Targeting Green Support Payments:
The Geographic Interface between Agriculture and the Environment

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Introduction

Quadrennial omnibus farm legislation has for the last fifteen years presented an opportunity to propose and debate new programs to conserve and protect natural resources affected by agricultural production. The 1981 Farm Act included the Farmland Protection Policy Act, directing USDA to identify and track Federal actions with adverse effects on farmland and was the first farm act to contain an explicit title for conservation programs. In the 1985 Food Security Act, the Conservation Reserve Program (CRP) recast familiar long-term land retirement programs in a new light targeted more directly at reducing soil erosion and attendant water quality problems from highly erodible cropland. Other innovative programs addressed adverse environmental impacts caused, in part, by farm commodity program payments. The so-called conservation compliance, sodbuster, and swampbuster provisions mitigated impacts on soil and wetlands by requiring implementation of conservation plans on highly erodible cropland and denying payments for new cropland developed on highly erodible soils or from wetlands.

The 1990 Food, Agriculture, Conservation, and Trade Act refined these earlier programs and proposed three innovations. The Wetland Reserve Program (WRP) compensated landowners for restoring their cropland to wetland and permanently foregoing crop production. The Water Quality Incentives Program (WQIP) provided a voluntary incentive program through agreements to assist farm owners and operators in developing and implementing a water quality improvement plan. The Integrated Farm Management Program (IFM) established a voluntary program designed to assist producers in adopting integrated, multiyear, site-specific farm management plans and reducing farm program barriers to resource stewardship practices and systems.

The 1995 Farm Bill debate offers new opportunities to further refine existing conservation programs and develop new ones. Increased and broadened environmental awareness of agricultural's environmental role, declining farm program payments, and the prospect of a changing basis for farm support payments are all cited as arguments in favor of paying farmers to change land use or farming systems in order to provide environmental services (Ervin, 1993; Osborn, et al., 1993; Runge, 1994). This concept, variously labeled green recoupling, stewardship payments, or green support payments, could take several forms: a renewed and

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targeted CRP, extended conservation compliance, or incentive and cost-sharing programs such as ACP, WQIP, and IFM (Ribaudo et al., 1990; Heimlich and Osborn, 1993; Allen, 1993, 1994; Reynolds, et al. 1994; NRC, 1993).

Regardless of the exact mechanisms on which a green support program is based, knowledge of the geographic association between agriculture and environmental problems is critical. The objective of this paper is to show how environmental indicators, developed using readily available data, can provide information on the geographic distribution of potential environmental damages from agricultural production. Such targeting indicates potential benefits for green support programs aimed at improving environmental conditions. The ability to identify, prioritize, and target environmental problems is important for designing cost-effective programs, assessing which producers gain or lose from changes in support mechanisms, and assessing the types and magnitudes of environmental benefits achieved.

This analysis advances the development of environmental indicators by explicitly recognizing that the environment is fundamentally a spatial phenomenon requiring spatial indicators, and by actually constructing quantitative indicators of the potential for specific types of environmental damages. This effort builds on an environmental benefits index developed to assess CRP bids after the 1990 FACTA. The indicators described here are better indicators of the benefits they are designed to represent than those used in earlier efforts, most of which were based primarily on cropland soil erosion. Nonetheless, this set of indicators should not be construed as complete or final. Both new environmental problems and new sources of data are arising or being developed that should be incorporated. These environmental indicators do demonstrate the feasibility of targeting programs to environmental improvement objectives in order to achieve greater cost-effectiveness.

Environmental indicators presented here represent a significant improvement on previous efforts to geographically locate environmental problems associated with U.S. agriculture at the national scale. They demonstrate the feasibility of using readily available sources of data to characterize the relative environmental performance of cropland in different parts of the country. These indicators are thus illustrative of a method that can be used and further refined, rather than a definitive or final answer.

The measures developed here are indicators of potential environmental problems (type 1 in Nelson, 1994), and for the most part do not reflect any direct measurement of environmental harm created by agricultural production. This potential for environmental harm may, or may not, be realized depending on whether mitigating conditions not captured in the indicator are present. For example, potential pesticide leaching may be expressed as pesticide loads to surface water if artificial drainage diverts water percolating below the root zone away from groundwater.

The costs of potential environmental damages, or benefits of remediation are proxied by population weights attached to each observation. The relative value of soil productivity lost to erosion is proxied by cash rent. These weights are a first, crude approach to measuring, or at least proxying for the cost of environmental externalities. These weights, while tentative, provide valuable information to target programs directed at preventing or improving environmental problems associated with agricultural production.

Targeting for Cost-Effectiveness

The cost-effectiveness of environmental programs dealing with problems related to agricultural production can be improved by targeting land with the greatest environmental benefits and recognizing the opportunity cost of foregoing all or part of agricultural production. An issue for green support programs is the degree of correspondence between current constituents now receiving farm program payments and cropland with potential environmental problems. A GIS analysis at the national level can indicate areas of overlap between where high and low farm program payments are received and where potential environmental problem indices are high and low.

Why is targeting needed for conservation and environmental programs? Just as with any program that has limited resources, conservation programs cannot be expected to achieve optimal results unless the funds are directed where they can generate the greatest improvement for the funds available. Targeting can be done in different ways and at more than one level within a particular program. For example, focusing the Conservation Reserve and Conservation Compliance Programs on highly erodible cropland in the 1985 Food Security Act "targeted" the programs to a subcategory of U.S. cropland that was responsible for a large portion of total cropland soil erosion. Criteria for other environmentally sensitive lands (wetlands, scour erosion areas, water quality areas) were added to the CRP later.

After the 1990 Farm Act, changes in CRP bid assessment procedures resulted in further targeting to enroll only the most cost-effective land submitted. Proxies for environmental benefits were developed based on readily available data reflecting onsite soil productivity, surface and groundwater quality, and assistance to farmers most affected by conservation compliance (figure 1). Where appropriate, these indicators were weighted by the population affected. Bid assessment was centralized in Washington, using data on bids provided by local ASCS and SCS offices.

As an alternative to centralized targeting, program funding could be allocated to each state or region based on the kind of environmental indicators developed here and expected program costs. This kind of targeting would leave the choice of specific participants to local decision makers, perhaps based on uniform guidelines from Washington.

Questions about how green support programs could be targeted include:

- Should programs be targeted to areas of intensive agricultural production, or areas where many people are affected by environmental problems associated with agricultural production?

•What criteria beyond highly erodible land should be considered? What are agriculture's most pressing potential environmental problems?

•Can better measures of potential offsite environmental effects be developed?

To facilitate discussion of green support programs, I developed potential indices based on a variety of offsite impacts beyond soil erosion (see table 1 and Appendix). Other indicators were considered for inclusion, but rejected because data were lacking or relatively simple computational methods were not available. Among these were a water quantity measure (excess or residual irrigation), phosphorus runoff (no data on current soil concentrations), and animal manure loadings (will be incorporated into nitrogen runoff calculations).

Most of the indicators are mapped in two ways: their pure physical form and with a socio-economic weighting. Weighting indices by population, value, or other variables assumed to be proportional to benefits from conservation programs changes the magnitude of potential environmental effects compared with unweighted indices. This may be desirable if the objective is to target economic benefits from green support programs rather than the physical problem itself.

For example, weighting sediment production by the population of watersheds likely to be affected by the delivered sediment reduces the importance of sediment produced in sparsely populated southern Iowa and northern Missouri, and in the Palouse region of eastern Washington and Idaho (figures 2 and 3). Population weighting emphasizes sediment delivered in the densely populated Northeast, around the Chicago lakeshore, and in the St. Louis area. Examining current erosion rates versus topsoil depth as a measure of potential productivity loss highlights problems with high erosion rates on thin soils in eastern Montana and Colorado, the Texas panhandle, South Dakota, eastern Nebraska, and along the east bank of the Mississippi Delta (figures 14 and 15). However, weighting by the cash rent value deemphasizes areas with less valuable soils in favor of erosion on the highly productive soils in the Corn Belt.

Weighting to proxy for damages associated with the indicators introduces other problems. Is population an adequate proxy for these damages? If so, which population? Arguably, nutrients and pesticides from the Corn Belt can effect water quality far downstream in the Mississippi and even into the Gulf of Mexico, as they were monitored to do with the unusual Midwest flooding in 1993 (Taylor, et al. 1994; Goolsby, et al. 1993.). The wildlife structure and diversity indicator is not weighted using population, but it could be argued that increases in common game species habitat primarily benefit local populations within 100 miles or so. While these problems are left for later research, weighted versions of the indicators are presented to stimulate discussion.

Table 1--Indicators of potential environmental benefits

Indicator	Affected Resource	Externality	Description	Weight
Sediment production	Surface water quality	Siltation of reservoirs, ditches, etc. (Clark et al. 1985, Ribaudo, 1986)	Gross sheet and rill erosion times delivery ratio	Watershed population
Nitrogen runoff	Surface water quality	Eutrophication, algae growth, biological oxygen demand (NRC, 1993)	Residual nitrogen in soil surface and rainfall runoff	Watershed population
Filter strips	Surface water quality	Immobilization of sediment, pesticides and nutrients in runoff (Dillaha, et al., 1989; NRC, 1993)	Cropland within 100 feet of stream or lake	Watershed population
Pesticide leaching	Groundwater quality	Pesticide contamination of drinking water supplies (Kellogg et al., 1992)	Pesticide and soil leaching potential	Population using groundwater
Nitrate leaching	Groundwater quality	Nitrate contamination of drinking water supplies (Kellogg et al., 1992)	Nitrate and soil leaching potential	Population using groundwater
Habitat structure and diversity	Wildlife habitat	Loss of wildlife numbers (USDA, 1989)	Change in breeding and feeding habitat structure and diversity	None
Threatened and endangered species	Wildlife habitat	Loss of biodiversity (Brady and Flather)	Number of listed species with known and potential habitat	None
Soil productivity	Soil erosion	Loss of sustainable production (Batie, 1983)	Topsoil depth divided by loss of depth from erosion per year	Dryland cash rent per year
Windblown dust	Soil erosion	Health, cleanliness and maintenance costs of windblown dust (Huszar and Piper, 1986)	Wind erosion rate	County population
Pesticide exposure	Other	Human and environmental exposure to toxic materials (Kovach, et al., 1992)	Pounds of active ingredient times toxicity and persistence	None
Flood peak reduction	Other	Damages from increased flooding (NRC, 1992)	Cropland on former wetlands within the 100 year floodplain	Watershed population

Results of Mapping Agricultural Environmental Indicators

The maps presented here are based on data for the 323,000 cropland points in 1982 National Resources Inventory, matched to their respective soil interpretations from the SOILS 5 database. They are mapped to 18,530 NRI polygons, a three-way layering of county, major land resource area (MLRA), and hydrologic unit (watershed) boundaries developed by Margaret Maizel in cooperative work with ERS (Kellogg, et al., 1992). All indices are developed at the sample point level, then aggregated to the NRI polygon for mapping by taking the acreage-weighted average of the index value. Indices are normalized to a 0-100 interval by dividing the average NRI polygon score by the maximum score for any NRI polygon and multiplying by 100. The composite index is summed across index components at the NRI polygon level, then renormalized to the 0-100 interval based on the maximum polygon sum. The composite thus implies equal weighting of the index components included.

Caution should be exercised in interpreting these maps. Most of the maps included in this publication show the location of areas with high potential for the indicated environmental problem. That is, darker shaded polygons reflect a higher acreage-weighted average value for the indicator than lighter shaded polygons, reflecting greater potential problems. Neither the acreage affected nor the cost-effectiveness of enrolling cropland acres in these areas can be deduced from these maps. There tends to be an inverse relationship between the amount of cropland and the index value and between the cost of enrolling such cropland and the index value where indices are weighted by population affected, since there tends to be less cropland and more expensive cropland near population centers.

Surface Water Quality

Indicators of surface water quality problems include sediment production, nitrogen runoff, and the presence or absence of cropland near water bodies.

Potential Sediment Production--Potential sediment production is the fraction of water-caused soil erosion that reaches water bodies. This measure modifies gross sheet and rill erosion using a delivery ratio calculated on the basis of the land cover and slope characteristics of the land adjacent to NRI sample points in each NRI polygon. Thus, even sample points with very high erosion rates can be buffered by the presence of flatter land in soil-retarding cover in the adjacent area. Because of reduced rainfall, this problem is largely absent west of the 100th meridian, except for pockets in the coastal valleys of California and Oregon. Focusing on potential sediment production, rather than gross soil erosion, shifts attention to the Corn Belt and Appalachia.

Unweighted--Sediment production is concentrated along east and west slopes of the Appalachian mountains from eastern Pennsylvania to northern Georgia and from western Pennsylvania to northern Mississippi (figure 2). It is also a problem in the Corn Belt, along the Missouri and Mississippi rivers in southern Iowa and northern Missouri and in southern Wisconsin and western Illinois.

Population weighted--Weighting by populations potentially affected in the watershed emphasizes densely populated areas in the eastern Pennsylvania and New Jersey, around the St. Louis area in Missouri, and along the lake plain near Chicago in Wisconsin and Illinois. Sparsely populated areas in southern Iowa and northern Missouri are deemphasized (figure 3). Maximum population-weighted index values occur in Chester (PA) and Fairfax (VA) counties.

Potential Nitrogen Runoff--Potential nitrogen runoff depends on residual nitrogen above crop requirements and the infiltration and water-holding characteristics of the soils. In this measure, residual nitrogen applications above crop requirements and runoff are the key factors in a calculation of relative nitrogen loadings to surface waters, while watershed population proxies for potential damages.

Unweighted--Potential nitrogen runoff is concentrated in the Coastal Plain of the Southeast, Florida, and Gulf Coasts; along the western edge of the Michigan peninsula and the sandy outwash areas of central Wisconsin and Minnesota; in the claypans of eastern Texas; and in the eroded tablelands of central Nebraska (figure 4). Contrast this map with complementary areas on the unweighted map of potential nitrogen leaching.

Population weighted--Areas with heavy loadings weighted by the population using groundwater include the Boston area, eastern Pennsylvania and New Jersey, the Potomac drainage, South Carolina's Edisto River drainage, south Florida, the Chattahoochee-Flint drainage in Georgia and Alabama, drainages around Detroit and Chicago, the Trinity River drainage around Houston-Galveston, southern California, and the immediate San Francisco Bay drainage (figure 5). Relatively uniform unweighted nitrogen runoff values, when combined with population weights, reflect the population more than the underlying physical phenomenon. Maximum index values occur in San Bernardino (CA) and Middlesex (NJ) counties.

Potential for Filter Strips--Cropland within 100 feet of streams and lakes potentially contributes more pollutants to streams but could buffer water resources from upland runoff if planted to permanent vegetation. Cropland within 100 feet of water is assumed to be appropriate for conversion to permanent vegetative cover as filter strips. Wildlife benefits from filter strip development may occur, but are not accounted for here.

Unweighted--This index is fragmented in a wide scattering of polygons in many regions (figure 6). The Corn Belt, Lake States, Northeast, and Appalachian regions have the highest index values, but scattered areas in the Dakotas, Montana, Idaho and eastern Oregon also rate highly, as well as the southern San Joaquin valley of California.

Population weighted--When weighted by watershed population, the index remains fragmented, rather than concentrated, but is clustered along both slopes of the Appalachian ridge (figure 7). Population weighting emphasizes the Northeast, Florida, and areas around Santa Fe, New Mexico, Cheyenne, Wyoming, and coastal California. Maximum index values occur in Middlesex (NJ) and Ventura (CA) counties.

Groundwater Quality
Indicators of groundwater quality problems include potential for leaching pesticides and nitrate to groundwater supplies.

Potential Pesticide Leaching--Pesticide leaching is a function of both the characteristics of the pesticide and the leachability of the soils to which they are applied. This index is based on the GWVIP measure developed in Kellogg, et al. (1992).

Unweighted--The greatest physical potential for pesticide leaching occurs in the coastal plain and Piedmont soils of the Southeast and Mid-Atlantic region (figure 8). Important, but lower, potential exists along the Mississippi Valley from Illinois to Louisiana, and along the Ohio Valley in Indiana, Illinois, and Michigan. Central Nebraska and California's Central Valley also have important potential for pesticide leaching.

Population weighted--Weighting the index by the population using groundwater supplies emphasizes densely populated areas of eastern Pennsylvania and New Jersey, the North Carolina coastal plain, Florida, Gulf coast Alabama, the Chicago area, Phoenix, and most of the Central Valley, southern California, and the coastal valleys (figure 9). More sparsely populated areas or areas with less dependence on groundwater, such as northern Alabama and Georgia and western North and South Carolina, are deemphasized. The maximum value for pesticides occurs in Dade (FL) county.

Potential Nitrate Leaching--Nitrate leaching depends on the quantity of residual nitrogen above crop needs and the leachability of the soils to which it is applied. This index is based on the GWVIN measure developed in Kellogg, et al. (1992).

Unweighted--The greatest physical potential nitrate leaching targets scattered areas in the Southern coastal plain and the areas west of the Appalachian and Allegheny mountains, and irrigated areas in Arizona (figure 10). Secondary areas are the Illinois and Ohio corn grain producing areas.

