Floodplain Connectivity Restoration Opportunities and Suitability Modeling Utilizing GIS Technology

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Abstract

Historically wetlands have been converted to agricultural production because of their native fertility and ability to hold moisture. Diverse opinions are increasingly expressed with regards to wetland policy, whether it is protection, development, or resource extraction. Also of interest is the reclamation of agricultural converted wetlands to meet wetland mitigation needs. An example of such an area is the Lower Zumbro River watershed. Originally the Zumbro River delta was connected to the Zumbro River and used by the Mississippi River for flood conveyance. In 1974, the Zumbro River stretch below Kellogg, Minnesota was straightened and levees were constructed. The historical floodplain was changed and floodwater was forced eastward into the Mississippi River. These areas to the north and south of the levees are largely used today for agricultural production.

In this study Geographic Information Systems (GIS) analysis was used to assess the potential for restoration through reconnection of floodwater to the Zumbro River floodplain. The Minnesota Department of Natural Resources (MNDNR) concludes that the levees shunt the flow of the Zumbro River into the Mississippi River and eliminate natural flooding phenomenon. It is understood that while reconnection of floodwater to the floodplain would benefit the river environment it would also reduce the agricultural productivity of the land. The most suitable areas based on spatial relationships would be identified should the decision be made to proceed with restoration efforts in the Zumbro River floodplain. This study uses the Spatial Analyst extension of Arcview 3.0a GIS and attempts to examine these issues and outline general alternative strategies for wetland restoration.

To complete the study, spatial coverages were assembled (location of levees, land classification, and proximity to existing Management Areas), and floodplain suitability modeling was performed. A suitability model was created to determine if these data could be used to identify and prioritize opportunities for floodplain restoration. After devising a classification scheme, suitability values were assigned, and sub-sections of the study areas were defined. In the last step, these suitability findings were compared with agricultural and wetland landuse/land cover areas. The resulting coverage revealed the regions to the south and southeast as best suited for land conservation programs or as potential sites for wetland mitigation.

Introduction

Utilizing Geographic Information Systems (GIS) in wetland management and mitigation procedures is critical, as it helps facilitate regulated developments. Natural resource managers rely on the technologies available to solve the problems created by an expanding urban ecosystem. The applications of a GIS have become intertwined into the management of wetlands for the purposes of site mitigation, modeling of potential problems, and tracking the destruction and conversion processes in these wetland areas. As long as development continues in the floodplain and wetlands are filled, problems will continue to arise. The capabilities of GIS are often used to predict and assist in solving the problems created by the additional stress applied to the wetlands by land development.

Identification of wetlands is essential and there are many factors affecting the classification of a wetland. The classification system is paramount in identification of wetland areas for regulation and maintenance of these sensitive areas. The characteristics for wetland classification are type of plant species, hydrologic qualities, and soils classification. Since it is spatially possible to identify, classify and protect wetlands, GIS has become a leading tool for wetland managers. GIS provides an immense advantage as the technological age progresses, by utilizing the wide variety of applications offered to resource managers.

Wetlands are an important part of the environment as they are key to many cleansing functions. Wetlands provide areas that exhibit large regions of biodiversity, provide fish and wildlife habitat, act as sinks and filters for pollution, and are essential to the health of the environment. Wetlands are utilized for recreation, hunting, fishing, aesthetic, economic, and educational values. The nine-foot navigation channel of the Upper Mississippi River has changed the physical characteristics and floodplain dynamics affecting all the biological systems and their functions associated with the floodplain ecosystem. The loss of normal floodplain connectivity, seasonal water level fluctuation, and “natural” river processes has eliminated many of the wetland areas in the Upper Mississippi River (MNDNR, 1998).

