23.5	2,850	2,458	-13.7	1	0	-100.0	2,185	2,451	12.2
Wisconsin	3,906	3,803	-2.6	751	1,001	33.3	163	145	-11.2	2	0	-100.0	2,818	2,402	-14.7
Region Total	13,831	13,405	-3.1	7,708	9,703	25.9	3,663	3,145	-14.2	2	0	-100.0	6,372	6,104	-4.2
Northern Plains															
Kansas	1,852	2,900	56.6	1,911	2,350	23.0	12,020	11,400	-5.2	3,312	3,750	13.3	2,400	2,601	8.3
Nebraska	8,300	9,002	8.5	2,500	3,501	40.0	2,363	2,001	-15.3	1,702	950	-44.2	3,650	3,146	-13.8
North Dakota	1,011	799	-21.0	703	1,300	85.0	11,703	11,582	-1.0	1	0	-100.0	2,902	2,401	-17.3
South Dakota	3,817	3,754	-1.6	2,303	3,501	52.0	4,482	4,174	-6.9	581	272	-53.1	4,117	4,094	-0.5
Region Total	14,980	16,456	9.9	7,416	10,652	43.6	30,567	29,158	-4.6	5,596	4,973	-11.1	13,069	12,241	-6.3
Total	**65,627**	**65,817**	**0.3**	**45,347**	**55,712**	**22.9**	**39,268**	**36,530**	**-7.0**	**6,601**	**5,569**	**-15.6**	**28,095**	**26,548**	**-5.5**

allows farmers to plant crops for the market rather than for the government, which in recent years means that soybean acreage increased.

Where did farmers find the 10.3 million acres of land to devote to increased soybean production? The first source is a decrease in acreage devoted to other crops. Aggregate wheat acreage decreased by 3 million acres. Grain sorghum decreased by 1 million acres while hay decreased by 1.5 million acres. The other source of new soybean land was land brought out of CRP. Many CRP contracts expired in 1996 and a large proportion of CRP land brought into production in 1997 was planted to soybeans. As shown in Table 5.2, about 800,000 acres of CRP was brought back into production in the Corn Belt. In Iowa alone, 300,000 acres of CRP land from 1992 was put into production in 1997. Almost all of these acres were soybeans. The remaining soybean land was found by decreased acreage for other crops that are grown in the region, which include small grains and other oilseeds.

This switchover to soybeans illustrates the new flexibility of the U.S. agricultural sector. The sector is now able to respond to changes in market prices, which was one of the justifications for passing the FAIR Act.

Environment

The increased flexibility provided by the FAIR Act and higher commodity prices increased soybean acreage, while reducing the amount of land devoted

Table 5.2. ARMS conservation reserve and tillage acres

	Conservation Reserve Program			Conservation Tillage		
Region	**1992**	**1997**	**Change**	**1992**	**1997**	**Change**
	1,000 acres		percent	1,000 acres		percent
Corn Belt						
Illinois	711	732	2.9	10,862	8,615	-20.7
Indiana	415	380	-8.5	4,270	5,735	34.3
Iowa	2,097	1,745	-16.8	10,238	12,642	23.5
Missouri	1,604	1,626	1.4	5,672	6,389	12.7
Ohio	316	325	2.9	3,878	4,714	21.6
Region Total	5,143	4,806	-6.5	34,919	38,095	9.1
Lake States						
Michigan	255	326	28.1	2,017	2,751	36.4
Minnesota	1,812	1,560	-13.9	4,057	4,545	12.0
Wisconsin	665	666	0.2	1,757	2,070	17.8
Region Total	2,731	2,552	-6.6	7,830	9,366	19.6
Northern Plains						
Kansas	2,864	2,851	-0.4	5,447	6,665	22.4
Nebraska	1,363	1,249	-8.3	8,429	9,965	18.2
North Dakota	2,902	2,827	-2.6	4,288	4,858	13.3
South Dakota	1,762	1,695	-3.8	3,927	5,469	39.3
Region Total	8,890	8,622	-3.0	22,091	26,957	22.0
Total	**16,764**	**15,981**	**-4.7**	**64,840**	**74,418**	**14.8**

to CRP and other less intensively cultivated crops. This increased farming intensity is likely to result in adverse environmental consequences; however, they will be mitigated by retaining Conservation Compliance, which requires farmers to develop and implement conservation plans in order to remain eligible for federal farm programs. Partly as a result of Conservation Compliance, farmers have drastically increased the percentage of acreage farmed using conservation tillage (Table 5.2). Between 1992 and 1997, conservation tillage acreage increased by nearly 15 percent over the study region, from 64.8 to 74.4 million acres. With the exception of Illinois where conservation tillage decreased remarkably, all other states showed significant increases.

Understanding the environmental impacts of the FAIR Act and high commodity prices on the environment is confounded by Conservation Compliance. While the environmental impacts of increased soybean production are determined by a number of climatic and land resource characteristics, a few generalizations are possible. Converting CRP to soybean production increases soil erosion and chemical runoff and leaching. Planting soybeans instead of wheat and other less intensively farmed crops also increases soil erosion and chemical runoff and leaching. The environmental impact of retaining Conservation Compliance can either complement or counteract the effect of increased soybean production. Conservation tillage slows erosion by reducing runoff, but also allows more water to leach dissolved chemicals below the root zone. RAPS is designed to decompose the environmental changes into a cropping effect that shows the impact of the FAIR Act combined with higher commodity prices, and a tillage effect that shows the impact of Conservation Compliance and other extraneous factors that have influenced farm management practices.

Since the environmental impact of changes in crop choice and management vary widely according to climactic and land resource characteristics, RAPS uses ARMS to predict the spatial distribution of cropping and management decisions for 1992 and 1997 given NASS estimates of planted acres. SIPP then uses ARMS predictions to evaluate the effect of cropping choices and management practices on indicators of erosion, soil organic carbon, nitrogen, and atrazine lost from agricultural production to the environment where they can end up in the atmosphere, groundwater supplies, and surface water supplies.

Soil Erosion

About 30 percent of U.S. farmland has been abandoned over the last 200 years primarily because of soil erosion. In the last 150 years, Iowa has lost half of its topsoil to erosion. Pimentel et al. (1995) estimates that soil erosion costs the United States $44 billion annually. Soil erosion removes fertile topsoil, which reduces soil quality and land productivity. Pimental et al. attributes about 40 percent of annual U.S. losses, $19 billion, to decreased soil fertility, and another 20 percent, $8 billion, to erosion control costs. Soil erosion also contributes to water and air pollution. About 60 percent of eroded soil enters streams and rivers, increasing water treatment costs, reducing reservoir storage capacity, disrupting drainage, increasing flooding, and damaging sensitive aquatic ecosystems. Wind erosion damages property by sandblasting and reduces air quality, which adversely affects human health. Pimentel et al. attributes the remaining 40 percent of the annual erosion losses, $17 billion, to pollution damage.

The FAIR Act's elimination of price supports increased soil erosion; however, maintaining Conservation Compliance mitigated this increase so that soil erosion actually fell between 1992 and 1997. In 1992, 14.2 billion tons of soil were lost to erosion in the study region (Table 5.3). This total declined by almost 4 percent, falling to 13.7 billion tons. Increased planting flexibility and higher commodity prices tended to increase soil erosion, with the exception of Ohio's small decrease, because farmers moved to more erosive corn and soybean rotations. With the exception of Illinois where use of conservation tillage generally decreased, Conservation Compliance and changes in cultivation decreased soil erosion. For all the Corn Belt states except Illinois, Michigan, and all the Northern Plains states except North Dakota, increases in soil erosion due to increased planting flexibility and higher commodity prices were more than offset by Conservation Compliance and less erosive cultivation.

High levels of water erosion are concentrated along the major river valleys where the land has steeper slopes: the Missouri River in Iowa, Nebraska, and Kansas, the Mississippi River in Iowa, Wisconsin and Illinois, and to some extent the Ohio River, especially in Illinois (Figure 5.1). The highest wind erosion levels occur in Kansas and Nebraska, with a broad band stretching from central Iowa to North Dakota also noticeable (Figure 5.2).

