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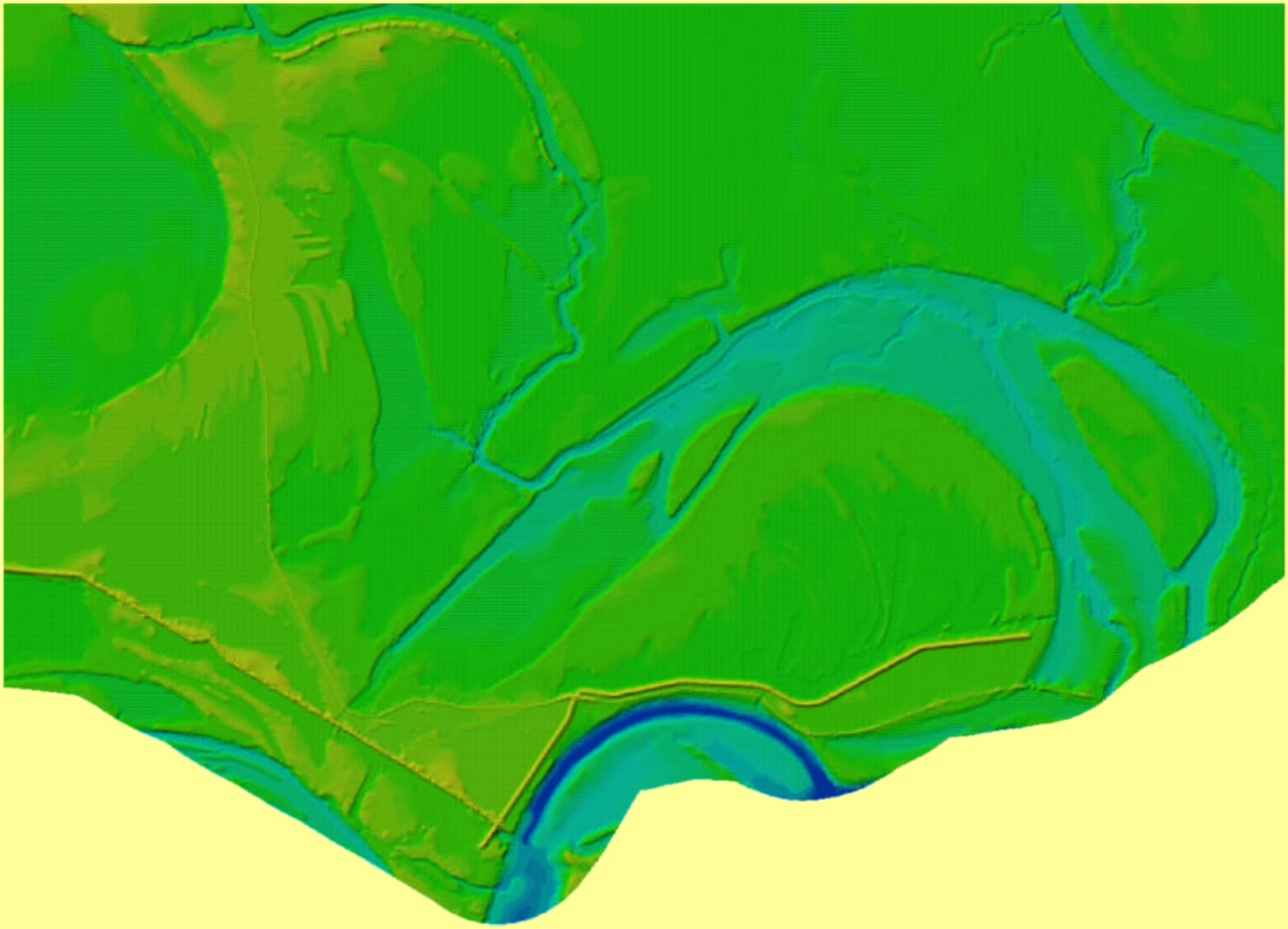
A DECISION SUPPORT SYSTEM FOR PRIORITIZING FORESTED WETLAND RESTORATION IN THE YAZOO BACKWATER AREA, MISSISSIPPI



U.S. Department of the Interior
U.S. Geological Survey
Water-Resources Investigations Report 00-4199

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By Charles G. O'Hara, Angela A. Davis, and Barbara A. Kleiss

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Pearl, Mississippi
2000

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CONVERSION FACTORS

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	hectare

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ABSTRACT

A working prototype decision support system (DSS) was developed for the Yazoo Backwater Area, Mississippi, to help planners and managers prioritize, plan, conduct, and optimize forested wetland restoration activities. The DSS comprises geographic information system (GIS) spatial data themes, application programs that provide a cumulative analysis of the relative ability of sites to function as wetlands, and output data that are specific to a given restoration analysis scenario. The DSS input includes GIS data themes such as geomorphology, soils, land use, elevation, farmed wetlands, flood frequency, topographic depressions, streams, public lands, roads, and permanent water bodies, which can be used as spatial templates to define areal hydrologic settings. These GIS data themes can then be ranked and combined to estimate the relative suitability of a potential wetland restoration site, thereby, determining relative wetland equivalence on the landscape.

The GIS applications used in this DSS perform the following three functions: assess the ecology (the Eco-Assessor); reclassify land-use in areas selected for restoration (the Tree-Translator); and generate output data to compare restoration scenarios (the Parameter-Generator). Areas selected for reforestation are translated (in the GIS) into "forested" land use, and the tree species that are "planted" on the landscape (in the DSS) either compose an ecologically optimal or an economically optimal community of tree species. Output from the DSS can be compared and analyzed by using economic, statistical, graphical, and tabular methods. Output data for seven selected scenarios were generated for the Yazoo Backwater Area and are presented as examples to illustrate the flexibility of the DSS to identify areas that meet restoration objectives.

INTRODUCTION

Forested wetlands, once the predominant land cover on the Mississippi River Alluvial Plain (Creaseman and others, 1992), provide habitat for wildlife, water-quality benefits, flood storage, and many other ecological and environmental benefits. Ongoing efforts by Federal, State, and local agencies and organizations to restore forested wetlands have been somewhat successful. Although landscape methods to prioritize potential restoration sites and to model restoration activities in selected areas offer an improved approach to evaluate, select, and restore forested wetlands, further improvements in tools and methods are needed.

In the past, selecting areas for wetland restoration was based largely on identifying landowners willing to sell their land. Coupled with the lack of a quantitative approach for prioritizing and selecting potential restoration sites, scientists tended to overlook how restoration activities were to be implemented on the landscape.

Wetland restoration requires extensive site-specific fieldwork by wetland experts, biologists, and ecologists. Preliminary fieldwork is not practical, however, where large areas of land are to be considered for restoration over a broad regional extent. The task of visiting all potential areas and conducting site evaluations prior to screening, prioritizing, and selecting suitable sites becomes physically impossible. Planning large-scale restoration efforts having a broad regional extent can best be accommodated by using a decision support system (DSS) based on a geographic information system (GIS). A DSS makes it possible to evaluate different restoration scenarios; to select from among these scenarios those areas for restoration that best meet current wetland restoration program goals; and to plan activities to optimize the economic and/or ecologic benefits of the restoration.

Until recently, development and use of a DSS to select sites and evaluate restoration scenarios was impeded by the lack of input data, the cost of developing digital data, the lack of tools to develop and compare alternate scenarios, and the difficulty of integrating output data results into various types of independent analysis programs. Recent improvements in data availability, GIS applications, and computer technology have made possible the development of systems that can be used to integrate data, provide flexible analysis methods, and allow interchange of data between various analysis tools.

This report presents a working prototype GIS-based DSS developed to support analyses and decisions related to forested wetland restoration efforts in the Yazoo River Basin in Mississippi. The documented DSS used available data, the most conservative of which were used when more than one source was available for a given data layer or theme. Descriptions of the DSS and the input data themes, details of how the data are used in the DSS, and a discussion of selected example output scenarios are provided. The reader should note that the maps are intended to help illustrate the concept and methods used to develop the DSS, and are not intended to convey site-specific data.

This report is the result of an interagency agreement between the U.S. Geological Survey (USGS) and the U.S. Environmental Protection Agency (EPA). The purpose of the agreement was to develop a DSS to facilitate evaluating alternate forested wetland restoration scenarios for areas subject to backwater flooding in the lower part of the Yazoo River Basin in Mississippi (hereafter referred to as the Yazoo Backwater Area or the study area). Concurrent with the DSS work, an economic evaluation of the costs and benefits of reforestation scenarios (Shabman and Zepp, 2000) was performed by researchers at Virginia Polytechnic Institute and State University (Virginia Tech).

The Yazoo Backwater Area includes all or parts of six counties in central western Mississippi including Humphreys, Issaquena, Sharkey, Warren, Washington, and Yazoo (fig. 1). The Yazoo Backwater Area is bounded by the Mississippi River levee on the west and by levees and the valley wall of the bluff hills on the east and south. The southern extent of the Yazoo Backwater Area is just north of Vicksburg, Mississippi. The Yazoo Backwater Area extends north about 100 kilometers to just north of Belzoni, Mississippi.

THE DECISION SUPPORT SYSTEM

A user-friendly, modular, broad-based prototype DSS was developed as a new approach to identify, prioritize, and select sites (or scenarios) for wetland restoration activities, and specifically to optimize these activities in the Yazoo Backwater Area. This prototype wetland restoration DSS addresses these objectives by providing a set of applications that perform functions, which have been grouped into the following modules:

Module 1 -- Ecological Assessment: The Eco-Assessor

- Identify areas eligible for reforestation.
- Identify areas most likely to sustain a functional wetland.
- Select areas that maximize the wetland functions performed.

Module 2 – Land-Use Conversion: The Tree-Translator

- Select tree species for locations where the likelihood of survival is high.
- Optimize the benefits of reforestation based upon predefined ecologic and/or economic criteria.

Module 3 -- Output Data File Preparation: The Parameter-Generator

- Prepare output data files that report functional restorability, acreages, flood ranges, soil types, and other factors that can be used to evaluate the scenario.

The DSS comprises GIS spatial data themes, applications that provide a cumulative analysis of the relative ability of sites to function as a wetland, and output data specific to a given restoration analysis scenario. The combination of input data, application programs, and output data make it possible to select the most eligible areas that best fit the restoration objectives. A DSS lacking input and output data is simply an analysis tool; however, a DSS containing output data can be used in the decision-making process.

All GIS data themes used in this DSS are in the Arc/INFO grid-data format, and are in the Universal Transverse Mercator, Zone 15 (UTM 15) projection, North American Datum of 1927 (NAD 27). Data that were needed, but not grid-based were converted to the Arc/INFO grid-data format. All image data were provided with a 25-meter cell size, and all other data layers were provided or developed at a 25-meter cell size resolution except for elevation data, which were generated at a 10-meter cell size. To facilitate analysis, all data layers were aligned, and in most cases, resampled and realigned prior to analysis.

No new GIS data themes were generated for this DSS. Some spatial data layers used in the DSS are dated, and many of the analysis layers are the result of modifying or manipulating existing data. Uncertainties were involved in using dated information in the DSS, especially since the system

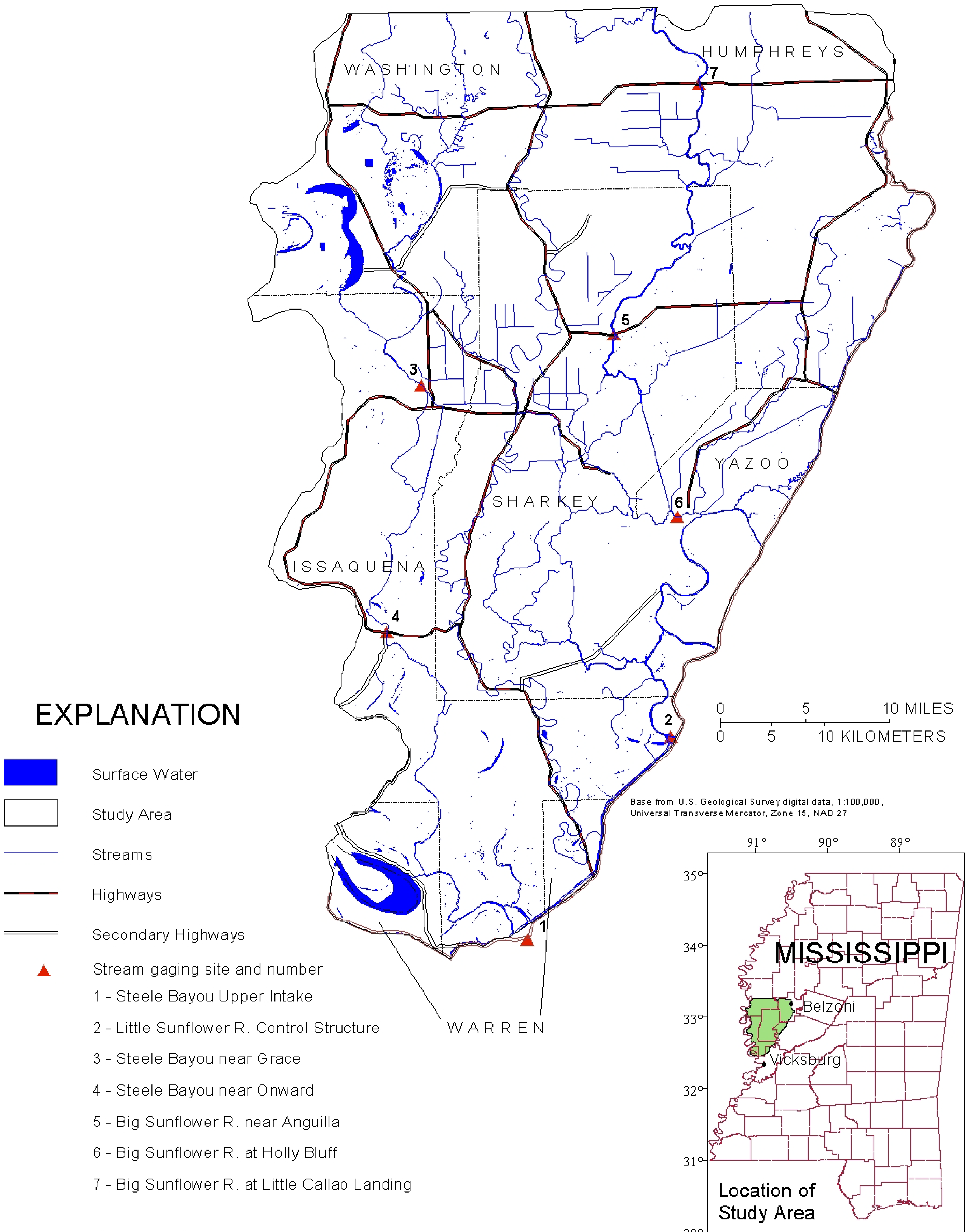

Figure 1. The Yazoo Backwater Area, Mississippi.

employs new methods of analysis and approaches to ecological problem solving. Many of the spatial data used in this DSS were provided without full metadata and without exact provenance. This DSS, however, was designed as a modular, broad-based analysis tool that integrates many data sources and uses modular analysis blocks to arrive at a result, thereby minimizing the effect of inaccuracy in any single data set. This manner of DSS development ensured that improved data of a specific type could replace older data of the same type used in the initial DSS. Thus, information sources used in this DSS can be updated and improved as needed or desired, and the modular analysis tools can be modified as needed to accommodate new restoration objectives.