Management of these converted wetland areas has become increasingly important as wetlands are being filled in and destroyed at an alarming rate. The benefits to agriculture are that the wetlands provide rich moist soils that have the ability to grow cash crops with minimal fertilizer application. As agriculture exploits these areas, the ability of the soil to regenerate and maintain wetland characteristics degrades. Returning wetlands to their historical use has recently become a great concern for those involved in land management. The United States Department of Agriculture (USDA) has created several wetland conservation programs to contend with these issues (Despain, 1995). The chosen study area is in a historic floodway and has been converted to agricultural land. Furthermore, secondary rivers, such as the Zumbro River, have become a concern since the flood of 1993 on the Mississippi River. The Mississippi River ecosystem stability relies on the ability of tributary rivers to hold excess floodwaters, reducing flood peaks downstream, as well as allowing for channel scouring and deposition of sediment along the natural river deltas (MNDNR, 1998).

Data used for spatial analysis included data obtained from the Minnesota Department of Natural Resources (DNR), Environmental Protection Agency (EPA), Scientific Assessment and Strategy Team (SAST), National Wetlands Inventory (NWI) and Environmental Management Technical Center (EMTC-USGS) web site. These coverages included landuse/land cover, levees, floodplains, 1993 flood extent, transportation features, USGS Digital Ortho Quarter Quads (DOQQ), and management areas. The availability of soil data would have been beneficial, but was not available for this analysis

The GIS provides the necessary vehicle for analysis and information forecasting while being applied to the project area. Modeling with GIS provides visual representations of the environmental characteristics and land ownership. Developing a suitability model requires all the variables impacting the factual, visual, and potential opportunities for returning connectivity to the floodplain be included. The goal of a suitability model is to forecast and identify spatially viable areas for consideration in management actions. Using the GIS allows the manager to determine features on the land to be merged and connected for quick display and manipulation. Therefore, a suitability model would help put areas of interest in a clear order of priority. The model can then be used to display the existing feature inventory and show the changing land features, landuse, and goals for future reference.

Study Area

The history of the lower Zumbro River delta shows dynamic changes over the last century. During high water periods in pre-settlement times, Mississippi River flood waters entered the delta to the north and flowed to the south through the Zumbro River floodplain, continued on through the Weaver Bottoms then back into the main channel. The lower Zumbro River delta was drained by landowners in the 1950's by the use of levees. These failed in 1965 with the occurrence of a 200-year flood event. The Mississippi River floodwaters again flowed through the Zumbro River floodplain as the levees were overtopped. For a very long time, floodwater flows from the Mississippi River through the lower Zumbro River floodplain have accounted for a small percentage of the total Mississippi River flood discharge. In 1974 a flood control project was started and levees were erected to straighten the river directing floodwater to the Mississippi River to the east through the sand prairie area (Johnson, 1996). The connection to the delta region of the old Zumbro River was lost and all the sedimentation occurs in the Mississippi River, south of Lock and Dam number 4.

The location of the study area is in the lower regions of Pool 4 and upper regions of Pool 5. Pool 4 starts above Lock and Dam 4 near Kellogg, MN in Wabasha County (Figure 1). The outline

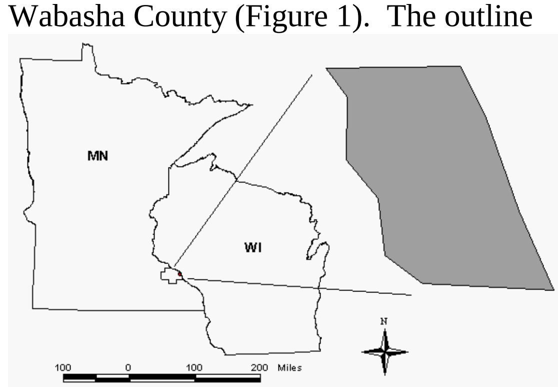


Figure 1. Location of Study Area

of the study area follows the Minnesota

side of the Mississippi River Valley from Teepeota Point to the Weaver Bottoms. The Mississippi River flows around the study area from the north, along the eastern edge, and curves back to form the southern boundary. The study area is bounded on the western edge by US Highway 61. Public owned lands bound the study area on three edges. The State of Minnesota Wildlife Management areas lie to the north and south. The United States Fish and Wildlife Service Upper Mississippi Fish and Wildlife Refuge is on the eastern edge. The total acreage of the study area is 980 acres. Furthermore, the Zumbro River splits the study area into a north and south section. The levee straightened river is observed as the river is forced to drain to the east (Figure 2).