Soil Organic Carbon

Soil organic carbon exerts a profound influence on soil structure and properties such as available water-holding capacity, permeability, bulk density, and pH. High levels of SOC generally

Table 5.3. Soil erosion

Region	1992	1997	Crop Change	Tillage Change	Net Change	
			million tons			percent
Corn Belt						
Illinois	166.61	187.28	5.34	15.32	20.66	12.4
Indiana	71.02	61.95	3.03	-12.11	-9.08	-12.8
Iowa	252.13	223.89	5.44	-33.68	-28.24	-11.2
Missouri	85.37	78.08	0.82	-8.12	-7.30	-8.5
Ohio	55.54	50.37	-1.37	-3.80	-5.17	-9.3
Region Total	630.69	601.56	13.26	-42.39	-29.12	-4.6
Lake States						
Michigan	31.37	28.51	1.60	-4.46	-2.86	-9.1
Minnesota	102.59	103.12	3.13	-2.61	0.53	0.5
Wisconsin	59.09	62.46	4.03	-0.66	3.37	5.7
Region Total	193.05	194.09	8.77	-7.73	1.04	0.5
Northern Plains						
Kansas	242.02	236.56	5.74	-11.20	-5.46	-2.3
Nebraska	174.34	156.87	3.68	-21.15	-17.47	-10.0
North Dakota	97.71	98.55	3.31	-2.47	0.84	0.9
South Dakota	82.85	80.68	6.50	-8.68	-2.17	-2.6
Region Total	596.93	572.66	19.22	-43.49	-24.26	-4.1
Total	**1,420.67**	**1,368.32**	**41.26**	**-93.61**	**-52.35**	**-3.7**

coincide with good soil quality. The rate of loss of SOC is highly correlated with soil erosion since organic matter resides in the eroded soils. The loss of SOC through erosion also helps explain lost soil fertility. In addition, tillage increases soil aeration resulting in the microbial conversion of SOC to CO_2, a significant greenhouse gas. As a result agricultural soils are generally a net CO_2 source, with global annual net emissions of about 13 percent of fossil fuel emissions (Schlesinger 1995).

Cropping flexibility and increased commodity prices have had a negative environmental effect on the rate of loss of SOC, but this effect has generally been offset by Conservation Compliance and improved soil management. The rate of loss of SOC fell nearly 3 percent, from 36.2 to 35.2 million tons, between 1992 and 1997 (Table 5.4). The decrease in the rate of loss of SOC due to Conservation Compliance and changes in cultivation were substantially larger than the increase in the rate of loss caused by planting flexibility and higher commodity prices. Illinois and North Dakota are the only states that show a net increase. Illinois's net increase is attributable to its remarkable decline in the use of conservation tillage, while North Dakota's net increase is attributable to soybean acres replacing hay, sorghum, and wheat acres.

The map of the annual rate of change in SOC losses (Figure 5.3) shows that most agricultural soils in the Midwest are losing SOC, a typical finding for U.S. agriculture (Kern and Johnson 1993; Mitchell et al. 1997). Referring to Figure 3.1, the more productive land with high levels of SOC generally has the highest loss rates; however, high loss rates in western Kansas and North Dakota are worrisome, since there is relatively little

Table 5.4. Soil organic carbon gained annually by cropland

Region	1992	1997	Crop Change	Tillage Change	Net Change	
		1,000 tons				percent
Corn Belt						
Illinois	-3,409.87	-3,728.07	-46.37	-271.84	-318.21	-9.3
Indiana	-1,244.78	-1,055.64	43.14	146.00	189.14	15.2
Iowa	-5,418.22	-4,984.52	-26.61	460.31	433.71	8.0
Missouri	-1,575.61	-1,481.47	7.69	86.45	94.14	6.0
Ohio	-2,158.24	-2,055.79	39.06	63.39	102.45	4.7
Region Total	-13,806.72	-13,305.49	16.92	484.31	501.23	3.6
Lake States						
Michigan	-225.48	-97.50	65.47	62.51	127.98	56.8
Minnesota	-3,805.85	-3,747.52	-2.44	60.76	58.32	1.5
Wisconsin	-94.80	-93.47	-13.69	15.02	1.33	1.4
Region Total	-4,126.13	-3,938.49	49.34	138.30	187.64	4.5
Northern Plains						
Kansas	-6,094.27	-6,028.87	-51.98	117.38	65.40	1.1
Nebraska	-3,558.76	-3,350.96	-27.04	234.84	207.80	5.8
North Dakota	-5,699.38	-5,744.83	-103.02	57.58	-45.44	-0.8
South Dakota	-2,927.40	-2,793.81	-5.31	138.90	133.59	4.6
Region Total	-18,279.82	-17,918.48	-187.35	548.69	361.34	2.0
Total	**-36,212.67**	**-35,162.46**	**-121.09**	**1,171.30**	**1,050.21**	**2.9**

SOC there already. The areas of SOC accumulation around the Great Lakes are generally on productive land and are indications of good soil management.

Nitrogen

Nitrogen lost from agriculture through leaching or runoff is usually found in ground and surface water as nitrate where it can have adverse consequences. The U.S. Geological Survey's National Water Quality Assessment Program (NWQAP) reports that nitrate concentrations were highest in groundwater from agricultural areas, with about 12 percent of domestic wells exceeding the EPA's drinking water standard (USGS 1996). NWQAP also found elevated surface water nitrate levels associated with agricultural areas. The primary health concern from drinking water high in nitrates is methemoglobinemia, a condition in which hemoglobin cannot carry sufficient oxygen through the blood. Infants are especially at risk, and pregnant women and nursing mothers are advised to avoid drinking water high in nitrates. Livestock are also at risk. The primary environmental concern of nitrate contamination is eutrophication and the resulting dissolved oxygen depletion (hypoxia). Currently, the most prominent example of hypoxia appears in the Gulf of Mexico (Beardsley 1997). The cause of hypoxia in the Gulf of Mexico has been linked convincingly to dissolved nutrients flowing in from the Mississippi River. Since commercial fertilizers are the dominant source of nitrogen in the Mississippi River basin, agriculture is a leading suspect (Battaglin et al. 1997).

The FAIR Act exacerbated already increasing nitrogen losses from Conservation Compliance increasing leaching. Nitrogen losses increased 1.6 percent between 1992 and 1997 from 1.41 million tons to 1.44 million tons (Table 5.5). This increase is due to cropping flexibility, higher commodity prices, conservation compliance, and other changes in cultivation practices. The increase in nitrogen losses due to cropping flexibility and higher commodity prices is attributable to an increase in corn and soybean rotations, and a movement of cropland out of hay, sorghum, wheat, and CRP. With the exception of Illinois, Conservation Compliance increased the amount of land cultivated using conservation tillage, which generally increases nitrogen leaching. The Corn Belt and Lake States led this trend because leaching is a more significant source of nitrogen losses in these states. With the exception of North Dakota where the increase in soybean production was particularly pronounced, the Northern Plains experienced decreasing nitrogen losses because climactic and land resource characteristics are not as prone to leaching.

The map of nitrogen leaching below the root zone (Figure 5.4) shows high losses occurring in the eastern part of the study region, as well as in north central Iowa and south central Minnesota. These are areas of high nitrogen application rates and plentiful rainfall. The map shows projections of the quantity leached below the root zone, not concentrations. Areas receiving high rainfall, such as the eastern Corn Belt, dilute leached nitrogen far more than in central Nebraska or Kansas. In addition, many of these same areas are heavily tiled, so that much of the nitrogen leached below the root zone actually passes through a tile line and into surface water.

The map of nitrogen runoff losses (Figure 5.5) shows a broad band of high loss stretching from Kansas, through

Nebraska and Iowa, and down into Illinois. Again these are quantities of nitrogen lost in runoff, not concentrations.

Atrazine

Atrazine was one of the first commercial herbicides available, and is still widely used for controlling broadleaf and grassy weeds, especially in corn. It can be washed from fields and into surface water supplies in the form of runoff, leached through the soil into groundwater, and volatilized into the atmosphere from the soil surface and plant leaves. As a result, atrazine is the most commonly detected herbicide in water. The USGS reports in the Midcontinent Herbicide Project's Significant Findings (1997) that atrazine and its metabolites are found year round in the ground and surface water of the Midwest. During the spring when concentrations are highest, streams and rivers can exceed the safe drinking water standard for weeks. From April through July, rainfall in the Midwest and Northeast contains detectable levels of volatilized atrazine. In a recent study of more than 1,000 municipal wells in Iowa between 1982 and 1995, Kolpin et al. (1997) reports an atrazine detection frequency of 19.5 percent. On the positive side, they also report a statistically significant decrease in median atrazine concentrations. The EPA currently classifies atrazine as a possible human carcinogen, and a possible link between triazine exposure and human breast cancer has resulted in a special review of atrazine and other triazine herbicides.

