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

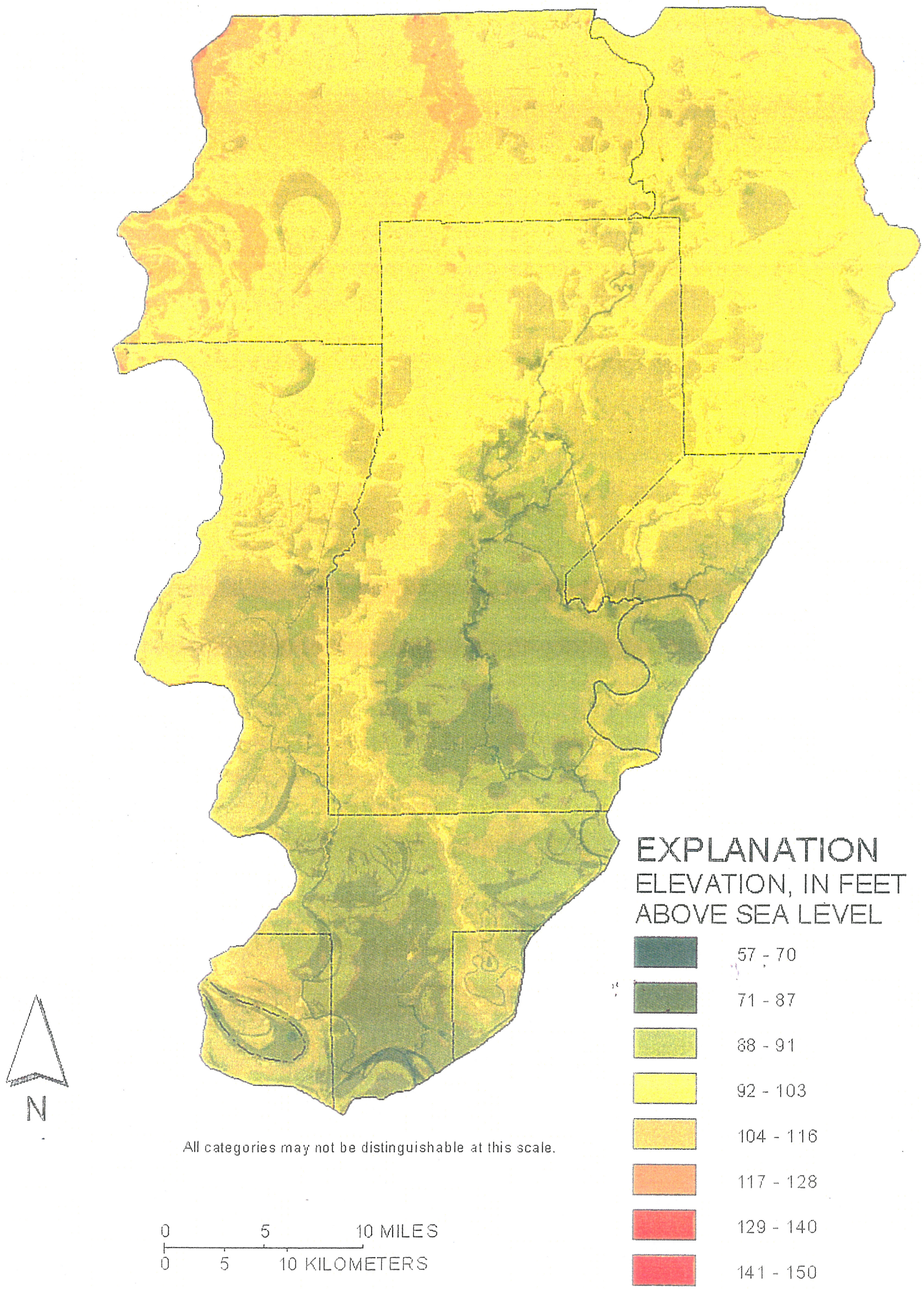

Figure 8. Elevations in the Yazoo Backwater Area, Mississippi.