Population weighted--Weighting the index by the population using groundwater supplies emphasizes southern New England, eastern Pennsylvania, New Jersey, the Carolina and Gulf coastal plain, scattered areas around Lake Michigan, the Phoenix-Tucson area of Arizona, and California's southern Central Valley (figure 11). The maximum value for nitrates is in Suffolk (NY) county.

Wildlife Habitat
Indicators of wildlife problems include potential for improvement of wildlife habitat and the presence of actual or potential habitat for species threatened or endangered by agricultural development.

Potential for Wildlife Habitat Improvement--The quality of wildlife habitat depends on the structure of vegetative cover at each site and the diversity of covers on surrounding sites. This index is derived from data collected in the 1982 NRI by SCS National biologist Carl Thomas. It measures general (non species-specific) changes in the habitat structure at the sample point, primarily in going from cropland to grass cover, and the diversity of land uses around the sample point. The more intensive the current crop production system (particularly in regard to winter cover) and the less monotonic the surrounding land use pattern, the higher the index. Concentrations include eastern North Carolina, northern Florida, the Louisiana delta, and scattering throughout the Southwest (figure 12). Maximum index values occur in Union (PA) and Adams (NE) counties. There is no population-weighted version of this map.

Species Threatened and Endangered by Agricultural Development--This index is based on counts of T&E species by county from FWS listings indicating agriculture development as a contributor to the T&E status. Concentrations are in Florida, California, southern Arizona, Nevada, water resources developments along the Tennessee river in Tennessee and Alabama, a stepping-stone pattern along the flyway of the whooping crane in Texas, Nebraska, and the Dakotas, and in south central Missouri (figure 13). Maximum index values occur in Highland and Polk (FL) counties. There is no population-weighted version of this map.

Soil Erosion

Indicators of problems associated with soil erosion include potential loss of soil productivity and potential for offsite problems caused by windblown soil.

Potential Soil Productivity Loss--Soil erosion rates, topsoil depths, and current soil productivity are key factors in soil productivity losses. Two factors are reflected in the unweighted version of this index: topsoil depth and the depth potentially lost to wind and water erosion each year. Thinner soils with higher erosion rates have fewer years of productivity remaining than thicker soils at lower erosion rates. A third economic factor is added in the weighted map, the value of the soil lost, represented by productivity-adjusted dryland cash rent. Thus the darkest areas on these maps have combinations of thin topsoil, high erosion rates, and valuable land.

Unweighted--Examining current erosion rates versus topsoil depth as a measure of potential productivity loss highlights problems with high erosion rates on thin soils in eastern Montana and Colorado, the Texas panhandle, South Dakota, eastern Nebraska, and along the east bank of the Mississippi Delta (figure 14).

Value weighted--Weighting by cash rent, four major concentrations appear on the map, the largest being centered on Iowa, Illinois, and Missouri in the Corn Belt (figure 15). A second concentration is the eastern bluffs of the Mississippi in western Kentucky, Tennessee, and Mississippi along the eastern edge of the Mississippi Delta. A third concentration is the irrigated cotton area of the Texas Panhandle, stretching up to the eastern edge of Colorado. The final concentration is a band of eastern Washington and Oregon around the Palouse wheat area. The maximum value occurs in Franklin (IN) county. Weighting by the cash rent value deemphasizes areas with less valuable soils in favor of erosion on the highly productive soils in the Corn Belt.

Potential Windblown Dust--This measure proxies for damages associated with windblown dust from wind erosion. Notice that basic data on wind erosion were not collected by SCS east of the 100th meridian except for states in which localized wind erosion problems were known to exist (Florida, the Eastern Shore, southern New Jersey, lake shores in Ohio, Indiana, and Michigan, and the loess soils of northeastern Arkansas).

Unweighted--Unweighted wind erosion is highest in the Rio Grande valley of Texas, the 1930's Dust Bowl of panhandle Texas, Oklahoma, southwestern Kansas, and eastern Colorado, eastern Montana, and scattered cropland areas of the Mountain states (figure 16).

Population weighted--Severe wind erosion rates, high affected populations, or a combination of the two map heavily using this indicator. Notable concentrations include Dade County, Florida, southern Texas near Corpus Christi and Brownsville, the Texas panhandle southwest of Lubbock, the Denver and Colorado Springs areas, areas around Billings, Montana, California's southern Central Valley near Bakersfield-Fresno, and the eastern Washington area around Richland (figure 17). The maximum index value occurs in Riverside (CA) county.

Other Indicators
Other indicators of interest include potential exposure to agricultural pesticides and potential for reducing flood damages through wetland restoration in floodplains.

Potential Flood Peak Reduction--With the Midwest floods fresh in the public mind, wetland restoration in floodplains to improve out-of-bank storage is topical. One aspect of floodplain management is the use and drainage of land within the 100-year floodplain, particularly land drained for crop production on former wetlands (hydric soils). A proxy for flood damages is achieved through weighting by the watershed population potentially affected.
Unweighted--Floodplain cropland is concentrated in the Missouri, Mississippi, Ohio and Red river valleys of North and South Dakota, Minnesota, Iowa, Wisconsin, Illinois, Missouri, and the Mississippi Delta (figure 18).

Population weighted--Concentrations are in eastern North Carolina, the Ohio-Mississippi confluence and lower Mississippi, the Iowa-Cedar Rivers area, the Grand-Osage rivers in Missouri, the Red River of the North in Minnesota/North Dakota, and the watersheds of the Front Range in Colorado (figure 19). Maximum index values occur in Somerset and Monmouth (NJ) counties.

Potential Pesticide Exposure--Exposure to pesticides is a function of the amount applied, and the persistence and toxicity of the material. This measure is based on the characteristics of the pesticides applied, measured by the ratio of soil half-life to acute oral toxicity to mammals. Thus, higher amounts applied of more toxic pesticides that persist in the soil longer are assumed to be more potentially harmful than smaller applications of less toxic pesticides that degrade more rapidly. Clusters occur in northern Maine, eastern North Carolina and southern Virginia, Florida, southern Georgia and eastern Alabama, southern Arizona, parts of California's Central Valley, and Idaho's Snake River valley (figure 20). The Corn Belt and northern Plains have relatively uniform and low scores. Maximum index values occur in Cameron (TX) and Autauga (AL) counties. There is no weighted version of this map.

Composite Environmental Benefits Index

Finally, geographic information systems capabilities allow the various indices to be combined into a composite index which gives an aggregate measure of agricultural environmental performance. Further, the composite index can be combined with data on other farm and economic factors. For example, the composite environmental index can be combined with the distribution of farm program payments to show areas with high relative environmental problems that also receive high levels of farm program payments. This kind of geographic analysis can be a useful way to assess how much existing programs can be redirected toward environmental objectives without alienating current program constituents.

Composite index--Summing across all the environmental indicators (weighted by affected populations or dryland cash rent) shows that the greatest environmental problems associated with agriculture are located in Long Island, eastern Pennsylvania and New Jersey, eastern North Carolina, Florida, Alabama, along the Chicago lake plain, in the Mississippi Delta region of Missouri, Tennessee, Arkansas, Louisiana, and Mississippi, in southern Texas, and in the south part of California's Central Valley and south central Arizona (figure 21). Secondary areas with lower overall composite scores are in the Corn Belt, along the southern coastal plain, and in the Texas panhandle.

Farm and Economic Factors

A number of farm and economic factors are useful to put the environmental indicators into perspective. Findings regarding these factors include:

Agricultural Diversity--Groupings of farms by county into regional farming clusters were constructed by Sommer and Hines (1991) and adapted for this publication. Agricultural enterprises that do not enjoy government income and price support programs include poultry; sheep, cattle, and other livestock; and vegetable, fruit, and nursery crops (figure 22). Poultry production is clustered in a broad crescent through the Southeast from the Delmarva peninsula, through Virginia, North and South Carolina, Georgia, Alabama, Mississippi, and Arkansas. Sheep, cattle and other livestock occur in Virginia and West Virginia, from southern Missouri through east Texas, and in the Mountain states. Vegetable, fruit, and nursery production hugs the coasts, particularly the Northeast, Lake State, Florida, and the Pacific coast from Washington to southern California and Arizona.

Farm types with government income and price supports include corn, soybeans and hogs; dairy and other crops; cattle, wheat and other grains; tobacco; and cotton (figure 22). The corn, soybean, hog complex is centered in the traditional Corn Belt, extending into western Kentucky and Tennessee. Dairy is important in the Lake states, the Northeast, and New England. Cattle and wheat dominate the northern Mountain states and the Great Plains, but are important in smaller clusters in eastern Virginia and North Carolina, in southern Georgia, and, in rice production in northeast Arkansas and along the Texas/Louisiana coast. Tobacco clusters in Kentucky, eastern Tennessee, Virginia, and North and South Carolina. Cotton is the important enterprise in the Mississippi Delta region, the Texas panhandle, and in Arizona and California.

Cropland productivity--Cropland productivity, as measured by net cash returns per acre of cropland, is highest in coastal areas where climate, soil, and irrigated conditions favor production of high-value crops and in areas where proximity to population favor production of perishable crops, or where integrated livestock operations draw from extended cropping areas (figure 23). The next rank of productive lands is centered in the Corn Belt, Lake, Northeastern, and Southern coastal plain.

Farm Program Payments--While many enterprises enjoy significant government support, the absolute dollar value of farm program payments is highest in the Corn Belt, the wheat areas of the northern and central Plains, Mississippi Delta, in the cotton areas of the Texas panhandle, Arizona and California's Central Valley, and in the wheat growing areas of eastern Washington and Oregon (figure 24). These data reflect conditions in 1997.

Farm Program Payments and Environmental Indicators--Since 1985, conservation compliance, swampbuster, and sodbuster provisions of farm legislation have exerted positive leverage on environmental problems associated with agricultural production. The degree to which environmental concerns shown by the indicators mapped here can be dealt with through conservation compliance mechanisms depends on the coincidence between program payments and the problem conditions. Relatively little overlap exists between areas with high program payments per acre and the highest population-weighted composite environmental indicator. For scattered areas across Iowa and Illinois, Louisiana, coastal and panhandle Texas, Arizona, and the northern Central Valley, conservation compliance could leverage significant additional environmental gains. Moderate farm program payment levels are associated with the highest environmental problems in broader bands of the Southeastern coastal plain, the eastern Corn Belt and the Missouri and Mississippi Valleys, eastern Texas, and the Central Valley. Large parts of Florida, the Northeast, the Southeastern piedmont, Louisiana, and coastal California have high composite environmental scores, but little or no farm program payments with which to leverage changes in farm production practices. In these areas, environmental gains must be purchased with positive inducements, such as a green support program, or compelled through regulatory programs.

Large parts of the most intensively farmed areas of the country, including much of the Corn Belt and Great Plains, have lower farm program payments and less critical environmental problems, as measured by the population-weighted composite score.

Conclusions

What can we learn from these maps about designing programs to address agriculture's environmental problems? Four lessons seem clear.

Different objectives affect different areas. The intensity of different environmental problems associated with agricultural production is not distributed uniformly across the country generally, nor is it uniformly distributed across areas with significant agricultural production. This results from the joint distributions of intensive agricultural production practices and vulnerable resource conditions. The design of a green support payment program must take into account the varying distributions of environmental problems by specifically addressing which problems or mix of problems the program aims to solve and what mechanisms are selected to provide incentives or leverage.

The greatest physical problems may not coincide with the greatest program benefits. Green support program design must choose between targeting areas with the greatest potential physical problems and areas with the greatest potential social and economic benefits from addressing physical problems. Weighting an indicator by affected population shows that these two targeting strategies do not always coincide.

The relative importance of different environmental problems changes the areas targeted. While environmental indicators can show the distributions of potential environmental problems, and they can be combined to identify areas with multiple problems, they cannot show which environmental problems are more or less important. Stated differently, problems with equally high index values may not be equally important. The relative importance of different problems is a subject for political consensus or far more intensive analysis of risks than can be encompassed here.

The relative importance of environmental objectives and income support or other farm program goals changes the areas targeted. The current distribution of farm program payments is not greatly correlated with may of the environmental indicators developed here. If a green support payment program supplants existing income support programs, many current recipients will lose and producers that do not currently receive payments will gain. Mixing income support and environmental improvement objectives may require less than optimal environmental performance.

It seems likely that some kind of environmental indicators will be instrumental in identifying environmental problems to be addressed through new farm programs and efficiently targeting available funds to areas with the greatest potential benefits. The indicators developed here can be a starting point in that process.

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APPENDIX

This appendix provides more detailed descriptions of the environmental indicators mapped in this paper.

Water Quality

Given the importance which the public attaches to nonpoint source water quality problems associated the agriculture, four measures of surface and groundwater quality problems are included in the environmental index.

Surface Water--Three measures of surface water quality are included in the index: potential sediment delivered to streams, potential nitrogen runoff from excess commercial fertilizer, and the potential for filter strips. All are weighted by the population in the watershed, to reflect the differential potential for reducing damages from degraded water quality.

Sediment delivery is calculated based on the distance to water, measured from every NRI sample point, and the amount and average slope of intervening land uses. Shanholtz and Kleene (1992) calculate delivered sediment by multiplying gross erosion times a delivery ratio (DR) calculated as a function of land cover, flow path length, and slope as:

$DR = e^{-kdSf}$

Where k = land cover coefficient = 0.4233 for cropland
0.71 for pasture
1.1842 for non agricultural woodland

d = is the flow path length from the field to the nearest stream
S_f = slope function = $e^{-n(S + S0)} + S_{fmin}$

Where n = 16.1
S0 = 0.057
S_{fmin} = 0.60
S = slope percent of the land use segment in the flow path.

and DR is calculated over all land use/slope segments in the intervening flow path. The flow path distance is proxied by the distance to water variable measured at each NRI sample point, but the land use and slope makeup of the intervening flow path can't be determined. As a proxy, we determined the acreage and average slope of cropland, pasture, and forestland in each NRI polygon and assumed that, on average, those values would apply to the flow path from each NRI sample point in the polygon.

Following Yagow, et al. (1993, 1990), runoff N loss is calculated as the sum of runoff-extracted N. Runoff-extracted N is the product of soil soluble N in the top centimeter of the soil and runoff volume:

$RON = .443 * CSOIL * R * 0.20 * 10^{-2}$

$$\text{Where } CSOIL = \frac{(QPORE + XNFERT * 0.05 * 73)}{.01 * (QSOIL + I)}$$

QPORE = 0.1 * CPORE * POR
CPORE = concentration of N in soil pore water = 5 mg/l
POR = soil porosity = 1-(BD/2.65)

BD = soil bulk density (from SOILS5)
QSOIL = mm of water in the top cm of soil at saturation = 10 * POR
XNFERT = excess nitrogen, kg/ha, calculated by Wen Huang for corn, wheat, and cotton crops grown at each NRI sample point.
0.05, 73 = scaling factor for annual net mineralization and annual net mineralization rate in kg/ha.

Finally, there is much support for riparian filter strips bordering streams that will intercept sediment and nutrient runoff from upland fields, before they reach surface waters. We identified NRI points representing fields within 100 feet of water bodies as having potential for filter strips.

Shortcomings and future plans--It would be nice to include sediment associated phosphorus as a surface water quality index component, but there are no available data on soil phosphorus concentrations. In addition soil phosphorus concentration can only be changed by altering fertilizer inputs over a period of several years. Retiring land in a CRP program would not appreciably affect the soil phosphorus concentration, but would reduce sediment associated phosphorus losses by reducing the amount of sediment delivered by reducing the amount of sheet and rill erosion.

Shortcomings of the nitrogen runoff map are in the nitrogen data, the populations used for weighting, and possibly the runoff calculation. Excess N calculations are for corn, wheat, and cotton only, done by Wen Huang (1992). They are based on early Cropping Practices data averaged across counties, then reaveraged across the entire state. Excess N does not include any contribution from animal manures. The watershed populations used are for the 105 Water Resources Council subareas, which are quite large. The runoff calculation produces N runoff at zero excess N because it uses the change in soil pore water nitrogen and is not particularly sensitive to large excess N loadings.

Improvements will use new excess N calculations for all crops (wheat, corn, cotton, rice, and potatoes) from 1991 and 1992 Cropping Practices Surveys, the fruit and vegetable survey data, and Area studies data, and will include a calculation of N from animal manure, where applied. I may change the way the calculation is done, as well. New watershed population estimates will be made for 8-digit hydologic unit watershed, more closely approximating the populations directly affected over a smaller area. Low level estimates of N runoff will be censored.

Groundwater--Measures of groundwater vulnerability to pesticide and nitrate leaching are used which include both the propensity and amount of material subject to leaching and the leaching potential of the soil. Both measures are weighted by the population using groundwater sources in the county.