Atrazine losses decreased 12.4 percent between 1992 and 1997, from 199 to 174 million tons (Table 5.6). Increases in atrazine losses due to cropping flexibility and higher commodity prices were again more than offset by Conservation Compliance and a general decrease in application

Table 5.5. Nitrogen lost from cropland

Region	1992	1997	Crop Change	Tillage Change	Net Change	
		1,000 tons				percent
Corn Belt						
Illinois	188.68	192.52	5.70	-1.87	3.83	2.0
Indiana	151.71	153.53	0.28	1.55	1.83	1.2
Iowa	152.23	154.68	2.16	0.29	2.45	1.6
Missouri	98.24	101.34	2.43	0.67	3.10	3.2
Ohio	127.87	132.45	3.77	0.81	4.58	3.6
Region Total	718.72	734.51	14.33	1.45	15.79	2.2
Lake States						
Michigan	86.08	90.83	4.12	0.62	4.75	5.5
Minnesota	172.85	175.44	2.39	0.20	2.59	1.5
Wisconsin	67.86	70.65	2.62	0.16	2.79	4.1
Region Total	326.79	336.92	9.14	0.99	10.13	3.1
Northern Plains						
Kansas	142.99	141.46	-1.50	-0.02	-1.53	-1.1
Nebraska	111.66	108.47	-2.77	-0.42	-3.20	-2.9
North Dakota	78.69	81.45	2.34	0.42	2.76	3.5
South Dakota	35.69	34.72	-0.46	-0.51	-0.97	-2.7
Region Total	369.04	366.10	-2.40	-0.53	-2.93	-0.8
Total	**1,414.55**	**1,437.53**	**21.08**	**1.90**	**22.98**	**1.6**

rates and the percentage of acres receiving atrazine applications. The most significant increases in atrazine losses due to the FAIR Act were in Kansas and Illinois. The increase in Kansas is attributable to a large increase in corn acres in general. While there was almost no change in corn acres in Illinois, a significant increase in continuous corn and corn and soybean rotations increased atrazine losses. Conservation Compliance and changes in farming practices generally decreased atrazine losses as farmers generally reduced atrazine application rates and the percentage of acres receiving atrazine applications. Nebraska is a noticeable exception because atrazine application rates and the percentage of acres receiving atrazine increased.

Atrazine leaching is most prevalent in northeast and central Nebraska, along the Mississippi River through Wisconsin, Iowa, and Missouri, and much of Illinois and Indiana (Figure 5.6). As with nitrogen, atrazine losses are quantities and not concentrations. The map of atrazine losses in runoff (Figure 5.7) shows the highest losses in Nebraska and Kansas, and along the Mississippi and Ohio River valleys in Missouri, Illinois, and Indiana. The map of atrazine volatilization (Figure 5.8) shows high losses in Nebraska, with other areas of high loss in Indiana, Michigan, and to some extent Illinois and Ohio. In general, there is a low level of volatilization loss throughout the Midwest wherever corn or sorghum is grown, unlike atrazine leaching and runoff, which tend to be more concentrated in certain areas. These widespread low-level volatilization losses explain why atrazine is detected in rainfall throughout the Midwest and Northeast in the spring and summer.

Table 5.6. Atrazine lost from cropland

Region	1992	1997	Crop Change	Tillage Change	Net Change	
		1,000 tons				percent
Corn Belt						
Illinois	32.42	28.51	4.37	-8.27	-3.91	-12.1
Indiana	26.89	26.80	-0.20	0.12	-0.08	-0.3
Iowa	9.55	7.70	-0.83	-1.02	-1.85	-19.4
Missouri	18.23	17.43	0.55	-1.35	-0.79	-4.4
Ohio	7.72	6.47	-0.26	-0.99	-1.25	-16.2
Region Total	94.80	86.92	3.63	-11.51	-7.88	-8.3
Lake States						
Michigan	8.01	6.74	0.68	-1.94	-1.26	-15.8
Minnesota	2.43	2.45	0.15	-0.13	0.02	0.9
Wisconsin	4.98	4.81	0.01	-0.18	-0.17	-3.3
Region Total	15.41	14.00	0.84	-2.25	-1.41	-9.2
Northern Plains						
Kansas	55.02	36.64	4.79	-23.17	-18.38	-33.4
Nebraska	32.47	35.66	1.82	1.38	3.20	9.8
North Dakota	0.07	0.06	0.00	-0.01	-0.01	-15.1
South Dakota	0.78	0.56	0.03	-0.25	-0.22	-27.9
Region Total	88.33	72.92	6.64	-22.05	-15.41	-17.4
Total	**198.54**	**173.83**	**11.11**	**-35.81**	**-24.70**	**-12.4**

Livestock Production

Livestock production generates substantial quantities of waste containing important crop nutrients such as nitrogen and phosphate. If sufficient crop acreage is available to assimilate these nutrients, livestock waste can be a valuable resource. Over the past three decades, there has been significant structural change in livestock production. Fewer farms are producing more animals in more confined areas. Concentrating animals concentrates waste and poses a significant waste management challenge for farmers. If this challenge is not met successfully, livestock waste can threaten both ground and surface water quality through the leaching and runoff of nutrients and pathogens, and the potential for accidental spills from waste confinement facilities.

Between 1982 and 1992, livestock production in the Midwest declined by nearly 2.5 percent (Table 5.7). Most of this decline occurred because cattle inventories declined dramatically in the Corn Belt and Lake States; a decline that was only partially offset by the increase in cattle numbers on less productive cropland in the Northern Plains. The trend in hog inventories was generally mixed. In the Corn Belt, large declines in Illinois, Missouri, and Ohio were partially offset by a large increase in Indiana. The large decrease in hogs in Wisconsin was offset by increases in Minnesota and Michigan. With the exception of Kansas, the Northern Plains saw large increases in hog inventories. Poultry inventories, though generally small, experienced significant increases throughout the study region.

The flight of cattle from the Corn Belt and Lake States resulted in a 3 percent decrease in aggregate waste production, from 1.38 to 1.34 billion tons between 1982 and 1992 (Table 5.8). Nitrogen from animal waste decreased 2.5 percent from 8.71 to 8.49 million tons, while phosphate decreased 2 percent from 4.77 to 4.68 million tons. While aggregate waste, nitrogen, and phosphate decreased in the Corn Belt and Lake States, they increased in the Northern Plains, where there were generally increases in cattle, hog, and poultry inventories.

Figure 5.9 shows high per acre animal waste generation in regions with high livestock inventories. Large inventories of beef cattle in Nebraska and poultry in southern Missouri are readily apparent, while along the Mississippi River in Iowa, Minnesota, and Wisconsin the mixture of livestock as a whole creates large inventories. In these areas in 1992, livestock generated more than 4 tons of animal waste containing more than 50 pounds of nitrogen and 30 pounds of phosphate per acre of cropland.

Table 5.7. Livestock inventories

Region	Hogs			Cattle			Poultry			All Livestock		
	1982	1992	Change	1982	1992	Change	1982	1992	Change	1982	1992	Change
	million pounds		percent	million pounds		percent	million pounds		percent	million pounds		percent
Corn Belt												
Illinois	5,747	5,437	-5.4	3,757	2,870	-23.6	38	40	5.7	9,542	8,347	-12.5
Indiana	4,157	4,464	7.4	2,366	1,814	-23.3	172	228	32.5	6,696	6,506	-2.8
Iowa	13,893	13,782	-0.8	9,349	7,092	-24.1	83	128	53.8	23,325	21,002	-10.0
Missouri	2,976	2,712	-8.9	7,085	6,745	-4.8	112	171	52.9	10,172	9,627	-5.4
Ohio	2,001	1,891	-5.5	2,719	2,463	-9.4	96	199	106.8	4,817	4,554	-5.5
Region Total	28,775	28,286	-1.7	25,277	20,984	-17.0	501	766	52.8	54,553	50,036	-8.3
Lake States												
Michigan	998	1,157	16.0	2,314	2,037	-12.0	68	84	23.4	3,381	3,279	-3.0
Minnesota	4,304	4,524	5.1	5,733	4,622	-19.4	166	276	66.9	10,203	9,422	-7.7
Wisconsin	1,389	1,122	-19.2	8,204	7,191	-12.3	40	48	20.5	9,633	8,361	-13.2
Region Total	6,691	6,803	1.7	16,251	13,850	-14.8	274	409	49.3	23,216	21,062	-9.3
Northern Plains												
Kansas	1,608	1,477	-8.2	8,873	10,903	22.9	12	17	49.8	10,492	12,397	18.2
Nebraska	3,841	4,054	5.5	10,924	10,978	0.5	20	32	61.4	14,786	15,065	1.9
North Dakota	248	334	34.8	3,015	3,308	9.7	3	7	101.6	3,266	3,649	11.7
South Dakota	1,677	1,909	13.8	5,754	6,940	20.6	17	24	43.0	7,448	8,872	19.1
Region Total	7,374	7,773	5.4	28,566	32,129	12.5	52	80	55.4	35,992	39,982	11.1
Total	**42,840**	**42,862**	**0.1**	**70,094**	**66,963**	**-4.5**	**827**	**1,255**	**51.8**	**113,761**	**111,080**	**-2.4**