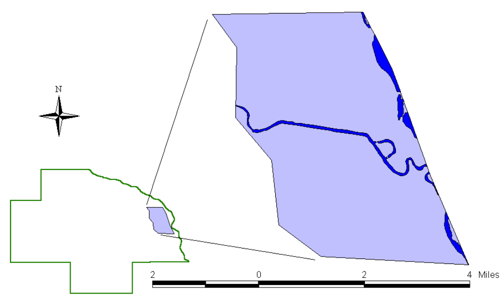


Figure 2. Zumbro River Delta

Methods

A GIS was used in the spatial coverage generation and analyses. Floodplain data existed from the Long Term Resource Monitoring Program (LTRMP) as well as the current classifications for the land features. Analysis of these data included a determination of spatial relationships between land structures, wetland features, political boundaries, and the analysis of land classification for areas of high suitability for restoration. Additional inquiries were made to determine the amount of change in agricultural and wetlands classifications that occurred over the past century as well as determination of suitability of wetland and agricultural classified land.

Data Collection

Data themes were obtained from the Minnesota Department of Natural Resources (MNDNR) and the Environmental Management and Technical Center (EMTC-USGS) web site. Additional data came from the Scientific Assessment and Strategy Team (SAST), Environmental Protection Agency (EPA), Minnesota Department of Transportation (MNDOT), United States Geologic Survey (USGS), and the National Wetlands Inventory (NWI-USFWS). These sources provided a comprehensive collection of spatial data relating to floodplains, wetland, and land-use issues.

Most coverages were obtained in ArcView 3.0a format while some were converted from Arc/Info and exported to a compatible format with ArcView. All themes were projected in the Universal Transverse Mercator (UTM) in Zone 15, North American Datum 1983 (NAD83).

Creation of Coverages

The SAST data were used to determine the Mississippi River floodplain extent. These data also contained the levees coverages, but did not include the levees contained within the study area. These coverages were downloaded from the SAST homepage and converted to shapefile format by utilizing the Spatial Data Transfer Standard (SDTS) and an AML to convert these files in Arc/Info format. After converting the files into an Arc/Info format the coverages were in Albers Conic projection and needed to be projected to UTM's. Arc/Info was used to project the coverages, as well as to define the coverages as North American Datum 1927 (NAD27). Further conversion from NAD27 to NAD83 was completed and these coverages were in the same spatial configuration as the other coverages. After using the *build* command in Arc/Info, the SAST coverages were exported from Arc/Info to a file format able to be converted for use in ArcView. All coverages were clipped to the extent of the study area using the Xtools extension of ArcView.

A levees coverage for the Zumbro River was needed and was not available. As a result, the Zumbro River levees were identified on Digital Ortho Quarter Quads (DOQQ). DOQQ's are black and white raster images developed from aerial photographs with a one meter resolution. From heads-up digitizing using the DOQQ as a background a levees coverage was created.

Creation of Suitability Values

The first features of consideration were the historical land classification and the historical Zumbro River channel. Personal discretion in assignment of values was used and may be changed to meet the needs of other users. These features were classified on a scale of one to ten with assignment by landuse classification. The location of the old Zumbro River channel was given a value of ten and each 100 feet from the channel the value was decreased by one. The rationale was that seasonal flooding would choose the old river channel first for holding floodwaters as being the path of least resistance. The historical land-use was also chosen and classified for suitability by land classification. (Table 1.)

Table 1. Summary of historical land-use assigned values

Land_Cover 1890	Value
Open Water	10
Emergents	8
Sand/Mud	8
Woody Terrestrial	6
Agriculture	6
Grasses/Forbes	4
Urban/Developed	2
No Coverage	0

These values were arbitrarily chosen based on the assumption that the features exhibiting wetland characteristics would be given the highest values.