The groundwater vulnerability index for pesticides (GWVIP) was developed by Kellogg et al. (1992). GWVIP is a function of soil leaching potential, pesticide leaching potential, precipitation, and chemical use. It is an extension of the national level Soil-Pesticide Interaction Screening Procedure (SPISP) developed by the Soil Conservation Service (Goss and Wauchope, 1990). Chemical use at each NRI sample point was inferred on the basis of the crop grown using chemical use data by crop and State assembled by Leonard Gianessi (Gianessi and Puffer, 1992, 1990). GWVIP does not depend on the amount of chemical applied, but the type of chemical, it's leaching potential, and the leaching potential of the soil to which the chemical is applied.

The groundwater vulnerability index to nitrates developed by Kellogg et al. was based on work by Williams and Goss and excess nitrogen calculations done by Wen Huang (1992) and Huang et al. (1990). Excess nitrogen per acre is the difference between the amount of nitrogen from commercial fertilizer applied, including credit for nitrogen fixed by previous leguminous crops, and amount taken up by the crop. Excess nitrogen calculations were limited to corn, wheat, and cotton crops, and did not include nitrogen contributions from applied animal manure. GWVIN is calculated in the same way as GWVIP, except that estimated excess nitrogen applied replaces the pesticide use and leaching class information used in calculating GWVIP.
Shortcomings and future plans--The GWVIP is based on Leonard Gianessi's pesticide data at the state level, allocated proportionally to the county level based on 1987 Census expenditures on ag chemicals. While GWVIP does reflect both material and soil leaching characteristics, it ignores differences in the potential harm of the chemical leached. The

GWVIN is based on Wen's excess N calculations for only corn, wheat, and cotton and ignores manure.

We intend to use the new excess N calculations discussed above. We are updating pesticide application data from the CPS, F&V surveys and Area studies, averaged across state parts of MLRA's. We also intend to weight the pesticide applications by their "nastiness", the ratio of soil half-life to acute oral toxicity to mammals. This will account for differences between equally leachable pesticides that have different potential harmfulness.

Wildlife Habitat

Wildlife habitat concerns embrace both relatively common species, such as pheasant, deer, and cottontail rabbit, that adapt readily to farm environments, and rarer endemic species that are often driven to the point of extinction by agricultural development and agricultural production. To measure general changes in wildlife habitat, we use a habitat structure index developed by Carl Thomas and implemented in the 1982 NRI (USDA, 1987; Streeter, et al, 1983).

This approach describes habitat as a series of layers, each consisting of different types of vegetation and occupying a different space in the environment. Areas with more layers tend to be capable of supporting a greater diversity of species because of the larger number of available habitats. Six layers of habitat were used in constructing the Habitat Structure Index (HSI) developed for this analysis: water surface, terrestrial subsurface, understory, shrub midstory, tree bole, and tree canopy.

The layers of habitat available for wildlife depend upon the type of land cover. Six covers were considered in the analysis: fruits, nuts and other horticulture; row crops, small grains, and vegetables; grass and hayland; grass and pastureland; rangeland; and forestland. The habitat layers within each cover type vary from 3 for row crops to 5 for forestland. In addition to the number of layers present, the condition of the layers affects the habitat potential. Therefore, each layer is rated using variables describing the condition of the layer, such as tree canopy density and rangeland condition. Each layer is rated between 0 and 1 by dividing through by the maximum number of potential layers. The resulting HSI value can be interpreted as the percent of maximum potential habitat structure available. In this index, the difference in HSI between the current cropland cover and grass is calculated, measuring the potential improvement in HSI if the land were idled, or the decline in habitat structure from conversion to cropland.

In addition to habitat structure at the NRI sample point, wildlife is also affected by the diversity of uses in the surrounding landscape. Distance variables are collected in the NRI, measured in terms of feet to the nearest occurrence of water, wetlands, cropland, and other land uses. The distances are used to calculate a habitat diversity index (HDI) by summing the inverse distance-weighted presence of additional land uses. Both change in HSI and HDI components are multiplied to produce the habitat index (HI). The difference between the HI in cropped use and in CRP cover is calculated to reflect the change in habitat value that either has occurred or could occur with restoration of permanent cover in CRP.

To measure the impact on endemic wildlife species, the number of endangered species in counties with known and potential habitat was obtained from a joint Soil Conservation Service/Forest Service study (Brady and Flather; Biodata Inc.). When each of the 809 species listed as threatened or endangered were formally added to the endangered species list, counties in which the species is known to be found or that have appropriate habitat but no known populations, were added to the database. One or more of 63 reasons for species endangerment were also recorded in the database, including species threatened by agricultural development which was selected as the criteria for this indicator.

Shortcomings and future plans--The habitat structure index is intended to be evaluated in relation to a particular specie's or guild of species' habitat needs. That is, does the habitat being evaluated supply the particular breeding and feeding niches needed to support the species under consideration. However, the greater the number of habitat layers provided, the better the habitat can support a variety of species, giving a rationale for using the index as a general measure of habitat structure. The diversity component also has a drawback in that it does not measure change in diversity from changing cover at the sample point. However, an accurate measure of the amount of land changing cover relative to existing covers nearby would be needed to calculate change in HDI, and that data is not available. The threatened and endangered species index could be improved if sub-county delineations of habitat were available, but this would be a marginal improvement. There are no plans to change these two indices.

Neither of these indices is weighted by affected population because it is difficult to determine what the affected populations should be. Wildlife is enjoyed both consumptively and nonconsumptively by large numbers of people who are often willing to travel long distances. However, most hunting and nature watching is probably done relatively close to home. The problem of population weighting is even more difficult for threatened and endangered species because, for many of the more obscure species, existence values presumably make up a large part of the value set. For these reasons, there are no plans to weight the wildlife habitat indices by affected populations.

Soil Erosion

The erodibility index (EI) used by USDA for CRP and conservation compliance eligibility divides potential sheet and rill or wind erosion by the soil loss tolerance factor (T value) to reflect the vulnerability of the soil to productivity loss (Heimlich and Bills, 1986; McCormack and Heimlich, 1985). However, many soil scientists argue that currently used T values do not accurately reflect true soil vulnerability to degradation (Cook, 1983; 1982). CRP eligibility rules have also reflected disagreement as to whether potential erosion or actual erosion should be used.

As an alternative to T values, we convert the total erosion from both sheet and rill and wind, in tons per acre per year, to inches per year using the soil bulk density. This rate of soil loss in inches is divided into the topsoil depth (A horizon) from the Soil Interpretive Record (SOIL 5) associated with each NRI cropland observation. This measures how many years it would take to deplete the topsoil, at current rates of erosion. Finally, in order to reflect the relative economic value of different soils, we multiply the inverse of this measure by the productivity-adjusted dryland cash rental rate. Thus, low erosion rates or deep topsoil that will last a long time are given less weight, and more productive soils are given more weight. The resulting measure is:

$$SDI = (PE/TD)*R$$

whereSDI = the soil degradation index;
TD = topsoil depth, measured as depth of the A horizon in inches;
PE = potential erosion from water or wind, described above, converted to inches/year;
R = soil-specific productivity adjusted dryland cash rent, calculated from average county rents, adjusted for differences in relative productivity of the soils occurring at 1982 NRI sample points.

A second measure reflects potential for offsite air quality damages associated with wind erosion. The amount of wind erosion at each NRI sample point is weighted by the population of the county in which the point occurs. Weighting by county population reflects the potential pool of damages from health, cleanup and maintenance expenditures associated with wind-borne dust (Piper, 1989; Huszar and Piper, 1986).

Shortcomings and future plans--A key simplifying assumption in this index arises from treating all erosion as completely removed from the field. In reality, both sheet and rill and wind erosion only move soil around on the surface of the field, with only a small fraction actually being removed from the site. Because good data are not available on differences in actual soil removal over space, the results of this assumption cannot be improved on.

County population is currently used as a proxy for potential economic damage. An improvement would be to develop population ellipses oriented in the direction of crop season prevailing wind and proportional to crop season average wind speed. Data from the EPIC weather generator are available to develop the ellipses, populated with ZIP coded population data contained within the ellipse. This would likely improve the accuracy of the map, but will not likely change the overall pattern of potential damages.

Other Environmental Problems

The two remaining environmental problems indexed are topical, relating to exposure to pesticides used in agricultural production and potential for improved floodplain management associated with cropland developed from wetlands in flood-prone areas.

Pesticide Exposure--Various indices have been developed to compare pesticide materials. Potential harm associated with agricultural chemical use is proportional to the amount of the material used, but also depends on the characteristics of materials applied. For example, all other things equal, pesticides produce greater harm the longer they take to degrade and the smaller the amount of material to achieve a given level of toxicity. Following Heimlich and Ogg (1982), we multiply pounds of each active ingredient applied by the soil half-life of each material and it's acute oral toxicity to rats.

$PEI = \Sigma\, AI * 1/LD_{50} * H$ summed over all pesticides in the crop rotation or on the crop

Where: AI = pounds of active ingredient

LD_{50} = Acute toxicity measure, lethal dose to 50 percent of lab animals. The lower this number is, the more toxic the material. We could substitute LC_{50}, which is an acute toxicity measure for aquatic organisms, or the HAL, the Health advisory level, which is a measure of chronic toxicity over an extended period.

H = half-life of the pesticide in soil. The shorter this period, the less time the environment is exposed to the material. We could also get different half-life measures associated with foliar surfaces or in the plant, but this one is more generally available.

Shortcomings and future plans--This index is based on Giannesi's pesticide data and the suggested improvement is as above. The components of the "nastiness" index are the two most readily available, but do not reflect most of the food safety concerns: chronic toxicity (such as EPA health advisory levels), fat solubility, and bioaccumulation. Nevertheless, this is a useful start and could provoke development or assembly of better data.

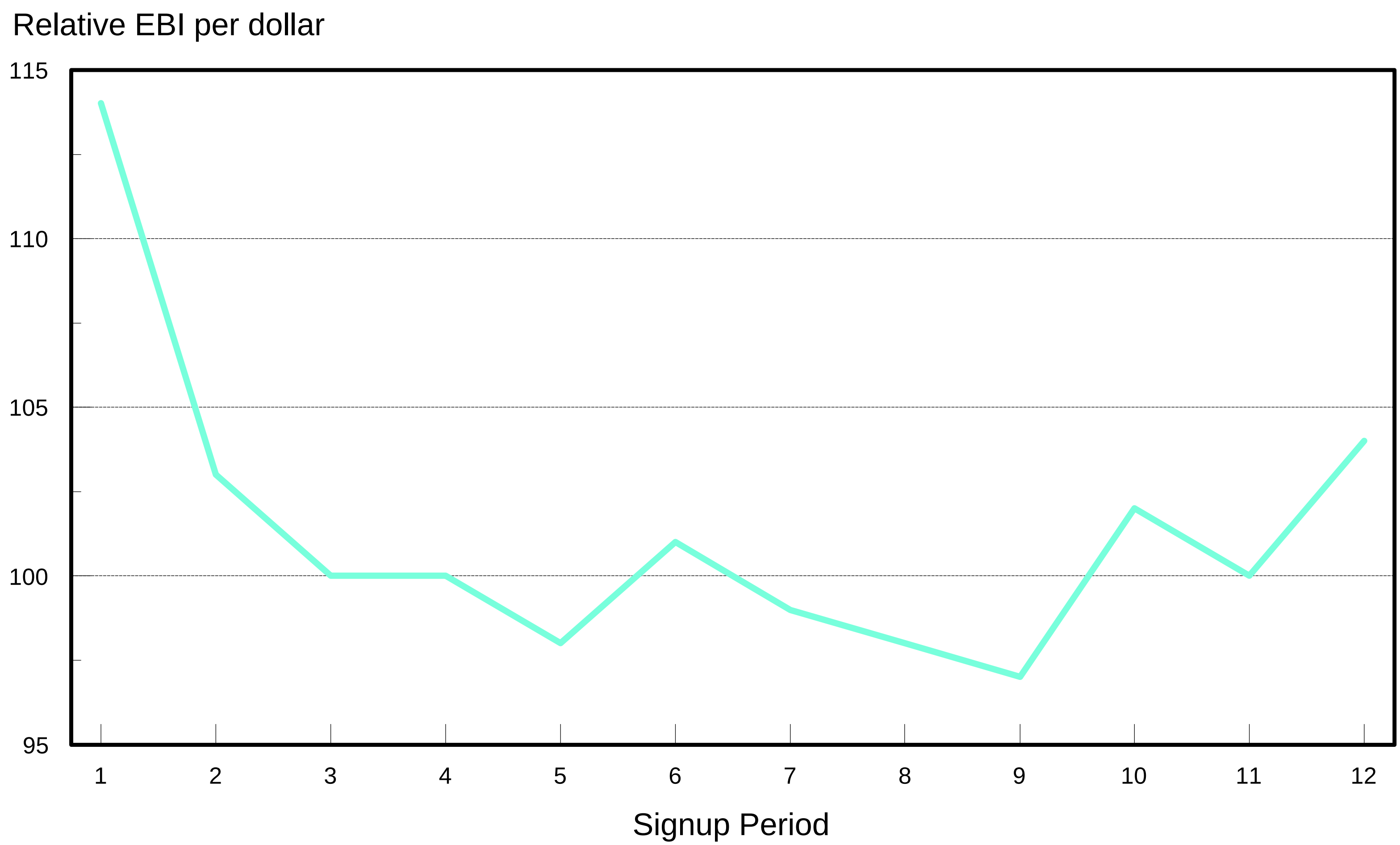
Floodplain Improvement--Record flooding on the upper Mississippi and Missouri rivers during 1993 focused attention on cropland developed from former wetlands and cropland in the floodplain. This measure identifies cropland with hydric soils, indicating that it was formerly wetland, that is also located within the 100 year floodplain. This was weighted by the population in the watershed to give an indication of possible damages from flooding that could be averted by restoring these areas to wetland.

DATA AVAILABILITY

The indices presented in this paper are available as a dataset by NRI polygon (combination of county FIPS code, major land resource area (MLRA), and 8-digit hydrologic (watershed) unit. Environmental indicators can be constructed using the GIS system and 1992 National Resources Inventory data, in conjunction with other data sets, for specific economic analyses.

Figure 1--Environmental Benefits Index

CRP Land Enrolled, by Signup



Source: Barbarika, Osborn, and Heimlich, 1994.

