Chapter 1

Multi-Scale GIS Data-Driven Method for Early Assessment of Wetlands Impacted by Transportation Corridors

Rodrigo Nobrega, Colin Brooks, Charles O'Hara and Bethany Stich

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/50349

1. Introduction

The correlation between transportation systems and adverse impacts on the natural environment have been investigated at different scales of observation (Kuitunen et al., 1998; Bouman et al., 1999; Corrales et al., 2000; Formann et al., 2003, Wheeler et al., 2005, Fletcher and Hutto, 2008). There is a growing body of literature reporting and quantifying the effects caused by transportation infrastructure on the proximate biophysical setting as shown in (Keller & Largiardèr, 2003) as well as on the socio-economic setting as shown in (Boarnet & Chalermpong, 2001). The environmental consequences of landscape fragmentation in different phases of transportation project development have been investigated and tabulated by (Corrales et al., 2000). However, the disparity of definitions for the biophysical landscape can make it difficult to communicate clearly and even more difficulty to establish consistent management policies. Landscape invariably comprises an area of land containing a mosaic of patches or land elements (McGarigal & Marks, 1995; Hilty et al., 2006). The overall knowledge-base of transportation systems and methods to consider, minimize, and mitigate adverse impacts on natural systems and biophysical settings have gradually been absorbed and adopted by transportation and Environmental Impact Assessment (EIA) practitioners to design balanced engineering solutions and deliver transportation infrastructure in an environmentally responsible manner. The body of science and knowledge supporting practitioners has grown through in-depth reviews about transportation and ecological effects (Spellerberg, 1998; and Formann et al., 2003) Similarly, the knowledge base concerning the impacts of land use on travel behaviour is also being investigated and developed from the transportation perspective (Mokhtarian & Cao, 2008; Litman, 2008).

Road development is a primary mechanism responsible for habitat, ecosystem, and overall biophysical fragmentation, replacing or modifying pre-existing land cover such as wetlands,

creating edge habitat and altering landscape structure and function (Saunders et al., 2002). While conserving the remaining natural environment as well as restoring environmentally impacted areas is vital for natural sustainability, transportation corridor development is required by society and results in our modern transportation infrastructure and travel patterns.

Previous lessons learned show that environmental issues should be considered early the transportation planning process in order to balance economic, engineering and natural sustainability perspectives (Amekudzi & Meyer, 2006). A highway design that meets the transportation corridor needs, while minimizing environmental impacts, requires cooperation and compromise among different parties. It is a pressing challenge for researchers and practitioners to develop and validate novel methods for transportation planning that deliver streamlined planning approaches and improved environmental benefits beyond those possible through traditional approaches (Spellerberg, 1998; Stefanakis & Kavouras, 2002; Mongkut & Saengkhao, 2003; Huang et al., 2003; Gregory et al., 2005). The integration of transportation demand, current and long term development plans, and economic and ecological impacts in time-series scenarios by using land cover and land use analysis is a good way to provide promising results (Saunders et al. 2002; Forman & Alexander, 1998). The use of Multi-Criteria Decision Making (MCDM) as a decision-making framework for transportation infrastructure planning, which can accommodate, model, and combine varying stakeholder values and help to resolve conflicting opinions, is an area that has only been recently explored. Initial results offer significant promise to streamline the National Environmental Policy Act (NEPA) process (Nobrega et al., 2009).

MCDM can facilitate the integration of different planning scenarios as well as the combination of different approaches for environmental sustainability in transportation planning. In modern transportation projects, considerations of both landscape analyses and natural-economic sustainability are mandatory under programs such as NEPA and similar state and local-level laws (Corrales et al., 2000). In 2003, Burnett and Blaschke demonstrated that advances in informatics and geographic information tools have made it possible to segment the complex environments supported by the ecological theory into factors that may be considered in a landscape analysis approach. Current reviews about geospatial landscape analysis in ecology reflect the relatively recent trend towards the use of remote sensing through object-based image analysis (Blaschke et al., 2001; Burnett & Blaschke, 2003; Aplin, 2005). Geographic Object-Based Image Analysis (GEOBIA) employs polygons as bounding areas which delimit the landscape and enable data and image analyses that transcend traditional per-pixel approaches such as spectral-based analysis (Nobrega, 2007; Hay & Castilla, 2008). The use of object-based segments for landscape analysis enable the generation of a large number of parameters based not only on intrinsic values extracted from the polygons, but also extrinsic values computed from the geometry, texture, and context of the objects. This information can be used to form a classification decision hierarchy and provide results that may be combined with existing GIS information to offer significant and innovative results to benefit transportation planning and management and streamline the Environmental Analysis processes (Nobrega, 2007).

2. Background

2.1. Watersheds as natural biophysical landscape segments

Hydrological watersheds are natural subdivisions of the landscape and exercise influence on other natural and man-made features. Wetlands are among the most sensitive of natural features and are vital components of the habitat requiring protection from adverse impacts that may be caused by human development and infrastructure projects. Indeed, NEPA requires transportation planners to consider possible impacts on the hydrological system including stream crossings, flood plains, land cover, and wetlands as part of maintaining the ecological and biophysical balance within the local watersheds (Amekudzi & Meyer, 2006).

This research describes the use of a collaborative, interactive, and iterative multi-scale approach to assess and rank hydrologically segmented features and wetlands to deliver enhanced understanding of how these biophysical systems are affected by transportation infrastructure projects. This chapter addresses a two-level object-based landscape analysis computed from hydrological sub-watersheds from Hydrologic Unit Code 12-level (HUC-12), wetlands, and a subsegment of the proposed Interstate 269 (I-269, a proposed bypass around Memphis, Tennessee, in the southern United States of America) as major objects of interest. Firstly, parameters are extracted per watershed from percentage of wetlands, zoning, existing and current developments, and density of perennial and intermittent streams. Watersheds are ranked according the potential for risk on the natural environment, as described below. The watersheds are considered as primary objects in this hierarchical landscape analysis. After ranking these objects, the next step in the hierarchical analysis process is identifying and ranking wetlands based on potential for adverse impact. For each watershed, topographic analysis (computed from LiDAR elevation data) and computer-assisted image interpretations are performed to enhance the delineation of the wetlands. Wetlands are analyzed according their distance from planned developments, planned roads and the I-269 corridor.

It should be recognized that there are limitations inherent to geospatial data and their analysis within any research framework, and the practical implementation of innovative contributions for geospatial analysis depends upon properly designing and structuring approaches that may be implemented in a practical and feasible framework available in readily available GIS software. In this paper, a top-down GIS framework for landscape analysis is proposed using hydrological watersheds as reference objects for segmentation of the landscape. This segmentation facilitates the geographical analysis of biophysical subdivisions of the landscape based on a watershed approach to conduct contextual, geometrical, and hierarchical analysis. The overall idea is quite similar to standard approaches in object-oriented landscape analysis; however, the use of watersheds as a segmentation layer enables the analysis to consider biophysical subdivision as parts of transportation corridor planning and enables the use of output results in cumulative cost surfaces that may be employed to refine land use and corridor plans and improve agency coordination during the NEPA process.

2.2. Landscape analysis

Landscapes are shaped by the interaction of social and ecological systems (Brunckhorst, 2005). Current and future use of land, productivity and patterns of sustainability are continually modified by humans within the landscape in spatial scales across time in different magnitudes (Ono et al., 2005). For environmentally-focused transportation planning, eco-regions and hydrological watersheds are keys concepts that must be considered in landscape analysis. Understanding landscape and watershed characteristics, the geographic context of sensitive environmental resources, and the services provides by natural systems, is vital to providing balanced solutions for sustainable development amidst natural resources that face economic and social issues (Figure 1). Despite the similarity in some points of view between creating subdivisions of eco-regions and watersheds, a common misunderstanding of each of these landscape subdivision frameworks has resulted in inconsistency in their use and, ultimately, to ineffective application in addressing landscape analysis (Omernik & Bailey, 1997).