Table 5.8. Livestock waste

Region	All Waste 1982	All Waste 1992	All Waste Change	Nitrogen 1982	Nitrogen 1992	Nitrogen Change	Phosphate 1982	Phosphate 1992	Phosphate Change
	1,000 tons		percent	1,000 tons		percent	1,000 tons		percent
Corn Belt									
Illinois	104,799	89,942	-14.2	683	592	-13.4	395	346	-12.4
Indiana	71,508	66,657	-6.8	479	458	-4.5	284	277	-2.4
Iowa	254,391	223,631	-12.1	1,640	1,475	-10.0	957	866	-9.5
Missouri	122,060	115,681	-5.2	761	729	-4.1	414	395	-4.6
Ohio	58,517	54,128	-7.5	376	359	-4.6	210	204	-3.1
Region Total	611,275	550,038	-10.0	3,939	3,613	-8.3	2,261	2,089	-7.6
Lake States									
Michigan	44,627	41,505	-7.0	282	265	-5.8	153	146	-4.3
Minnesota	125,118	110,984	-11.3	801	724	-9.6	445	412	-7.3
Wisconsin	143,435	124,916	-12.9	879	763	-13.2	452	393	-13.0
Region Total	313,180	277,404	-11.4	1,961	1,752	-10.7	1,050	952	-9.3
Northern Plains									
Kansas	134,492	162,630	20.9	835	990	18.6	426	509	19.5
Nebraska	184,085	186,482	1.3	1,130	1,158	2.5	606	617	1.8
North Dakota	42,464	47,901	12.8	264	291	10.1	131	149	13.5
South Dakota	92,012	111,333	21.0	574	687	19.6	300	361	20.5
Region Total	453,053	508,347	12.2	2,804	3,126	11.5	1,463	1,636	11.8
Total	**1,377,508**	**1,335,790**	**-3.0**	**8,705**	**8,491**	**-2.5**	**4,773**	**4,676**	**-2.0**

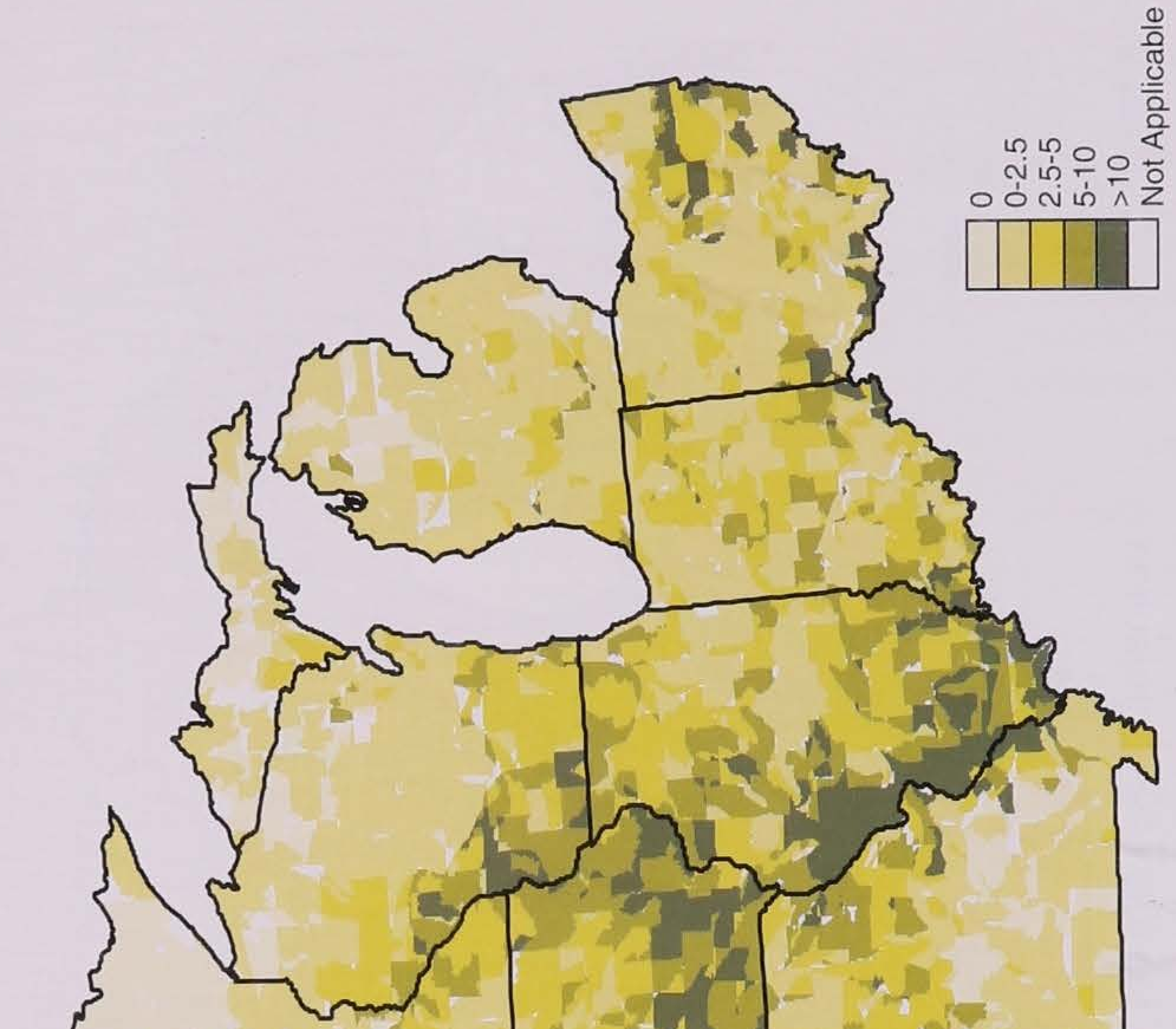
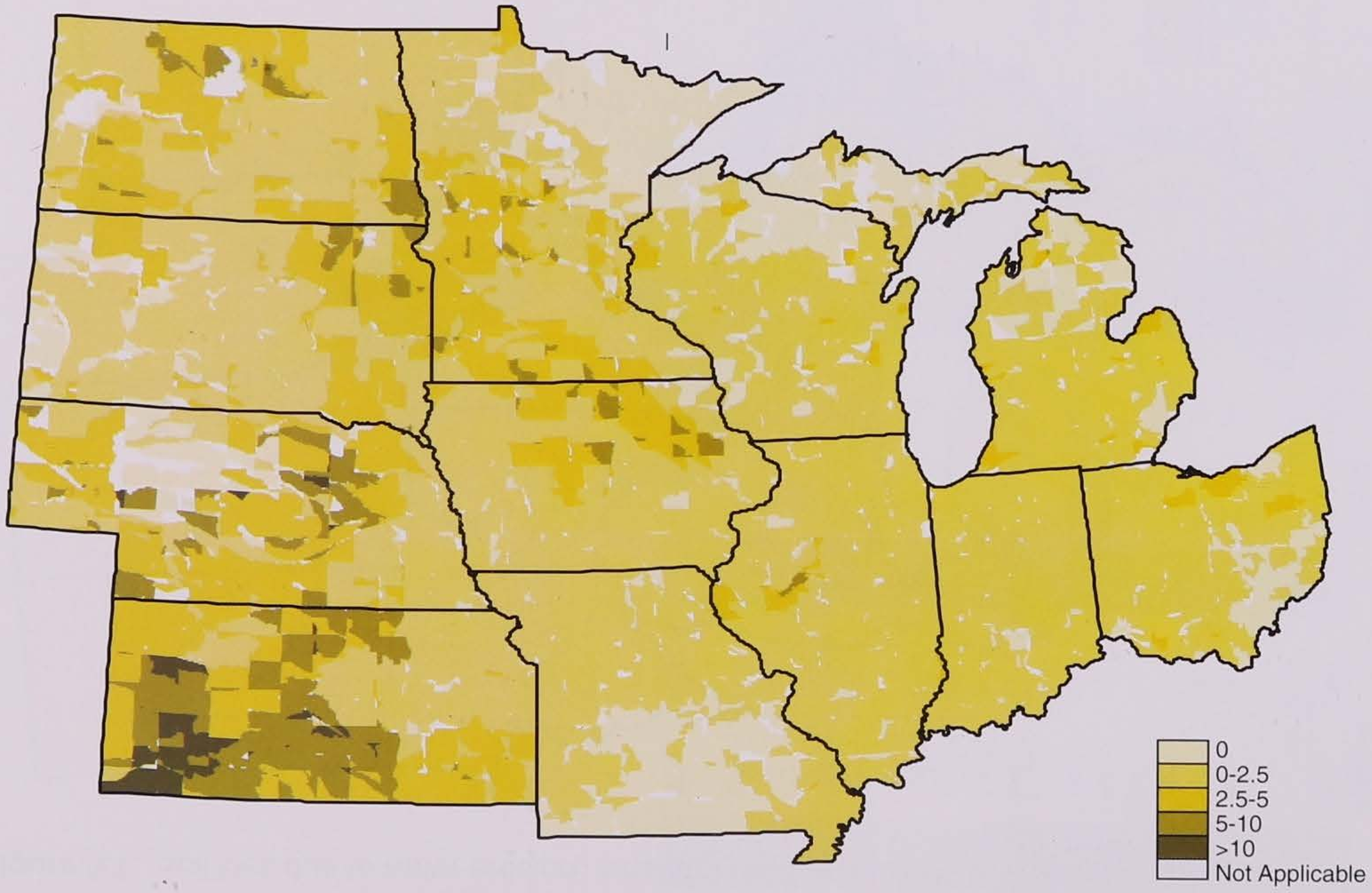