Module 1 -- Ecological Assessment: The Eco-Assessor

Selecting areas that replace or mitigate existing wetlands depends on understanding the relation of individual wetlands to the landscape (Bedford, 1996). Inevitable losses of wetland areas are typically allowed if those areas are replaced by an "equivalent" wetland elsewhere. Determining which available areas best favor the development of a sustainable replacement wetland is based on evaluating a combination of hydrologic and ecologic factors such as slope, climate, water availability, position on the landscape, soil, seed sources, and depth and duration of flooding. A fundamental premise in the development of this DSS is that GIS themes can be used as spatial templates to define areal hydrologic settings. Furthermore, one should be able to rank and combine these GIS themes to estimate the relative suitability of potential wetland restoration sites, thereby determining relative wetland equivalence on the landscape. If hydrologic settings can be combined to evaluate wetland equivalence, then GIS data themes, acting as spatial surrogates for defining hydrologic settings, can be ranked and combined at a landscape scale to provide a relative assessment of wetland equivalence. This is the premise used in the Eco-Assessor part of the DSS.

The Eco-Assessor comprises a compilation of GIS data themes and a suite of ESRI Arc/INFO Arc Macro Language (AML) programs developed to geographically determine, from among all eligible areas, the best locations (based on pre-defined objectives) for the restoration of wetlands in the Yazoo Backwater Area. The first processing step conducted by the Eco-Assessor is the application of an "eligibility mask," which was developed to select for further processing only those areas to be considered for wetland restoration. The eligibility mask removes from consideration all areas that are either already forested, under water, or part of the public lands. After a selection of eligible lands has been made, the Eco-Assessor can be used to develop various restoration scenarios that would emphasize particular restoration objectives.

The Eco-Assessor is an easy-to-use interface that combines GIS data layers in a rule-based, ecological assessment of the landscape and uses relative rankings for each GIS data theme, which are summed, to arrive at a cumulative functional restorability ranking. The Eco-Assessor combines the following GIS data layers: geomorphology, soils, regeneration distance, Natural Resources Conservation Service (NRCS) farmed wetlands, flood frequency, topographic depressions, stream buffers, public lands, roads, permanent water, and landscape factors. Each GIS data layer used in the assessment spatially represents a specific physical property associated with one or more wetland functions. Value ranges in each spatial data layer are ranked based on known hydrologic properties and the opinion of wetland and ecology experts. A high rank (associated with a data value or range) indicates that a particular geographic area will likely perform wetland functions well, and therefore, is suitable for wetland restoration. For example, shown in table 1 for the soils spatial data layer, areas designated as hydric receive a 10 ranking, whereas, areas that are non-hydric receive a 1 ranking. After the thematic data layers are ranked, the layers are summed into a cumulative functional restoration ranking. Areas with the highest aggregate score are most likely to favor the restoration of wetland function.

The organization and order of the analyses conducted in the Eco-Assessor module of the DSS is as follows.

- Identify areas eligible for reforestation by using a customized data set that masks out all areas that are not to be considered.

- Identify areas most likely to sustain a forested wetland by analyzing GIS data themes, which act as surrogate templates that approximate relative hydrologic wetland equivalence.

- Use logical, statistical, or spatial tools to select those areas that best meet the objectives of a specific restoration scenario.

Wetland functions are commonly used as comparative evaluation criteria to assess the relative ecological suitability of a wetland. Hydrogeomorphic Assessment (HGM) uses wetland functions to evaluate existing wetlands at a site-specific scale (Brinson, 1993). The Eco-Assessor is designed to consider wetland functions at a landscape scale by using spatial data grouped by wetland functions to provide a relative indication of how a forested wetland will function at a specific location.

Restorability, hydrology, water quality, and habitat are the major categories used to assess wetland function in the Eco-Assessor. The Eco-Assessor organizes the input data into categories based upon these four wetland functions (table 1). In developing the Eco-Assessor, the hydrology, water quality, and habitat function categories were designed to have approximately the same weight in the overall analysis, whereas restorability was designed to have a lesser weight in the analysis. As a result, if the restoration objective is to determine areas that will, on their own, convert most readily to a forested wetland, then the restorability category needs to be assigned more relative weight in the cumulative ranking.

Restorability

Restorability is assessed by determining the ability of a location to sustain a functional wetland. The wetland restorability section of the Eco-Assessor uses geomorphology, soils, regeneration distance, and farmed wetlands spatial data layers to act as surrogates for specific hydrologic settings that when combined, indicate the likelihood of whether a specific location can be restored to a wetland.

Geomorphology: In the Yazoo Backwater Area, the geomorphology data layer (fig. 2) indicates the fluvial environment that gave rise to specific landforms, and classifies the landscape into areas that are characterized as either abandoned channels, backswamps, or pointbar/valley trains. The ranking values for geomorphology categories range from a high of 1 to a low of 5. Abandoned channels, which are the lowest land formations in terms of elevation, are inundated frequently, and therefore, given a rank of 5.

Table 1. Ecologic rules used in the Eco-Assessor for the Yazoo Backwater Area, Mississippi [NRCS, Natural Resources Conservation Service]

Wetland function	Spatial data layer	Data Variable	Functional restoration ranking
Restorability	Environment of deposition	Abandoned channel	5
		Backswamp	3
		Pointbar	1
	Soils	Hydric	10
		Non-Hydric	1
	Regeneration distance	Within 60 meters of mature forest	5
		Between 60 and 120 meters	3
		Greater than 120 meters	1
	NRCS farmed wetlands	Farmed wetland	5
		Other	0
Hydrology	Flood frequency	Within the 0.5-year flood	20
		Within the 2-year flood	10
		Beyond the 2-year flod	5
	Topographic depressions	Topographic depressions	20
		Other	1
Water quality	Flood frequency	Within the 0.5-year flood	15
		Within the 2-year flood	10
		Beyond the 2-year flood	5
	Stream buffers	Stream Level 1 – within 90 meters	15
		Stream Level 2 – within 80 meters	15
		Stream Level 3 – within 70 meters	15
		Stream Level 4 – within 60 meters	15
		Stream Level 5 – within 50 meters	15
		Stream Level 6 – within 40 meters	15
		Stream Level 7 – within 30 meters	15
		Stream Level 8 – within 20 meters	15
		Stream Level 9 – within 10 meters	15
		Stream Level 0 – within 5 meters	15
		Other	0
Habitat	Wildlife management areas	Within 250 meters of wildlife management areas	10
		Between 250 and 500 meters	5
		Between 500 and 1,000 meters	1
		Beyond 1,000 meters	0
	Conservation areas	Within 60 meters of conservation areas	5
		Between 60 and 120 meters	3
		Between 120 and 500 meters	1
		Beyond 500 meters	0
	Primary roads	Within 50 meters of primary road	0
		Between 50 and 500 meters	1
		Beyond 500 meters	3
	Secondary roads	Within 50 meters of primary road	1
		Between 50 and 500 meters	2
		Beyond 500 meters	3
	Permanent water	Within 150 meters of permanent water	5
		Between 150 and 1,000 meters	1
		Beyond 1,000 meters	0
	Forest block size	Between 1 and 10 acres	1
		Between 10 and 320 acres	5
		Greater than 320 acres	10
	Core area ratio	Ratio of core area to total area of patch greater than 0.66	10
		Between 0.33 and 0.66	5
		Less than 0.33	1

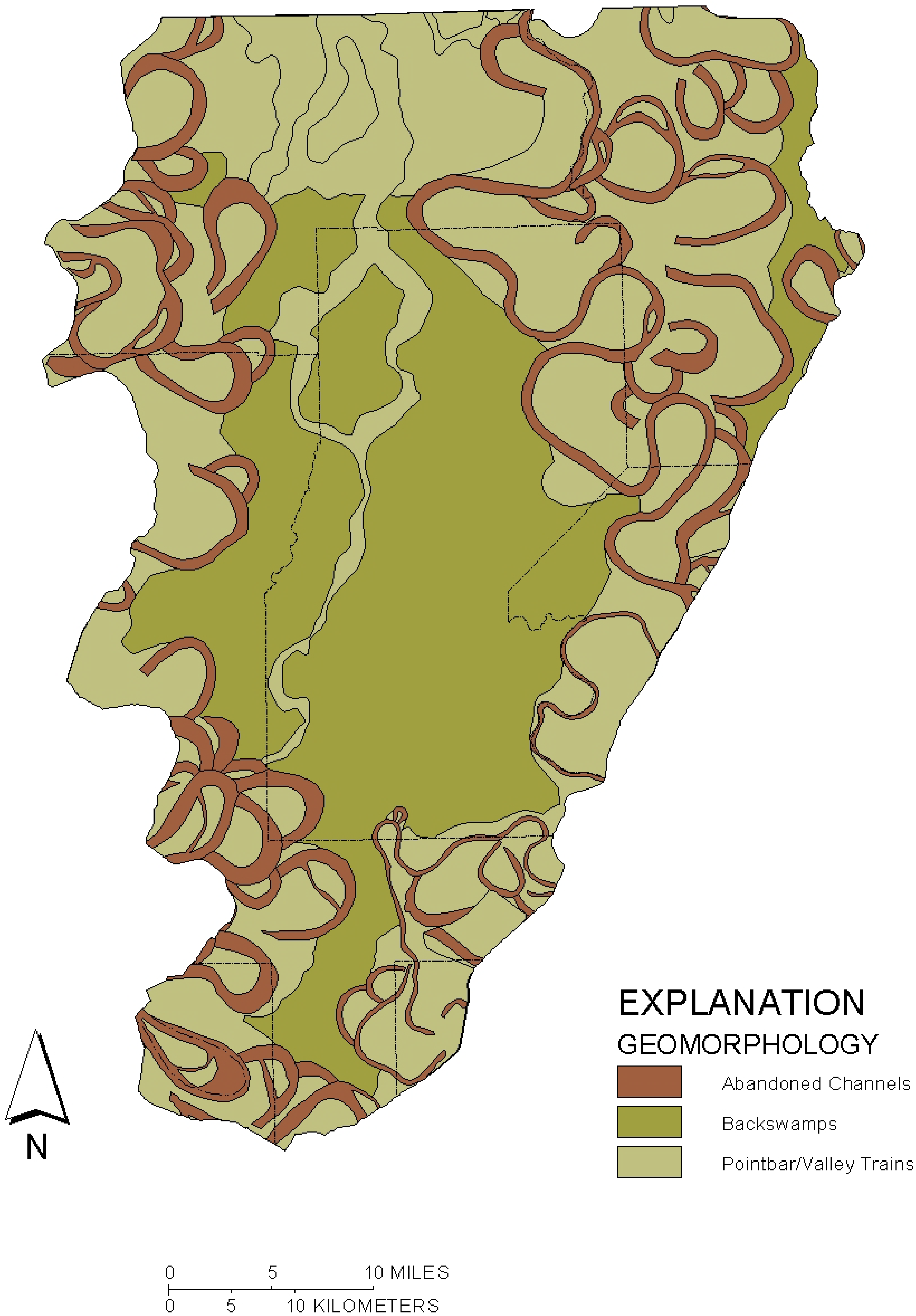

Figure 2. Geomorphology in the Yazoo Backwater Area, Mississippi. [based on U.S. Army Corps of Engineers data]

Although slightly higher in elevation than abandoned channels, backswamps are still low enough to be frequently inundated, and therefore, are given a rank of 3. Pointbar/ valley trains are slight ridges on the land surface; these ridges are the least wet of all the landforms, and therefore, and are given a rank of 1. The base source for the geomorphology GIS data compiled at 1: 250,000 scale was the report "Geo-morphology and Quaternary Geologic History of the Lower Mississippi Valley" (Saucier, 1994).

Soils: The soils data layer (fig. 3) areally classifies soils into hydric and non-hydric categories. Underwater areas that could not be evaluated were mapped as river bottom. Hydric soils, which are most conducive to sustaining wetlands, are given a rank of 10. Non-hydric soils are less conducive to sustaining wetlands, and therefore, are given a rank of 1. Hydric soils were defined by the NRCS. The base data for soils were acquired from NRCS county soil maps; the base data were digitally recompiled and modified for the Yazoo River Basin by the U.S. Army, Corps of Engineers (COE), as detailed in the report "Delineation of Wetlands of the Yazoo River Basin in Northwestern Mississippi" (Kirchner and others, 1992).

Regeneration Distance: The regeneration distance is a proximity grid of a location (cell) to a natural seed source as provided by existing forested areas. Restoration areas that are near existing mature forest tend to have a much higher species diversity than areas that are far from an existing stand of mature forest (Allen, 1990). Allen reported that the regeneration or growth of forest through natural seed source distribution is highly favorable to a distance of 60 meters from existing forest. In the Yazoo Backwater Area, locations within 60 meters of an existing forest are given a high rank of 5. Areas that are between 60 and 120 meters of an existing forest are given a rank of 3, and areas beyond 120 meters of an existing forest are given a rank of 1. Existing land-use data (fig. 4) were used to provide a GIS theme for forested areas, and a euclidean distance function was used to create a grid that provides distance moving away from areas classified as forest. Land-use data were provided by the COE, and are based upon the classification of 1988 Landsat satellite data into land-use categories.

Farmed Wetlands: Areas classified as farmed wetlands (fig. 5) indicate places on the landscape that are inundated for a substantial period of time, and therefore, are very likely to maintain sustainable wetlands; farmed wetlands are given a rank of 5. Areas not classified as farmed wetlands are given a rank of 0. Areas excluding potholes, playas, and pocosins were classified as farmed wetlands if there were a 50 percent chance of the area being flooded or ponded for at least 15 consecutive days during the growing season (U.S. Department of Agriculture, 1996). Data for farmed wetlands were provided by the NRCS and were developed from Landsat satellite imagery.

Hydrology

The wetland hydrology is assessed by determining the flood frequency and duration of a particular location within the landscape. Flood frequency and duration is evaluated by using local topographic depressions to indicate those areas where the duration of flooding is likely to extend for longer periods of time than in surrounding areas.