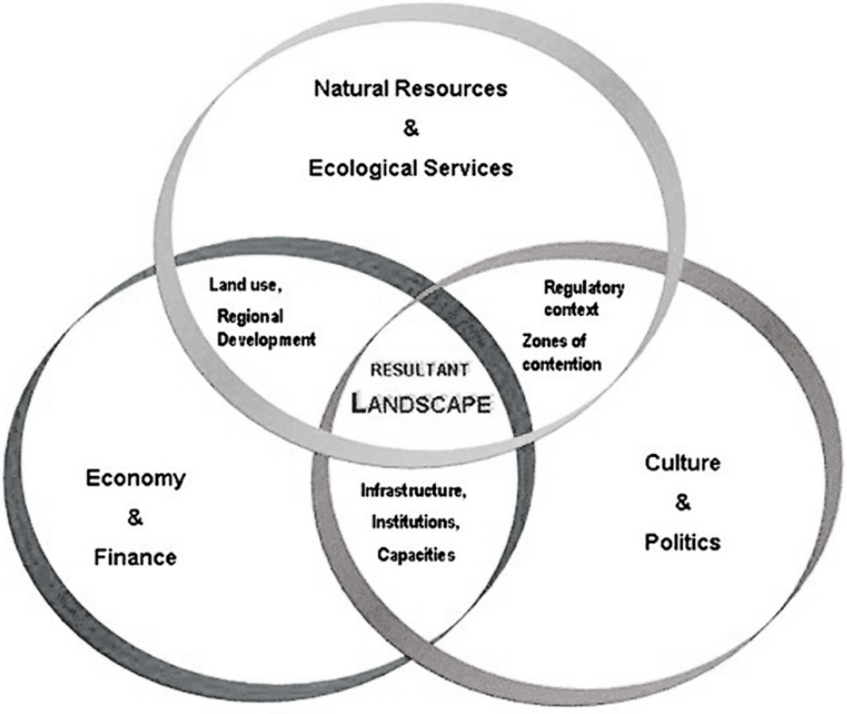

Figure 1. Complex spheres of interaction reflecting human values, identity, and activities affecting landscape change (Brunckhorst, 2005).

2.3. Geographic object-based analysis

The traditional methods of classifying remote sensing data are based upon statistical and cluster-based classification of single pixels in a digital image (Lillesand & Kiefer, 2004). Recent research indicates that pixel based classification methods may be less than optimal in producing high-accuracy land use / land cover maps since they do not consider the spatial relationships of landscape features (Schiewe et al., 2001). For example, a significant

proportion of the reflectance recorded for a single pixel is derived from the land area immediately surrounding the pixel (Townshend et al., 2000). Analyzing at the polygon object scale enables imagery classification to move beyond this traditional problem.

Contemporary object-based landscape analysis uses parameters derived from hierarchy, context and geometry of the image objects rather than pixel values. Despite a successful history with remote sensing, the accuracy of pixel-based image analysis can be compromised when applied to high resolution images (Nobrega, 2007).

The development and practice of object-based classification has grown as have the variety of methods and approaches of incorporating spatial context into the classification process. Most object-based approaches compliment the axiom of landscape ecology; that it is preferable to work with a meaningful object representing the true spatial pattern rather than a single pixel (Blaschke et al., 2001). Furthermore, the development or use of objects (at one or multiple scales) is always an initial primary phase of the analysis which emphasizes capturing, extracting, or refining the size, shape, and distribution of features of interest.

Object-based classification can be functionally decomposed into two major steps: segmentation and classification. In the segmentation step, relatively homogeneous image objects (polygons) are derived from both spectral and spatial information (Benz et al., 2004). In the classification phase, image objects are labeled as to their class membership by using established classification algorithms, knowledge-based approaches, fuzzy classification membership degrees or a combination of classification methods (Civco et al., 2002).

The commercial software package, Trimble eCognition Developer (formerly *Definiens Developer*), has been well received as a tool for performing object-based classifications of land cover (an example list of scientific papers using eCognition for various land cover mapping tasks is available at *http://www.ecognition.com/learn/resource-center/show-more?type=Scientific%20Paper*). For automated generation of segmentation objects, the application uses a region growing multi-scale segmentation algorithm for the delineation of image objects. The application also enables pre-existing spatial features to be used as objects within which segmentation may be constrained. eCognition provides two different classification methods that may be used separately or combined: a sample-based nearest neighbor classifier with fuzzy logic capabilities and a classifier that enables the development of hierarchic class-membership through a set of rule-based fuzzy logic membership functions.

This chapter presents an implementation of constrained segmentation in which naturally occurring objects provide the initial basis for identifying relevant features on the landscape within which classification and analysis that implement GEOBIA theory are explored. No segmentation objects are computed, since the objects of interest (watersheds and wetlands) already exist, and segmentation statistics are generated for these areas and used in subsequent phases of analysis. The method combines intrinsic and extrinsic information extracted from the objects and the analyses are organized hierarchically.

2.4. Spatial MCDC-AHP in transportation planning

Driven by the need to find a balanced solution among conflicting scenarios and because of the vast and growing availability of geospatial data, decision making theory has been explored by the environmental assessment community, including transportation planners.

Multi-Criteria Decision Making is a systematic methodology to generate, rank, compare, and make a selection from multiple conflicting alternatives using disparate data sources and attributes (Gal et al., 1999; Nobrega et al., 2009). The applicability of MCDM is being extended to many different fields including GIS, which is capable of handling massive amounts of geospatial data. Analytical Hierarchy Process is a decision making approach introduced by (Saaty, 1994) based on pair-wise comparisons among criteria and factors in different hierarchical levels. AHP is presented as an effective technique for combining heuristic inputs from stakeholders to achieve a consensus-based decision. The technique allows competing agency expert views as well as stakeholder opinions to be considered quantitatively in a decision making approach (MacFarlane et al., 2008). In keeping with the spirit of NEPA, AHP does not pre-select any specific alternative; it exposes all potential alternatives to the analysis and selection process.

AHP is robust and easily implemented in GIS for geospatial analysis. Results demonstrated in (Sadasivuni et al., 2009) and (Nobrega et al., 2009) showed that AHP can provide significant benefits in facilitating multi-criteria decision-making for planning. AHP is a tool useful for planning and can lead to stakeholder buy-in on planning approaches that consider resource allocation, benefit/cost analysis, the resolution of critical conflicts, and design and optimization. This chapter explores a practical application of spatial MCDM-AHP for transportation planning. The solution presents a semi-automated approach based on an adaptation of Dr. Saaty's theory.

3. The study area: Initial processing

The Interstate 69 is a proposed 1,600-mile long corridor that connects Canada to Mexico. The entire corridor is divided into 32 Segments of Independent Utility (SIU) for transportation planning and construction purposes. SIU-9 ranges from Millington, TN down to Hernando, MS, crossing the metropolitan area of Memphis, TN and reusing some existing roads such as I-55. However, a new I-269 bypassing the metropolitan Memphis, TN area to the east has been approved through an Environment Impact Statement (EIS) process and is entering the construction phase (Figure 2). The I-269 bypass is the test-bed for a series of research projects sponsored by the National Consortium for Remote Sensing in Transportation - Streamlined Environmental and Planning Process- (NCRST-SEPP). This work is concentrated in Desoto County-MS, which is traversed by the designed I-269.

The NCRST-SEPP project (*http://www.ncrste.msstate.edu/*) applied remote sensing technology and geospatial analysis to streamlining the EIS process for a specific on-the-ground transportation project. NCRST-SEPP research was designed to demonstrate the innovative application of commercial remote sensing and spatial information technologies in specific

environmental and planning tasks and activities, validating the use of those technologies by conducting rigorous comparison to traditional methods (Dumas et al., 2009).