Figure 5.1. Soil loss due to water erosion, tons/ac: 1997 projection

Figure 5.2. Soil loss due to wind erosion, tons/ac: 1997 projection



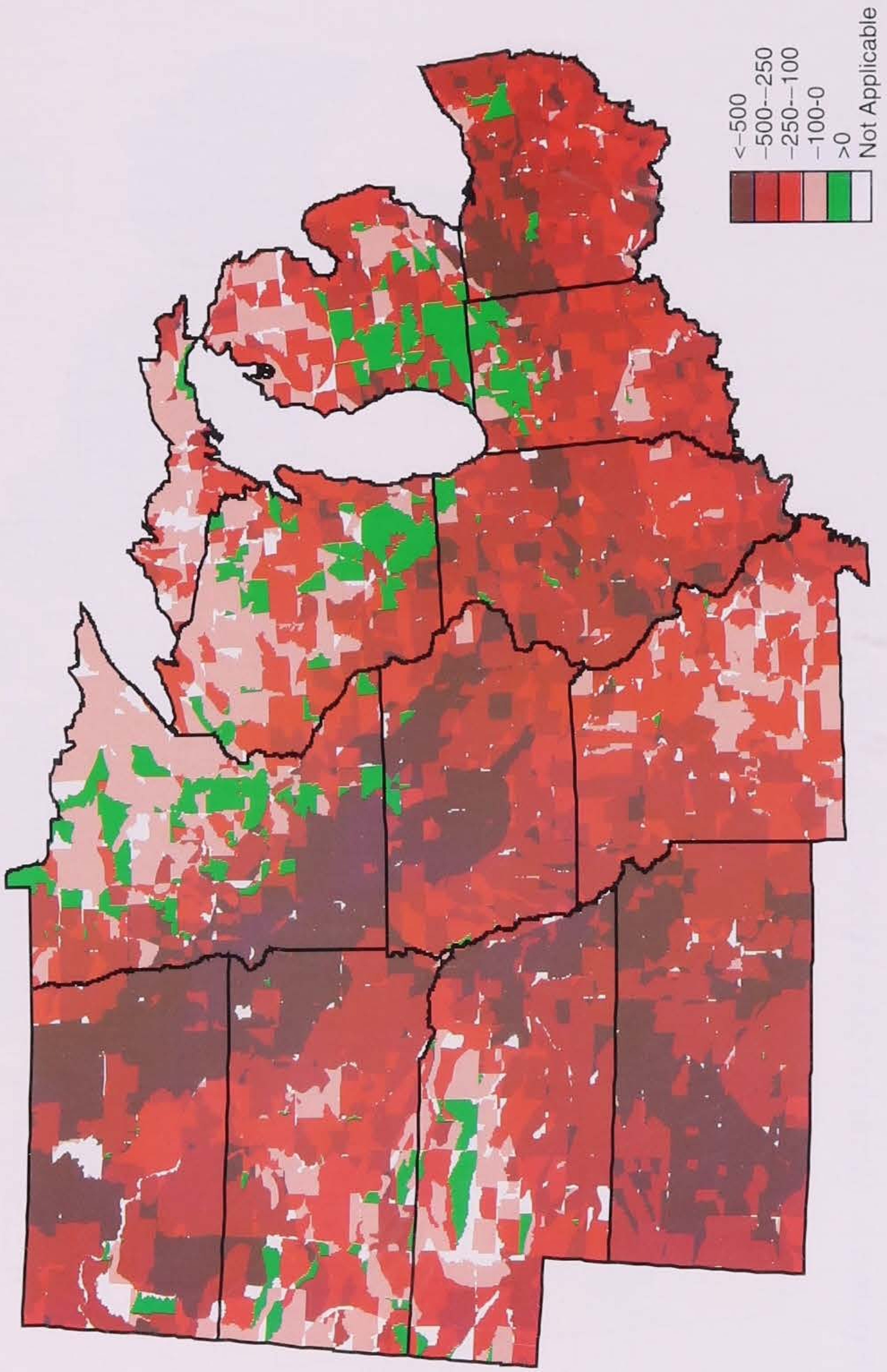


Figure 5. 