Flood Frequency: The flood-frequency data layer shows lands classified as being either

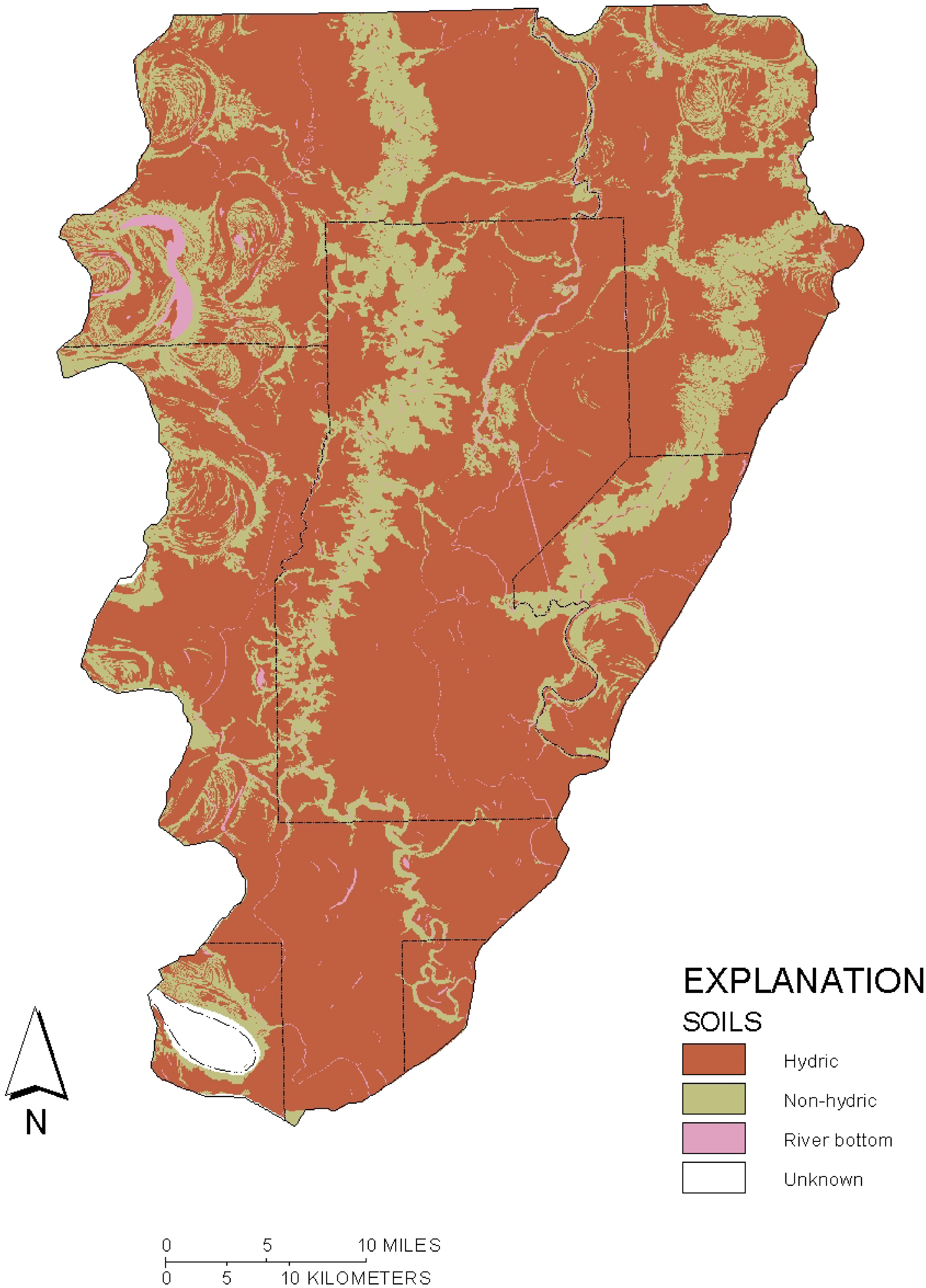

Figure 3. Hydric and non-hydric soils in the Yazoo Backwater Area, Mississippi.
[based on Natural Resources Conservation Service and U.S. Army Corps of Engineers data]

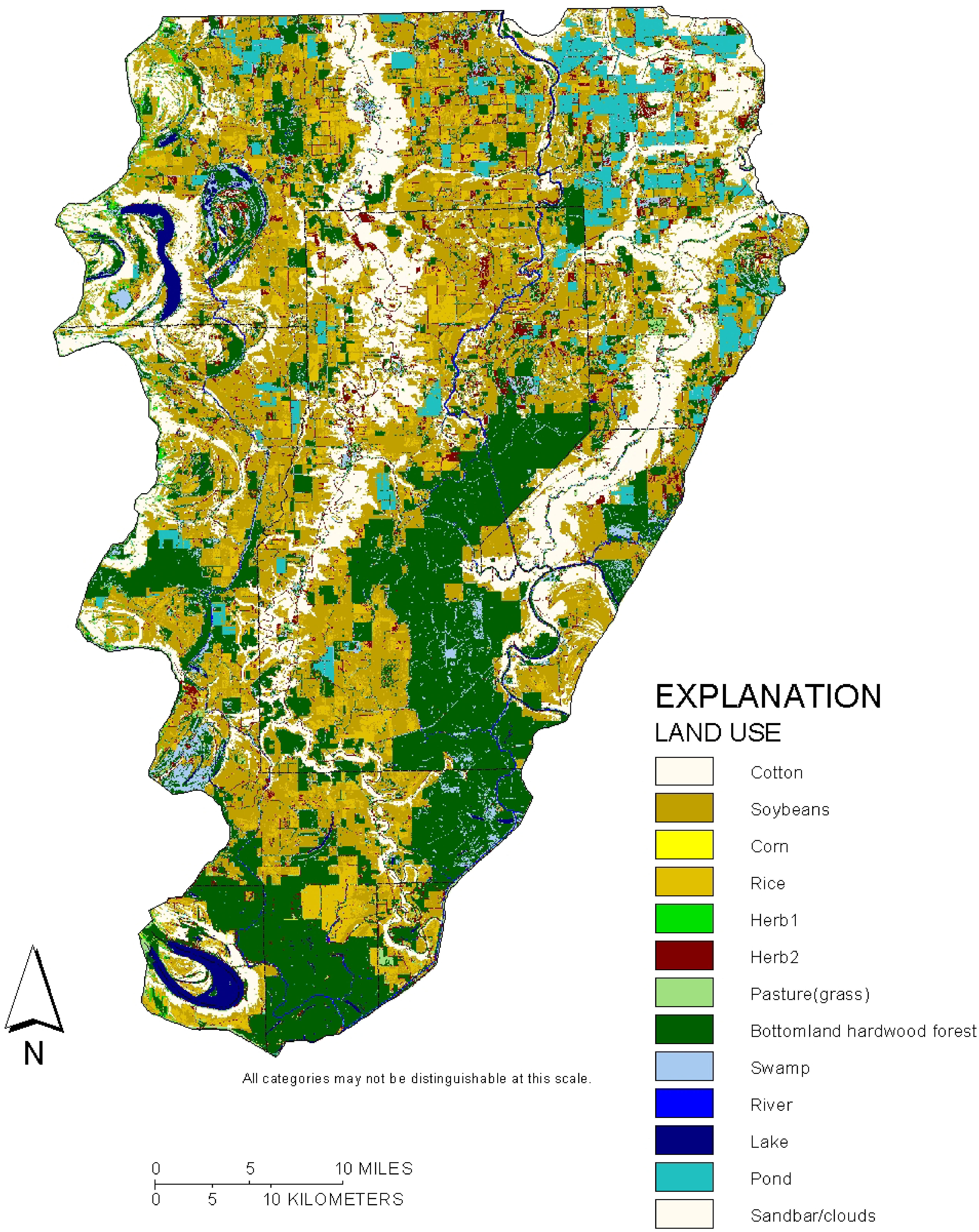

Figure 4. Land use in the Yazoo Backwater Area, Mississippi.
[based on U.S. Army Corps of Engineers 1988 satellite image data]

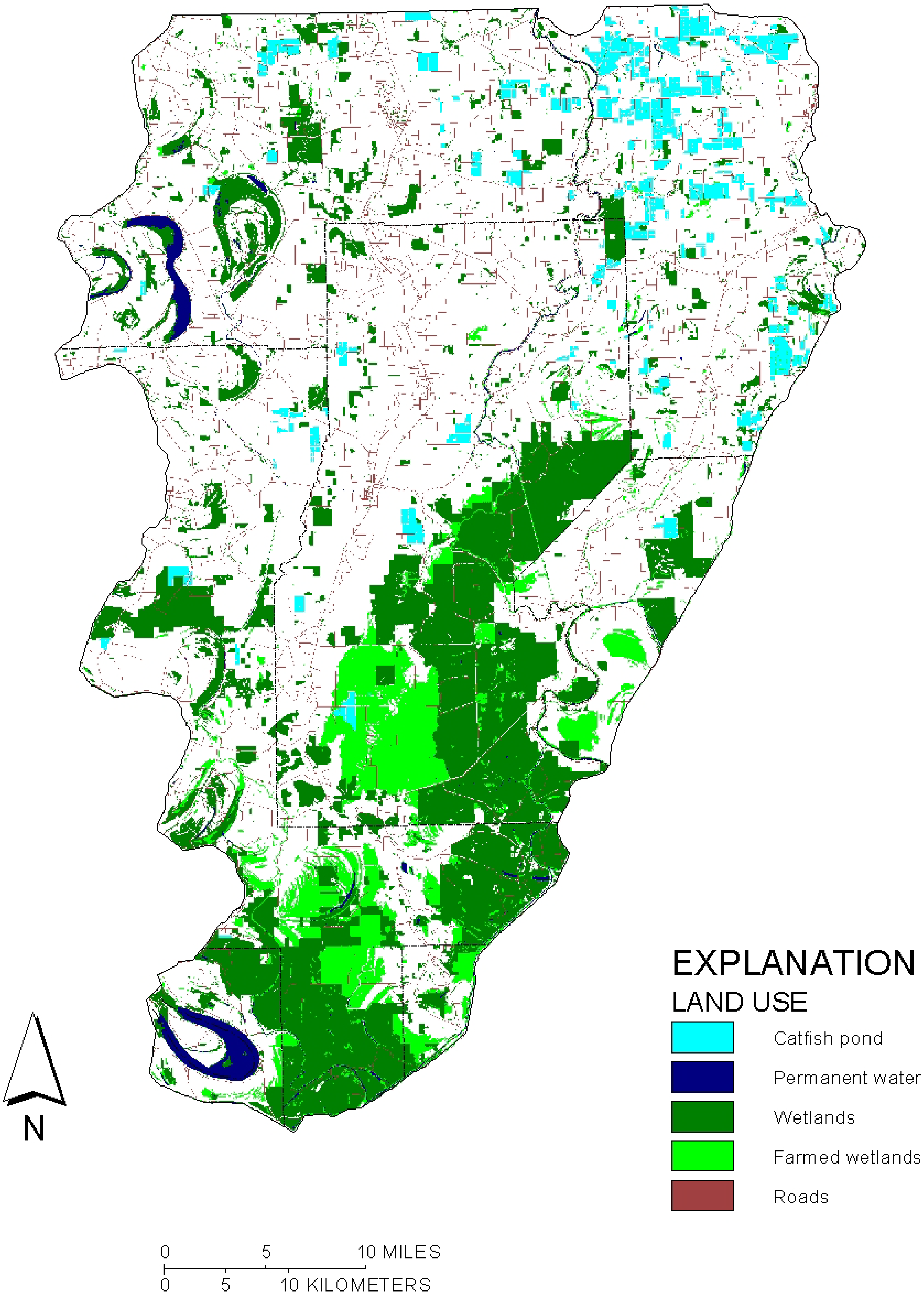

Figure 5. Land use in the Yazoo Backwater Area, Mississippi.
[based on Natural Resources Conservation Service data]

inundated by 0.5-year or the 2-year floods. Locations within 0.5-year flood areas are given a rank of 20 because these areas are the most frequently inundated, and therefore, are considered to be most likely to sustain a wetland. Locations identified within 2-year flood areas are given a rank of 10 because these areas have a 50 percent chance of being flooded each year, and therefore, are considered as viable sites to sustain a wetland. Although increasingly less likely to be inundated on a regular basis, locations within the study area classified outside the 2-year flood areas considered to be viable sites to sustain wetlands are given a rank of 5. Flood-frequency data were provided by the COE, Vicksburg District, as nominal flood-image data scenes for the 0.5-year and 2-year floods and were used to develop a composite flood-frequency image (fig. 6).

Topographic Depressions: The topographic depressions data layer (fig. 7) shows the locations of local sinks or depressions on the landscape in the study area. Topographic depressions indicate places on the landscape where water is likely to pond because these are points of low elevation surrounded by points of higher elevation. Once water enters a depression, there is no outlet through which the water can drain, which causes the water to remain in the sink until evaporation and/or seepage occurs resulting in flood-water storage and possible interaction with ground-water resources. Topographic depressions are given a rank of 20, and areas that are not in topographic depressions are given a rank of 1. The topographic depressions data layer was produced by creating a high resolution elevation data grid, performing a fill of all local depressions on the landscape, and then taking the difference between the filled and the unfilled elevation data layers (fig. 8). The high resolution elevation data were developed based on elevation contours from USGS 1:24,000 quadrangle maps for the area. The elevation contours from all of the quadrangles in the study area were used, as well as data for streams, railroads, and primary and secondary roads to create the high resolution elevation model with a 10-meter posting interval (cell size 10 meters).

Water Quality

The water-quality function is assessed by determining how well areas on the landscape filter, trap, or degrade chemical components such as nitrogen and phosphorous, which are commonly found in surface water. The water-quality function includes and provides for the analysis of flood frequency, stream buffers, and topographic depressions spatial data layers.

Flood Frequency: Flood frequency is a factor in both the wetland hydrology function, as well as the wetland water-quality function. In the water-quality function grouping, those locations within a 0.5-year flood area are given a rank of 15 because these areas are the most frequently inundated, and therefore, are most likely to benefit water quality. Locations within the 2-year flood area are not inundated as often, but are still viable sites for a wetland; these areas are likely to benefit water quality and are given a rank of 10. Those locations outside the 2-year flood area but within the study area are least likely to be inundated on a regular basis. As a result, these areas are least likely to benefit water quality and are given a rank of 5.