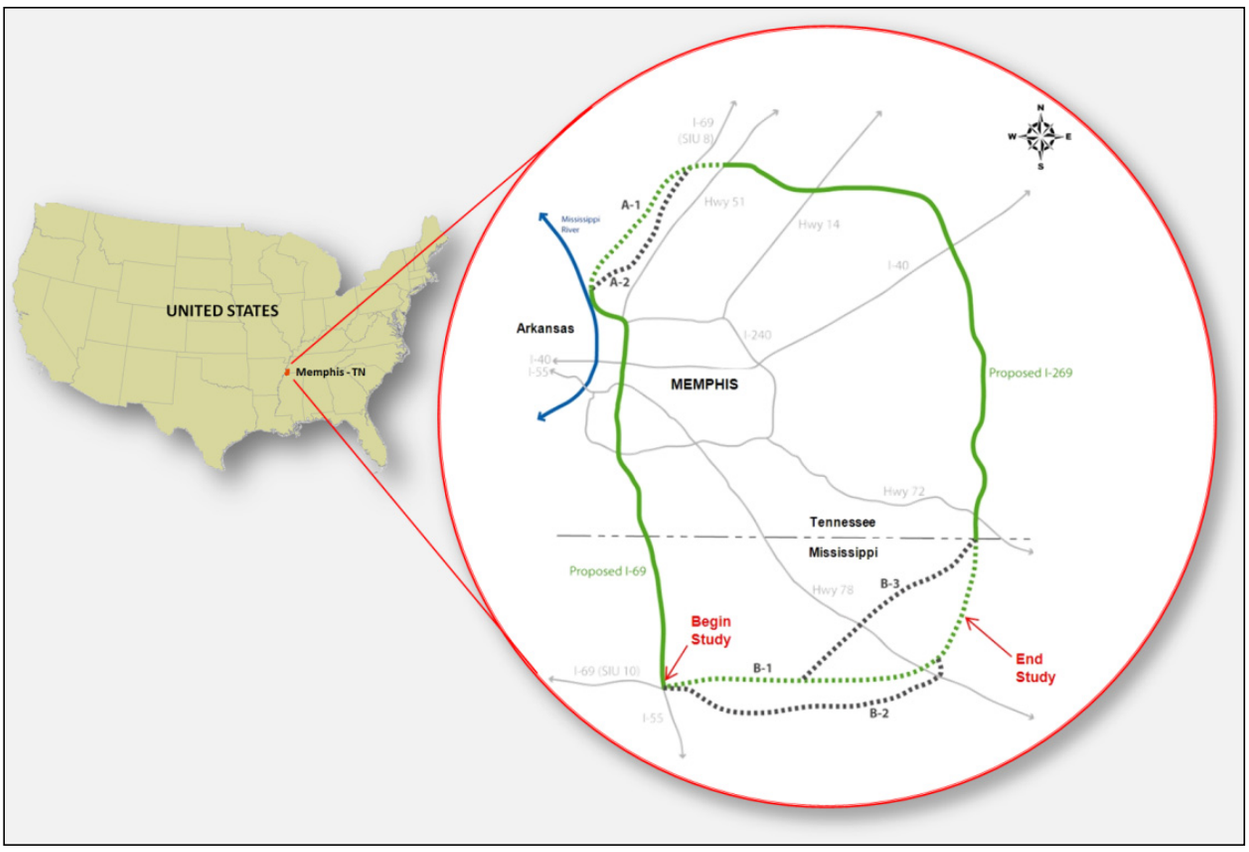

Figure 2. The route of the I-269 bypass including alternatives considered during the EIS process. The study extends along the I-269, in Desoto County, Mississippi, near Memphis-Tennessee.

To make the proposed top-down watershed-wetlands framework analysis useful, this work utilized local geodata provided by Desoto County, MS, such as the transportation network, hydrographical data, LiDAR elevation data, zoning and the county comprehensive plan. A large collection of three-inch resolution aerial images provided support to enhance evaluation of wetland locations. Additionally, wetlands and hydric soil information extracted from satellite radar imagery were used to cover the lack of National Wetlands Inventory federal wetlands data for this specific area (Brooks et al., 2009).

3.1. Overcoming the lack of NWI information in North Mississippi

In our investigation of efficient methods to provide early assessment to wetlands potentially impacted by transportation corridors, we adopted existing findings of woody wetlands in North Mississippi. According to (Brooks et al., 2009), the motivation in improved methods of mapping forested (or "woody") wetlands areas was two-fold: National Wetlands Inventory (NWI) digital mapping information of wetlands location is unavailable for approximately ¼ of the lower 48 U.S. States, including northwest Mississippi, based on the U.S. Fish and Wildlife Service NWI "*Wetlands Online Mapper*"; and forested wetlands are

very poorly mapped using traditional mapping methods including optical remote sensing (Sader et al., 1995; Bourgeau-Chavez et al., 2001).

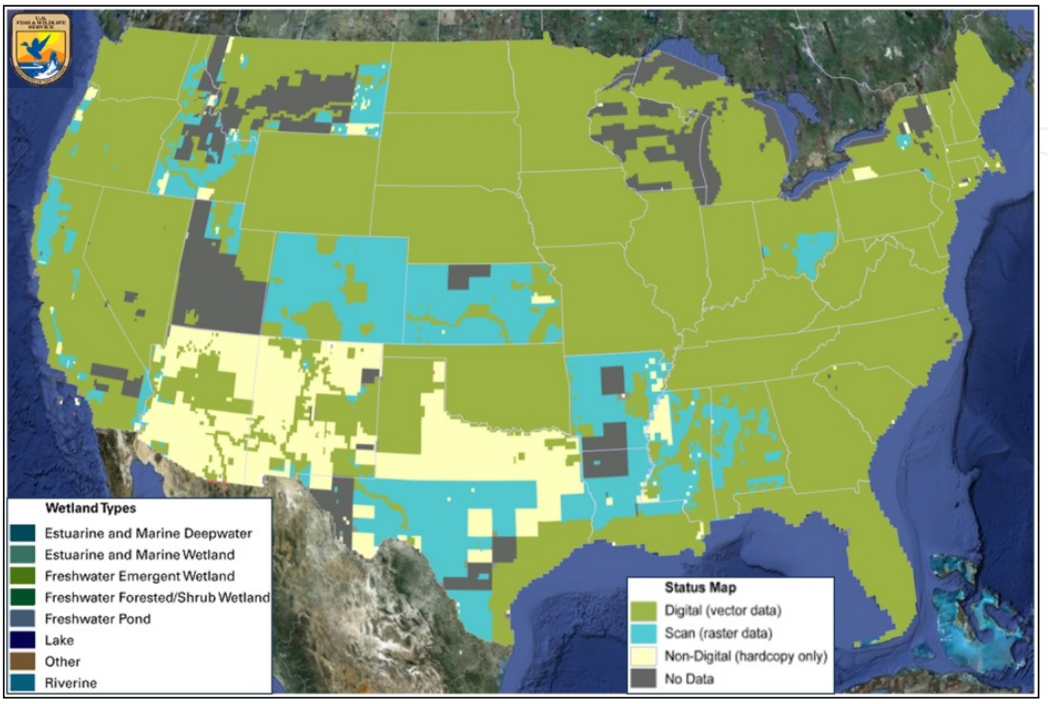

Figure 3. Availability of national wetland data (Modified from U.S. Fish and Wildlife Service, National Wetland Inventory, background image source: Google Earth.

Given this data gap and problems with available traditional sources, we adopted the results described by (Brooks et al., 2009) that used a combination of radar remote sensing data with object-based techniques to compute potential woody wetlands and create a soil moisture index map for the NCRST-SEPP project (Figure 4).

4. The top-down watershed-based landscape analysis

The partition of the landscape into hydrological watersheds was a logical ecologically-focused way to explore the context interactions between the natural and the man-made features. The methodology employed concepts of object-based geographical analysis to evaluate the level of landscape impact of the proposed transportation corridor scenarios. The focus on hydrological watersheds as principal objects made the main difference in comparison with the traditional object-oriented landscape analysis. Two levels of hierarchy were addressed in this work:

1. Watersheds were identified and ranked according certain criteria as a significant percentage of unfavourable zoning, density of streams, wetlands and future man-made constructions.
2. Wetlands identified and ranked for each watershed. This used topographical LiDAR data, image interpretation and the wetlands impacted by the designed I-269 corridor.