The second most important features, as understood with conversations with Minnesota Department of Natural Resources Mississippi River Hydrologist Scot Johnson, were the current stream and regulated wetland locations. The USGS Digital Line Graph (DLG) streams coverage contained both perennial and intermittent streams. In a GIS, streams are linear features and therefore have no spatial width. A ten-foot buffer from the streams was created to allow for an actual stream width. These buffered stream features were given a value of ten. Additional gradients of values of nine to one were assigned on 100-foot intervals from the buffered streams.

The regulations concerning the management of shoreland, floodplains, and wild and scenic rivers were consulted to understand how the wetland features were to be classified. The lower Zumbro River delta has the classification of a transition river, or a mixture of cultivated, pasture, and forested lands. The regulatory distance concerned with management of shoreland of a transition river is 300 feet. There are no regulations concerning the required distance for development from a wetland. A comparison was made to the required distance from the ordinary high water level in a wild area. The distance in a wild area is 300 feet, which was the distance chosen for calculation (MNDNR-Waters, 1998). The proximity to the regulated National Wetland Inventory (NWI) features was the key to understanding the overall suitability. The regulated areas were given the designated value of ten and a gradient of minus one each 100-foot buffer distance from the wetland.

Next the proximity to the levees and the Zumbro River was assessed. The levee structures would be of concern, as return of flow to the designated areas would occur through management of the levees. These structures were buffered in 100-foot intervals and the assigned proximity values for the levees on a gradient from the levees.

Finally, the public owned land of the wildlife management areas to the north and south was assigned suitability values. These lands are already regulated and managed for the priorities of the MNDNR. Considerations of proximity to these public lands allow for greater connectivity through out the extent of the study area. The public lands were again buffered in the same manner as the other features, using 100-foot intervals based on a scale of one to ten.

Suitability Modeling

Values used to create a suitability model were generated from various sources based upon the relationships that the individual coverages possess. Commonly used models contain a combination of empirical and process based components. Empirical based relationships allow for single relationships between two features while process based modeling relates these features on a more finely tuned temporal or spatial scale. A combination of these models is useful for developing a broad relationship at the field or watershed scale (Poiani, 1995). Specifically, the scope of the project lies in the spatial relationships of static functions such as landuse activities that can be categorized using a common set of parameters. These parameters include magnitude, frequency, areal extent, spatial distribution, and predictability that can be applied both to alternative activities and different levels of the same activity (Oak Ridge National Laboratory, 1998). The goal of the model was to create three levels of suitability (low, moderate, and high suitability) based on the spatial relationship of the features chosen for determination in the study area.

The first phase of modeling included the creation of buffer regions around the specified features. The buffer function in the Xtools extension of Arcview was used to delineate feature distances for creation of the coverages used for the assigning of suitability values. These buffer coverages were spatially joined to a single coverage with the *merge* function and attributed according to the classification of the suitability values.

The analysis process was accomplished using the Spatial Analyst extension of Arcview. For effective GIS modeling these coverages needed to be converted to grids with cells of 25 feet. The unattributed grid cells in the study areas were created without data. The classification of “no data” in the extent of the grids was calculated to zero using the *isnull* command in the Spatial Calculator of the Spatial Analyst extension. Upon assignment of a numeric value for each cell in the study area these coverages were merged using an additive function. The resulting coverage of all the cells in the study area was equivalent to the summary of all the coverages.

The product was a coverage containing values from all the previously classified values for each buffered feature. The coverage was divided by eight, for the number of spatial features considered in the model. The division allowed for the original scale of one to ten to be maintained. For the suitability model, the coverage was again divided by three and classified as low, moderate, or high-suitability for visual purposes. The acreage of each could be calculated and general spatial trends of suitability can be observed for the study area.

The second phase showed the classification of agriculture and wetlands in these regions. The second phase shows the acreage of each classification in the suitability coverage. This was accomplished by isolating the agricultural and wetlands landuse/land-cover data. These themes were combined with the suitability model to provide landuse themes that were classified as low, moderate, and high suitability of wetland and agriculture classifications. The NWI classification system allows for a system to be inherent in the delineation of the wetland classification. In Minnesota, the regulated classifications are types 3, 4, and 5 under the protected waters program. Wetland type 3 is shallow marsh, type 4 is deep marsh, and type 5 is shallow open water. These wetland types as well as grasslands in the riparian corridor were included in the analysis. Upon viewing color Infrared aerial photographs of the study area taken in 1993, there was evidence of a clear delineation between the riparian corridors and agriculture, but the grassland and wetland were difficult to delineate.