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).

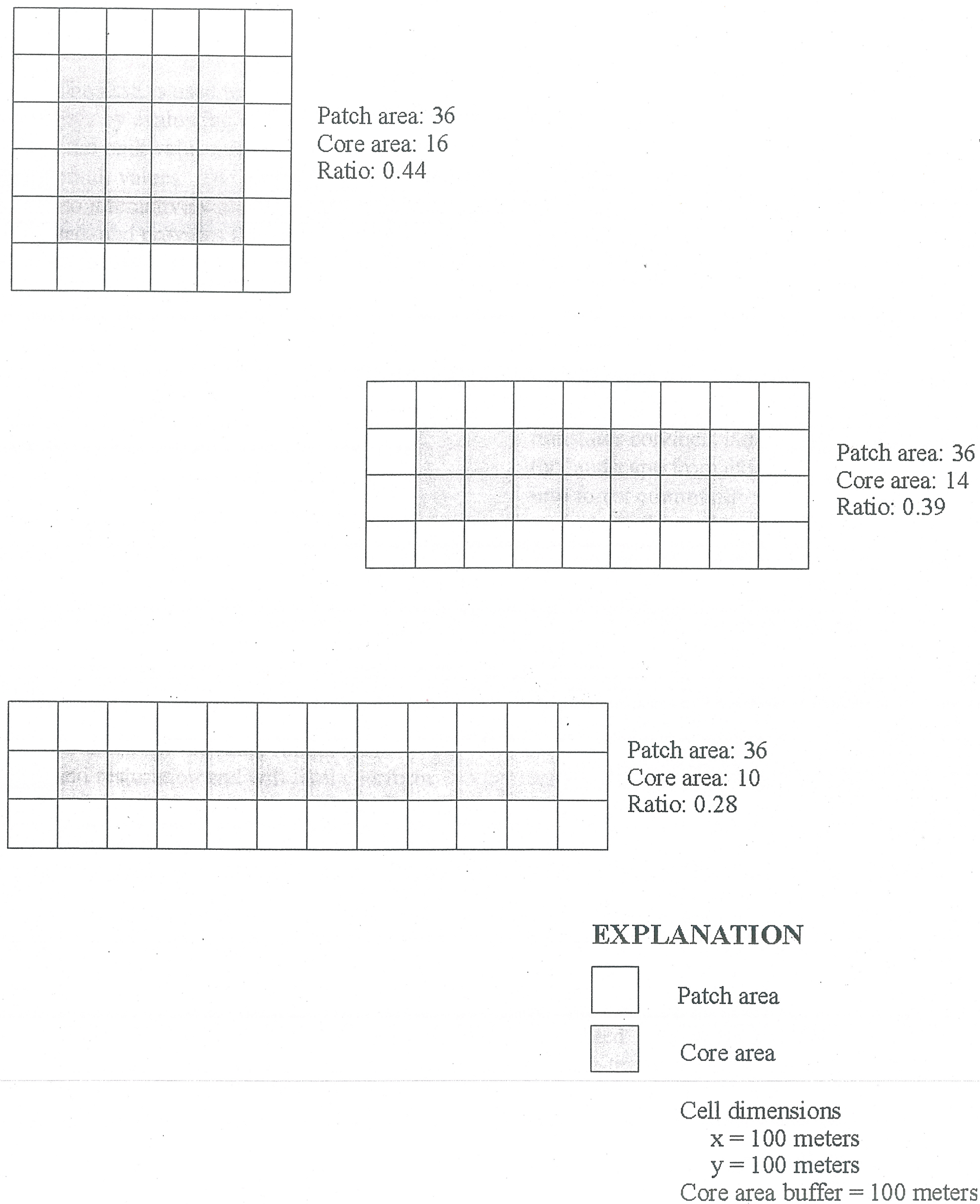

Figure 9. Example habitat patches showing total patch area, core area, and core area ratio for the Yazoo Backwater Area, Mississippi.