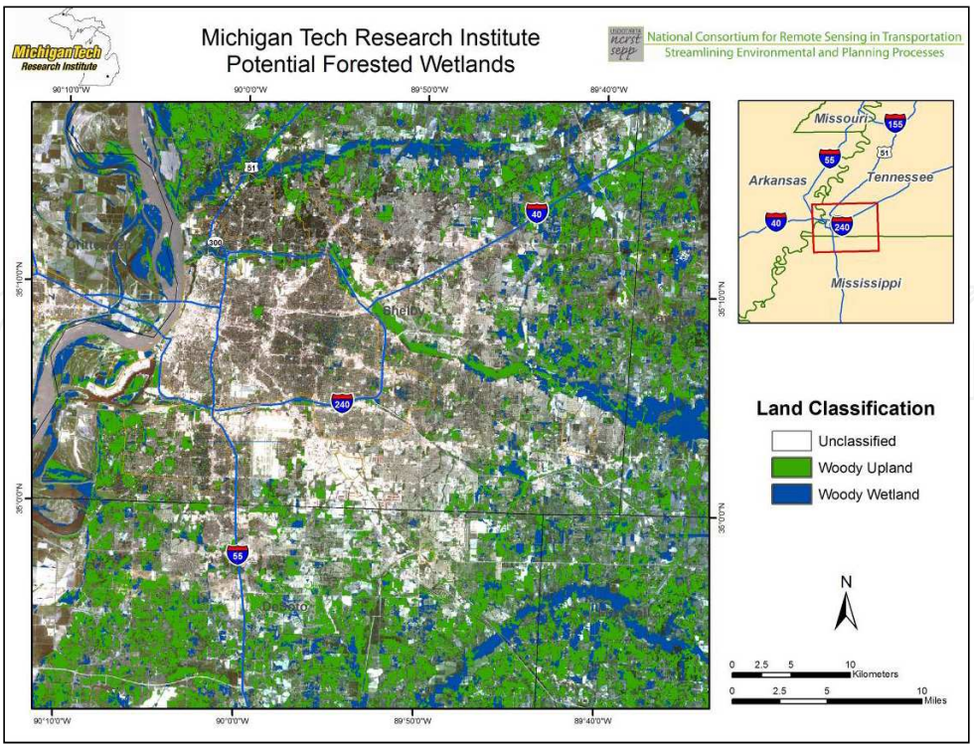

Figure 4. Potential woody wetlands product for the NCRST-SEPP I-269 study area.

4.1. Defining objects in a hierarchical landscape analysis in GIS

An I-269 area GIS was developed to improve the capabilities of geographical analysis by providing ways to access, process, store and disseminate large amounts of information in comparison with human tasks. The traditional GIS features (points, lines and polygons) enable a series of spatial operations as union, overlapping, intersection, etc. Some of these operations were used when integrating the watershed polygons and the landscape layers of information on the first level and when assessing and refining wetlands on the second level (Figure 5).

4.2. Level I: Identification of watersheds

The first step was the identification of the HUC-12 watersheds intersected by the part of the I-269 bypass that included alternative routes in the southeast part of the area located in northwest Mississippi. A simple spatial intersection operation highlighted ten watersheds as shown in Figure 6.

Selecting the watersheds intersected by the I-269 corridor options area caused a significant reduction in the field study area and, consequently, the optimization of the data to be processed. Thus, the next step assessed the numerical criteria that enabled ranking the selected watersheds. At this point, the polygons of the 10 selected watersheds were intersected with other layers of information such as 100 year floodplain, hydrograph, existing roads and urban features, planed roads and developments and zoning in order to extract features to quantify the system. Figure 7 illustrates the layers used in this intersection.

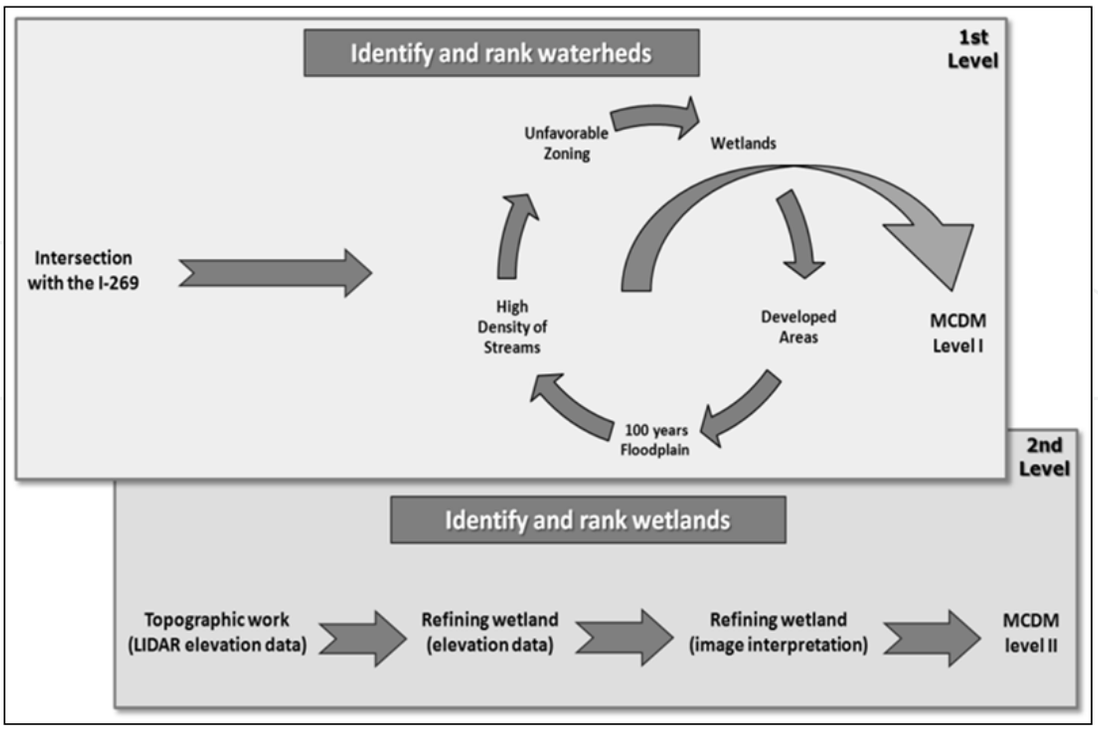

Figure 5. The basic workflow for the two levels of the hierarchical process.

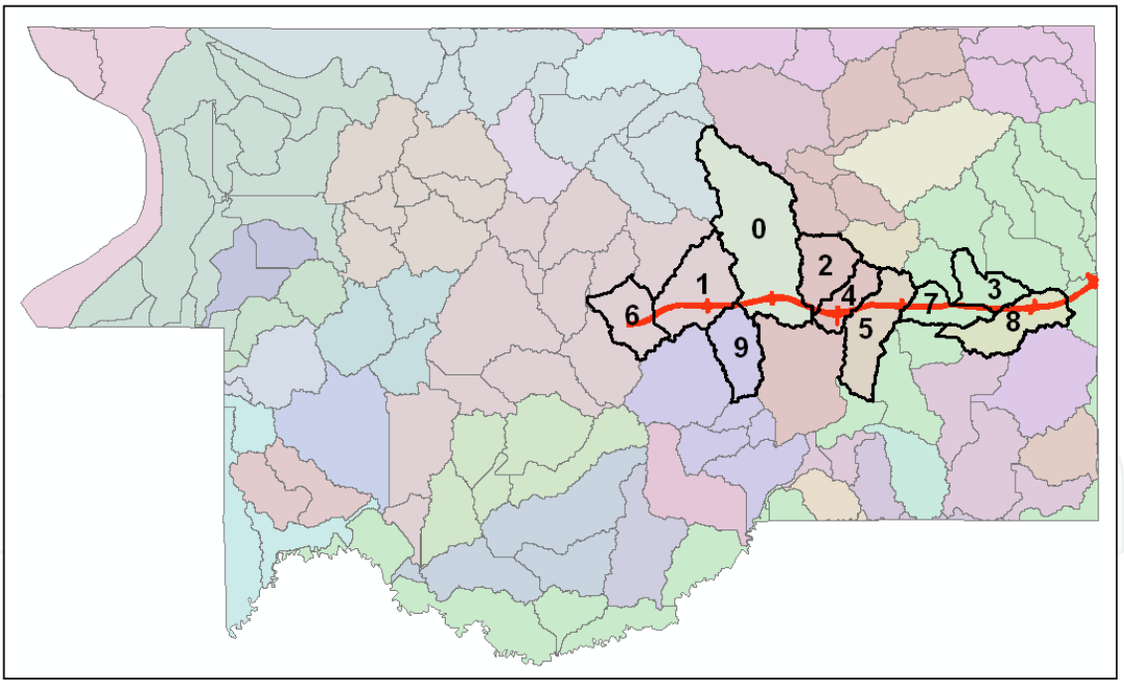

Figure 6. The HUC-12 watersheds intersected by the part I-269 analyzed in Desoto County-MS, which was the section with corridor options assessed as part of the EIS.