Stream Buffers: A stream buffer of at least 10 meters is necessary to filter nitrogen and phosphorous. Stream buffers are assigned by RF3 (U.S. Environmental Protection Agency River Reach File, version 3) stream level with a wider buffer strip given to larger

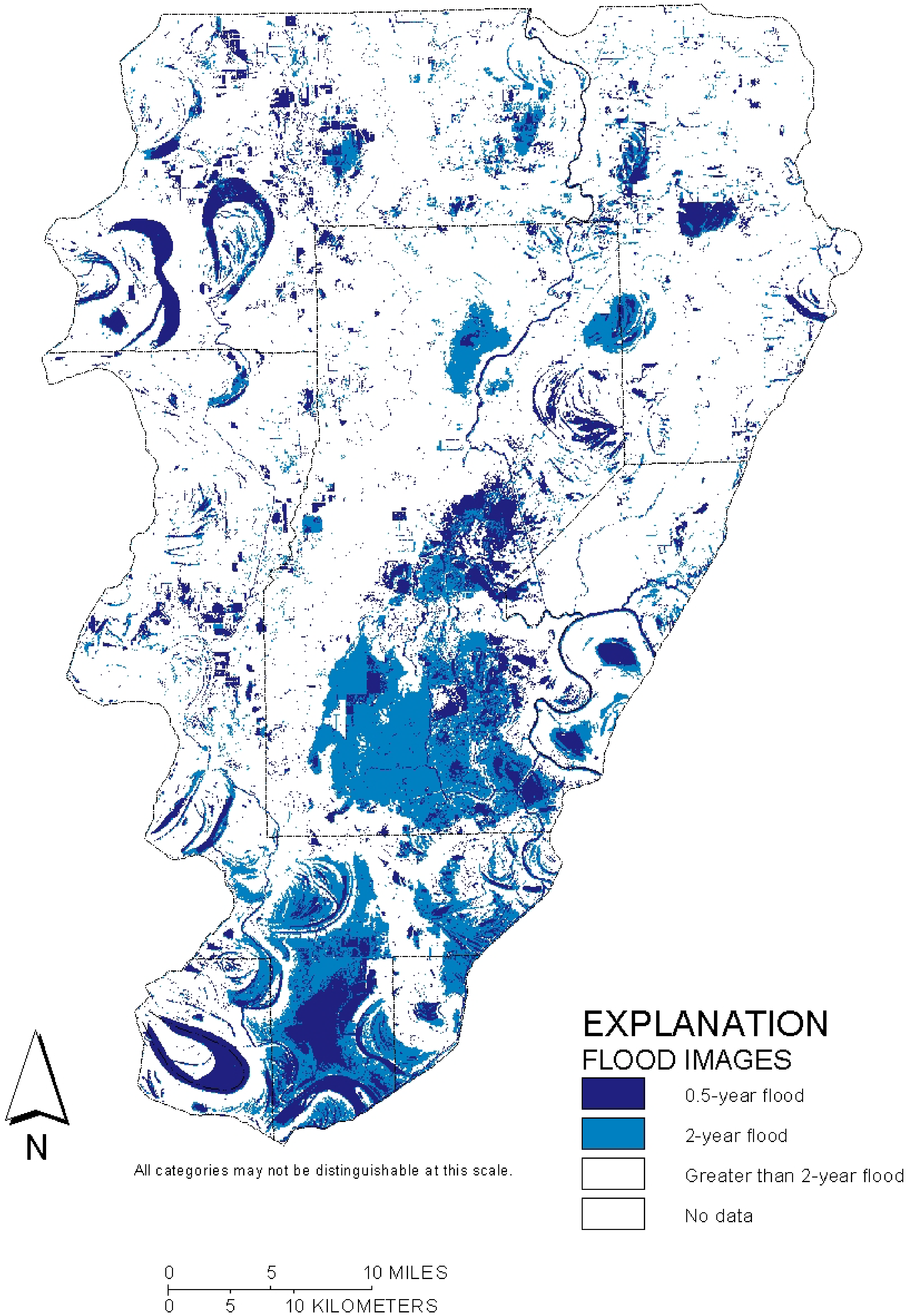

Figure 6. Spatial depiction of the 0.5- and 2-year or greater floods in the Yazoo Backwater Area, Mississippi. [based on U.S. Army Corps of Engineers flood image data]

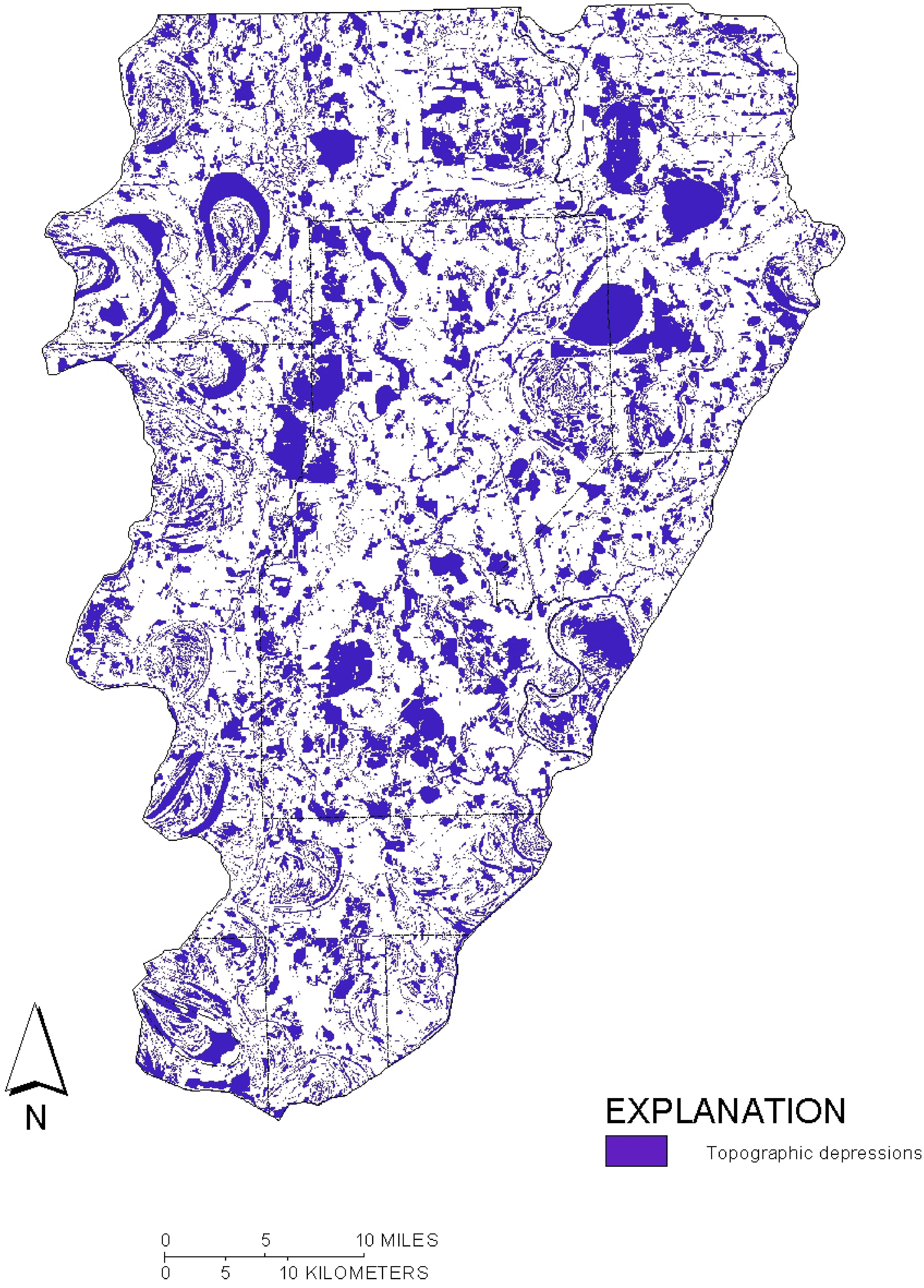

Figure 7. Topographic depressions within the Yazoo Backwater Area, Mississippi.

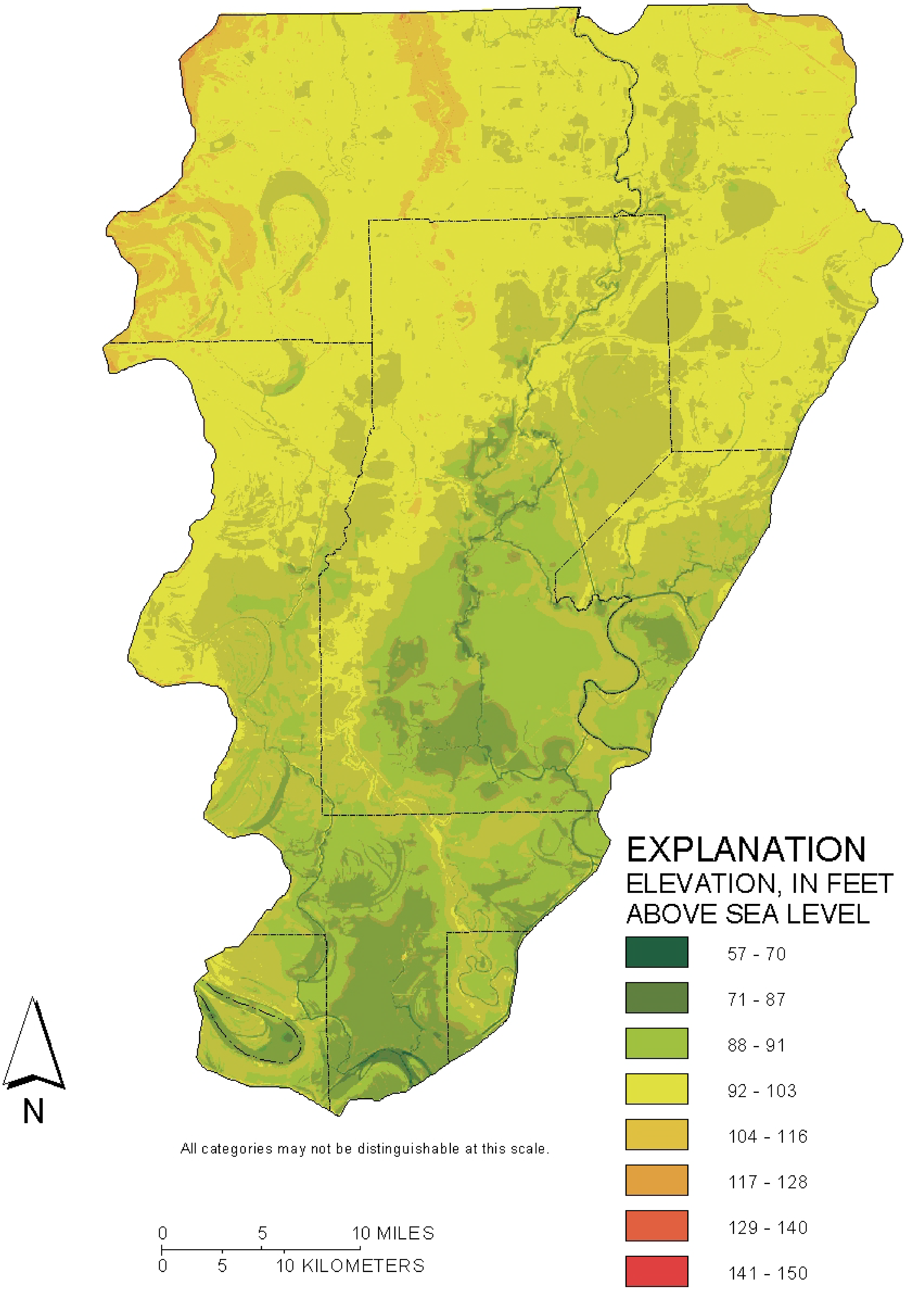

Figure 8. Elevations in the Yazoo Backwater Area, Mississippi.

streams (Dillaha and others, 1989; Howard and Allen, 1988). Areas adjacent to streams with a level of 9 or 0 are given a 10-meter buffer. The buffer distance changes according to stream level as shown in table 1. Stream buffers have been shown to mitigate the flow of nitrate, phosphorus, sediment, and sediment-borne chemicals in surface runoff and shallow ground water (Lowrance and others, 1997). Areas within stream buffers benefit water quality and are given a rank of 15, whereas areas outside of stream buffers are given a rank of 0. The EPA River Reach files were used to generate the GIS stream buffer layer.

Topographic Depressions: Topographic depressions retain flood waters. If water remains in a topographic depression for extended periods of time, suspended sediments will gradually settle out and anaerobic processes will begin. The amount of sediment that will be deposited in depression areas is higher than in nondepression areas because longer periods of inundation allow for longer settling times (Hupp and Morris, 1990; Kleiss, 1996). Both the trapping of sediments and the degradation of chemicals through anaerobic processes improve overall water quality (Mitsch and Gosselink, 1993). Areas within topographic depressions, therefore, are given a rank of 15, and areas outside of topographic depressions are given a rank of 0.

Habitat

The habitat function is assessed by determining how well areas on the landscape will support wildlife. The habitat function considers proximity to wildlife management areas and conservation areas, distance away from primary and secondary roads, proximity to permanent water bodies, and landscape factors such as forest block size and core area.

Public Lands: The public lands data layer is divided into two categories. The first category contains the managed wildlife areas, including national wildlife refuge and state wildlife management areas. The second category contains general conservation lands, including public land restoration, Delta National Forest, Farmer's Home Administration, and Wetland Reserve Program lands. Expanding existing public lands greatly benefits wildlife by increasing the interior space available for habitat. Also, any connections that can be made between two patches of land add valuable corridors for the movement of wildlife (Allen and Kennedy, 1989). Therefore, areas in proximity to wildlife management areas are given ranks that range from 10 to 0, and conservation areas are given ranks that range from 5 to 0 (table 1). To assess proximity, a distance grid was created from the public lands data layer, which was created by combining individual data layers provided by the U.S. Fish and Wildlife Service.

Roads: Roads are sources of noise, and areas in proximity to roads are likely to be disturbed by traffic; the more traffic, the greater the disturbance. Primary and secondary road GIS data layers were used to generate a grid of distance moving away from the roads. Distances away from primary and secondary roads were adapted from a Louisiana Department of Natural Resources study (Kinler, 1994), which ranked human disturbances by distance and type of disturbance (table 1). For the purposes of the Eco-Assessor, primary roads are considered to be a constant disturbance and receive lower ranks with proximity; ranks range from 0 to 3. Secondary roads are considered to be a frequent disturbance and receive slightly higher ranks with proximity compared to primary roads; ranks range from 1 to 3.

Permanent Water: Wildlife benefits by being near permanent water bodies because water is a basic requirement for living. In a study conducted in the same general geographic area (Wakeley and Marchi, 1992), six species were chosen for a habitat evaluation of the Upper Steele Bayou area in Mississippi. The six species, which are common to bottomland hardwood forest, include the barred owl (*Strix varia*), gray squirrel (*Sciurus carolinensis*), Carolina chickadee (*Parus carolinensis*), pileated woodpecker (*Dryocopus pileatus*), wood duck (*Aix sponsa*), and mink (*Mustela vison*) (Wakely and Marchi, 1992). Of these six species, the pileated woodpecker has the most quantitatively specific habitat requirements according to the U.S. Fish and Wildlife Service Habitat Suitability Index model (HSI). Minimum distance requirements to and from permanent water bodies, as well as minimum forest block size, are given in the HSI. For the pileated woodpecker, the HSI indicates that nesting habitat generally is not observed greater than 150 meters from water bodies (Schroeder, 1982). Natural resource agencies commonly use the habitat requirements for the pileated woodpecker to represent the habitat requirements for other cavity nesting birds (Renken and Wiggers, 1993). Thus, as detailed in table 1, ranking distance to permanent water bodies ranges from 5 to 0, so that areas within 150 meters of permanent water bodies receive the highest rank; ranks decrease with increasing distance to the water.

Forest Block Size: The landscape can be assessed by using factors such as patch size, core area, and patch shape. A patch of forested land less than 1 acre does not provide sufficient habitat for wildlife (Wakely and Marchi, 1992); therefore, any patch that is less than 1 acre is not considered. The larger the patch size, the greater the benefit to wildlife living within that habitat. There are two categories of wildlife species: generalists and specialists. Generalists can live in patches of various shapes and sizes because their populations are large and highly mobile. Conversely, specialists require large patches of forest with greater interior area and less edge (Kinler, 1994). As a result, specialists require the greatest conservation efforts, so greater weight is given to larger patches of land. Forest blocks are given ranks that range from 1 to 10 with increasing rank given to larger block sizes (table 1).

Core Area Ratio: The ratio between core area and total patch area is used to give more weight to patches of land that have a greater portion of interior area. Core area is defined by the Fragstats manual as “the area within a patch beyond some specified edge distance or buffer width” (McGarigal, 1995). The Eco-Assessor uses a buffer distance of 100 meters between the edge of the patch and the core. Any land that is within the interior of a patch and more than 100 meters from the edge is considered as core area. For a given patch of land, the number of cells considered to be core area divided by the number of cells in the entire patch results in a core area ratio, which provides a good indication of patch shape. A long, thin patch of land results in a lower ratio, whereas a long, wide patch of land results in a higher ratio (fig. 9). A patch of land with a high ratio provides wildlife habitat with fewer edge effects and more interior space. Increasing the amount of interior space available in a given patch gives rise to the number of interior species and species diversity (Ohman and Eriksson, 1998). Ranks associated with core area ratio range from 10 to 1 (table 1).