Figure 2--Potential Sediment Production

Sheet and rill erosion delivered to streams

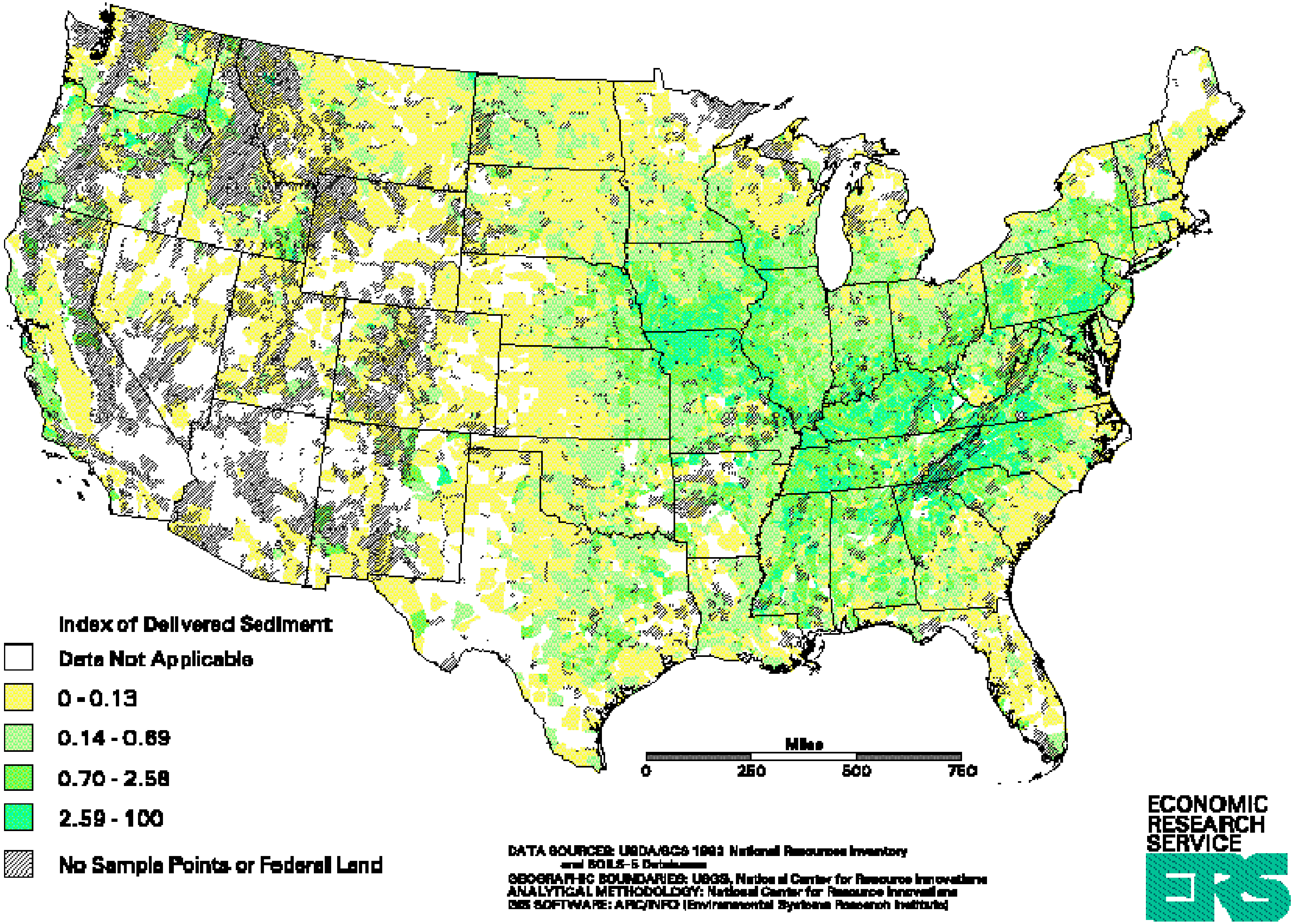


Figure 3--Potential Sediment Production

Sheet and rill erosion delivered to streams, weighted by watershed population

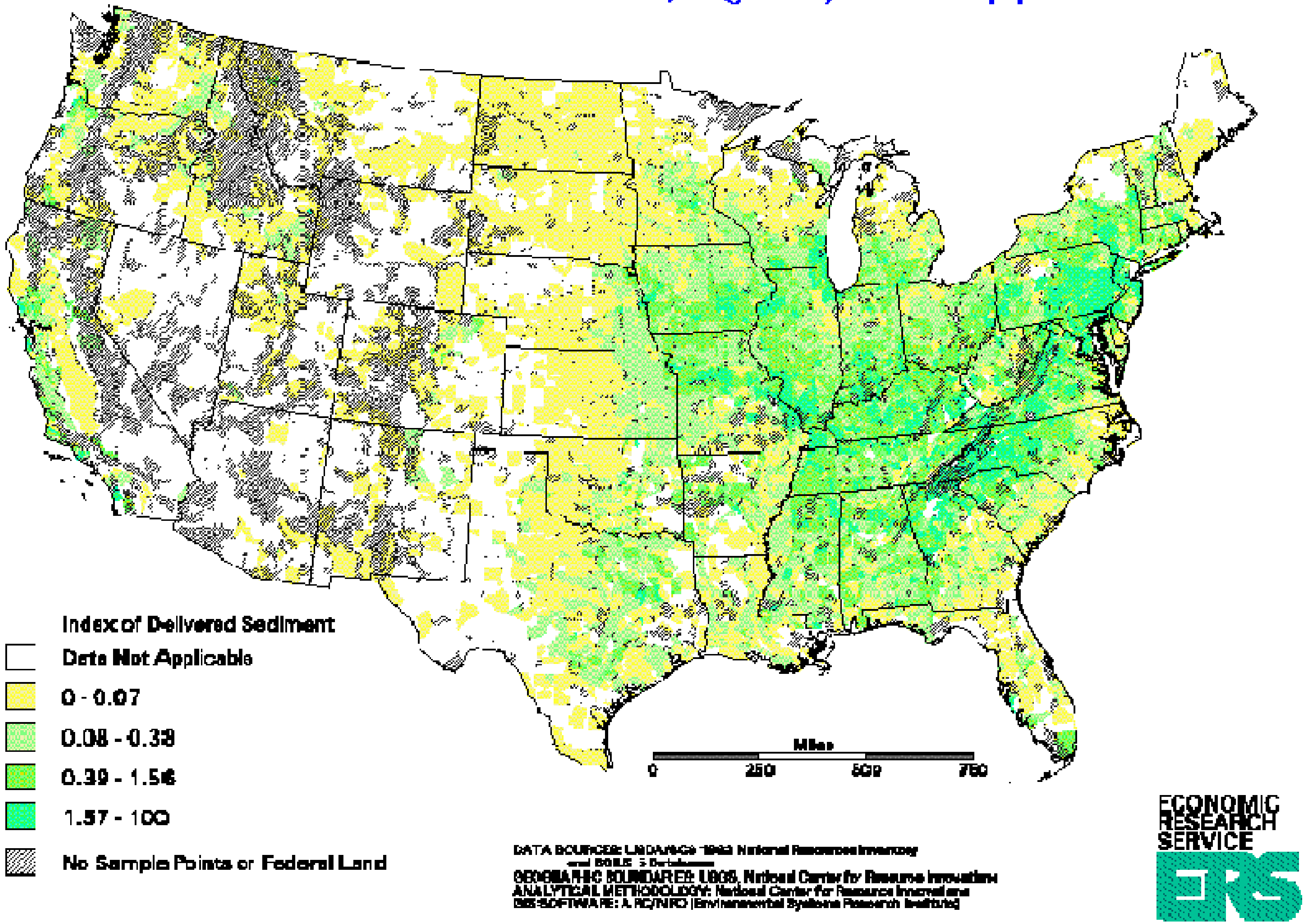


Figure 4--Potential Nitrogen Runoff

Excess nitrogen runoff to surface waters

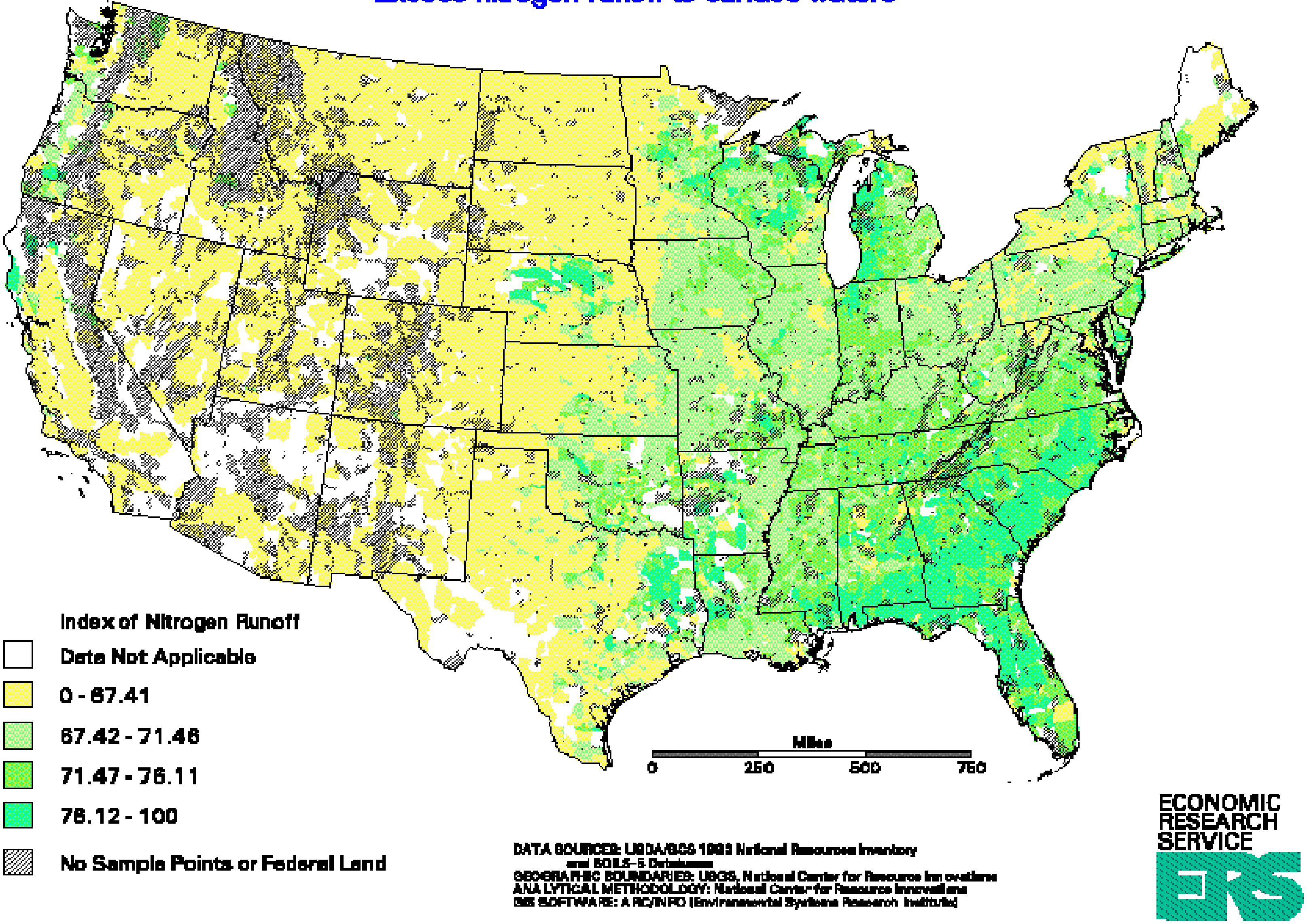


Figure 5--Potential Nitrogen Runoff

Excess nitrogen runoff to surface waters, weighted by watershed population

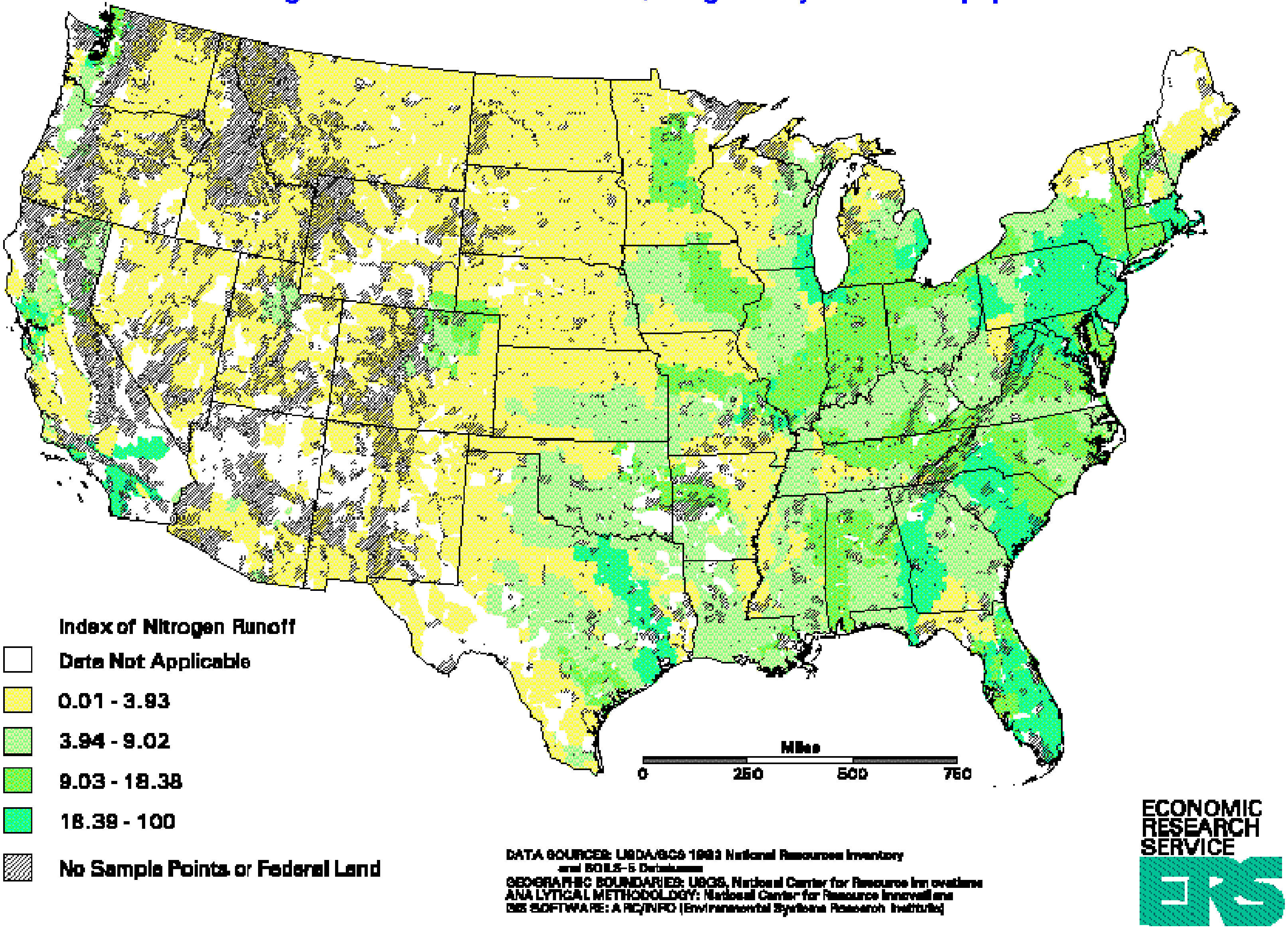


Figure 6--Potential for Filter Strips

Cropland within 100 feet of streams and lakes

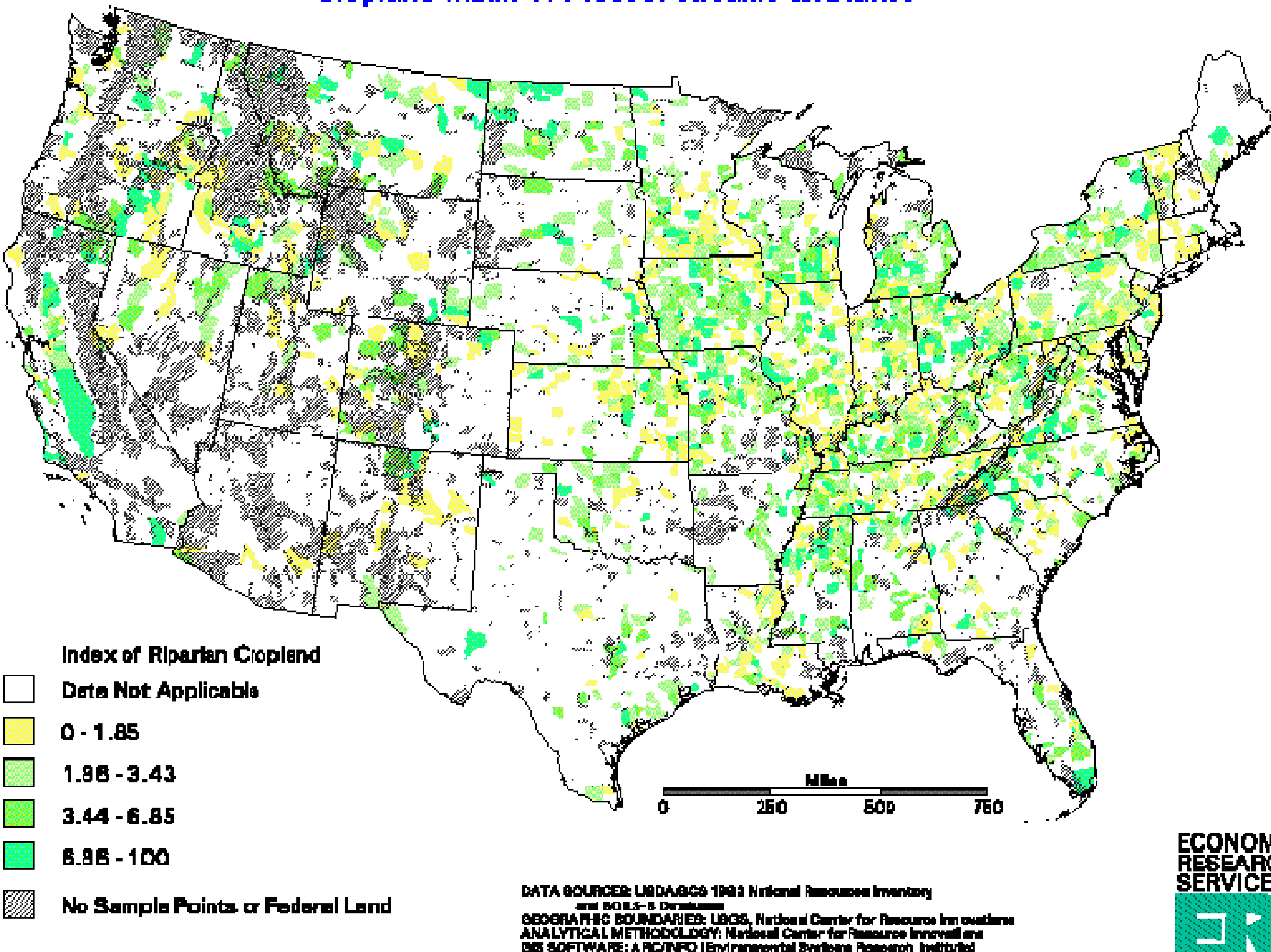


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Figure 7--Potential for Filter Strips