In order to make straightforward the process, the zoning map in particular was previously reorganized into 5 classes: agriculture (green), residential (yellow), agriculture-residential (light green), commercial (red) and industrial (orange). Similarly, the maps of existing roads and existing buildings provided by Desoto County GIS Department were combined to

produce a density map that reflects the urbanized areas. These steps were necessary since no map of this kind was found to be available in existing GIS databases.

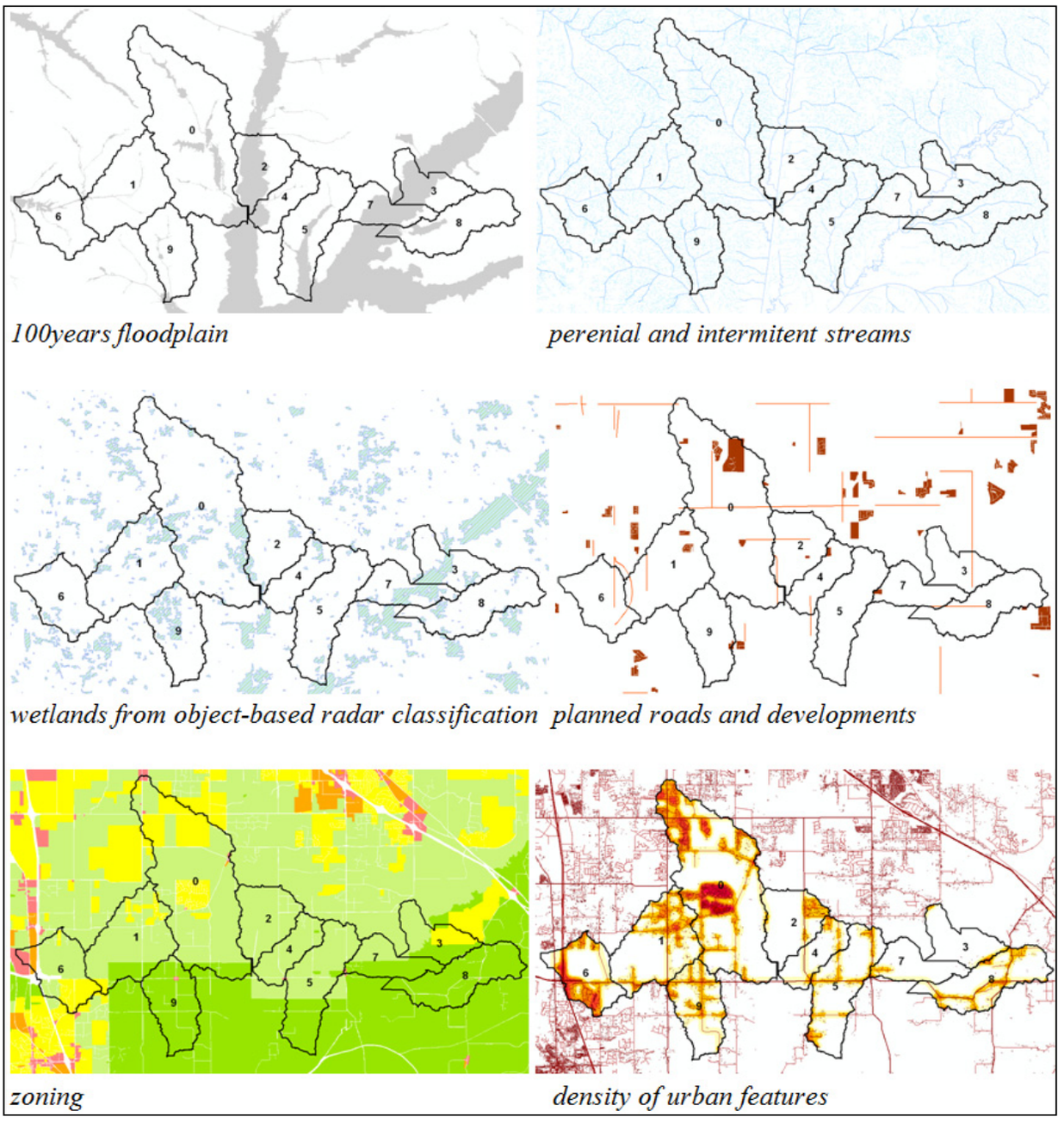

Figure 7. Spatial intersections between the selected wetlands and the layers of interest to assess watershed characteristics to be used in the MCDM process.

Aiming to simplify the decision making process, quite a few different impact factors were assigned to the layers of interest, ranging from 1 (low impact) to 9 (high impact). These values were hypothetical, but reflected the importance of the features due to the potential environmental impact upon existing wetlands. The percentage of covered areas was computed per watershed for the following GIS layers: *watersheds, 100 year floodplain, dense urban, future developments, residential, agriculture, agriculture-residential, commercial and*

industrial. Similarly, the density of linear features (km per Km^2) was computed per watershed for the layers *perennial streams*, *intermittent streams* and *planned roads*. Table 1 presents the relative values extracted per layer from the selected watersheds. These numbers were used to compute the ranking through the weighted average, as show in the Equation 1.

$$\text{Rank} = \left[(A+C+E+F+H) + 3*(J) + 5*(B+I) + 7*(K+L) + 9*(D+G) \right] / 50 \quad (1)$$

	Layer A	Layer B	Layer C	Layer D	Layer E	Layer F	Layer G	Layer H	Layer I	Layer J	Layer K	Layer L
Impact factor	1	5	1	9	1	1	9	1	5	3	7	7
watershed	Floodplain %	Dense Urban %	wetlands %	Future Develop. %	Streams km/km2	km/km2	planned roads k/km2	Agriculture %	Residencial %	Agri-Resid %	Comercial %	Industrial %
0	10.18	35.42	10.28	5.56	0.99	7.96	0.30	5.24	24.08	66.51	0.57	0.07
1	1.58	10.91	10.06	1.75	0.95	8.27	0.25	15.00	10.31	116.31	0.00	0.00
2	65.57	20.24	9.14	0.44	1.79	5.21	0.52	0.00	0.00	128.18	0.00	0.00
3	62.66	3.96	21.09	0.00	0.99	4.64	0.27	33.41	24.21	42.02	0.00	0.00
4	17.08	11.16	5.46	1.50	0.67	6.84	0.16	0.56	0.00	96.59	0.19	0.00
5	18.11	17.03	3.36	0.04	0.93	7.10	0.00	35.53	0.00	62.21	0.13	0.00
6	9.80	43.17	3.00	0.00	0.99	7.26	0.37	0.03	29.40	111.16	3.89	4.30
7	50.85	5.47	23.47	1.39	0.68	3.33	0.14	60.16	0.00	38.57	0.43	0.00
8	11.66	20.24	6.09	0.11	1.01	7.38	0.21	96.51	0.00	0.00	0.04	0.00
9	3.63	28.06	15.05	0.59	0.85	8.79	0.00	95.54	0.00	1.99	0.42	0.00

Table 1. Relative values computed per layer per watershed (percentage of area and density of linear features)

4.3. Level II: Identification of the wetlands

Unlike the federal and small-scale geodata, local (large-scale or ground-level) geodata normally demand substantial time to be computed due to the high resolution and accuracy involved. Aerial images, high resolution satellite images and LiDAR are the most data intensive information in GIS in terms of storage and interpretation requirements. Minimizing computational efforts by analyzing the landscape, subdividing the geography into semi-homogeneous units, selecting units for further detailed analysis, and prioritizing areas of interest is key to reducing the geographic extent of the study, reducing the computational cost of the study, and supporting the top-down approach in geospatial analysis in which the analysis funnels options down into a reduced set of possible alternatives.

Given the completion of Level I processing described, a series of GIS analyses using information extracted from the topographic surface, such as topographic depressions and flat areas, as well as image analysis such as land cover, provided enhanced inputs to refine wetlands feature geometry as well as classifications based on the radar-based wetland mapping results.

The following processes were developed for the watershed #0, which is second in the ranking as shown in the results section (Figure 8); it serves as a representative example for more detailed examination in this chapter. The reason is that the top-ranked watershed covers a small area and is mostly composed by developed areas and does not present a large

variety of landscape features (including wetlands) to illustrate the exercise proposed in this work.

The geospatial analysis was performed using map algebra, so features in vector formats were converted to raster format. Due to landscape analysis considerations and the potential implications of I-269 and planned roads, the layers of information selected in this level (Level II) emphasize the hydrographic and physical aspects, which are basis for engineering construction perspectives.