3. Annual soil organic carbon rate of change, kg/ha: 1997 projection

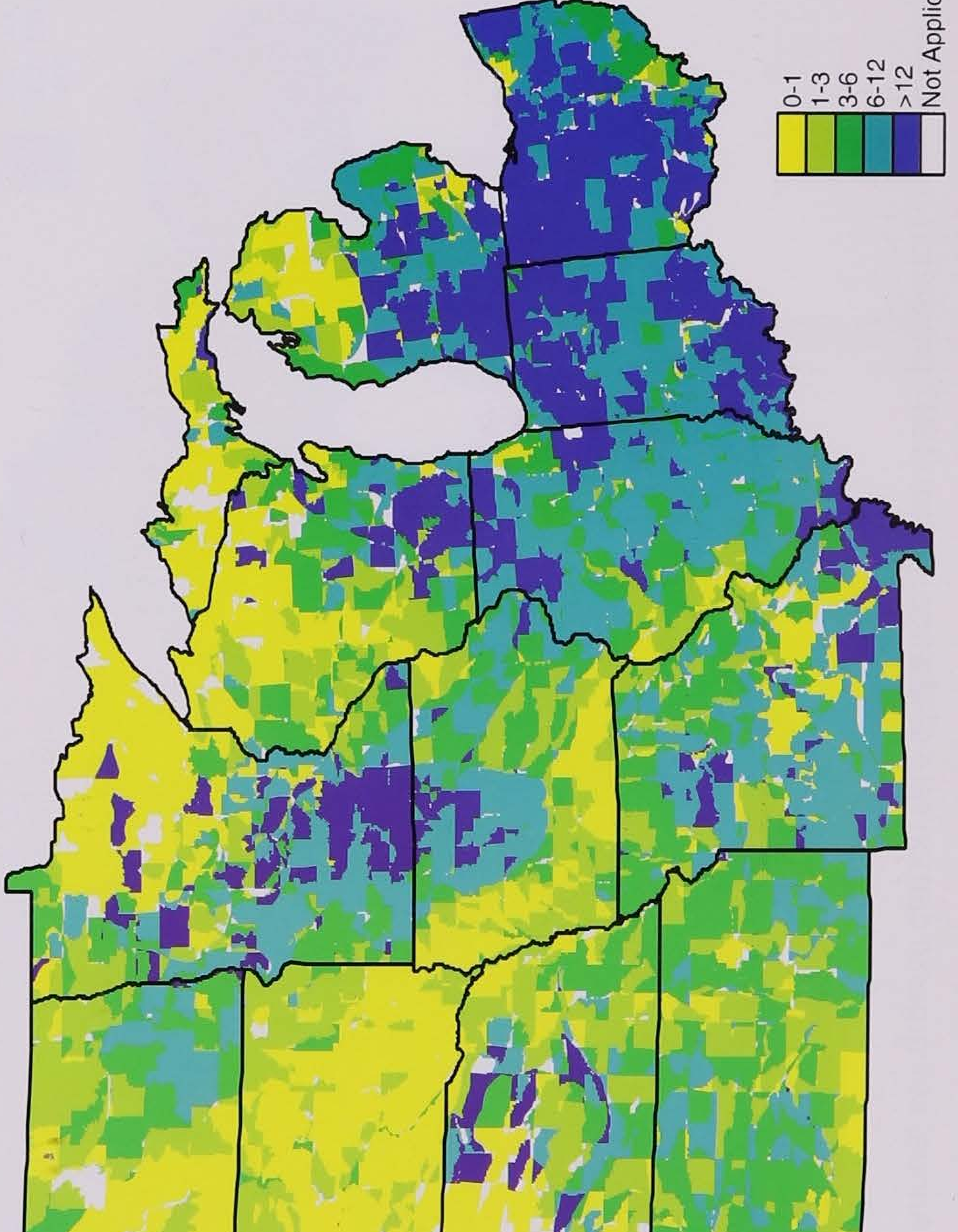


Figure 5.4. Nitrate-nitrogen leached, lb/ac: 1997 projection

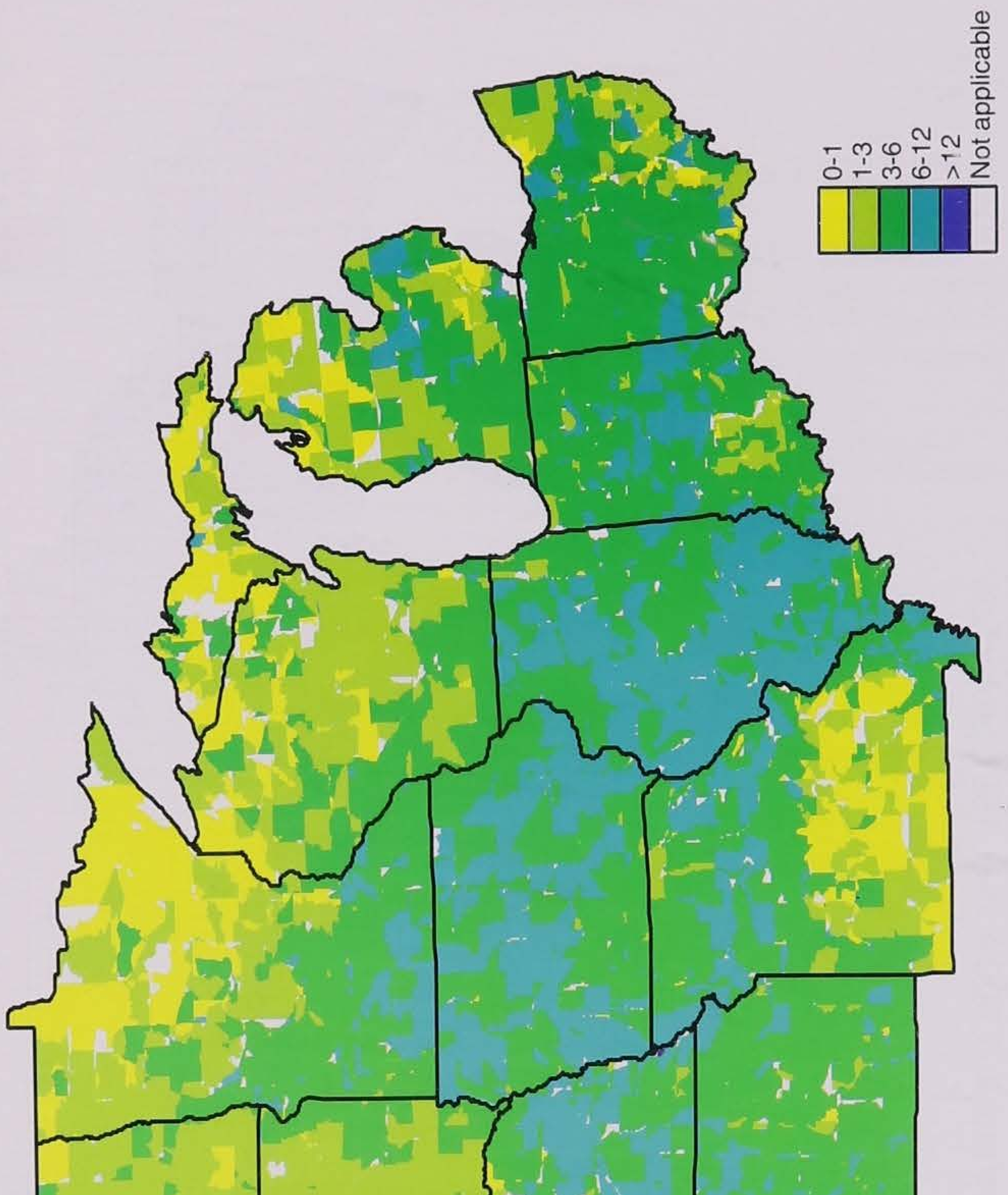
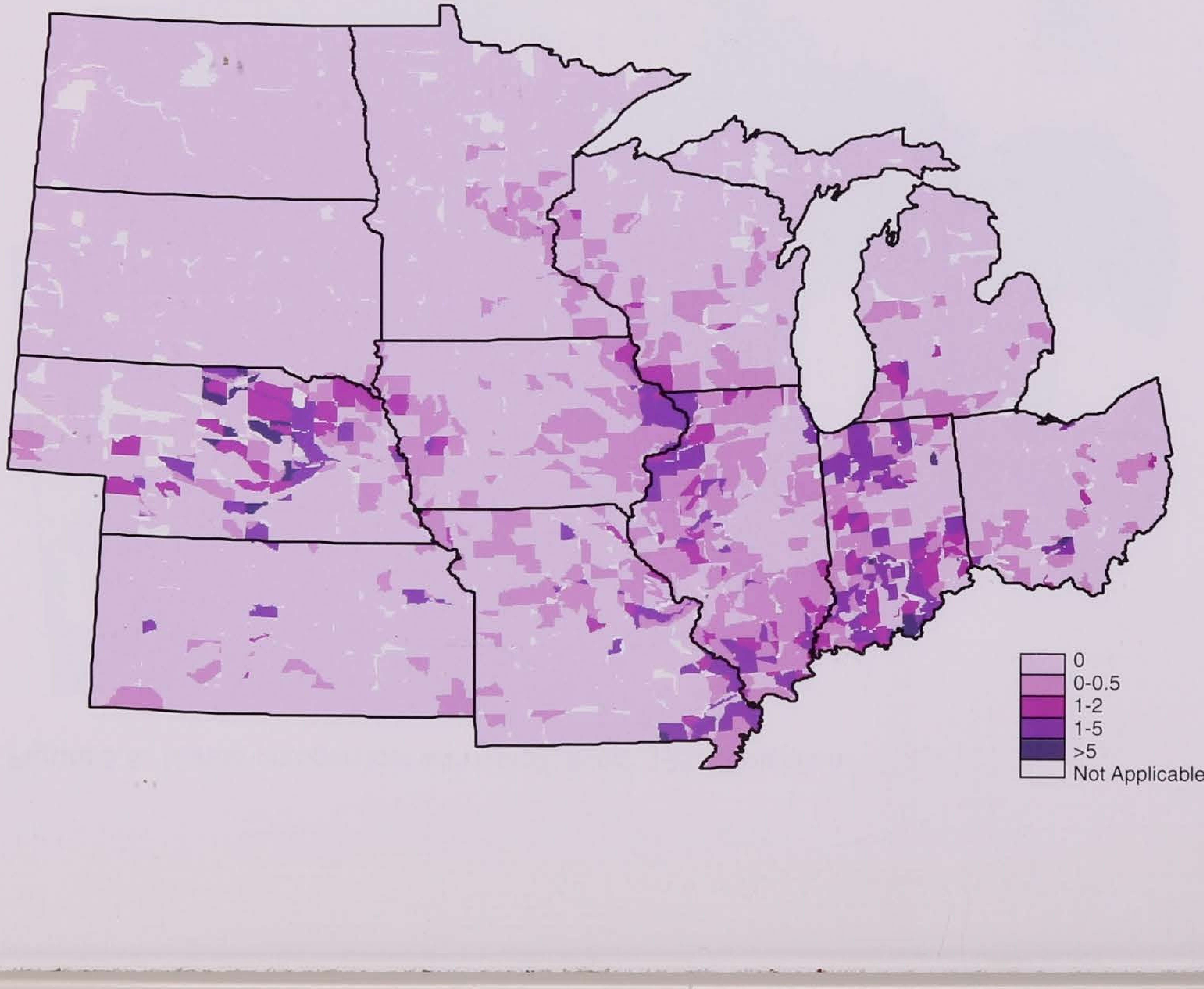