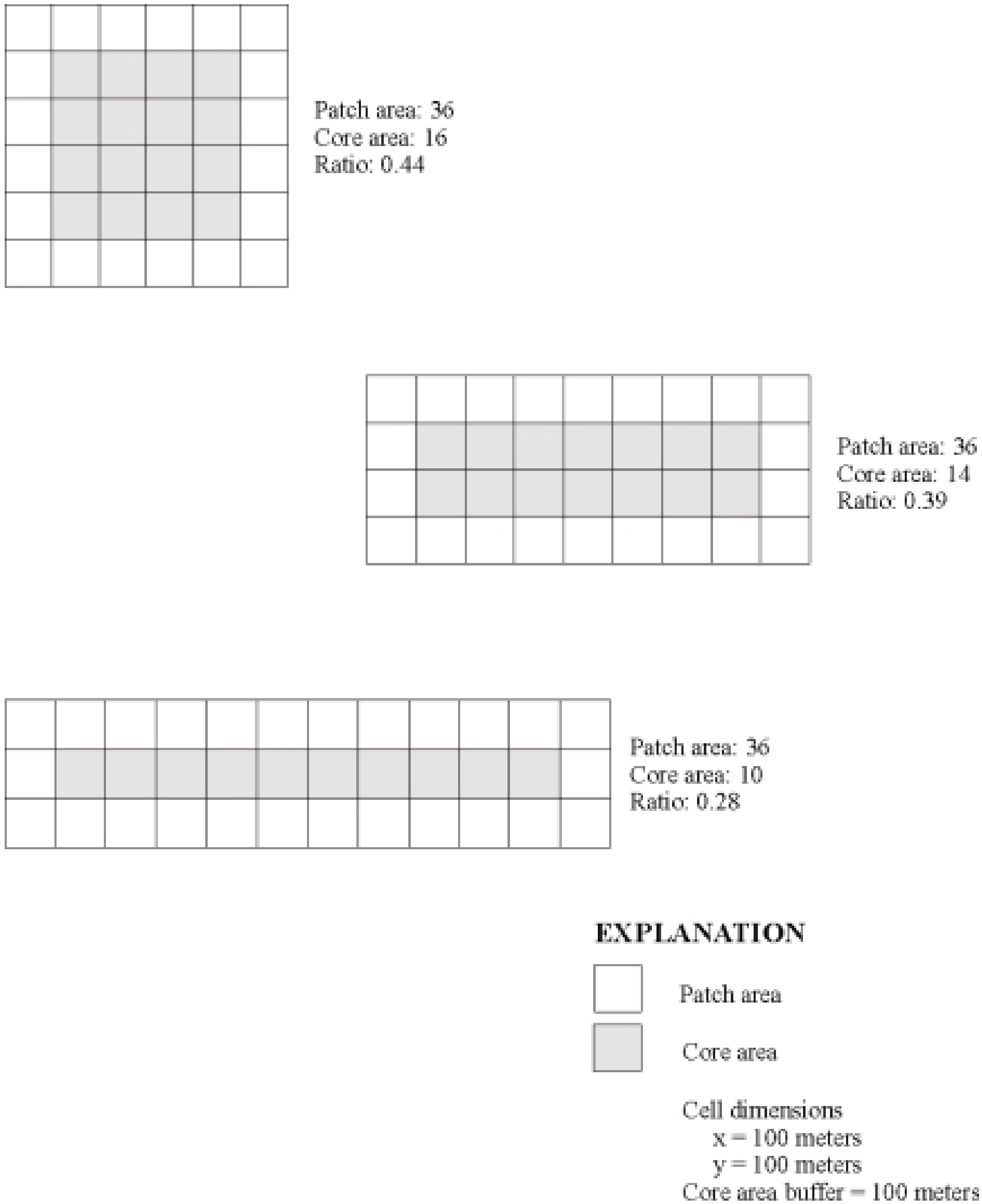

Figure 9. Example habitat patches showing total patch area, core area, and core area ratio for the Yazoo Backwater Area, Mississippi.

Cumulative Analysis

The DSS is used to conduct cumulative analysis by evaluating all of the data layers with the rank values, which are initially set as default values. The interface allows the user to interactively turn layers on or off, if desired, and provides the user with the ability to modify the assignment of rank values for each layer. Thus, a particular user-defined analysis may use only selected data layers (to emphasize particular wetland functions), and default ranking values likewise may be modified to emphasize the influence of a particular layer in the analysis. Rankings are always reset to default values for each analysis run, but modifications can be saved and stored for future runs or to help document a specific scenario. Once the Eco-Assessor has analyzed each data layer, the ranks for all data layers are summed. The summation results in a cumulative functional restoration (FR) rank for each cell of eligible land. The FR rank is then used to indicate which areas on the landscape are most suitable for wetland restoration and will likely perform wetland functions.

FR maximum is the grid generated by the Eco-Assessor that contains the total FR value for each eligible cell in the study area (fig. 10). FR maximum assumes that every eligible cell within the study area is selected for reforestation. The total FR value is the sum of the assigned rank for each data layer of a given cell. The resultant FR maximum spatial data layer has cells that have cumulative ranks that range from 15 to 140. The highest ranked areas are those that will be most suitable for wetland restoration and will most likely perform wetland functions.

Module 2 – Land-Use Conversion: The Tree-Translator

Selecting areas that can function as a wetland, and then "translating" the land use from the current land-use type to a forested land use is the fundamental activity of forested wetland restoration. The land use translation restoration activity is also the fundamental modeling step in the DSS. The translation of land use from areas that are typically cropped to a forested tree cover is accomplished by a part of the DSS that has been named the "Tree-Translator." The tree-translator conducts land-use translation of the landscape from existing land-use types into forest communities with consideration given to both, or either, ecologic and economic objectives. Areas selected for reforestation are translated (in the GIS) into forested land use, and the tree species that are planted on the landscape (in the DSS) either compose an ecologically optimal or an economically optimal community of tree species.

The Tree-Translator simulates reforestation by selecting tree species to be planted in locations where the species will grow best. Translation rules for reforesting that maximize either the ecologic or economic benefits of reforestation are listed in tables 2 and 3, respectively. The ecologic tree-translation rules use stream buffers, soil type, geomorphology, and flood frequency to guide the selection of tree species to be reforested. Tree species selected for use in the tree-translation scenarios were chosen by Virginia Tech economists who are modeling the economic consequences of reforestation in the study area. The placement of specific tree species on the landscape in settings where the trees will best flourish is based upon HGM studies conducted within the

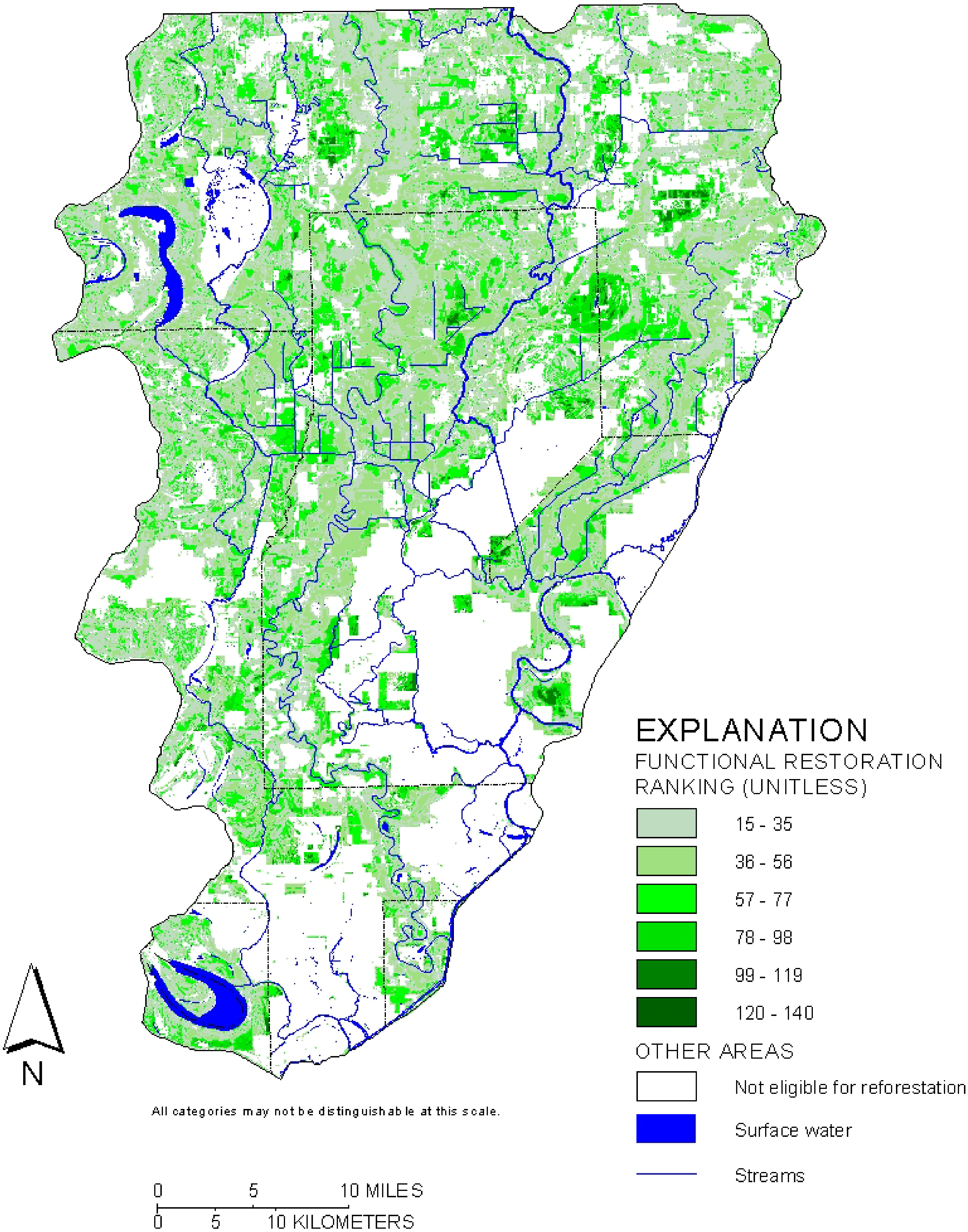

Figure 10. Functional restoration score for eligible areas within the Yazoo Backwater Area, Mississippi.

Table 2. Translation rules for establishing tree communities that maximize ecologic benefit [>, greater than; <, less than]

Tree species	Stream buffer	Soil type	Geomorphology	Hydrology (flood frequency)
cottonwood	within buffer	non-hydric	pointbar/valley train	> 2-year
cottonwood	within buffer	non-hydric	pointbar/valley train	0.5 – 2-year
sycamore	within buffer	non-hydric	pointbar/valley train	< 0.5-year
cottonwood	within buffer	non-hydric	backswamp	> 2-year
sycamore	within buffer	non-hydric	backswamp	0.5 – 2-year
cherrybark oak	within buffer	non-hydric	backswamp	< 0.5-year
sycamore	within buffer	non-hydric	abandoned channel	> 2-year
cherrybark oak	within buffer	non-hydric	abandoned channel	0.5 – 2-year
cherrybark oak	within buffer	non-hydric	abandoned channel	< 0.5-year
sweetgum	within buffer	hydric	pointbar/valley train	> 2-year
sweetgum	within buffer	hydric	pointbar/valley train	0.5 – 2-year
nutall oak	within buffer	hydric	pointbar/valley train	< 0.5-year
nutall oak	within buffer	hydric	backswamp	> 2-year
nutall oak	within buffer	hydric	backswamp	0.5 – 2-year
green ash	within buffer	hydric	backswamp	< 0.5-year
green ash	within buffer	hydric	abandoned channel	> 2-year
bald cypress	within buffer	hydric	abandoned channel	0.5 – 2-year
bald cypress	within buffer	hydric	abandoned channel	< 0.5-year
cherrybark oak	outside buffer	non-hydric	pointbar/valley train	> 2-year
cherrybark oak	outside buffer	non-hydric	pointbar/valley train	0.5 – 2-year
cherrybark oak	outside buffer	non-hydric	pointbar/valley train	< 0.5-year
cherrybark oak	outside buffer	non-hydric	backswamp	> 2-year
cherrybark oak	outside buffer	non-hydric	backswamp	0.5 – 2-year
cherrybark oak	outside buffer	non-hydric	backswamp	< 0.5-year
cherrybark oak	outside buffer	non-hydric	abandoned channel	> 2-year
cherrybark oak	outside buffer	non-hydric	abandoned channel	0.5 – 2-year
cherrybark oak	outside buffer	non-hydric	abandoned channel	< 0.5-year
sweetgum	outside buffer	hydric	pointbar/valley train	> 2-year
sweetgum	outside buffer	hydric	pointbar/valley train	0.5 – 2-year
nutall oak	outside buffer	hydric	pointbar/valley train	< 0.5-year
nutall oak	outside buffer	hydric	backswamp	> 2-year
nutall oak	outside buffer	hydric	backswamp	0.5 – 2-year
green ash	outside buffer	hydric	backswamp	< 0.5-year
green ash	outside buffer	hydric	abandoned channel	> 2-year
bald cypress	outside buffer	hydric	abandoned channel	0.5 – 2-year
bald cypress	outside buffer	hydric	abandoned channel	< 0.5-year

Table 3. Translation rules for establishing tree communities that maximize economic benefit

Tree species	Topographic depressions	Soil type
bald cypress	topographic depression	hydric
cottonwood	not a topographic depression	non-hydric
cottonwood	topographic depression	non-hydric
cottonwood	not a topographic depression	hydric

same geographic area. The tree species used in the ecologic tree-translator include, in order from dry to wet (Reed, 1988), cottonwood, sycamore, cherrybark oak, sweetgum, nutall oak, green ash, and bald cypress. Cottonwood trees ideally grow in areas with the least amount of water and the highest elevation. Bald cypress trees are better adapted to grow in low-elevation areas that are frequently inundated. The results of ecologic or economic tree-translation, if all available lands were translated into forested land use, are presented in figures 11 and 12, respectively. From an environmental standpoint, planting a diversity of tree species that best approximates the species distribution in a "reference" wetland is ideal to the restoration of a full spectrum of wetland functions.

The economic tree-translator rules use soil type and topographic depressions to guide the implementation of reforestation. The tree species used in the economic tree-translator are cottonwood and bald cypress. Economists evaluated the benefits of reforestation of selected areas on the landscape for both the ecologic and the economic tree-translation using a range of water tolerances, growth rates as a function of soil type, and economic returns through timber sales. Cottonwood was selected as the preferred economic tree crop because it has a shorter rotation, allows more frequent harvesting over a 120-year period, and yields higher net returns per acre. Bald cypress trees are not considered economically productive, but grows well under wet conditions (Reed, 1988). The tree-translator produced two output grids per scenario, one for the ecologic tree-translation and a second landscape planted for the economic tree-translation.