Cropland within 100 feet of streams and lakes, weighted by watershed population

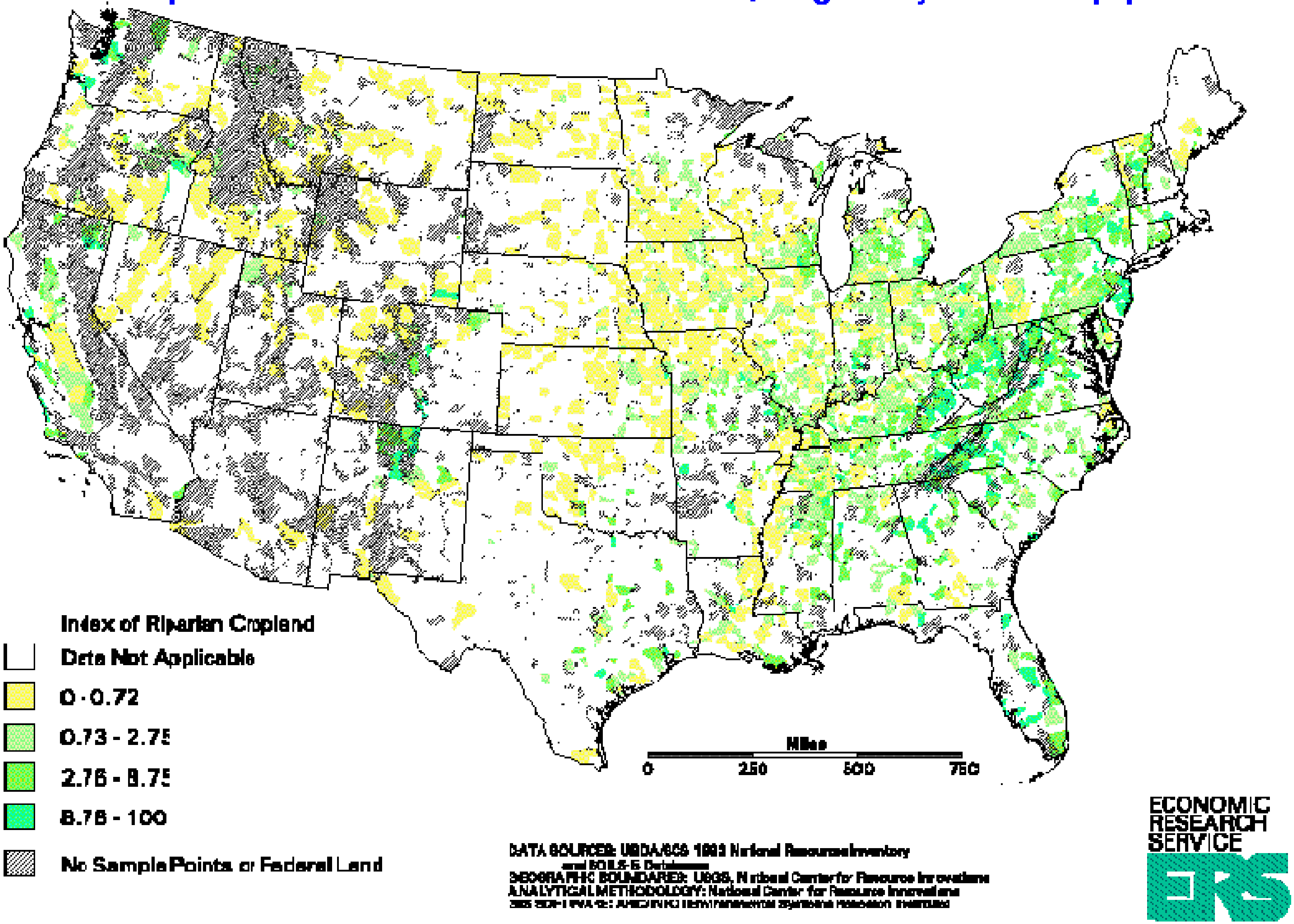


Figure 8--Potential Pesticide Leaching

Leaching classes of pesticides applied to leaching classes of cropland soils

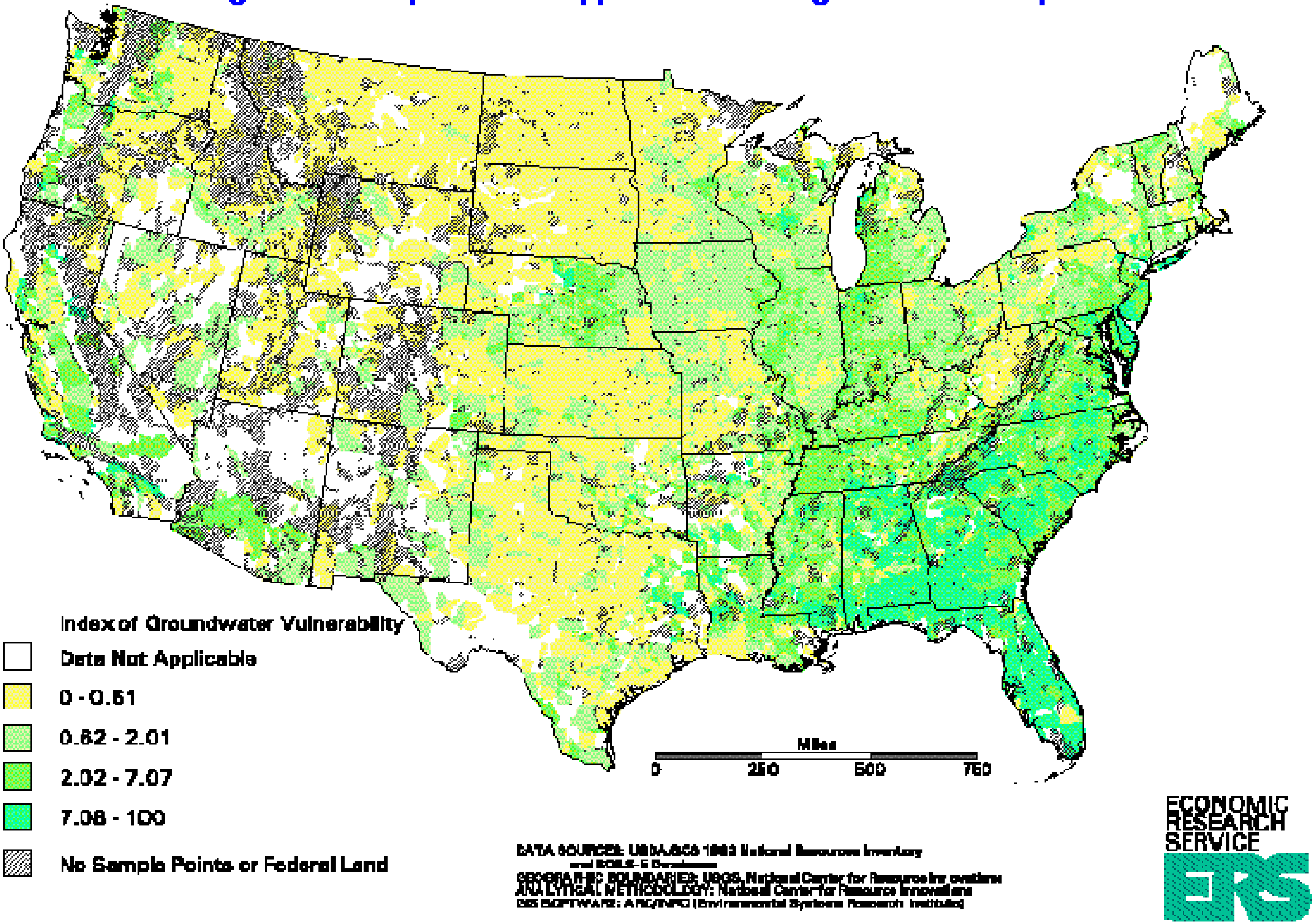


Figure 9--Potential Pesticide Leaching

Leaching classes of pesticides applied to leaching classes of cropland soils, weighted by population using groundwater

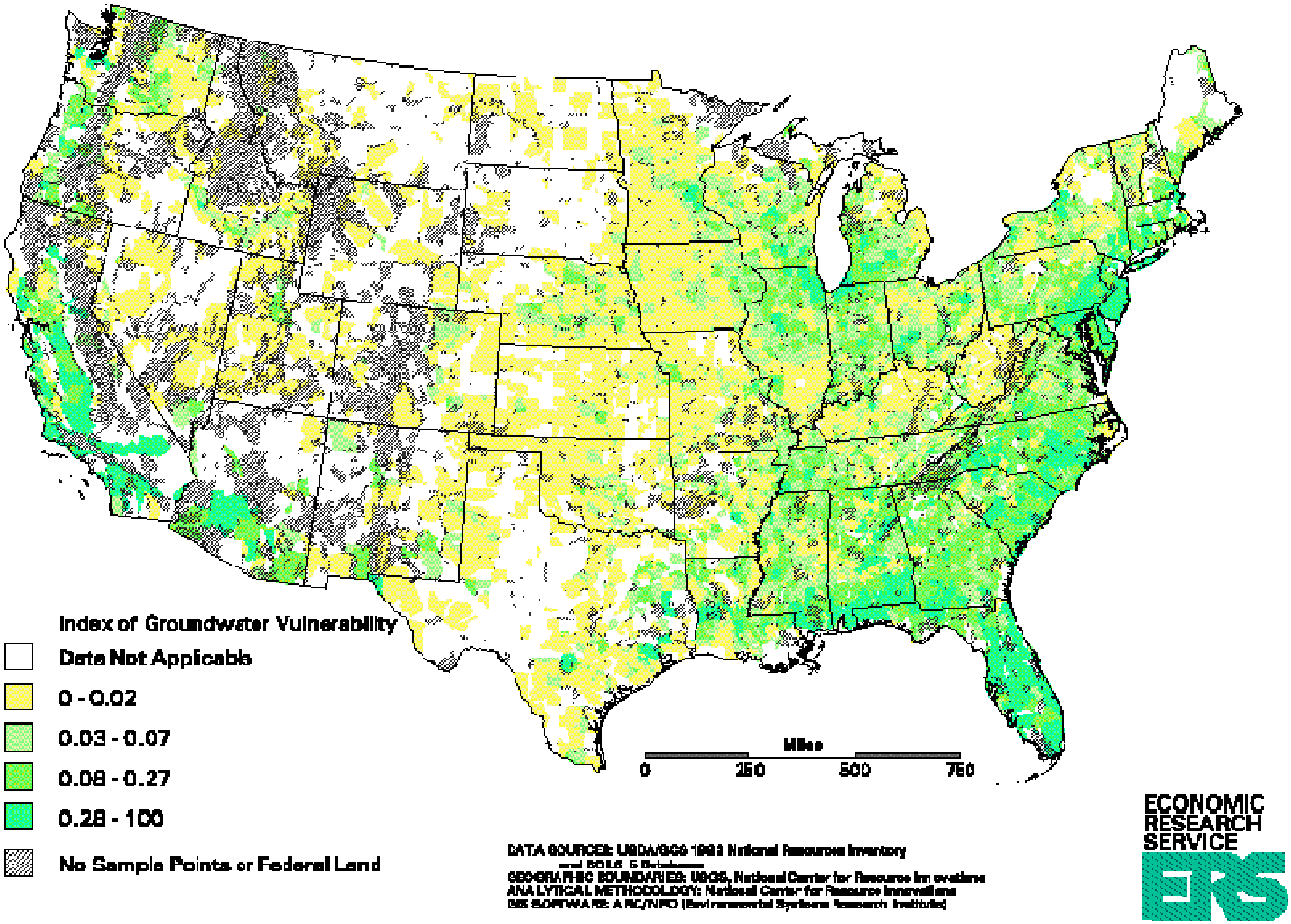
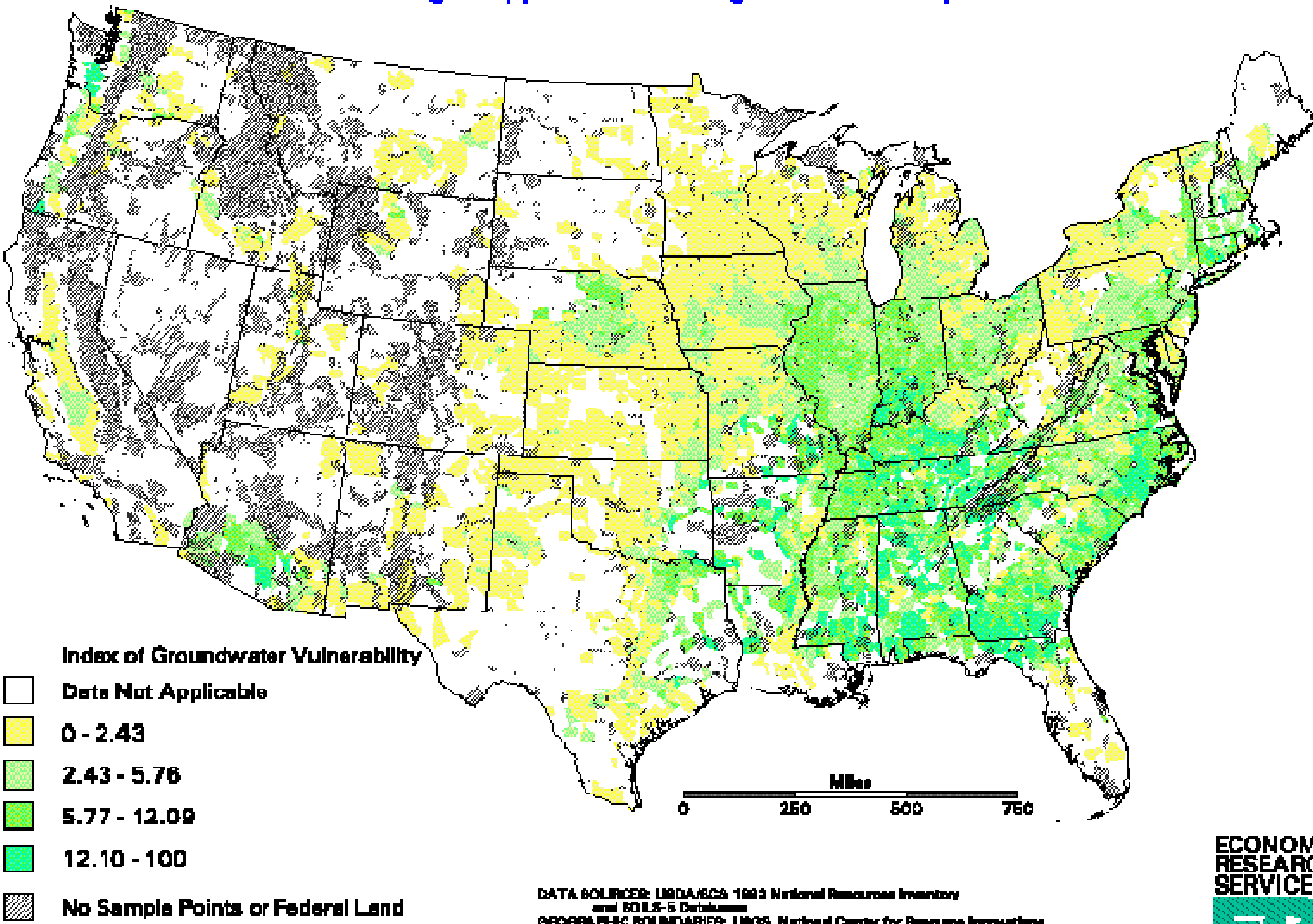


Figure 10--Potential Nitrate Leaching

Excess nitrogen applied to leaching classes of cropland soils



DATA SOURCES: USDA/SCS 1992 National Resources Inventory and SOILS-5 Databases
GEOGRAPHIC BOUNDARIES: USGS, National Center for Resource Innovations
ANALYTICAL METHODOLOGY: National Center for Resource Innovations
GIS SOFTWARE: ARC/INFO (Environmental Systems Research Institute)