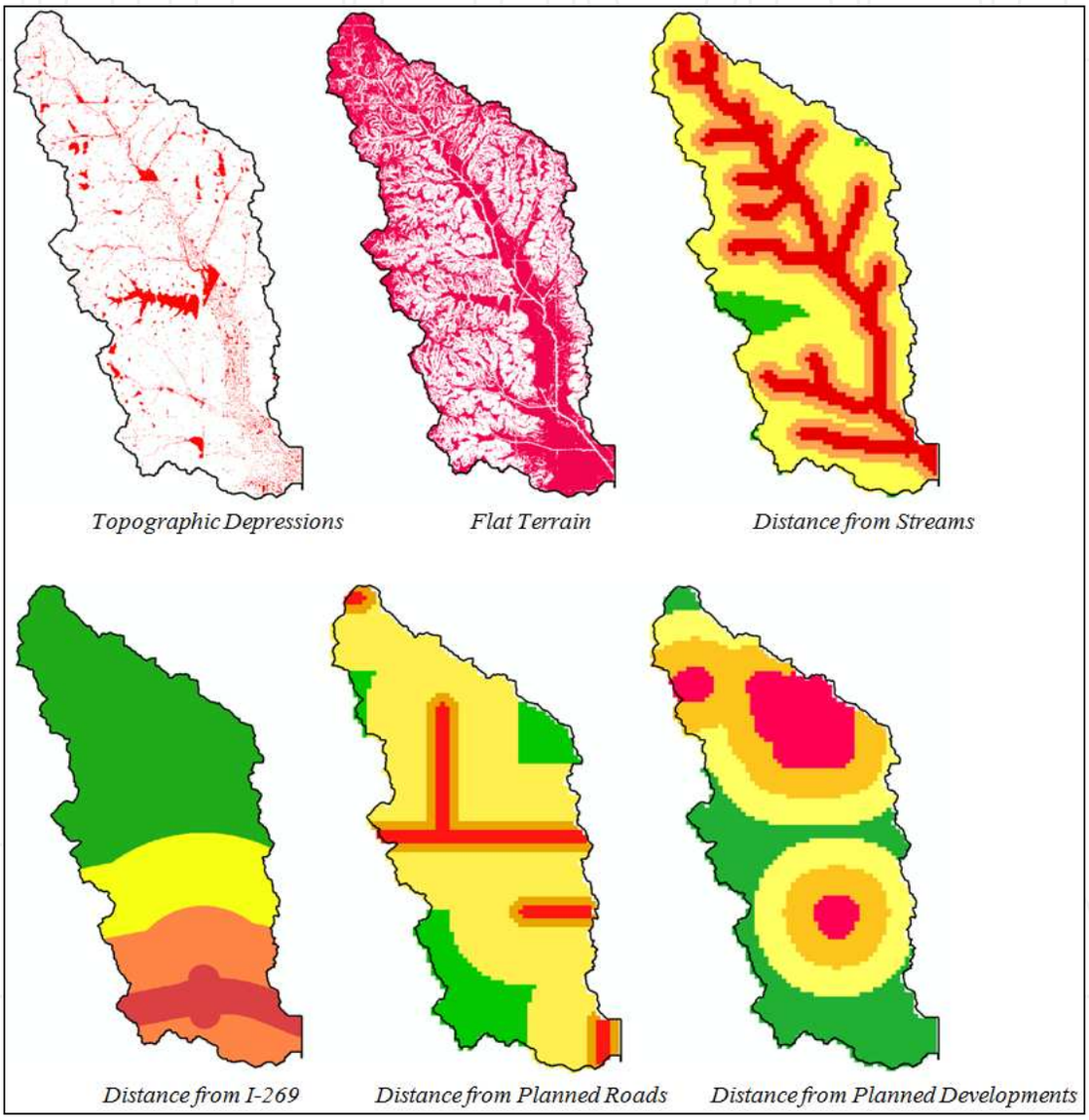

Figure 8. The layers employed to refine and rank the wetlands per watershed. For display purposes, the impact factor ranges from green (low) to red (high).

Table 2 presents the layers used to refine the wetlands features, their respective criteria for classification and the weight to be used on MCDM. Distance criteria and weights are hypothetical; however, they reflect the goal of the paper on assessing potential impacted wetlands.

LAYER	CRITERIA	WEIGHT
Topographic depressions		5
Flat terrain	Slope equal or less than 5%	3
Distance from perennial streams	0-100m, 100-300m, 300-1000m, > 1000m	5
Distance from I-269	0-300m, 300-1500m, 1500-3000m, > 3000m	9
Distance from planned roads	0-300m, 300-1500m, 1500-3000m, > 3000m	7
Distance from planned develop.	0-300m, 300-1000m, 1000-3000m, > 3000m	7

Table 2. Layers, criteria and weights used on level II analysis

The weights are included in the multi-criteria decision tool as input rankings. The tool was developed as part of the SEPP-NCRST project and implemented based on Saaty's AHP method (Figure 9). The normalized weights are used as factors in the map algebra equation that is responsible to produce the cumulative cost surface, where high "cost" would represent higher environmental impact.

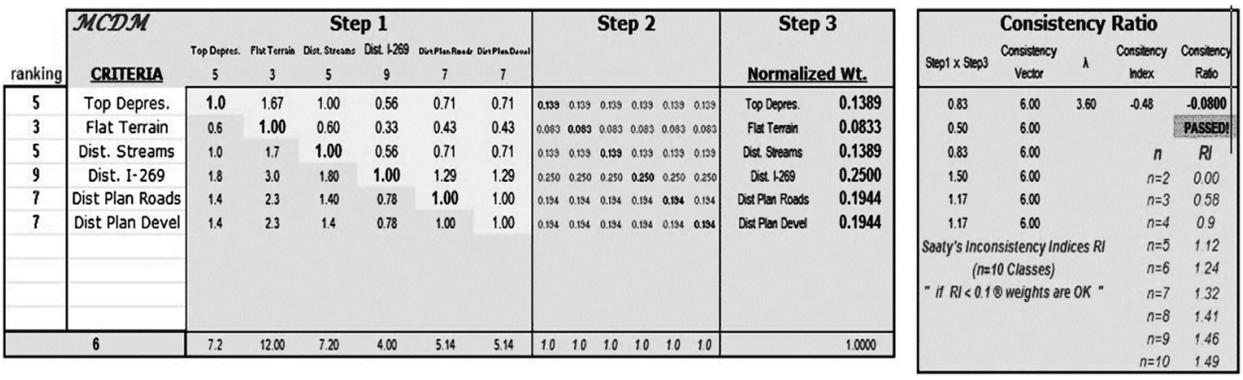

Figure 9. Multi-criteria decision making tool developed to compute normalized weights for the map algebra.

5. Results

5.1. Step 1

For the selected watersheds, impact factors were used to calculate a first-level ranking for watershed and wetland areas impact ranking. Watersheds were ranked and are shown in table 3 in relative order from highest of 15.6 (left-most) to lowest of 4.5 (right-most) on the table.

Watershed ID	6	0	2	1	4	3	5	7	9	8
Ranking	15.6	11.8	11.5	10.2	7.9	7.8	6.8	6	5.6	4.5

Table 3. Computed ranking of potentially impacted wetlands intersected by I-269 in the analysis area

5.2. Step 2

For a selected watershed, shown in figure 10 as the watershed #0, the cumulative cost surface shows that impacts are greatest in the lower part of the watershed (Figure 11). In this

area, the amount of upland drained is highest; the floodplain is broader and the wetlands are more frequent as are areas of likely ponded water (surface depressions). Over and above the actual number of stream crossings or acres of wetland impacted by a proposed transportation system, this analysis step illustrates that the landscape and hydrologic context of the ecologic and hydrologic features impacted can be shown to play a significant role in assessing the overall impacts of a transportation project on the hydrologic and biophysical systems traversed.