Module 3 - Output Data Preparation: The Parameter-Generator

Once a restoration scenario is generated, an ASCII text parameter file is created. The parameter file includes spatial subdivisions of the study area (COE reach basins), estimated inundation bands, soil type, and county boundaries. The spatial subdivisions and inundation/elevation bands are not used in the Eco-Assessor to prioritize areas, rather they are used only to spatially disaggregate areas to provide an estimate of the frequency of inundation for modeled areas. The COE provided reach-basin data that subdivide the study area into four areas or sub-basins. The elevation/inundation bands were derived from the high resolution elevation model, COE flood-image data, and flood-frequency data provided by the COE. Each row in the parameter file represents a unique combination of reach basins, inundation/elevation bands, soil type, and county boundaries with a given land-use type. Each unique combination of parameters can be treated as an analysis unit. In performing subsequent analyses of changes in land use, all cells that are characterized by the same parameters can be treated similarly. The parameter file includes a column for reach, inundation/elevation band, soil type, county, land use, total acres, FR rank, and the percentage of reforestation in each of the tree species. Parameter file output data can be used to compare scenarios and as an input data file to model the economic consequences of forested wetland restoration.

Restoration Scenarios

Reforesting all eligible areas within the Yazoo Backwater Area is unrealistic. Therefore, reforestation scenarios were created that reforest selected areas within the study area. For each scenario, ecologic and economic tree-translations were performed and an output parameter file was generated. The scenarios were developed by establishing spatial or statistical criteria for the selection of reforestation areas. Specific scenarios were developed to illustrate how several restoration objectives can be achieved including restoring areas within the 100-year floodplain, restoring areas that will maximize water-quality improvements, restoring areas that will maximize improvements in wildlife habitat, and several scenarios that illustrate restoring parts of or all of areas within the estimated 2-year floodplain.

In estimating areas inundated in the 2-year floodplain, several approaches were used including use of a composite 2-year flood image (COE nominal 2-year flood scene); use of an elevation/inundation interpolation surface (called HydroGrow) that estimates areas inundated between the areal extent of two known flood events; and selection of areas on a digital elevation model (DEM) surface with land-surface elevations less than the 2-year flood stage. The estimated areal extent of a flood event (or the extent of some other spatial data layer) can be used to limit the areas considered for restoration, and the FR rank can be used to further refine the selection of areas to be reforested.

Using the FR rank was important because it provides a metric to compare alternate scenarios on an ecologic basis. The FR rank ranged from 15 to 140 out of a possible 145. A graph of FR rank and cumulative evaluated acres is shown in figure 13. The total FR rank for a given scenario provides an indicator of the ecologic benefits of reforesting the area specified by the scenario. The total FR rank for a given scenario can be divided by the total number of acres for that scenario. The resultant FR-per-acre score provides a measure of the ecologic benefits of an area relative to the size of the area identified for restoration. A graphical comparison of FR-per-acre score for example scenarios is provided in figure 14. Seven scenarios were selected as examples of how the DSS can be used to target particular reforestation goals or wetland functional restoration objectives. A tabulation of FR rank, acres, and rank per area for the example scenarios is provided in table 4.

FR Maximum Scenario: For the FR maximum, all areas eligible for restoration within the extent of the 100-year floodplain (as indicated by the COE 100-year nominal flood scene) were selected for reforestation. All eligible areas were reforested for both the ecologic and ecologic tree species assemblage (figs. 10, 11, and 12).

Water-Quality Scenario: In the water-quality scenario, all eligible areas that are within stream buffers for all stream segments, as well as all areas classified as depressions (sinks) were selected (fig. 15).

Habitat Scenario: The habitat scenario selected all eligible areas that are ideal for habitat restoration by using only habitat metrics in the assessment. For the resultant output, the Eco-Assessor provides the ability to view a histogram of values, and the option to create an output that contains only a sub-selection of the result. For this scenario, areas were selected that have a habitat rank of 22 or better (fig. 16).

Hydrology Scenario: In the hydrology scenario, all eligible areas shown as inundated in the COE nominal 2-year flood scene (nominal image) were selected for reforestation (fig. 17).

HydroGrow-per-FR Scenario: In the HydroGrow-per-FR scenario, the areas that were considered for reforestation were limited to those within the estimated 2-year floodplain based on the HydroGrow interpolation surface. Within those areas, the FR score per acre was calculated for every analytical unit, which were sorted in descending order by FR score per acre. Every analytical unit that earned at least 319 FR points per acre was selected and reforested using the ecologic tree-translation rules (fig. 18).

DEM Ranges 1 and 2 Scenario: In this scenario, the DEM was used to select all eligible areas having an elevation lower than the elevation (stage) of the 2-year flood at the Steele Bayou gage (fig. 19).

HydroGrow Ranges 1 and 2 Scenario: All eligible areas shown as inundated in the HydroGrow 2-year flood estimate were selected for reforestation (fig. 20).

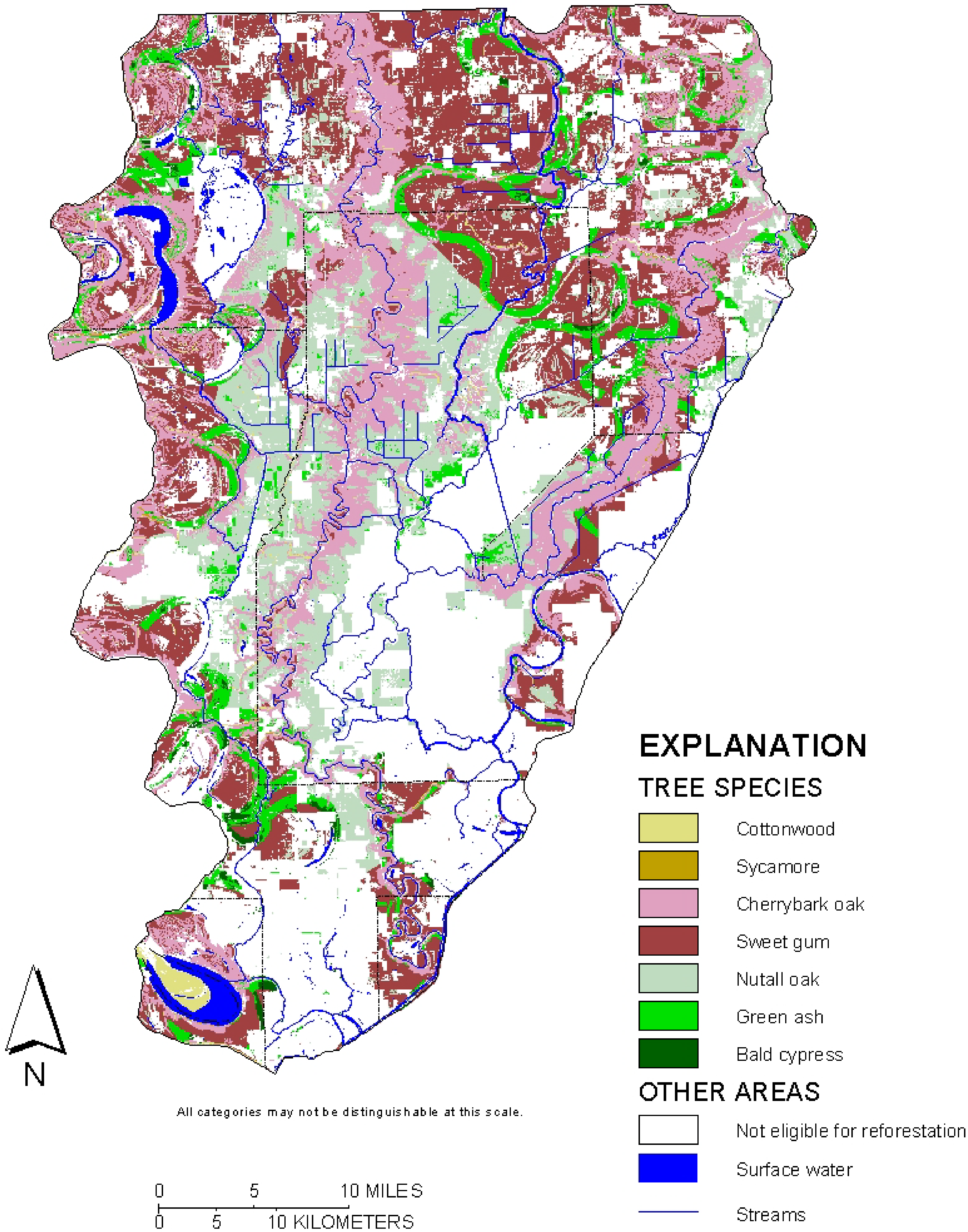

Figure 11. Reforestation by the ecologic Tree-Translator for the Yazoo Backwater Area, Mississippi.

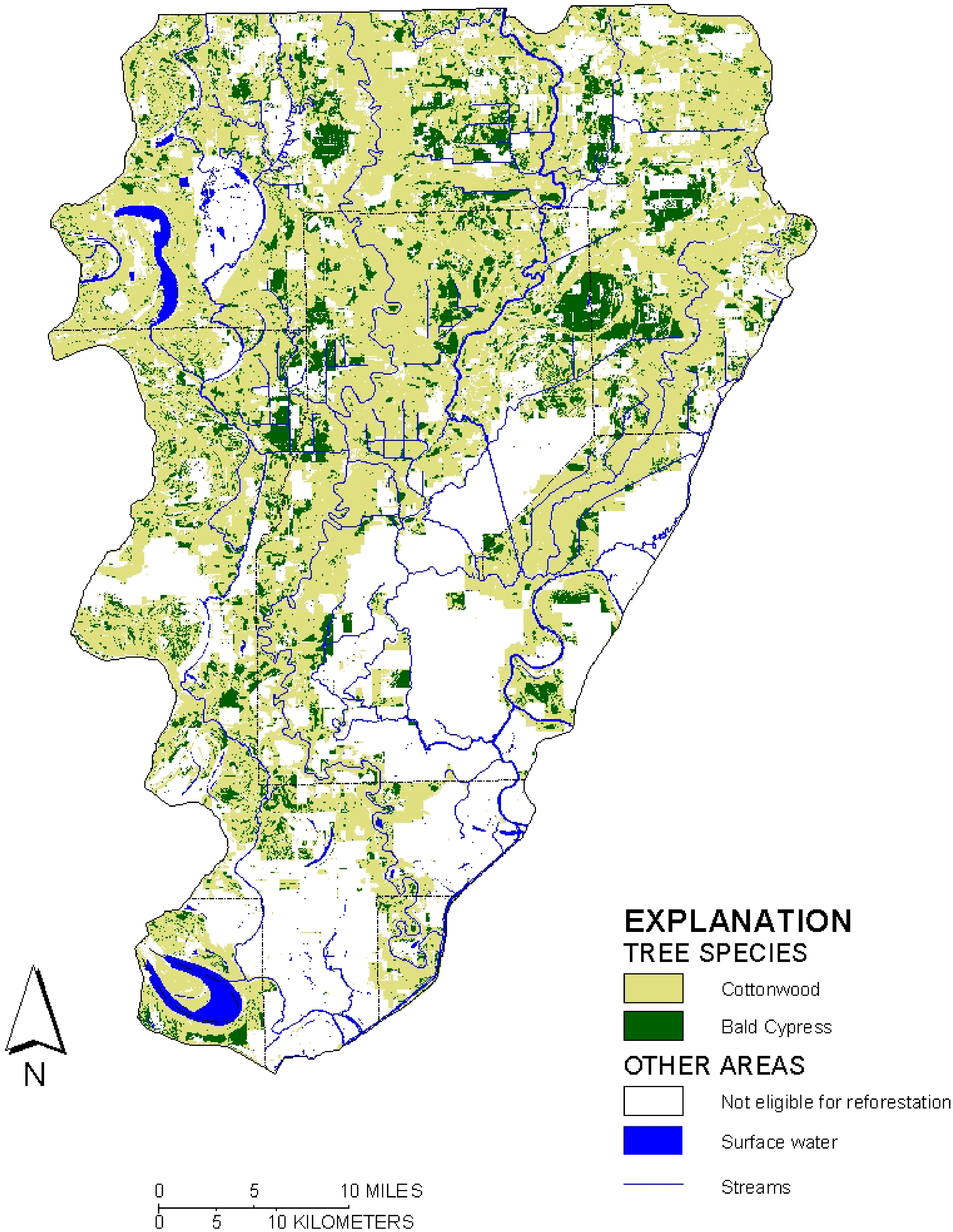

Figure 12. Reforestation by the economic Tree-Translator for the Yazoo Backwater Area, Mississippi.

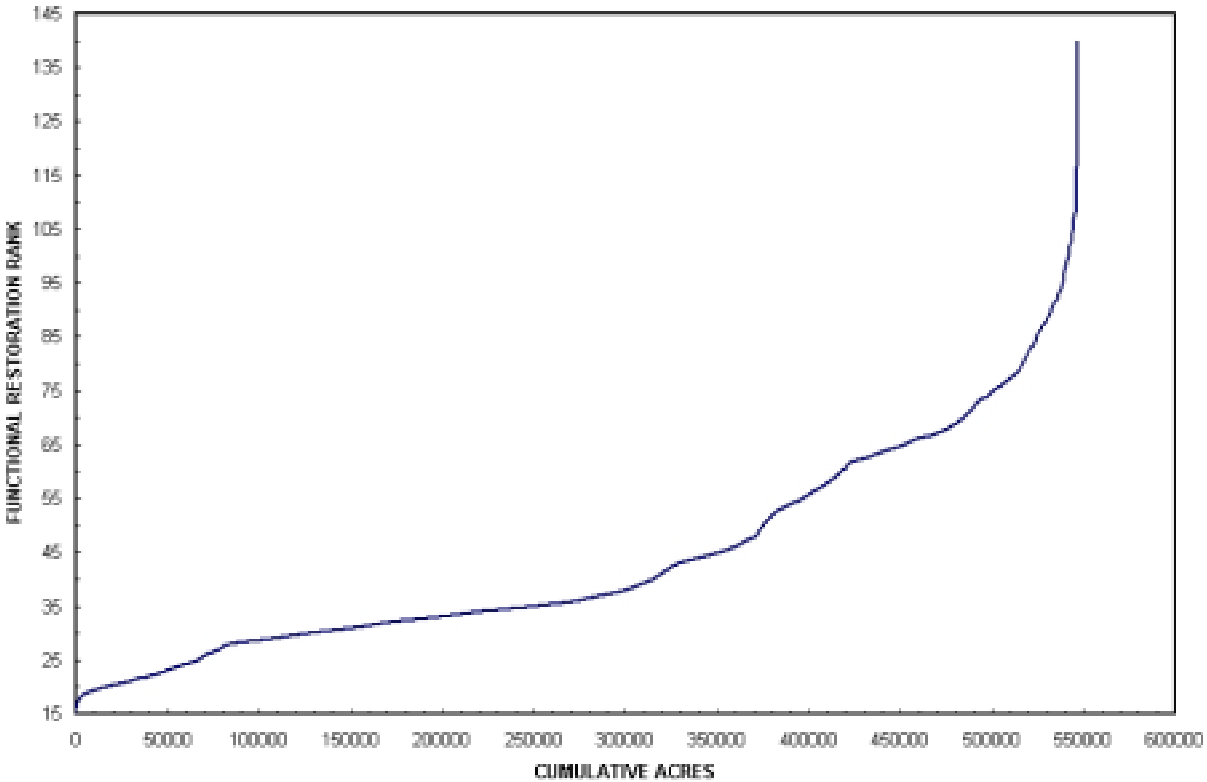

Figure 13. Cumulative curve of the functional restoration score versus acres of eligible land.