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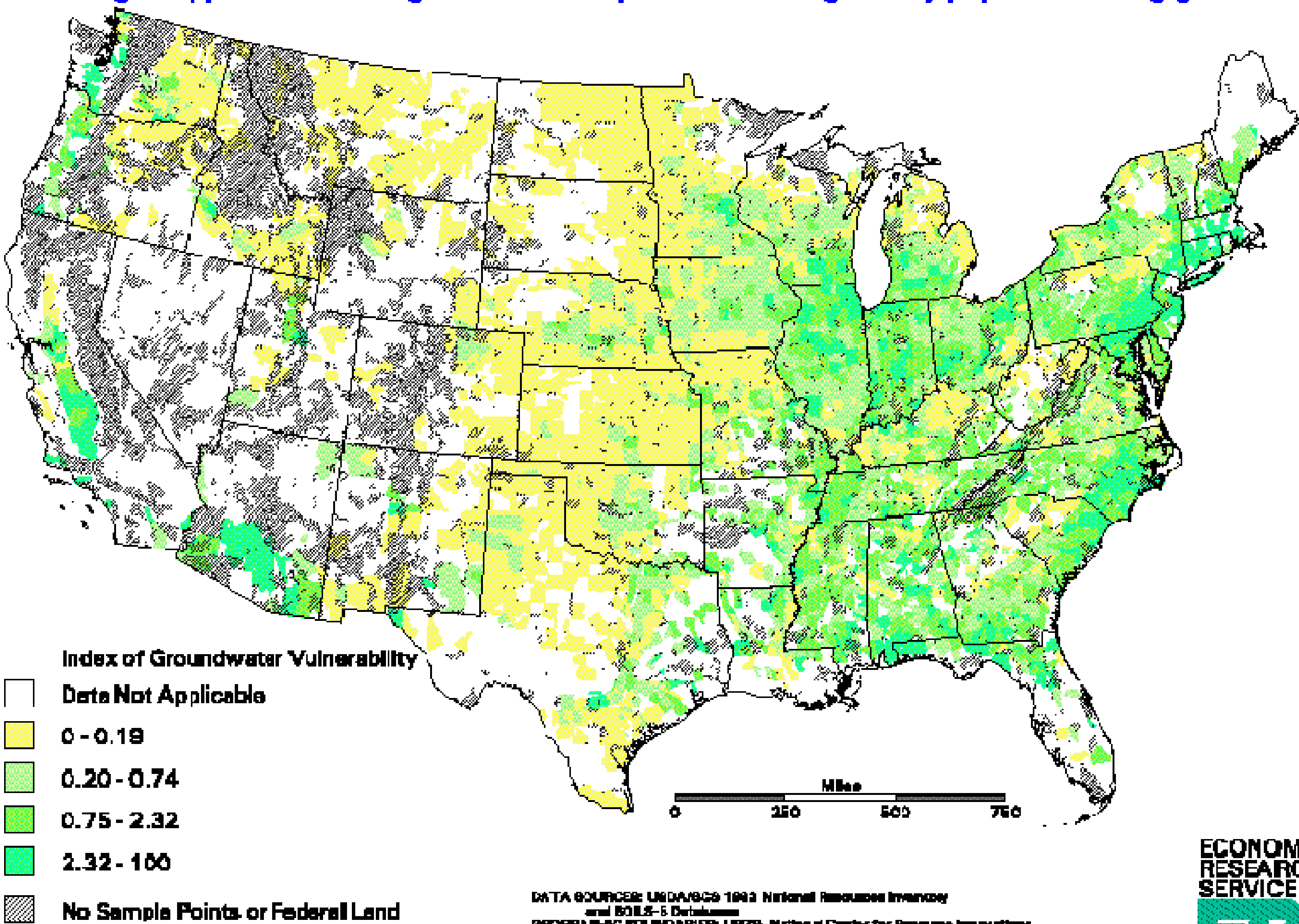
Figure 11--Potential Nitrate Leaching

Excess nitrogen applied to leaching classes of cropland soils, weighted by population using groundwater



DATA SOURCES: USDA/SCS 1992 National Resources Inventory and SOILS-5 Databases
GEOGRAPHIC BOUNDARIES: USGS, National Center for Resource Innovations
ANALYTICAL METHODOLOGY: National Center for Resource Innovations
GIS SOFTWARE: ARC/INFO (Environmental Systems Research Institute)

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Figure 12--Potential for Wildlife Habitat Improvement

Changes in habitat structure and diversity on cropland

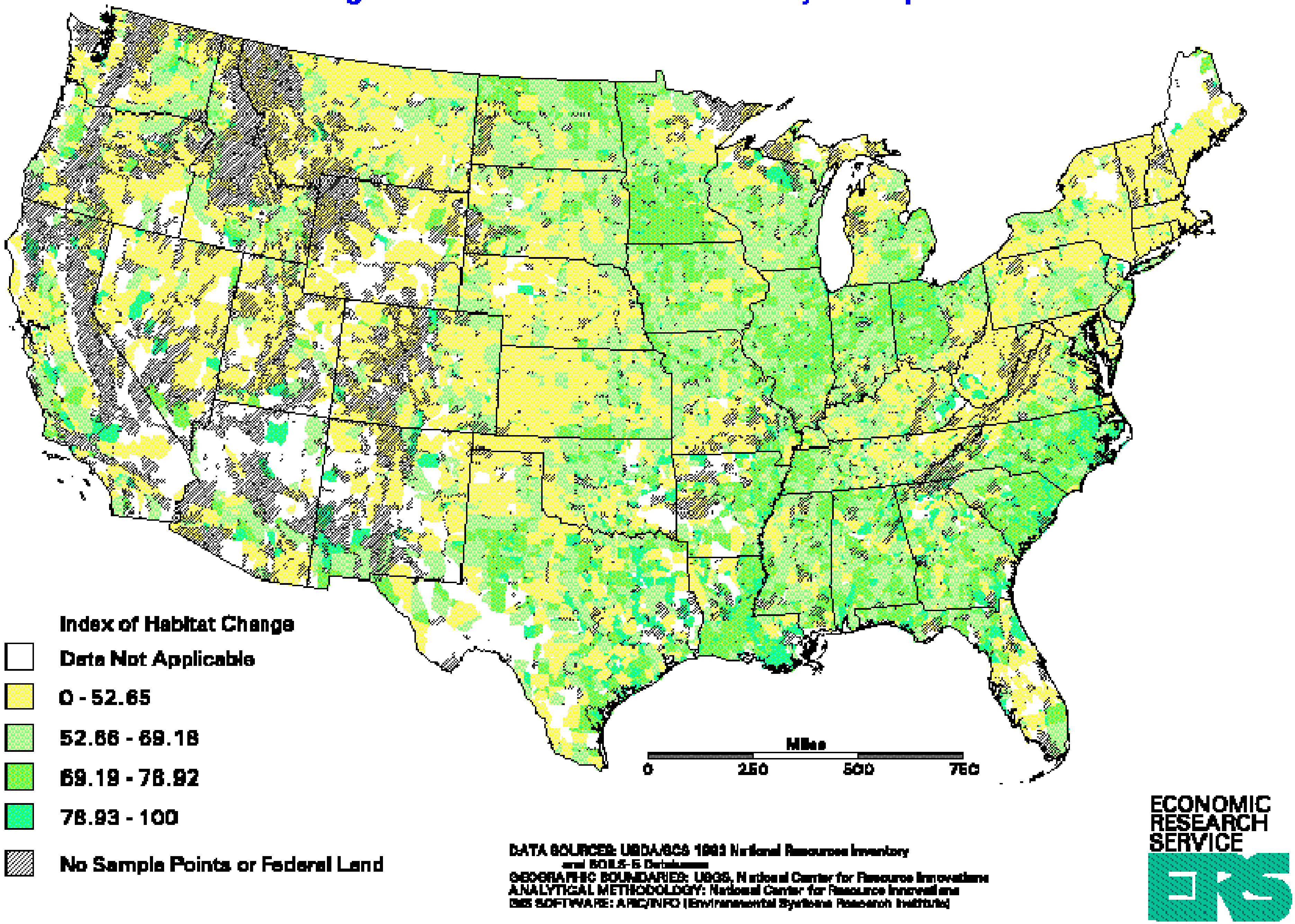


Figure 13--Species Threatened and Endangered by Agricultural Development

Number of species

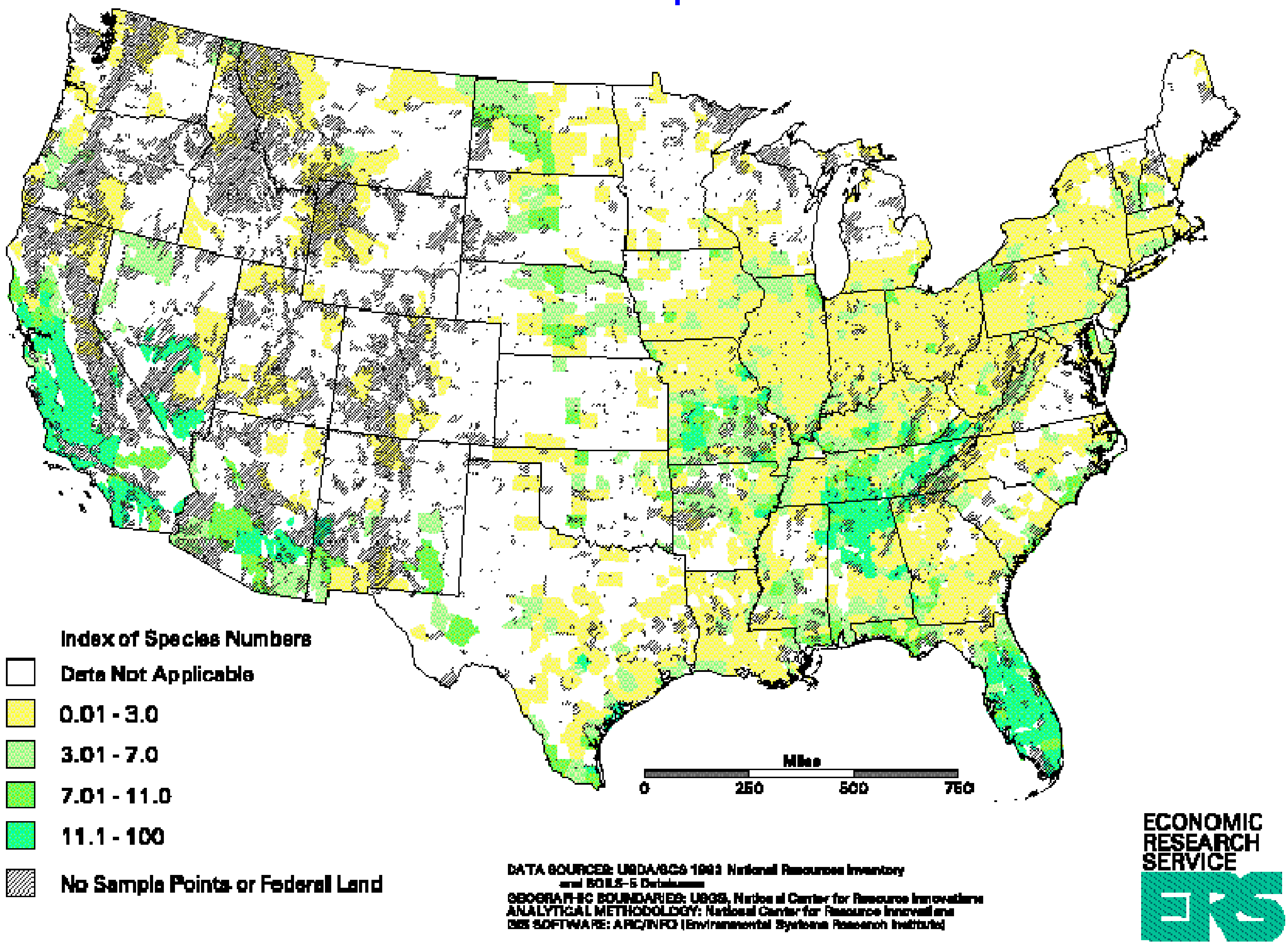
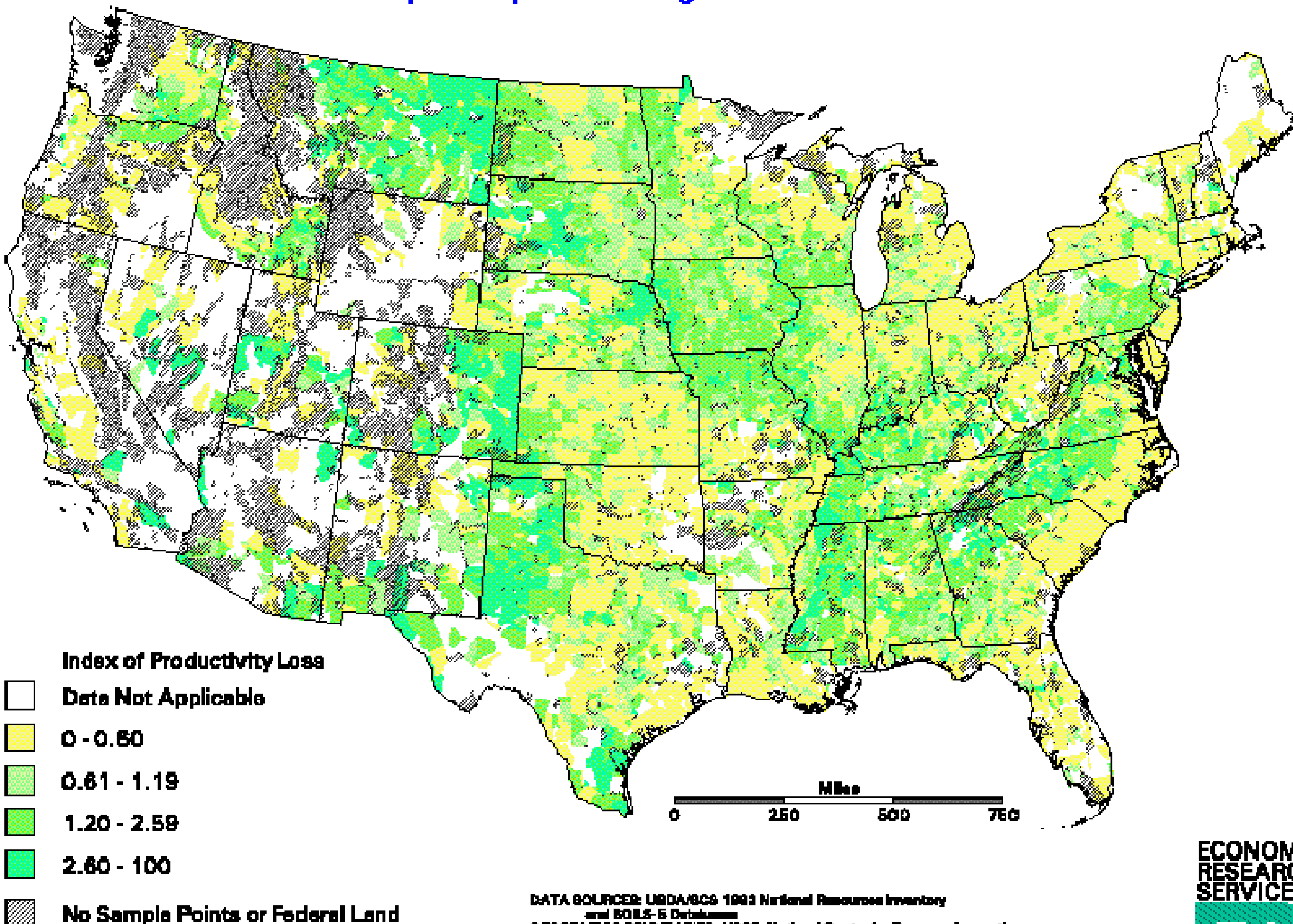


Figure 14--Potential Soil Productivity Loss

Years of topsoil depth remaining at current erosion rates



DATA SOURCES: USDA/SCS 1992 National Resources Inventory and SOILS-5 Databases
GEOGRAPHIC BOUNDARIES: USGS, National Center for Resource Innovations
ANALYTICAL METHODOLOGY: National Center for Resource Innovations
GIS SOFTWARE: ARC/INFO (Environmental Systems Research Institute)

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Figure 15--Potential Soil Productivity Loss

Dryland cash rent divided by years of topsoil depth remaining at current erosion rates