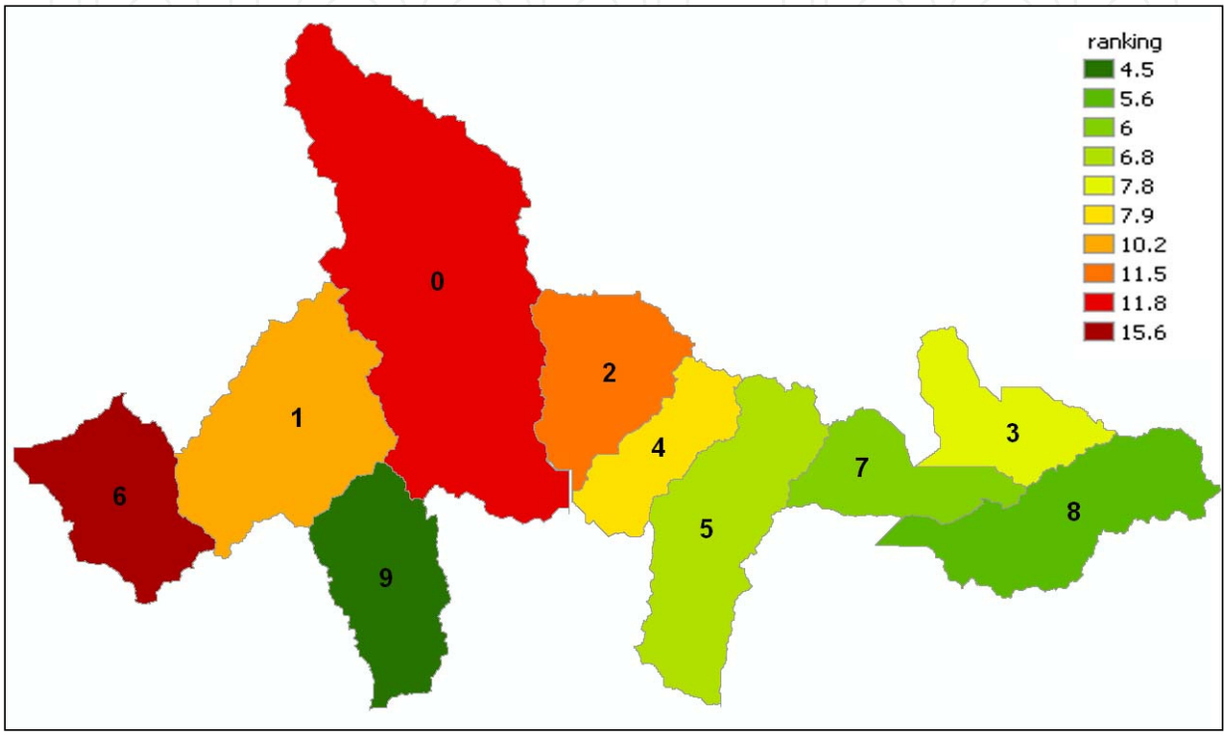

Figure 10. Potentially impacted watersheds intersected by the I-269 – Level I of proposed methodology.

6. Discussions and contributions

In addition to the landscape analysis and transportation planning issues, the results of this investigation showed that a top-down analytical framework based on GIS and MCDM offers value to the early assessment of potentially impacted areas affected by future transportation networks. The work was developed using a set of geospatial data ranging from federal to county, and were intentionally selected to be included in a multi-scale geographic object-based analysis. The hierarchical decision making framework supported the top-down approach through a simple customization of AHP in a GIS environment. The methods and rankings were hypothetically selected (and intentionally made simple) in order to encapsulate the idea and test the MCDM methodology for analysing the impacts of the I-269 study area.

Indeed, in an actual implementation, the relative weights assigned to factors and the rankings associated with factor properties would be subject to alternative assignments of values which would produce results that could significantly depart from those presented and enable a rich evaluation of potential alternatives, including ones based on agency and

public inputs. The results presented show a single scenario to illustrate the process rather than an exhaustive exploration of possible scenarios which might arise from collecting a cross-section of objective and subjective values from stakeholders.

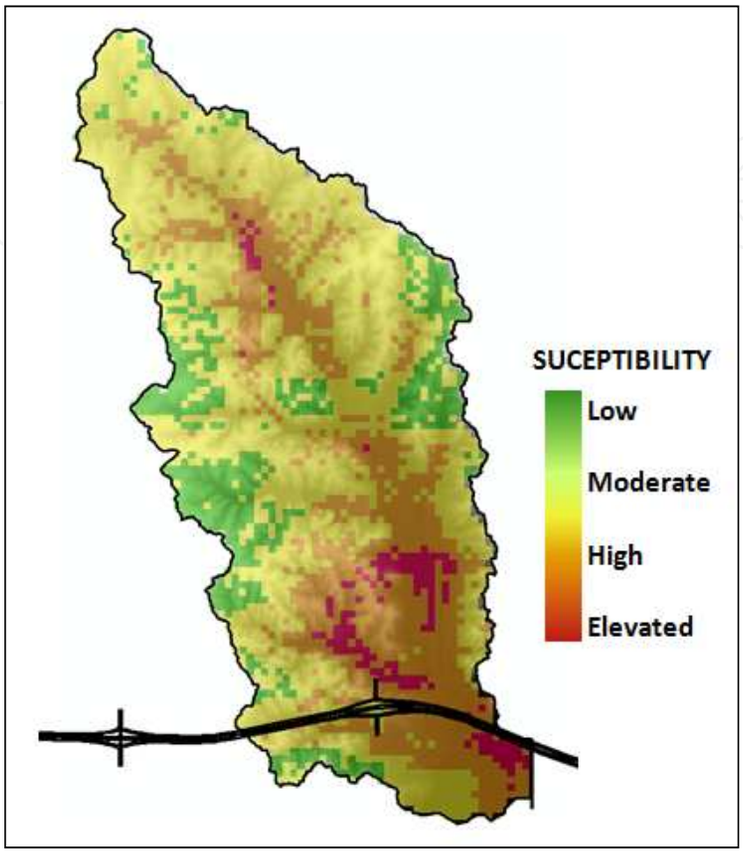

Figure 11. Potential impacted wetland areas (red-orange) highlighted in the cumulative cost surface.

The results demonstrate that the proposed top-down approach is a practical screening process valid to the early assessment and ranking of the impacted wetlands.

Desoto County (MS) is an example of many areas that are not fully mapped or adequately covered by Federal mapping efforts such as the detailed county-based soil surveying program and state-based wetland inventories. Therefore, the methodology demonstrates that the complementary use of wetlands computed from radar-based remote sensing can be used to overcome gaps of in the National Wetlands Inventory (NWI) (Bourgeau-Chavez et al., 2009). Indeed, a specific benefit of using remote sensing data is that they can enable the identification of features of interest where ground-based observations or surface-mapped results are limited or absent. For this reason, it is important to highlight that NWI and other relevant data, such as soil survey GIS layers, are not available nation-wide in high detail. Thus, the methodology presented in this paper can be reproduced from environmental and landscape applications, in particular for areas where other map-based products are not available.

The methods presented in this paper were intentionally simplified to highlight a set of framework approaches to help demonstrate the collection of technologies implemented, especially MCDM. Some concepts of geographic object-based analysis such as

neighbourhood relationships, contextual analysis, and others could be explored in more depth; however, such an effort would overshadow the desired explanation and synthesis of the more innovative characteristics highlighted in the methodology that focus on MCDM and AHP and their application to context-sensitive landscape analysis in the transportation planning and NEPA processes. Furthermore, it should be noted that the methods presented are both flexible and extensible. They may be adapted to other purposes, transferred to other geographic areas and transportation corridors, and extended to include additional data, steps, and analysis procedures. Follow-on studies are suggested to further explore the application and extension of the methods presented.

7. Conclusion

This chapter presents novel methods that leverage spatial implementation of MCDM-AHP in the integrated application of geospatial data to assist transportation decision making throughout the NEPA process. A significant finding is that advanced technologies in geographic object-based analysis can be used to partition the landscape into hydrological watersheds as a basis for context- and object-based analysis. The methodology employed object-based approaches to analyze the landscape and considered a plurality of data layers to derive ranking and weights for understanding the impacts of transportation infrastructure relative to the watershed as a whole as well as to the landscape position of possible transportation alignments within the watershed. The focus on hydrological watersheds as principal objects highlights an important difference in this new and innovative approach as compared to traditional environmental impact analysis.