A comparison of the historical landuse/land cover classified as agricultural with the current landuse classifications was made to understand the change in appearance of the landscape. The historical change in agriculture from pre-impoundment land-use to current coverage is useful for determination of the lands that were drained or filled for agricultural purposes. The extent of the historical coverage was erased from the current data set using the Xtools extension in Arcview.

Results

Data limitations

Most of the coverages originated from projection Universal Transverse Mercater, Zone 15 Datum NAD 27 and were presented at various scales. It is important to note that the data were converted from other projections and coordinate systems. The coverages were also converted from vector files to grids with 25-foot cells for analysis. The accuracy was compromised because cells have area, as they are interpolations of linear features with no area.

The SAST coverages were created from aerial photographs taken at scale of 1:10,000 feet during the peak flood on June 23, 1993. It has been assumed that these photographs missed the peak flood in the study area. It is known that the extent of the flood was much greater than these coverages portray and the peak of the flood for Minnesota was earlier than the flooding lower on the Mississippi. The SAST headquarters is in Missouri and the flight dates may have been set on the peak flood for the area closer to their location.

The LTRMP data were originally in a different land classification system than the current 1990 data used. These data originated from hand drawn maps and were generalized during digitizing.

The coverages in this project are a simplistic pilot for understanding the significance of the spatial relationship of land features. It is important to observe the interpolated coverage as a general model for determining siting priorities.

Spatial Analysis

The analysis consisted of developing coverages, from the previously described features. The first step was to use the Spatial Analyst extension and create a composite grid of all the data sets with the buffered and ranked attributes. The suitability model was divided into 25-foot cells; these patches of cells were in a wide variety of sizes from one cell to greater than ten acres of cells. A consistent cell size was maintained for all the grids created using the spatial analyst extension. The conversion also maintained the spatial extent of the study area during vector to raster conversion. The resulting data set was a grid encompassing the entire study area that gave a ranking attribute to each cell in the study area. These numbers ranged from zero to sixty-eight and needed to be generalized. The generalization function was a reclassification of the composite grid, which divided the ranking attributes by eight, for the number of spatial features present. The suitability model was for low, moderate, and high-suitability classifications, and the composite grid was divided by three to complete the requirements of modeling suitability (Figure 3). Finally, The

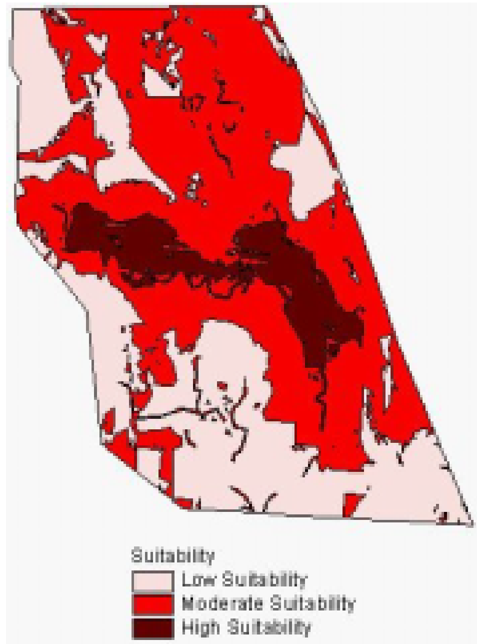


Figure 3. Suitability model

acreage for the three classifications was calculated (Table 2).