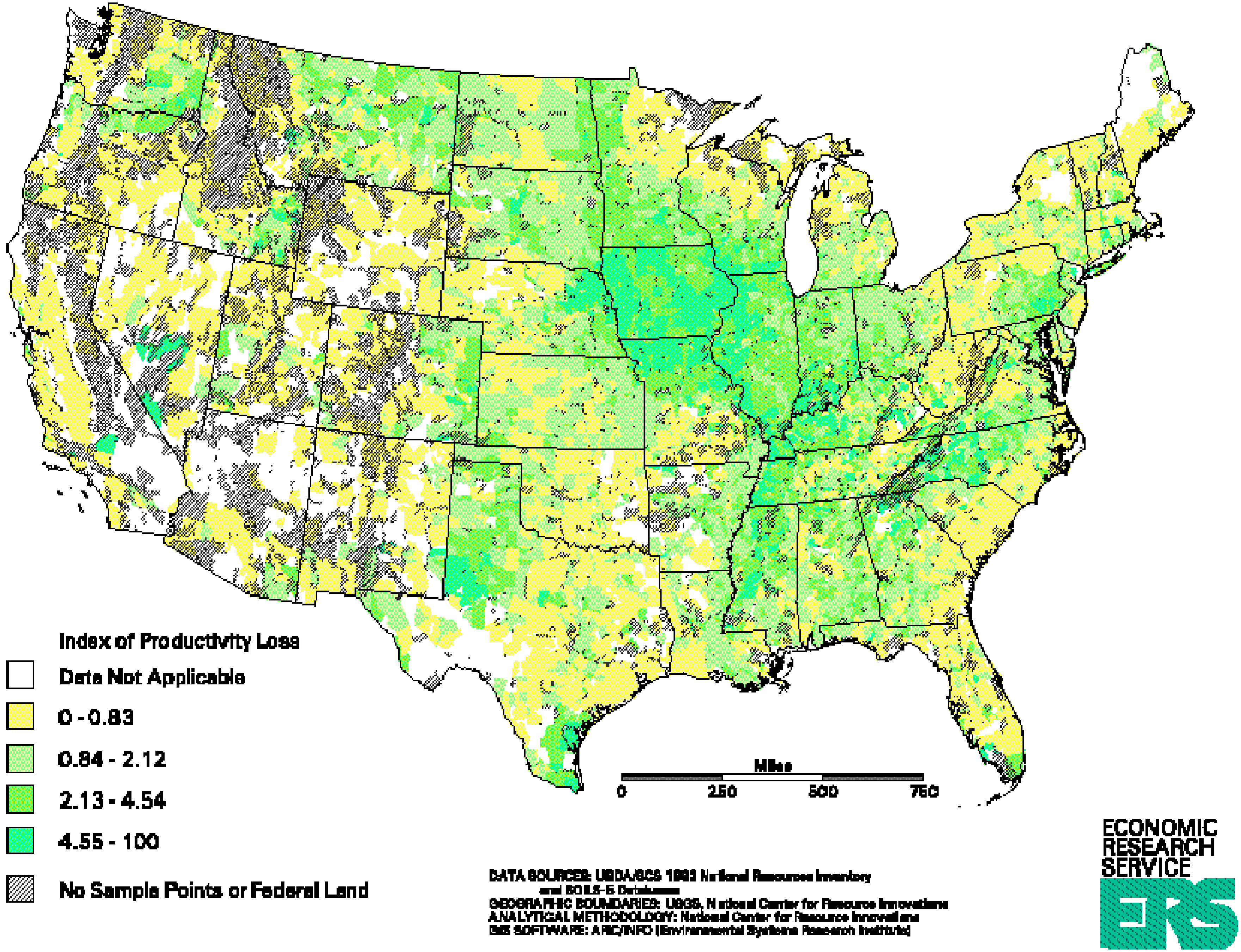

Figure 16--Potential Windblown Dust

Wind erosion

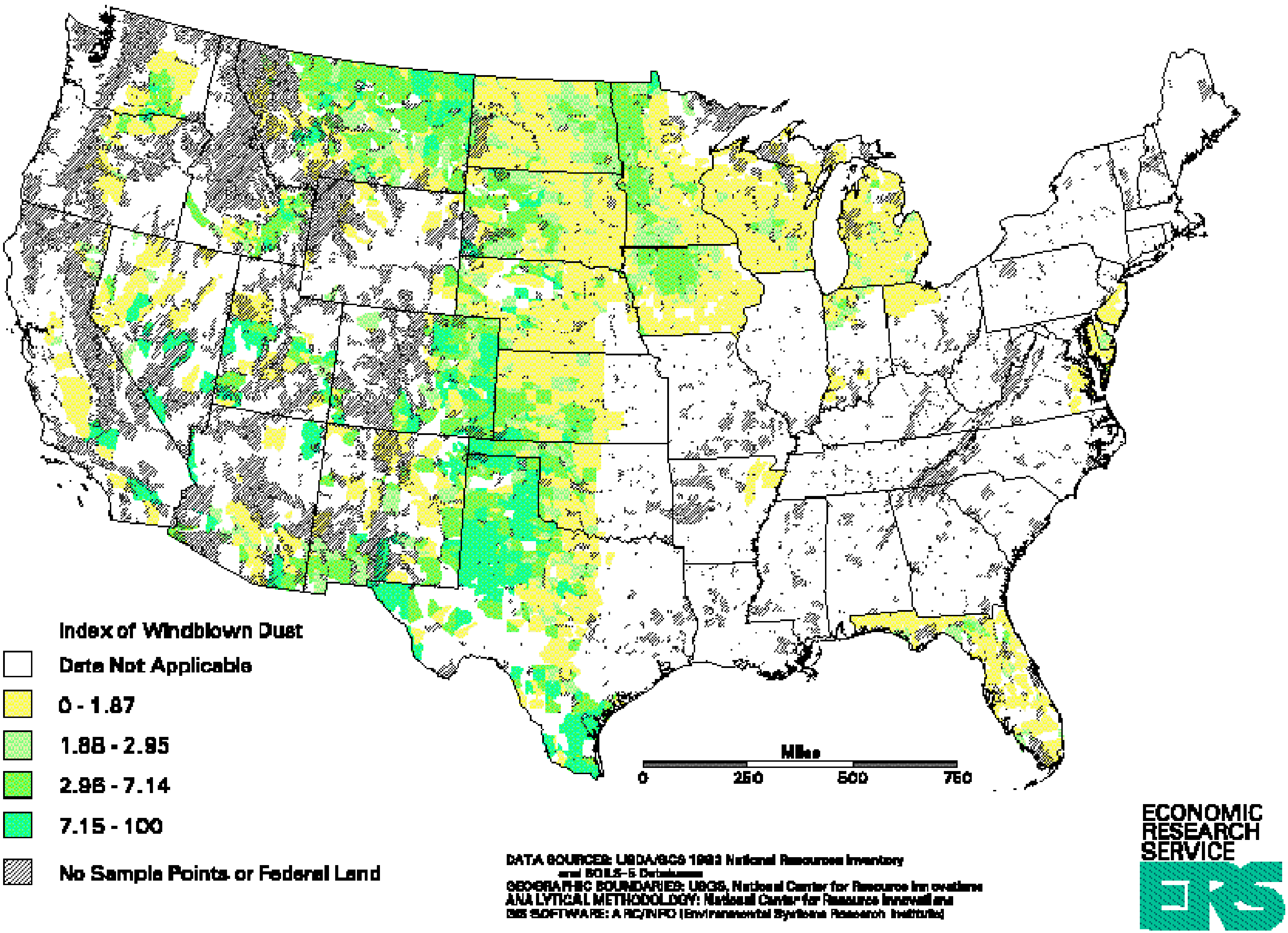

Figure 17--Potential Windblown Dust

Wind erosion, weighted by county population

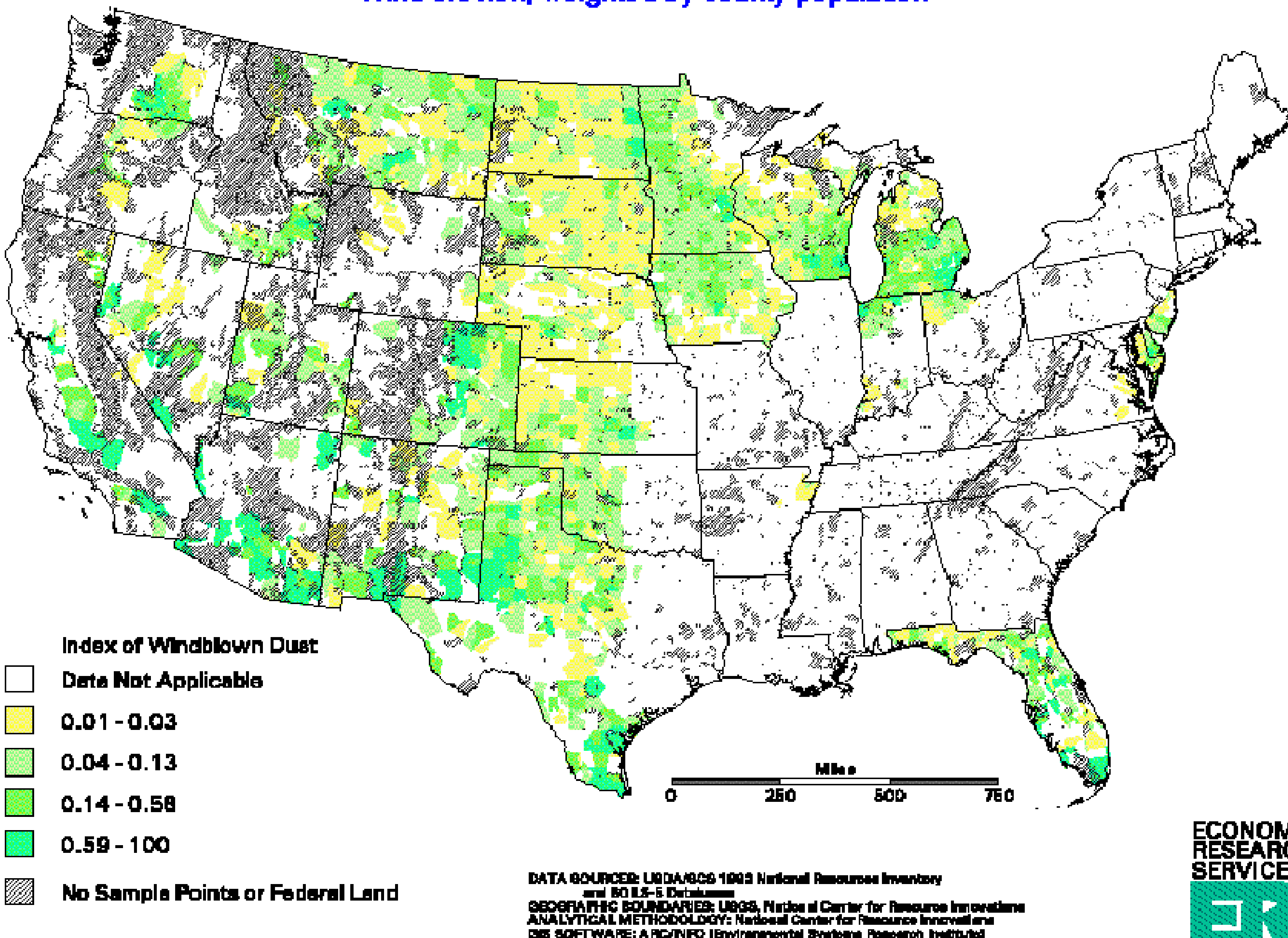

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Figure 18--Potential for Flood Peak Reduction

Cropland on hydric soils in the 100-year floodplain

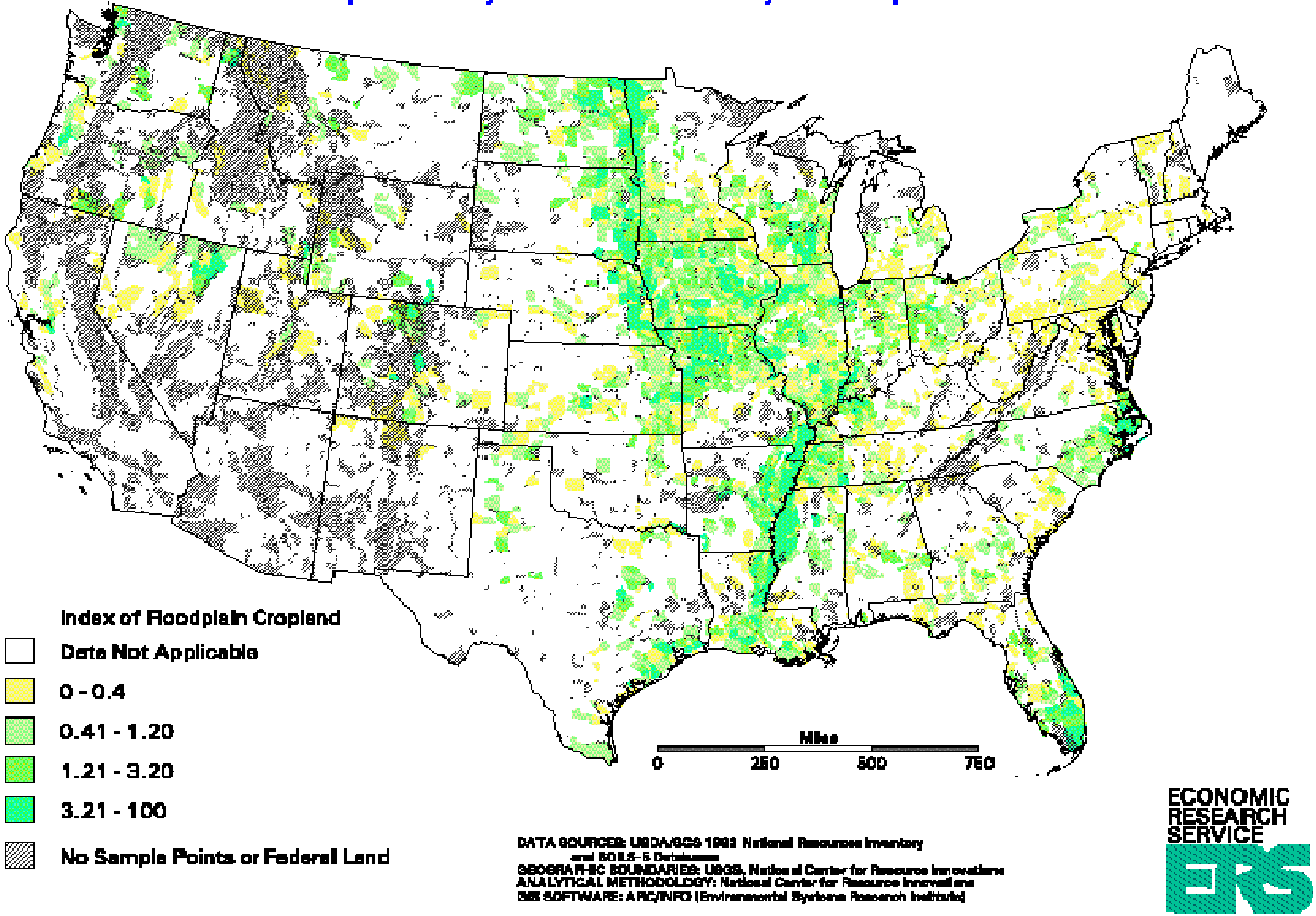


Figure 19--Potential Flood Peak Reduction

Cropland on hydric soils in the 100-year floodplain, weighted by watershed population