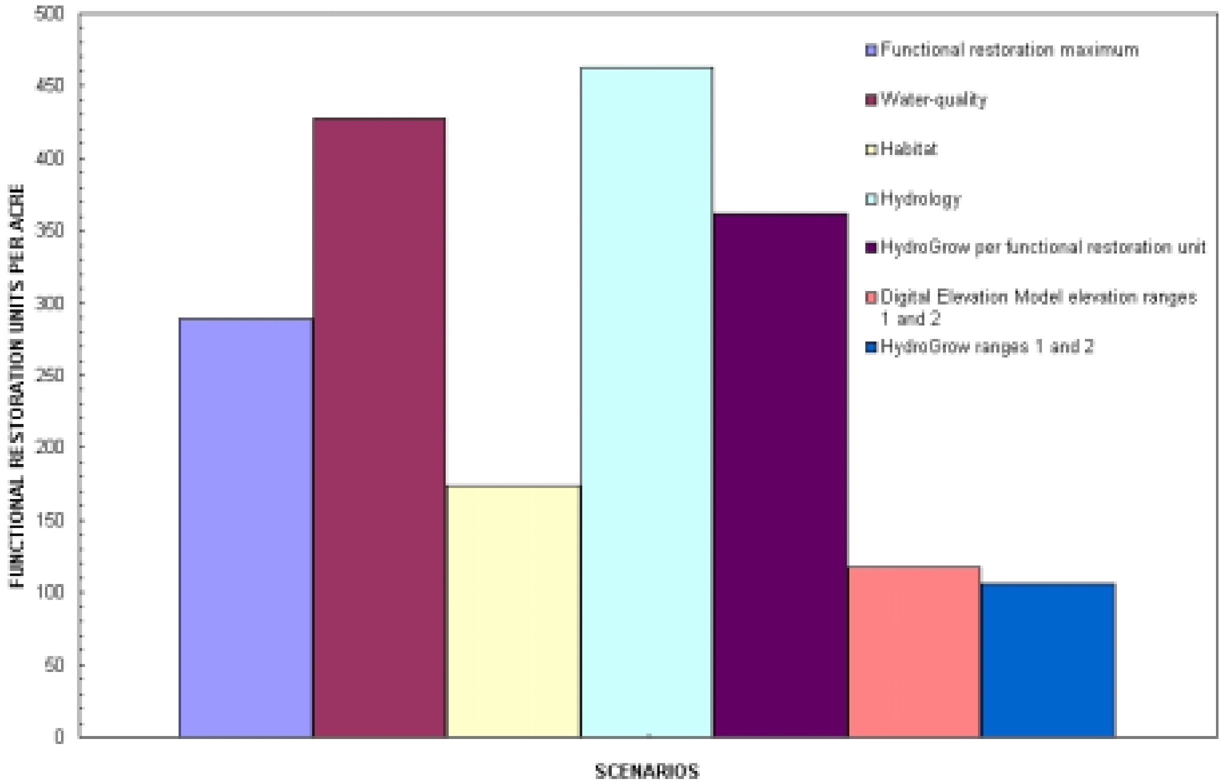

Figure 14. Functional restoration rank per acre for example scenarios.

Table 4. Functional restoration ranking and the number of acres reforested for example scenarios

Scenario	Number of eligible acres	Functional restoration rank	Functional restoration rank per 100,000	Functional restoration rank per acre
Functional restoration maximum	543,855	157,000,000	1,573.60	289
Water-quality	165,353	70,700,000	707.09	428
Habitat	215,022	37,300,000	372.54	173
Hydrology	61,407	28,400,000	284.02	463
Hydrogrow per functional restoration unit	88,038	31,900,000	318.75	362
Digital Elevation Model ranges 1 and 2	47,648	5,590,000	55.85	117
HydroGrow ranges 1 and 2	121,973	12,800,000	129.00	106

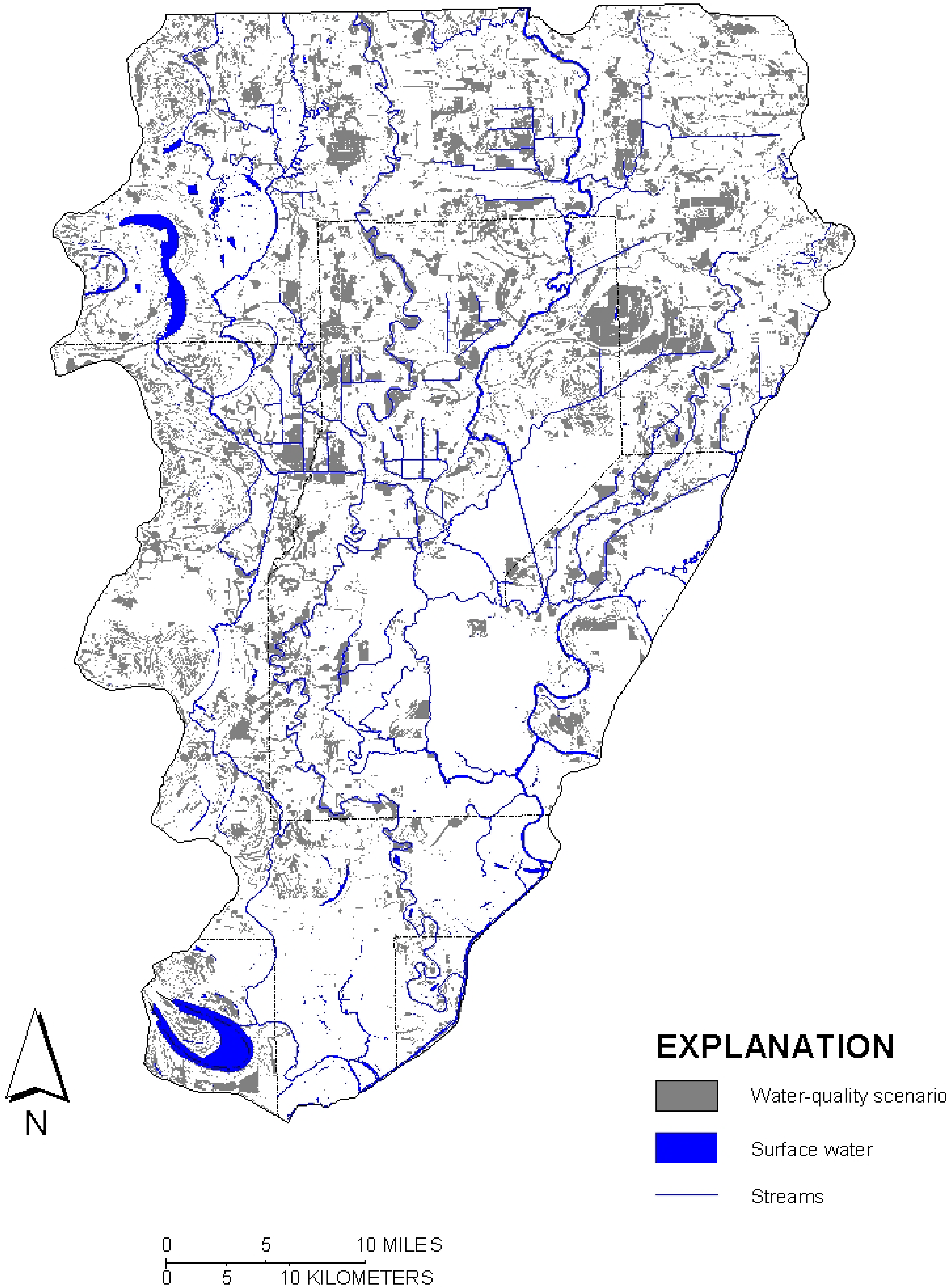

Figure 15. Areas recommended for restoration by using the water-quality scenario.

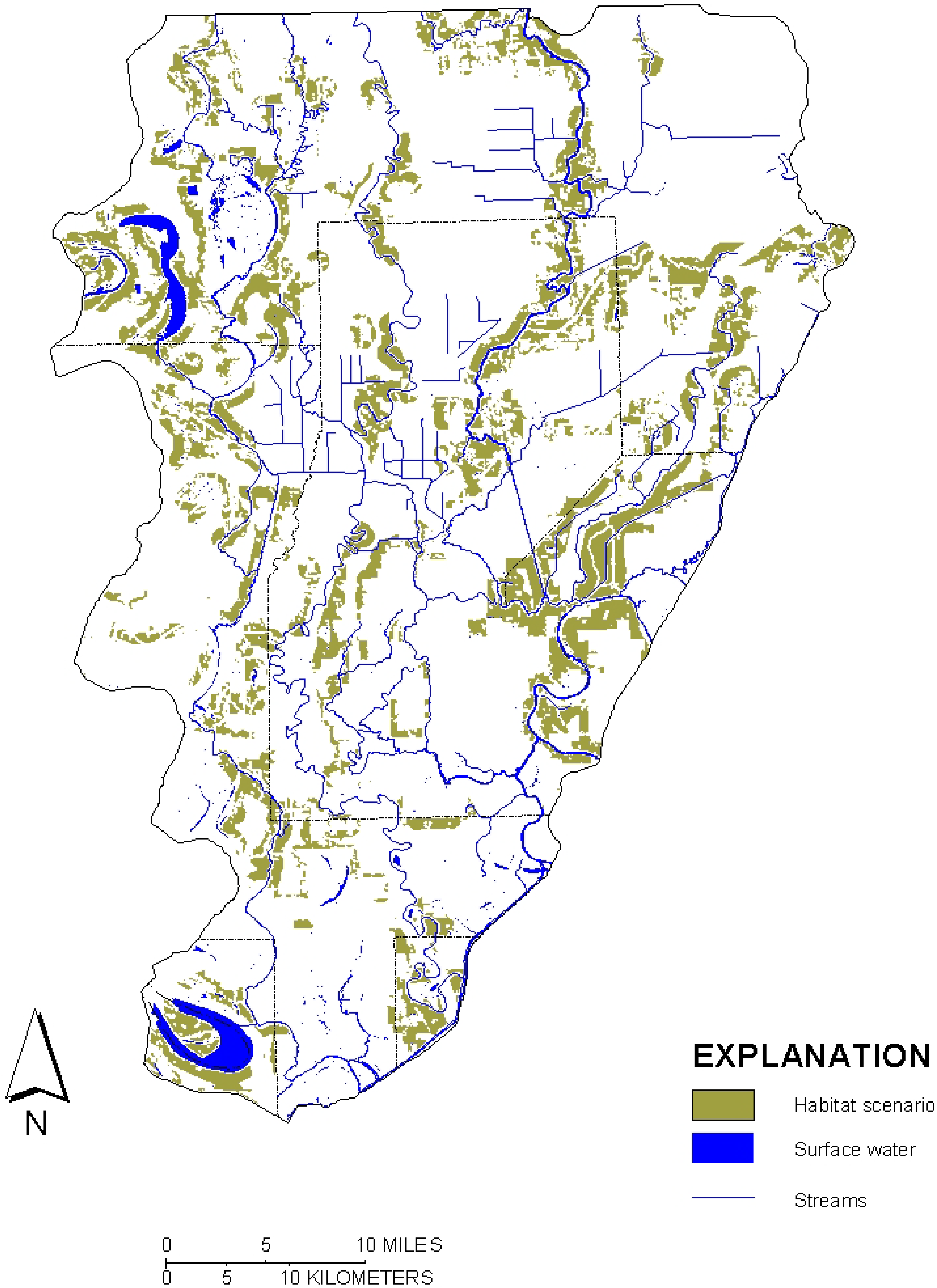

Figure 16. Areas recommended for restoration by using the habitat scenario.

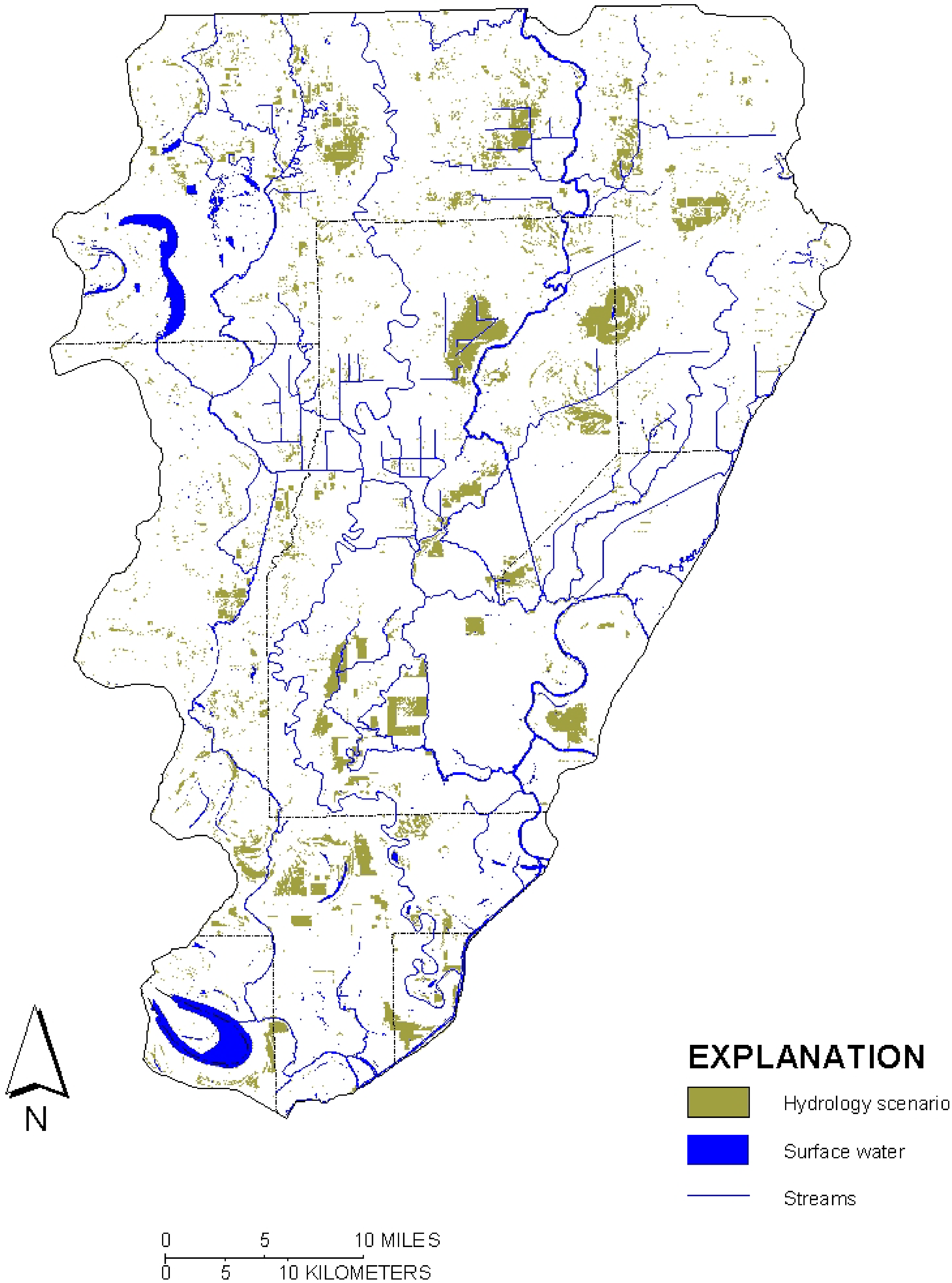

Figure 17. Areas recommended for restoration by using the hydrology scenario.