Table 2. Acreage for suitability model

Suitability Index	Acres
Low Suitability	368.4
Moderate Suitability	518.8
High Suitability	92.9
Total	980.1

The suitability model, with the values of one to ten, needed to be merged to the agricultural land classification. The Xtools extension of Arcview was used to complete the merging function between these coverages. The created suitability classification model contained the land patches used as agriculture as well as a suitability classification for each polygon while maintaining the extent of agriculture (Figure 4). The suitable agriculture coverage contained in the study area was separated into three

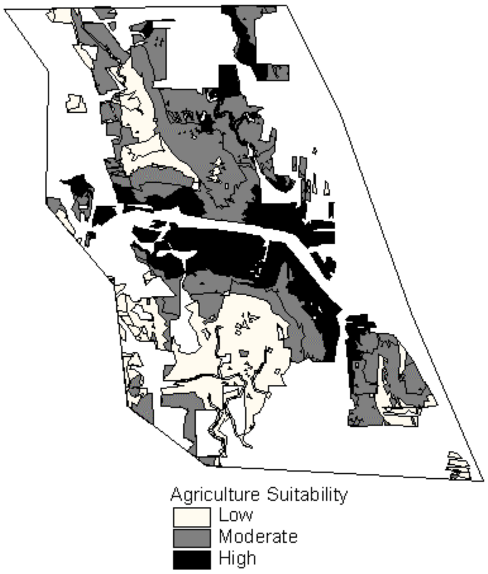


Figure 4. Agricultural suitability index

classifications of suitability (Table 3).

Table 3. Acreage for agricultural suitability

Suitability Index	Acres
Low Suitability	135.8
Moderate Suitability	219.3
High Suitability	110.7
Total	465.8

The combination of wetlands coverage and suitability values was completed the same as the agriculture

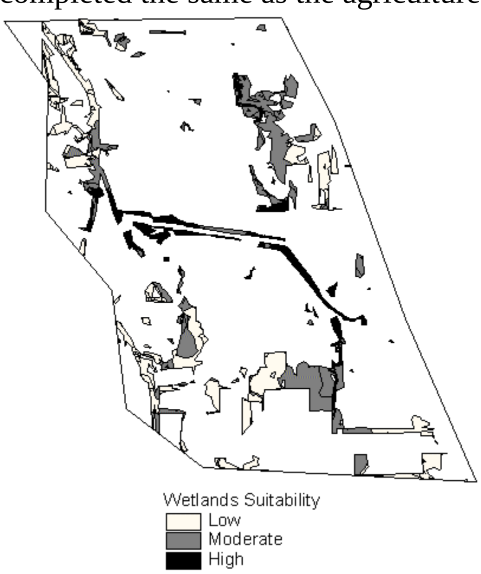


Figure 5. Wetland suitability index

(Figure 5). In the wetland classification, the open water and grassland areas encompassing the wetlands were also included in the classification for the wetland suitability index (Table 4).

Table 4. Acreage for wetland suitability index

Suitability Index	Acres
Low Suitability	64.0
Moderate Suitability	62.6
High Suitability	21.7
Total	148.3

The change in converted agriculture was observed to determine the change that occurred in the historical land cover. Two large areas were not explored in the 1890's land cover survey. These were located to the north and south of the current levees. These areas are believed to be wetlands that were too difficult to survey at that time (Johnson, 1999). When the 1890's data and the 1994 data are compared, minus the areas of 'no coverage' in the 1890's data we find twice as much agriculture today (Table 5).

Comparing the 1994 land cover with the 1890's data shows that today has almost four times the amount of agricultural land as was present in 1890 (Table 5). This additional land was made available for agriculture by drainage in the area and the erection of levees along the Zumbro River.

Table 5. Converted agricultural acreage

Land_Classification	Acres
1890's Agriculture	116.6
1990 minus "No Coverage"	235.5
Total Current Acreage	437.9

To further understand the suitability frequency, the number of patches with each suitability value was calculated. A graphical analysis of the number of polygons by suitability rating shows a normal distribution. The general trend shows the suitability value and the numbers of patches to be in the moderately suitable region. The general curvature provides an understanding as to the majority of the patches located in the moderate suitability range for wetlands (Figure 6) and agriculture (Figure 7).