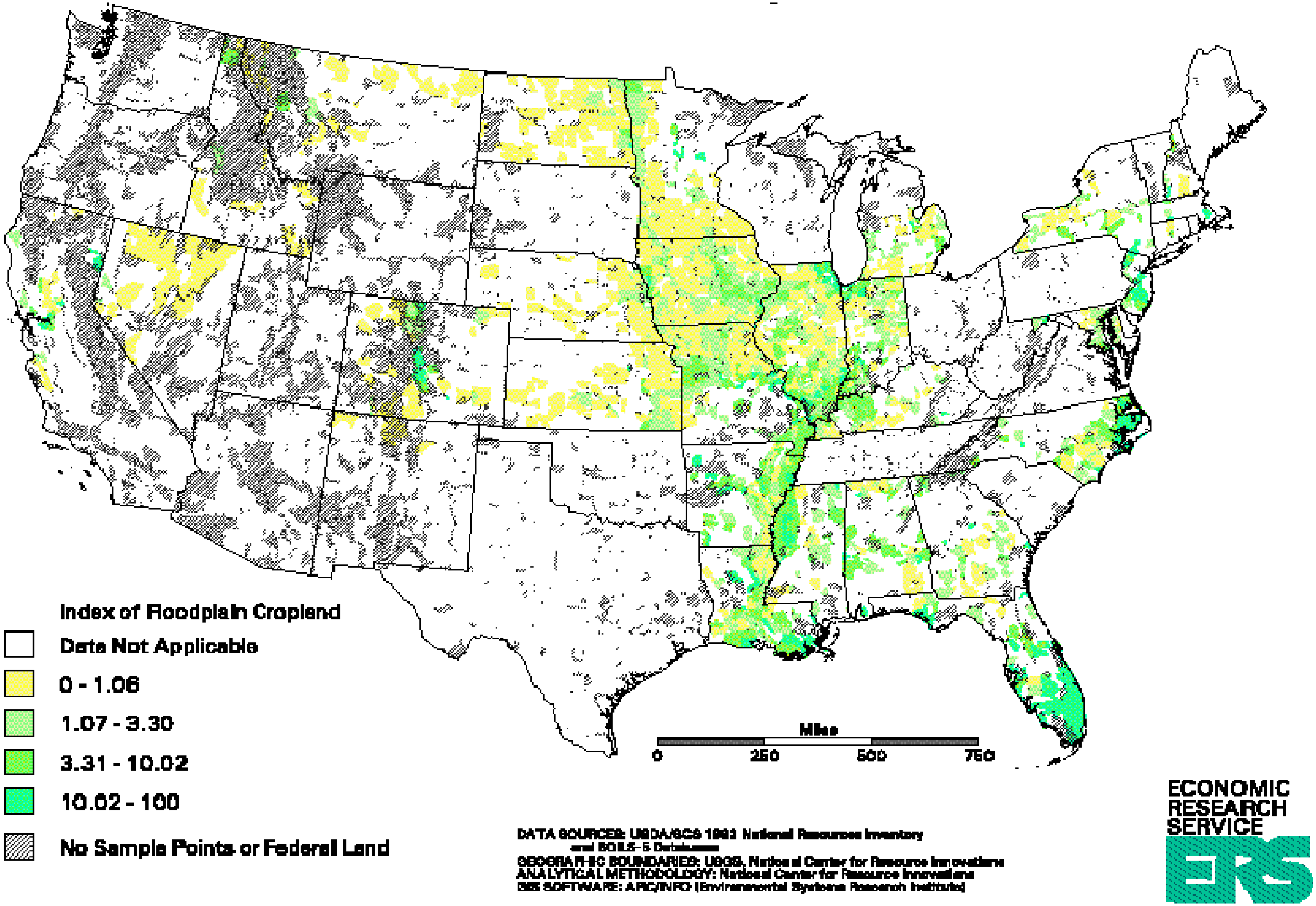


Figure 20--Potential Pesticide Exposure

Pounds of active ingredient applied, weighted by persistence and toxicity

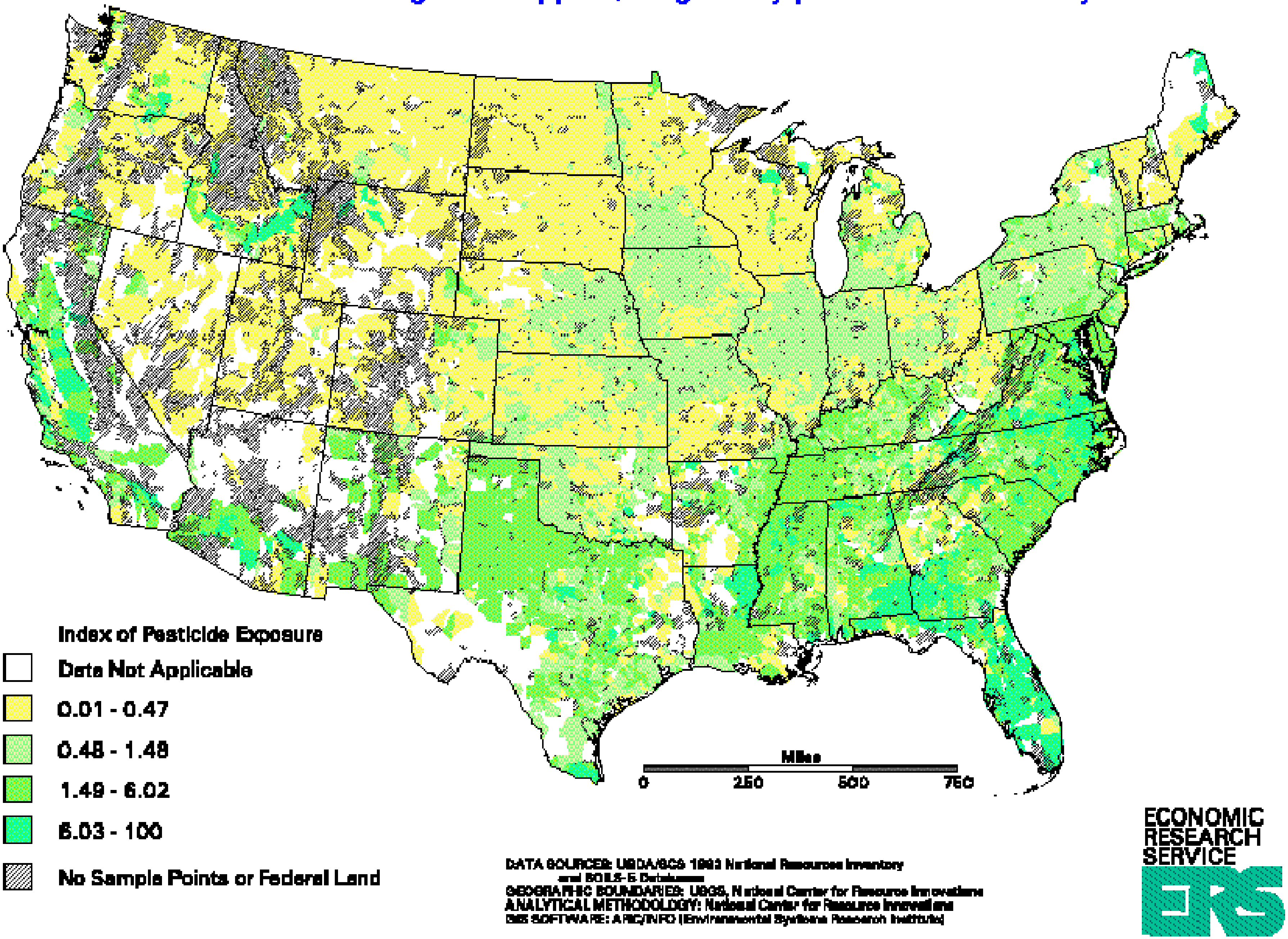


Figure 21--Composite Index

All weighted indices, summed and normalized

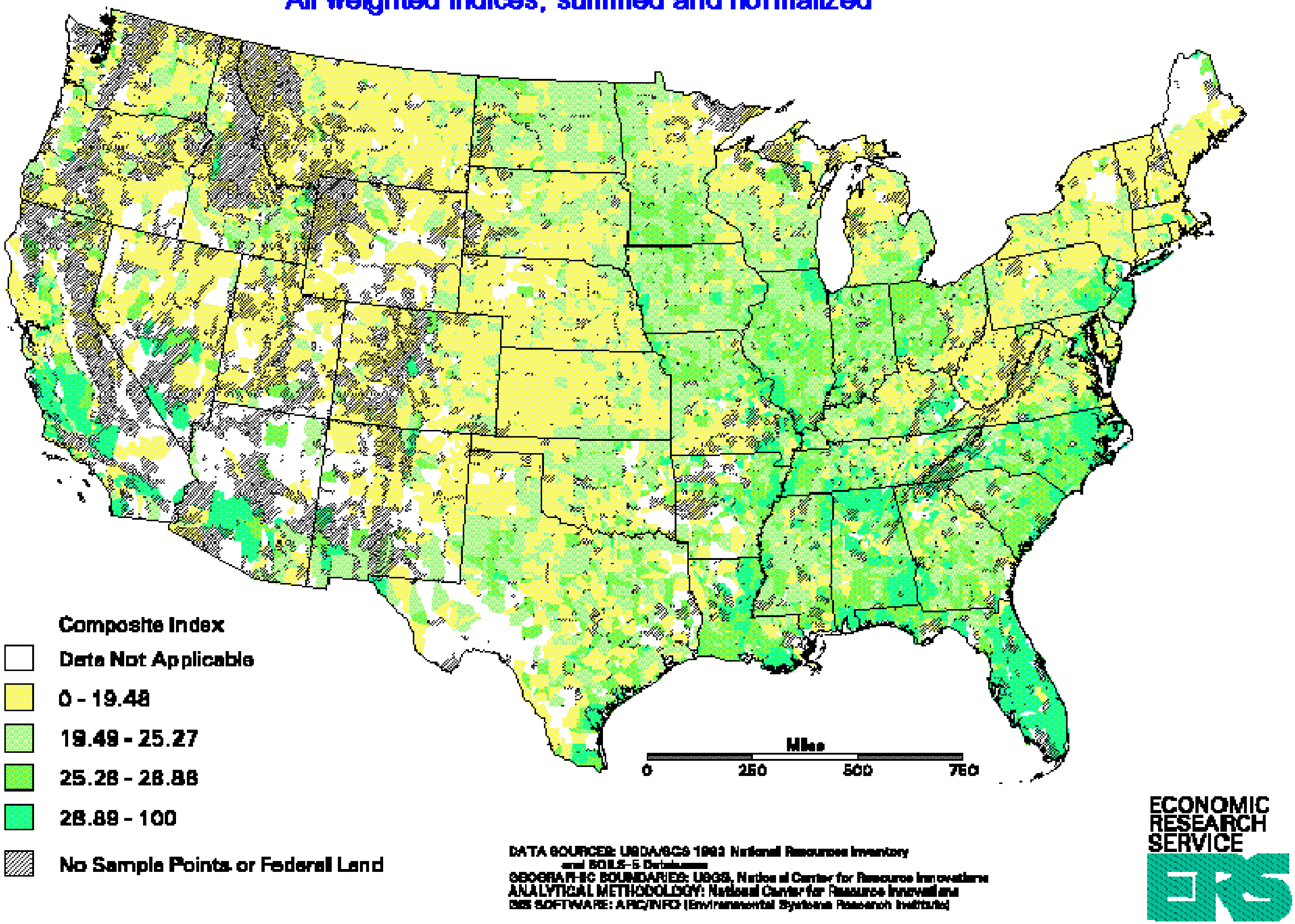


Figure 22

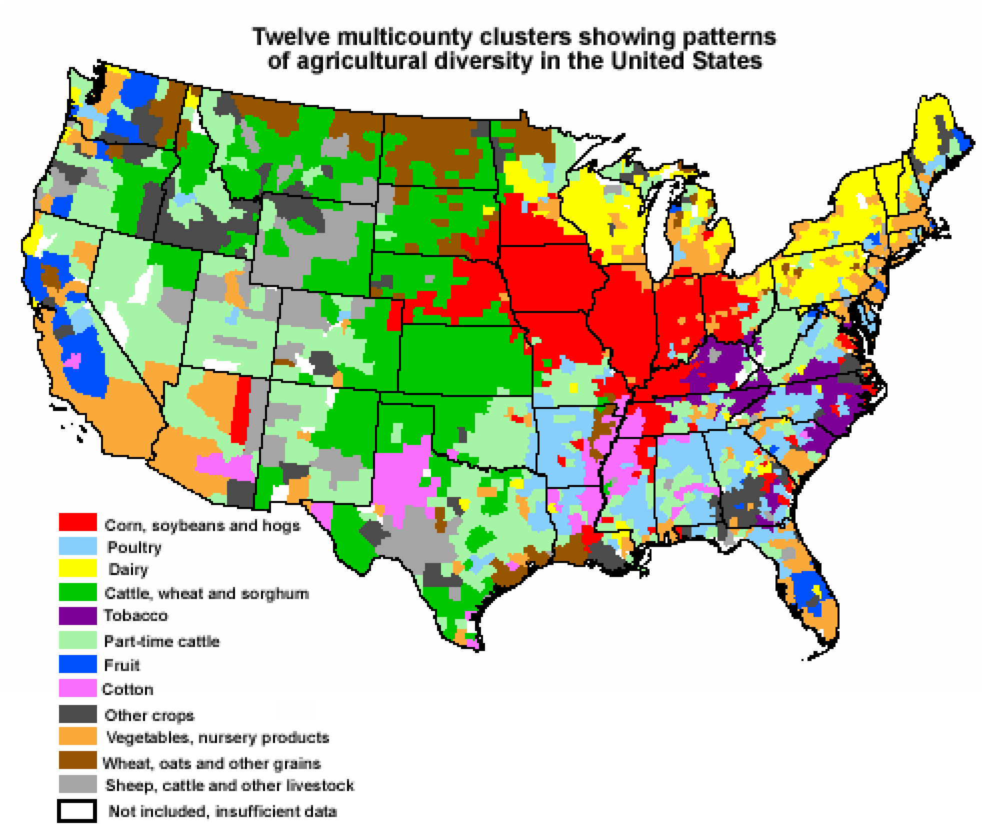

Twelve multicounty clusters showing patterns of agricultural diversity in the United States
Corn, soybeans and hogs
Poultry
Dairy
Cattle, wheat and sorghum
Tobacco
Part-time cattle
Fruit
Cotton
Other crops
Vegetables, nursery products
Wheat, oats and other grains
Sheep, cattle and other livestock
Not included, insufficient data

Figure 23

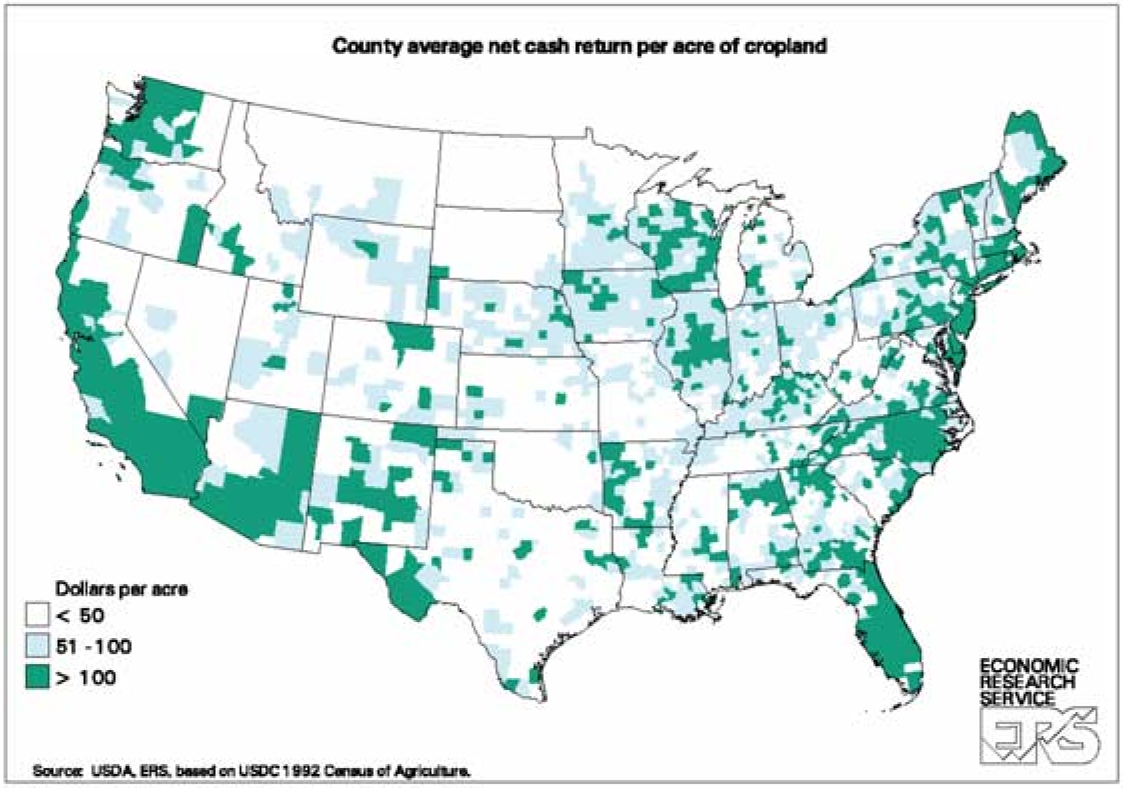
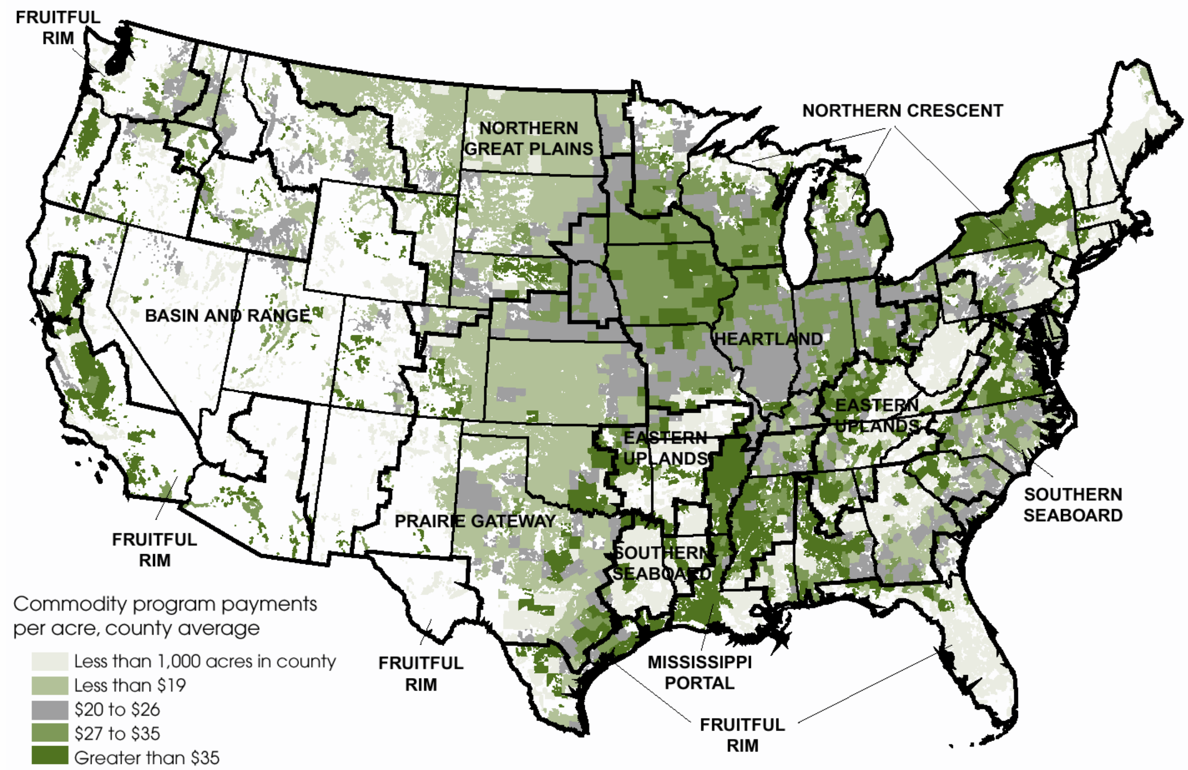

County average net cash return per acre of cropland
Dollars per acre
< 50
51 -100
> 100
ECONOMIC
RESEARCH
SERVICE
ERS
Source: USDA, ERS, based on USDC 1992 Census of Agriculture.

Figure 24

Farm Commodity Program Payments Vary Regionally



Based on acres in program crops from 1997 Census of Agriculture. Excludes conservation program payments.

Economic Research Service, USDA