Figure 5.5. Nitrate-nitrogen lost with runoff, lb/ac: 1997 projection

Figure 5.6. Atrazine leached, lb/1,000 acres: 1997 projection



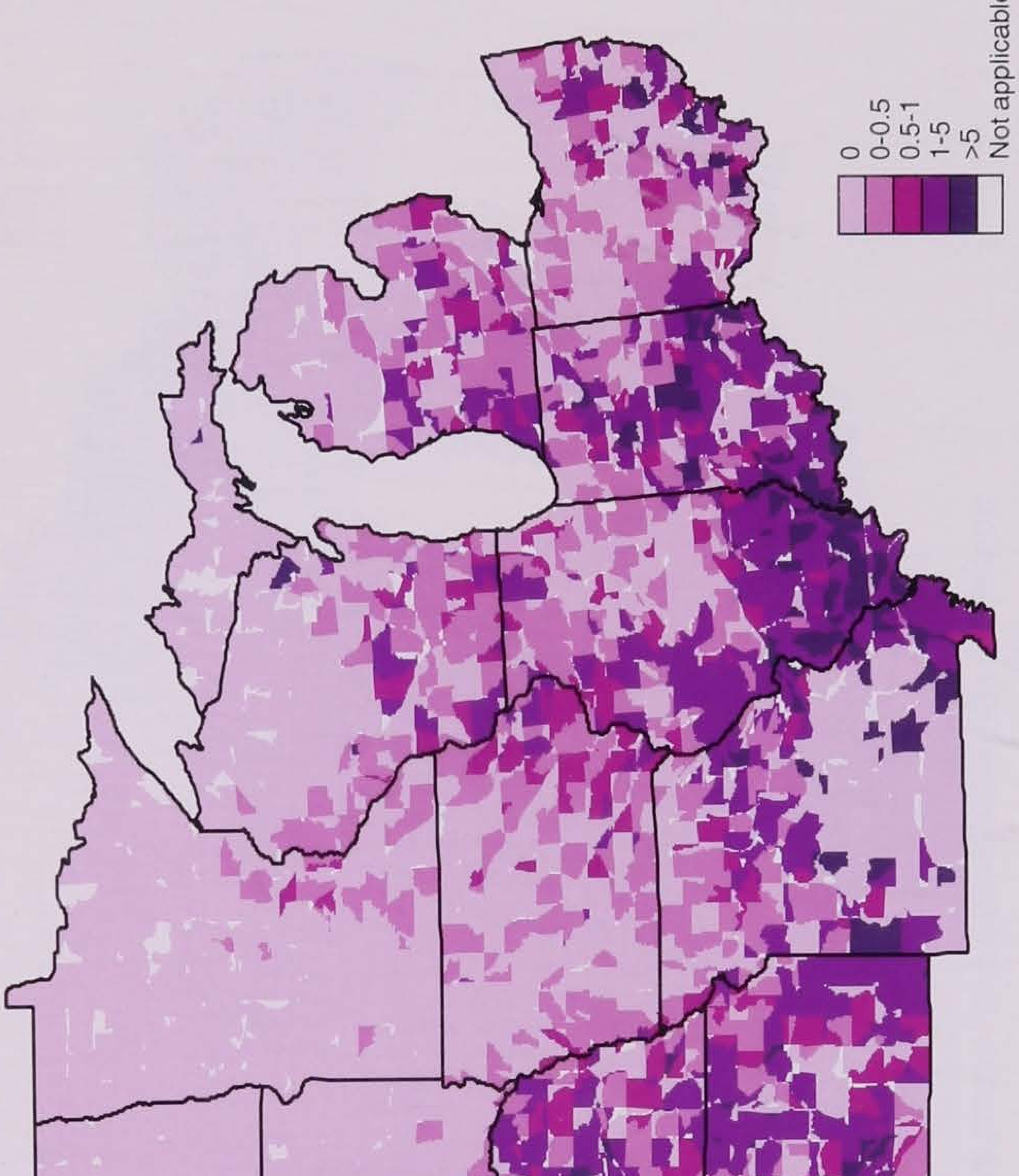


Figure 5.7. Atrazine lost with runoff, lb/1,000 acres: 1997 projection

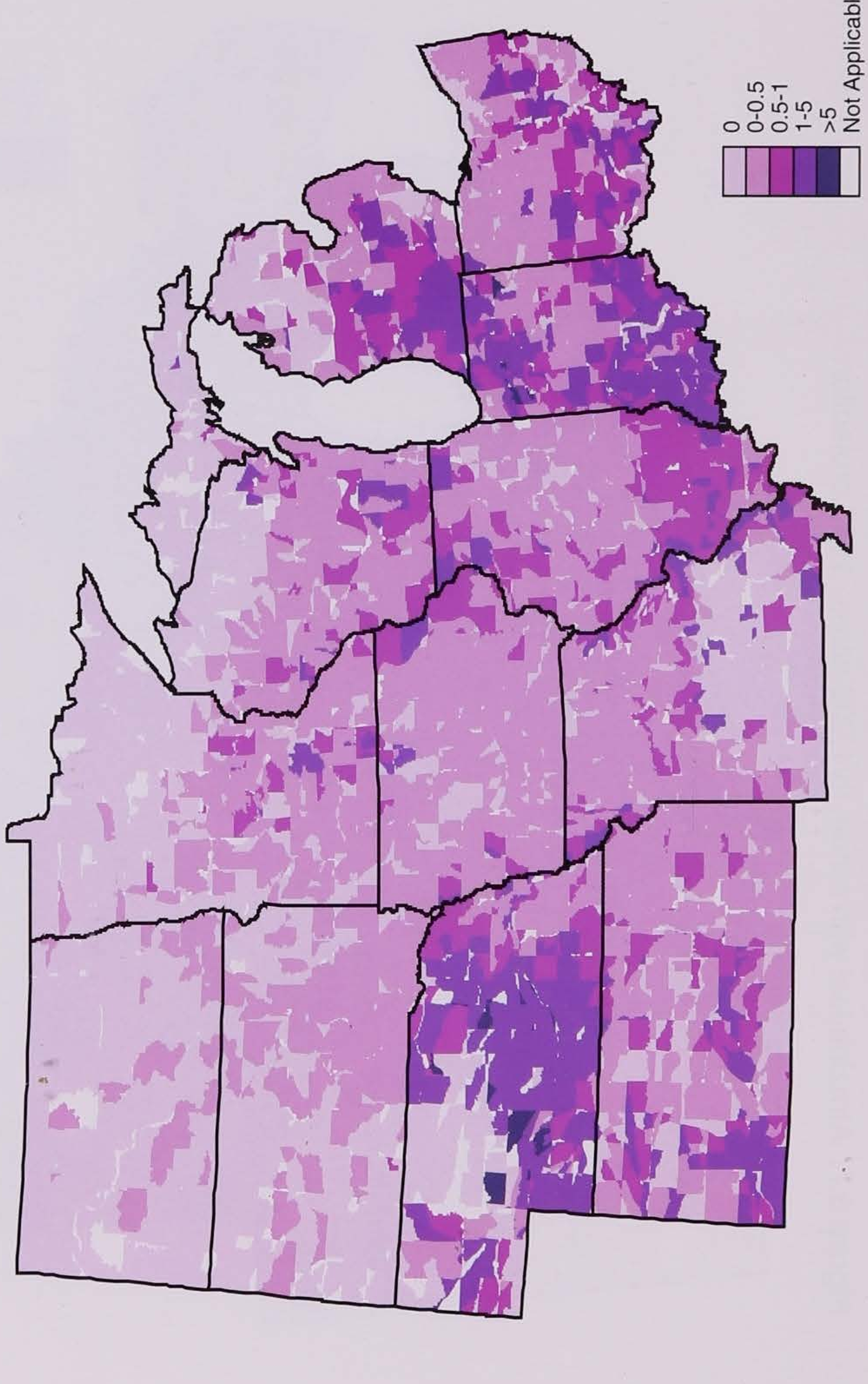


Figure 5.8. Atrazine volatilization, lb/1,000 acres: 1997 projection

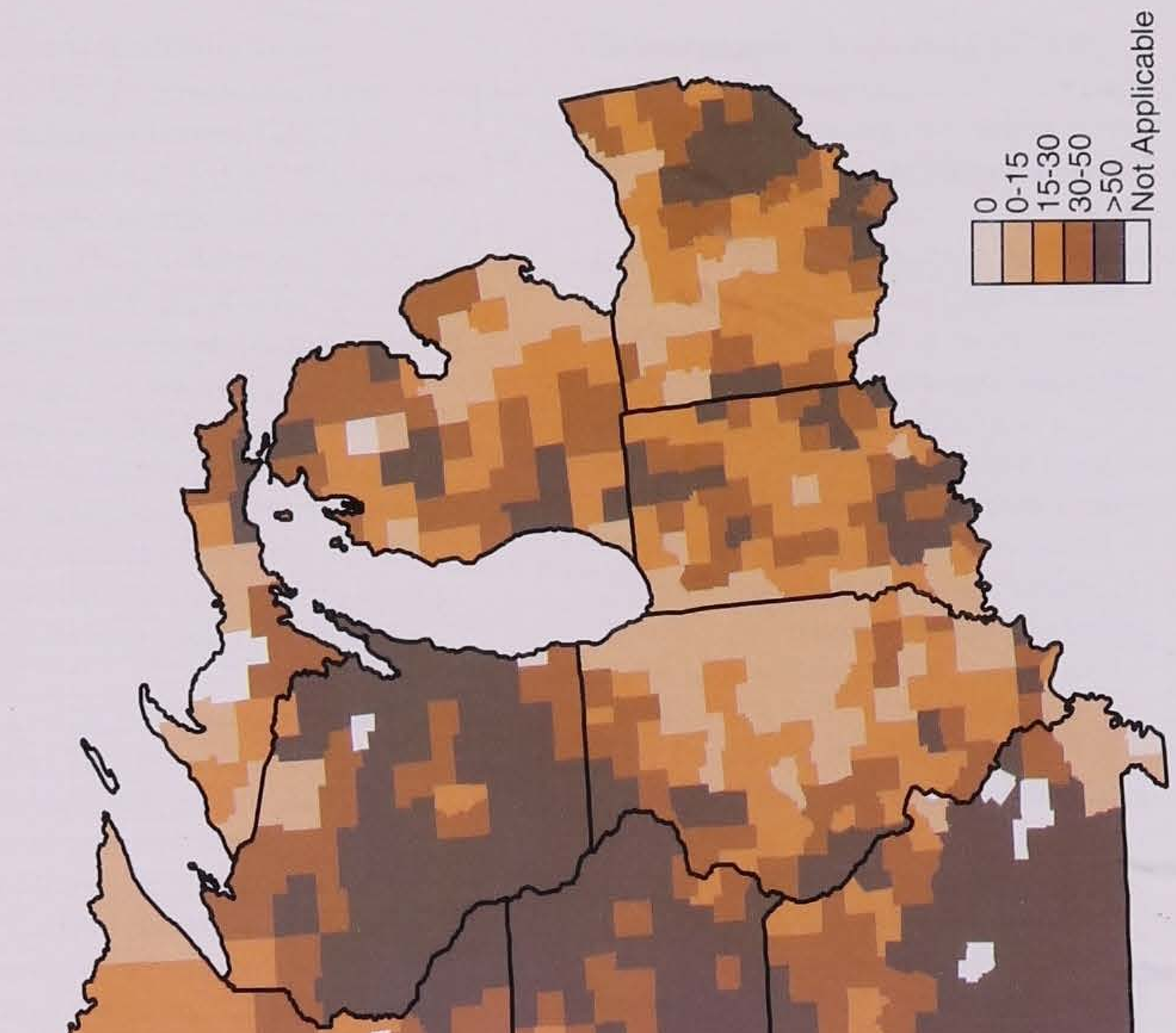


Figure 5.9. Nitrogen from livestock waste in 1992, lb/crop acres

6. CONCLUSIONS

Agricultural production in the central United States underwent significant changes between 1992 and 1997 due to the FAIR Act of 1996 and the continued implementation of Conservation Compliance. The FAIR Act brought to an end more than 60 years of crop subsidies that artificially increased the production of program crops (barley, corn, upland cotton, oats, rice, sorghum, and wheat), while lowering the production of oil seed crops such as soybeans. Conservation Compliance required farmers to develop and implement conservation plans in order to maintain their eligibility for federal subsidies.

As a result, soybean production increased by 22.9 percent, more than 10 million acres, due to greater planting flexibility as soybeans replaced program crops. Additionally, soybeans replaced much of the land coming out of CRP where contracts expired and the land was not re-enrolled because of high commodity prices or because it did not meet the FAIR Act's new eligibility requirements. While corn acreage showed a slight increase for the region as a whole due to an increase in states traditionally producing more wheat, traditional corn growing states tended to decrease corn acreage. Wheat acreage decreased by 7.0 percent, sorghum acreage by 15.6 percent, hay acreage by 5.5 percent, and CRP acreage by 4.7 percent. Finally, Conservation Compliance helped produce a 14.8 percent increase, 10 million acres, in land cultivated with conservation tillage.

The changes in agricultural production between 1992 and 1997 have generally resulted in an improvement in the environmental health of the central United States. While replacing less intensively farmed program crops and CRP with soybeans generally increased soil erosion, and the amount of organic carbon, nitrogen, and atrazine lost to the environment from agricultural