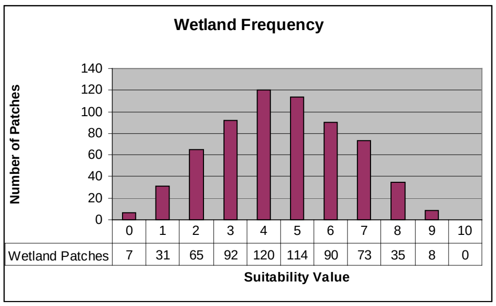


Figure 6. Number of patches by wetland suitability index.

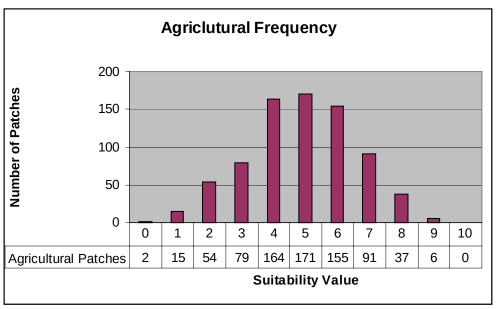


Figure 7. Number of patches by agricultural suitability index.

The relationships developed from the coverage created by merging suitability information with landuse classification is useful for identification of patch size and frequency of suitable areas.

Sub-areas were created to help locate the areas most suitable for restoration. The study area was broken into six sub-areas of roughly equal size using the river channel as a guide for separating north and south (Figure 8). The patch size and suitability indexes for the agricultural and wetland coverages were observed for the highest suitability

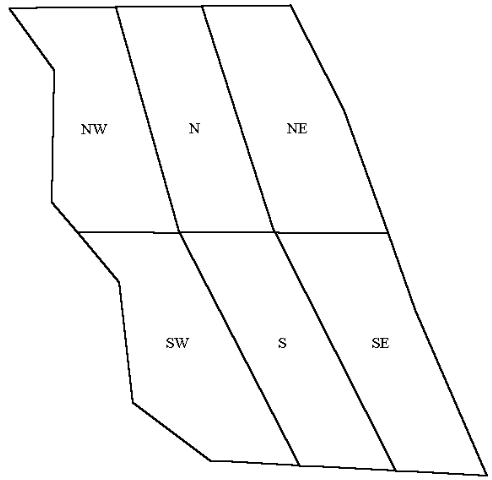


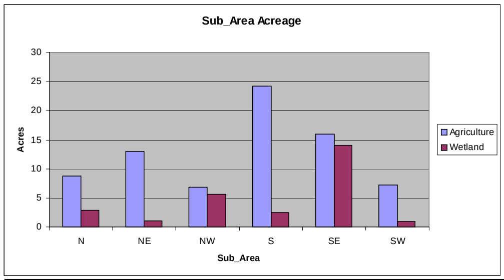
Figure 8. Plot Sections for Study Area

and patch size characteristics. The results of these comparison forms a rough understanding of which sub-areas would have the best potential for restoration. These best characteristics would have large areas with a high suitability index.

A value of seven was chosen for a level of high suitability. From the suitability model values greater than seven were selected. Polygons with areas greater than the median patch size were then merged with these highly suitable areas. The resulting coverage was again merged with the agricultural and wetlands classifications.

The observed data were again overlain on the sub-areas coverage and the polygons were separated into the six sub-areas (Figure 9). The sub-area with the largest area of suitable classification was in the southeastern corner of the study area. The southeastern sub-area had the most total acreage for the wetlands and agricultural landuse classifications while the southern sub-area had the most acreage of the highly suitable agricultural lands.

The lands containing the highest average patch size maintain higher connectivity values for potential



	N	NE	NW	S	SE	SW
Agriculture	**8.72**	**12.95**	**6.82**	**24.26**	**15.94**	**7.21**
Wetland	**2.83**	**1.04**	**5.66**	**2.49**	**14.04**	**0.89**
Total Acreage	**11.55**	**13.99**	**12.48**	**26.75**	**29.98**	**8.1**

Figure 9. Sub-areas containing the highest acreage of selected characteristics.

restoration. The sub-area with the highest average patch size for highly suitable land that is above the median patch size was in the southern sub-area. The southeastern sub-area also had a similarly large agricultural patch size. This shows the areas for greatest suitability with patch size to be in the southern and southeastern sub-areas (Table 6).