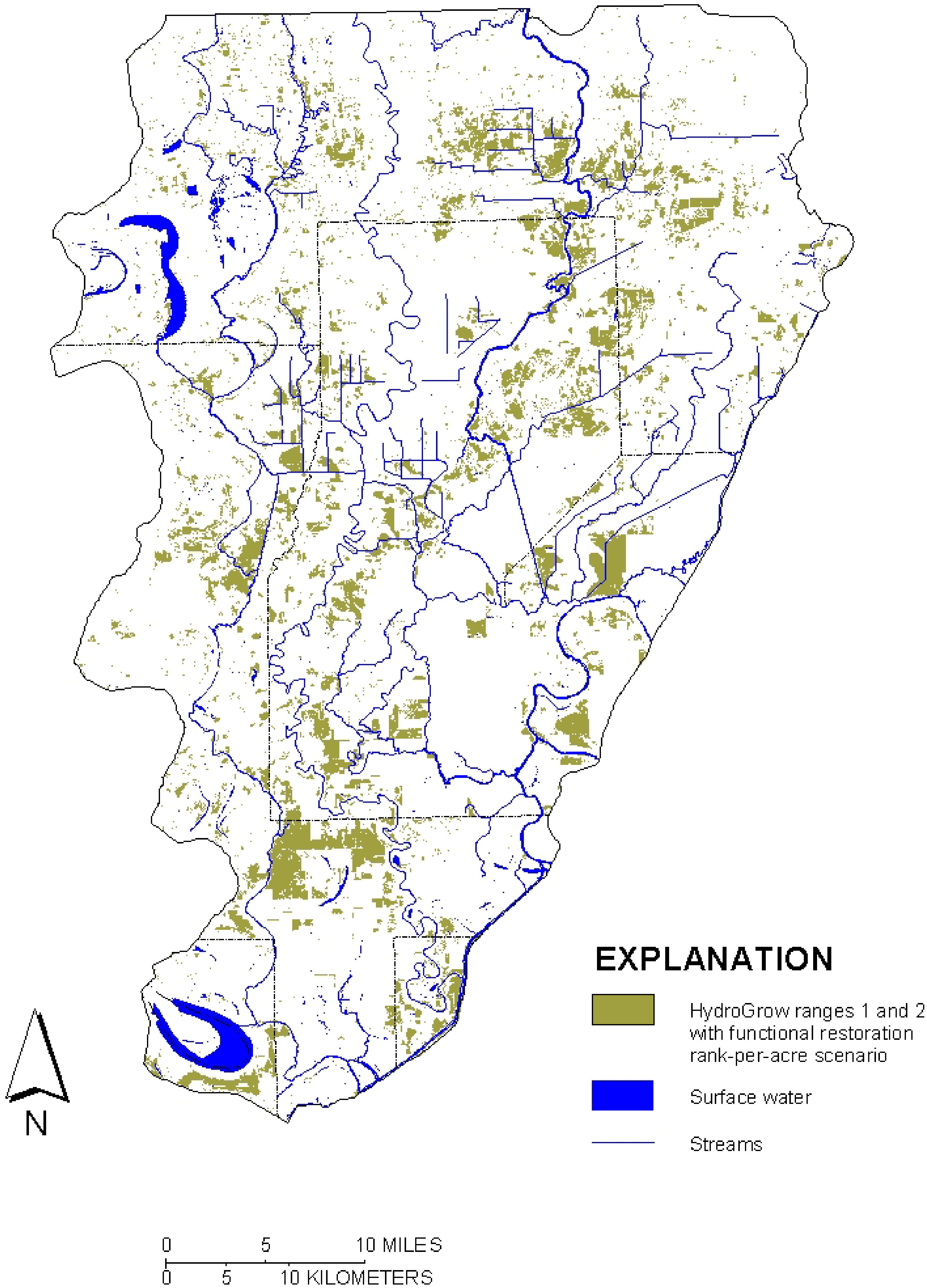

Figure 18. Areas recommended for restoration by using the HydroGrow ranges 1 and 2 with functional restoration rank-per-acre scenario.

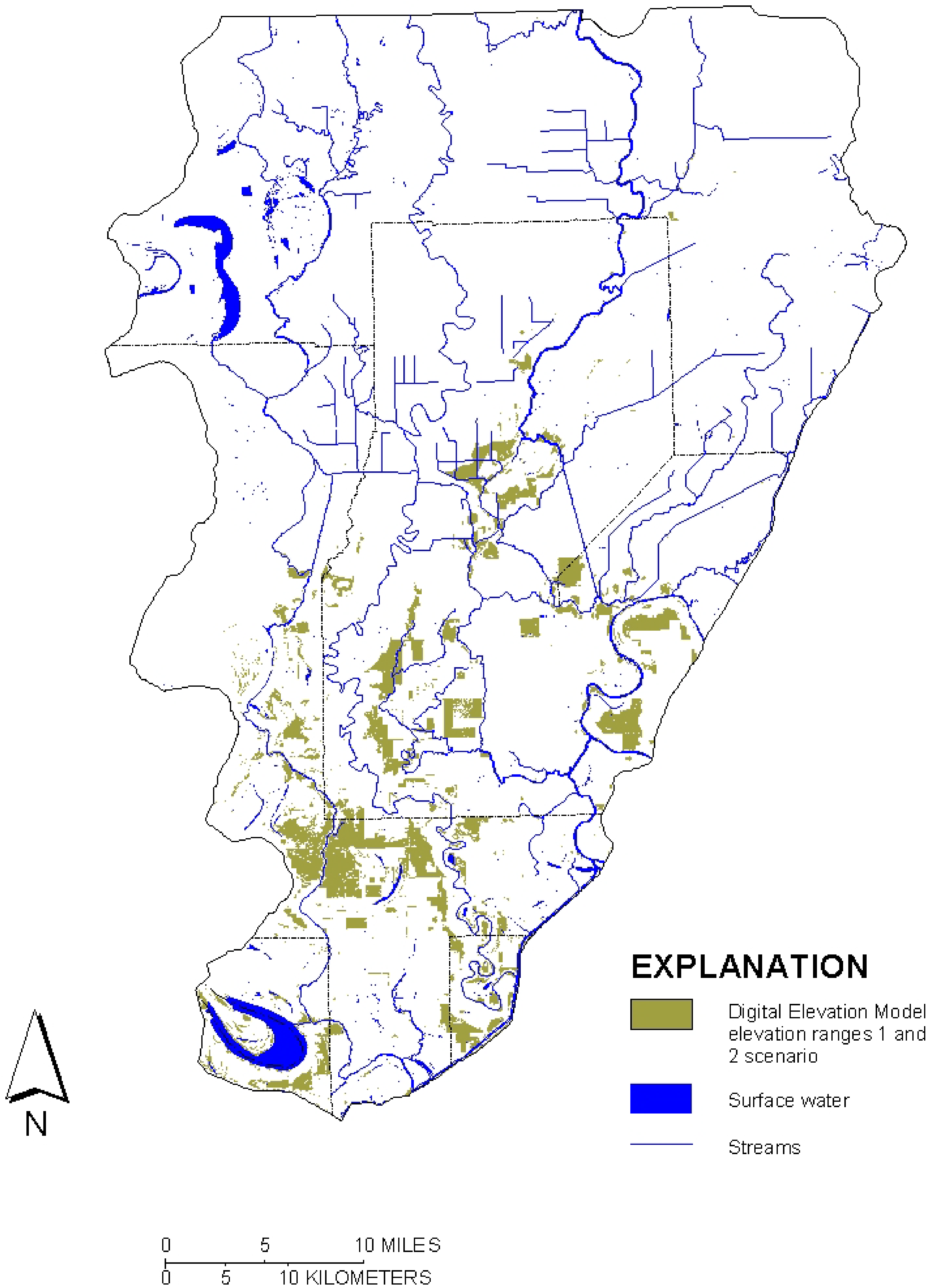

Figure 19. Areas recommended for restoration by using the digital elevation model elevation ranges 1 and 2 scenario.

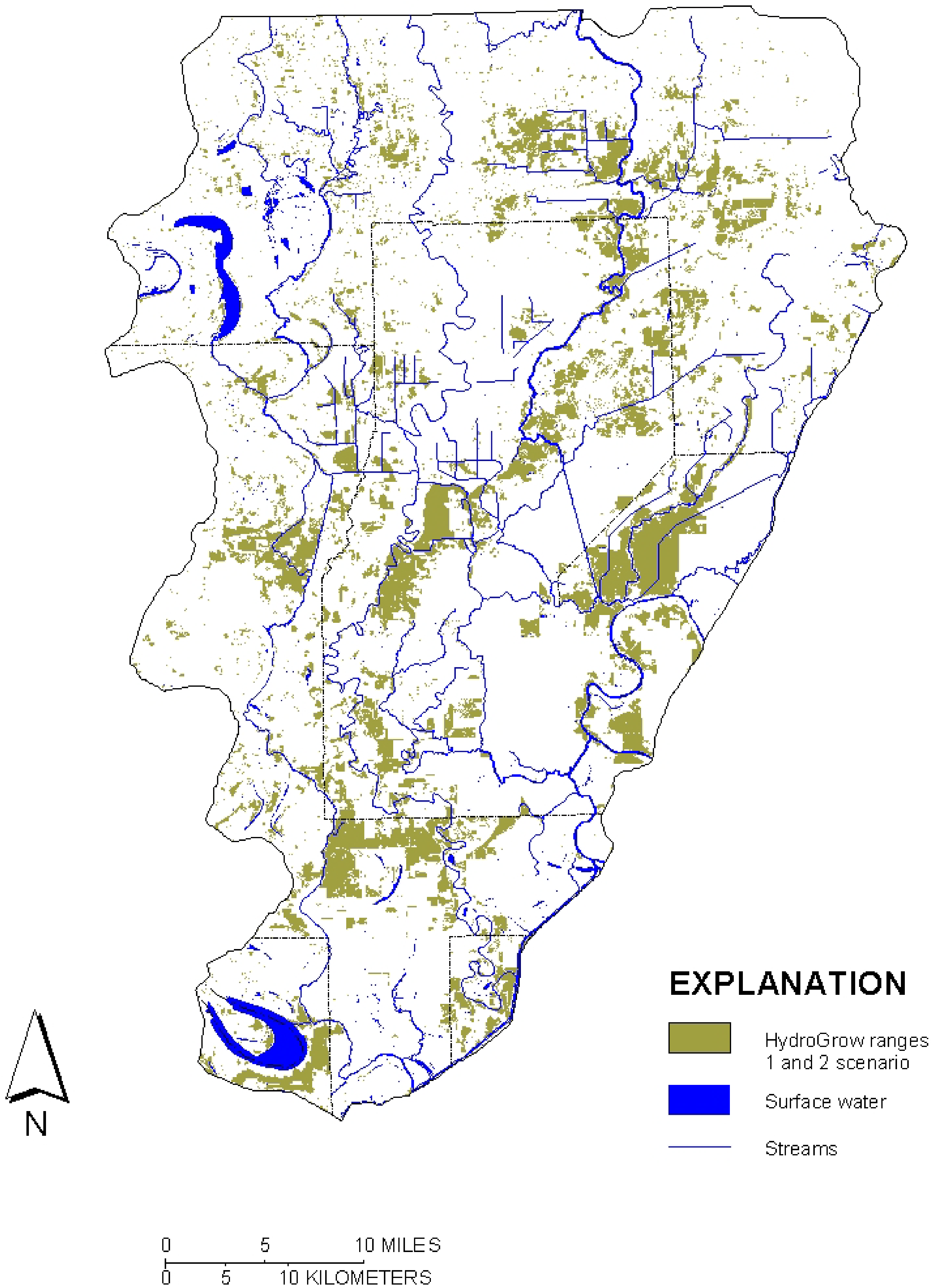

Figure 20. Areas recommended for restoration by using the HydroGrow ranges 1 and 2 scenario.

SUMMARY AND CONCLUSIONS

The decision support system (DSS) presented in this report provides a new approach to the process of identifying, prioritizing, and selecting sites (or scenarios) for forested wetland restoration. The data compiled and the tools used in this DSS facilitated the generation and consideration of restoration scenarios. The DSS can be used to ensure that reforested tree species have a high likelihood of survival. The DSS simulates reforestation by selecting areas for the highest ecologic benefit and then reforesting selected tree species that maximize either the ecologic or economic benefits. The DSS can be used to provide input data for economic models so that the consequences of reforestation can be determined.

Wetland restoration has been and will continue to be a process that requires substantial fieldwork and the on-site presence of experienced ecologists, biologists, and wetland hydrologists. This DSS does not replace the need for on-site restoration work. Rather, the system makes possible the prioritization and selection of sites using advanced tools, data, and modeling methods. The results produced by this DSS will provide a substantial benefit to those tasked with planning and managing large-scale forested wetland restoration activities over broad regions.

The benefits provided by using this tool can be increased through the use of improved data. The DSS easily supports the substitution of new data and improvements and/or modifications in the included applications. Most of the spatial data layers used in this DSS are dated. Although many of the spatial data used and included in the data list were provided without full metadata and without exact provenance, this DSS was serves as a modular, broad-based analysis tool that integrates many data sources in arriving at a result. Consequently, the effect of inaccuracy in any given data set is minimized. This manner of development ensured that the DSS can be used as a framework in which new, improved data of a specific type can replace older data of the same type, which were used in the initial DSS. Thus, this DSS can provide substantial benefits to current restoration activities, and can be updated and improved in the future to include new data that reflect new restoration objectives.

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Lance M. Cooper, Geographer, U.S. Geological Survey, Pearl, Mississippi

SCOPING MEETING ATTENDEES

Bill Ainslie, U.S. Environmental Protection Agency; Charles Baxter, U.S. Fish and Wildlife Service; Walter Belokon, Mississippi Automated Resource Information Service; Cindy Brown, The Nature Conservancy; Wade Bryant, U.S. Geological Survey; Shawn Clark, Mississippi Department of Environmental Quality; Jennifer Derby, U.S. Environmental Protection Agency; Ed Hackett, Natural Resources Conservation Service; Dave Johnson, U.S. Army Corps of Engineers; Delaney Johnson, Natural Resources Conservation Service; Chuck Klimas, Klimas and Associates; Larry Marcy, U.S. Fish and Wildlife Service; Gene Meier, U.S. Environmental Protection Agency; Richard Minnis, Mississippi Geographic Analysis Program; Allan Muellen, U.S. Fish and Wildlife Service; Dean Pennington, Yazoo Mississippi Delta Joint Water Management District; Karrie Pennington, Natural Resources Conservation Service; Richard Rebich, U.S. Geological Survey; Steve Reed, U.S. Army Corp of Engineers; Larry Rogers, Farm Service Agency; Logan Russell, Delta Land Trust; Dan Smith, U.S. Army Engineers Waterways Experiment Station; Mark Stiles, Yazoo Mississippi Delta Joint Water Management District; Mark Swan, The Nature Conservancy; Dan Twedt, U.S. Geological Survey; James Wanamaker, Mississippi Levee Board; Ramona Warren, Natural Resources Conservation Service; Wayne Watts, Mississippi Department of Wildlife, Fisheries and Parks; Mark Yarborough, The Nature Conservancy; Gary Young, U.S. Army Corps of Engineers