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

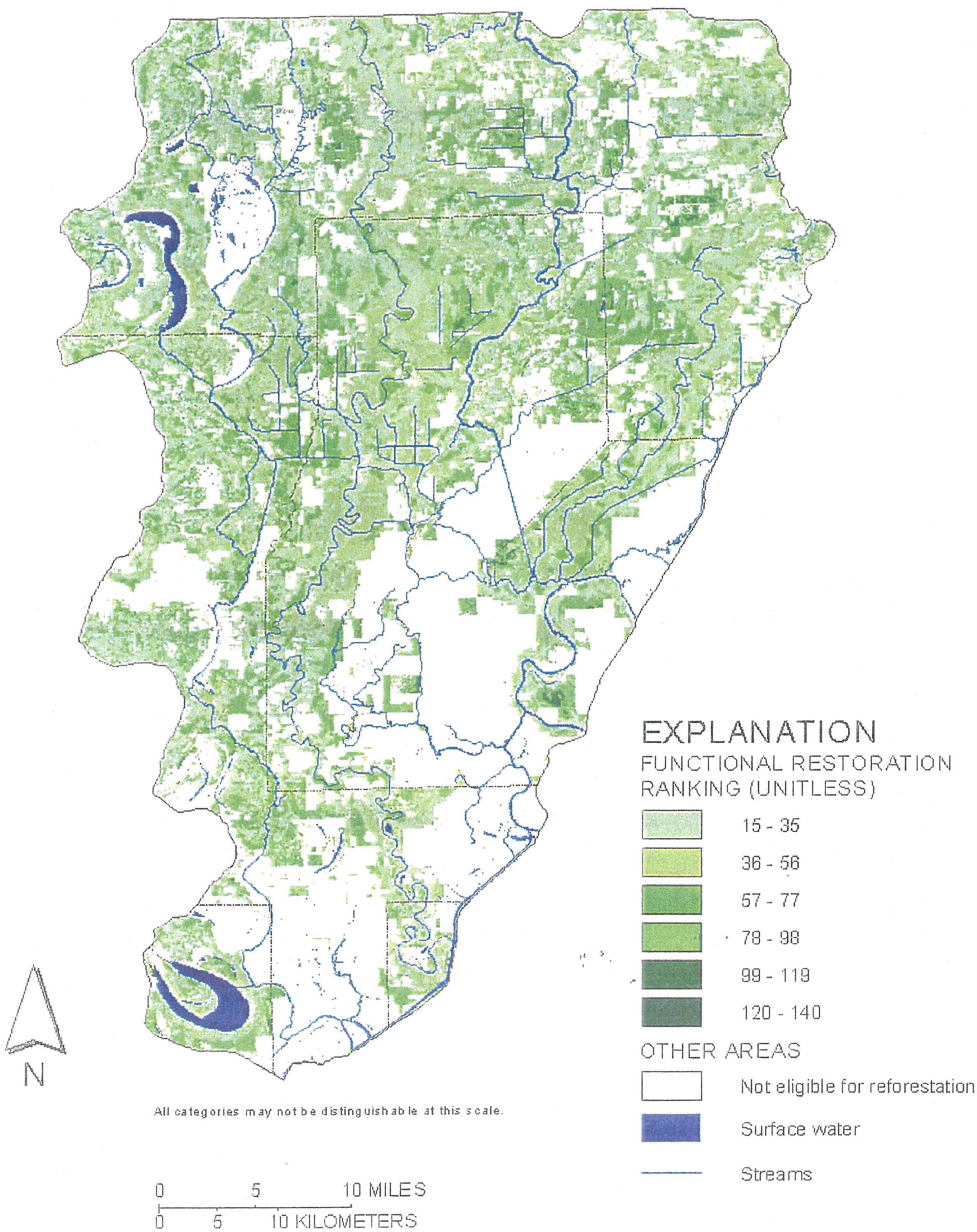

Figure 10. Functional restoration score for eligible areas within the Yazoo Backwater Area, Mississippi.

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