production, increased conservation tillage decreased erosion, and the loss of organic carbon and atrazine. Unfortunately, increasing conservation tillage also increased nitrogen lost to the environment. The net effect was a 3.7 percent, 52 million tons, decline in soil erosion; a 2.9 percent, more than 1 million ton, decrease in the rate of loss of soil organic carbon; a 1.6 percent, nearly 23 thousand ton, increase in nitrogen losses; and a 12.4 percent, about 24 thousand ton, decrease in the loss of atrazine.

Passage of the FAIR Act in 1996 diminished the government's influence on most farmers' decisions. The political decision has been made to free farmers from the guiding hand of Washington when it comes to planting and production decisions. This study has investigated the environmental implications of this freedom. Two important findings emerged. First, the overall effect of agriculture on environmental quality has modestly declined since 1992 in the 12 states studied. Soil erosion rates are down, carbon sequestration rates are up, and losses of atrazine from farm fields are down.

The second finding is that these beneficial changes have emerged not because farmers' planting freedom has resulted in less environmental damage, but rather because farmers have implemented their conservation compliance plans. Where adoption rates of consevation tillage are up, environmental damage is down. The results from this study indicate that farmers planting decisions have had relatively little overall environmental effect.

The importance of conservation compliance in lessening agriculture's effect on the environment raises an important policy question that Congress will be forced to address in the next few years. If the public interest is being served by Conservation Compliance, how will farmers be induced to maintain their conservation plans after current government payments end in 2002? The future efforts of the RAPS research team at Iowa State University will be devoted to documenting and tracking agriculture's effect on the environment over the next few years to help Congress judge the value of the environmental benefits that accrue from conservation compliance and other government-sponsored environmental programs.

7. SUPPORTING PUBLICATIONS

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