Table 6. Average patch size in acres by sub-area

	NW	N	NE	SW	S	SE
Wetland	0.22	0.12	0.24	0.22	0.47	0.18
Agriculture	0.53	0.71	0.29	0.65	0.96	0.7

Discussion

The use of these data were not perceived to be used for specific analysis, but more to provide a general understanding of the sites to be considered for potential restoration. With the limited amount of time, money, personnel, and information the process of determining potential sites for restoration proved to be a difficult task. As a result, there is potential for a GIS to have a significant impact on the site selection process. These sites can prove to have a greater impact on the environment if the flood control project were decommissioned and flow was reintroduced into the distributory channels of the Zumbro River (MNDNR, 1998). Other data would help to increase the understanding and accuracy that a model could summarize. Topographical and hydraulic information would also increase the overall integrity of the suitability factors.

The data developed show the trends for returning connectivity through restoration efforts rely on what the managing forces deem as the determining factors for selection. The southeast and south portions of the study area best fit the qualifications for increasing the potential for wetland restoration or agricultural conversion. These two areas had the highest amount of acreage available for restoration (Figure 9). All of the values were created using personal and subjective options that could be processed in an alternative fashion to produce different results. The values would change through additional selection or by applying different weighted values to the data layers.

A wetland or agricultural suitability model can be used to assess the loss/alteration of habitat and the resulting impact on biodiversity. The landscape perspective views the spatial aspects of a region in which a site occurs including the ecological, socioeconomic, and political pressures for changes. The suitability model helps to explain and predict some of the changes that consider the spatial relations and implications arising from land use changes. The loss of habitat from these changes can cause ill effects through edge effects and habitat fragmentation for species and ecological systems. The lower Zumbro River Delta has the historical characteristics for sustaining important habitats of a wide variety of species. Currently, the implications from this study are promising as the potential exists for major changes through acquisition from willing sellers or reallocation of resources in the study area.

Modeling the characteristics of land use patterns and ecosystem disruption resulting from land use activities was the intention of Oak Ridge National Laboratory studies. The research group has conducted similar studies for preliminary identification of suitable habitat for several species of birds and created a natural resource-susceptibility model. These studies found that the habitat models created through a GIS could predict with up to a 93% confidence level of existing suitable habitat with the available data.

The next logical step for determining the succession of the land identified through suitability modeling in the lower Zumbro River Delta would be a plan for reversion to their natural states. There are programs available to farmers through the United States Department of Agriculture (USDA) that provide monies for farmers using their best management practices for protection of wetlands. If the present flood control project were not decommissioned these agricultural lands would retain their current land classification. These wetlands depend on the spring floodwaters and delineation of wetlands depends on these waters for determination of regulation (Snyder, 1995). Farmers may retain ownership and receive contract payment for incentive to move farming operations from frequently flooded lands. Currently there are lands within one mile The Minnesota Department of Natural Resources provided the idea and funding for this project. Special thanks go to of the study area enrolled in the USDA Conservation Reserve Program and other programs like the Flood Risk Reduction Program and the Wetlands Reserve Program may also be available to landowners of the Zumbro River Delta.

The potential for the use of GIS in wetland suitability modeling and identification in agricultural regions has proven that spatial data can provide valuable insights. With the addition of more accurate and detailed data individual reaches of farmed wetlands can be identified with less field reconnaissance. Managing staff would have detailed information about study areas for basing priorities and delegating funds. The preliminary investigation of these sites through GIS has shown the ability to pilot creative studies with detailed research in field assessment techniques.

Crucial to understanding the model's results is the difference between suitability and predictive ability. It should be clearly emphasized that the results depict areas better suited for future consideration. These images do not necessarily show areas most likely to acquire. Local factors, among them, taxes, land availability, community attitudes toward re-development, would likely assert a significant influence on which lands would be chosen. In turn those lands may or may not coincide with those identified in the model's results. The results really show, from a theoretical perspective, areas of future consideration for reversion to historical land use in an ideal world.

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