Watersheds provide subdivisions which are biophysically and ecologically focused, enabling the application of spatial analysis methods which explore the context-sensitive interactions between natural and man-made features in a landscape. The results indicate that the object-based analysis of landscape context and position can provide understanding and insight for assessing transportation corridor impacts on the environment and ecosystems that extend beyond traditional approaches which simply quantify the number of stream crossings and the areas of wetlands impacted. The results show that example hypothetical but reasonable values can be assigned to various landscape features and that these values may be considered in the context of spatially enabled MCDM-AHP. The hierarchical decision making framework implemented through top-down GIS-based analysis enabled the adoption of the segments of the landscape by hydrologic areas. The combination of data, methods and values per level delivers results significant to making decisions, assessing impacts, and designing mitigation strategies that are contextually aligned and indicate an environmentally responsible attitude and sustainable focus for anthropogenic impacts on the environment

Author details

Rodrigo Nobrega, Charles O'Hara and Bethany Stich
Geosystems Research Institute, Mississippi State University, USA

Colin Brooks
Environmental Science Laboratory, Michigan Tech Research Institute, USA

Acknowledgement

The authors would like to thank the US Department of Transportation Research and Innovative Technology Administration (USDOT-RITA) for funding the research, as well as the Desoto County GIS Department for providing much of the GIS data.

8. References

Amekudzi, A. and M.M. Meyer. 2006. Considering the environment in transportation planning: review of emerging paradigms and practice in the United States. *Journal of Urban Planning and Development*. Vol. 132 (1), 42-52.

Aplin, P. 2005. Remote sensing: ecology. *Progress in Physical Geography*. Vol. 29 (2), 104-113.

Benz, U., Hofmann, P., Willhauck, G., Lingenfelder, I. and Heynen, M. 2004. Multiresolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. *ISPRS Journal of Photogrammetry and Remote Sensing*. Vol 58, 239-258.

Blaschke, T., Conradi, M. and Lang, S. 2001. Multi-scale image analysis for ecological monitoring of heterogeneous, small structured landscapes. *Proceedings of SPIE*, Toulouse, 35-44.

Blaschke, T., Lang, S., Lorup, E., Strobl, J. and Zeil, P. 2000. Object-oriented image processing in an integrated GIS/remote sensing environment and perspectives for environmental applications. In: Cremers, A. and Greve, K. (eds.): *Environmental Information for Planning, Politics and the Public*. Metropolis, Marburg. Vol 2, 555-570.

Boarnet, M. G. and Chalermpong, S. 2001. New highways, house prices and urban developments: a case study of Toll Roads in Orange County, CA. *Housing Policy Debate*. Vol 12 (3), 575-605.

Bouman, B.A.M., Jansen, H. G. P., Schipper, R.A., Nieuwenhuyse, A., Hengsdijk, H. and Bouna, J. 1999. A framework for integrated biophysical and economic land use analysis at different scales. *Agriculture, Ecosystems and Environment*. Vol 75, 55-73.

Bourgeau-Chavez, L.L, K. Riordan, R.B. Powell, N. Miller, and M. Nowels. 2009. Improving wetland characterization with multi-sensor, multi-temporal SAR and optical/infrared data fusion. *Advances in Geoscience and Remote Sensing*, InTech, G. Jedlovec, ed. pp. 679-708.

Bourgeau-Chavez, L.L., E.S. Kasischke, S.M. Brunzell, J.P. Mudd, K.B. Smith and A.L. Frick. 2001. Analysis of space-borne SAR data for wetland mapping in Virginia riparian ecosystems. *International Journal of Remote Sensing*, 22(18): 3665-3687.

Brinckhorst, D. J. 2005. Integration research for shaping sustainable regional landscapes. *Journal of Research Practice*, v. 1, n. 2

Brooks, C., Dajos, T., Bourgeau-Chavez, L. 2009. MTRI forested wetlands and soil moisture: inputs to the multi-criteria decision model. In: NCRST - SEPP: May 2009 Memphis

Workshop, 2009, Memphis, TN - USA. *National Consortium for Remote Sensing and Transportation Annual Meeting*, 2009 http://www.ncrste.msstate.edu/sepp_workshops/memphis_workshop_2009/presentations/mtri_memphis_yr2_rev2.pdf (accessed in July 10, 2010)

Burnett, C. and Blashke, T. 2003. A multi-scale segmentation/object relationship modelling methodology for landscape analysis. *Ecological Modelling*, V. 168, pp. 233-249.

Corrales, M.; Grant, M. and Chan, E. 2000. *Indicators of the environmental impacts of transportation: highway, rail, aviation and marine transport*. Diane Publishing, 244p.

Dumas, J., O'Hara, C and Stich, B. 2009. Context sensitive solutions and transportation planning: the detection of land-use, historical and cultural resources, community features and their integration into the planning process. *Proceedings of Transportation Research Board*, Washington DC, January 2009.

Fletcher Jr, R. J., Hutto and Richard L. 2008. Portioning the multi-scale effects of the human activity on the occurrence of riparian forest birds. *Landscape Ecology*. Vol 23, 727-739.

Forman, R.T.T. and L.E. Alexander. 2002. Roads and their major ecological effects. *Annual Review of Ecology and Systematics*. Vol. 29, 207-233.

Forman, R.T.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., Fahrig, L., France, R., Goldman, C.R., Heanue, K., Jones, J.A., Swanson, F.J., Turrentine, T. and Winter, T.C. 2003. *Road Ecology Science and Solutions*. Island Press, Washington, DC.

Gal, T., T.J. Stewart, T. Hanne (eds.). 1999. *Multicriteria decision making: advances in MCDM models, algorithms, theory, and applications*. Kluwer Academic Publishers, Norwell, MA. 560 pp.

Gregory A. Kiker, Todd S. Bridges, Arun Varghese, Thomas P. Seager, and Igor Linkov. 2005. *Application of Multicriteria Decision Analysis in Environmental Decision Making, Integrated Environmental Assessment and Management*. Vol 2, 95–108.

Hay, G.J. and G. Castilla. 2008. Geographic Object-Based Image Analysis (GEOBIA): A new name for a new discipline. *Lecture Notes in Geoinformation and Cartography*. Section 1, 75-89.

Hilty, J.A., C.Brooks, E.Heaton, and A.M. Merenlender. 2006. Forecasting the effect of land-use change on native and non-native mammalian predator distributions. *Biodiversity and Conservation*. Vol 15 (9), 2853-2871.

Huang, B., Cheu, R.L., and Y.S. Liew. 2003. GIS-AHP Model for HAZMAT Routing with Security Considerations. *Proceedings of IEEE 6th International Conference on Intelligent Transportation Systems*, October 2003, Shanghai, China.

Keller, I.; Largiardèr and C. R. 2003. *Recent habitat fragmentation caused by major roads leds to reduction of gene flow and loss of genetic variability in ground beetles*. The Royal Society, v. 270, pp 417-423.

Kuitunen, M., Rossi, E. and Stenroos, A. 1998. Do highways influence density of land birds? *Environmental Management*, Vol 22 (2), 297-302.

Lillesand, T.M, and Kiefer, R. W. 2004. *Remote Sensing and Image Interpretation* (4th ed.), N.Y., John Wiley & Sons.

Litman, T. A. 2008. *Land Use Impacts on Transport: How Land Use Factors Affect Travel Behavior*. [online]. Victoria Transportation Policy Institute, 58 p. Available from: http://www.vtpi.org/landtravel.pdf [Accessed 15 May 2009]

McGarigal, K., and B. J. Marks. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. [online]. Forest Science Department, Oregon State University, Corvallis-OR. Available from: http://www.umass.edu/landeco/pubs/Fragstats.pdf [Accessed 15 May 2009]

Mokhtarian, P. L. and Cao, X. 2008. Examining the impacts of residential self-selection on travel behavior: A focus on methodologies. *Transportation Research B*, v.42, 204-228.

Nobrega, R. A. A. 2007. Deteccao da malha viaria na periferia urbana de Sao Paulo utilizando imagens de alta resolucao espacial e classificação orientada a objetos. *Tese de Dourotado*, Escola Politecnica da Universidade de Sao Paulo, Sao Paulo. 165p.

Omernik, J. M. and Bailey, R. G. 1997. Distinguishing between watershed and ecoregions. *Journal of the American Water Association*. Vol 33 (5), 935-944.

Ono, S., Barros, M. T.L. and Conrado, G. 2005. A Utilizacao de SIG no planejamento e Gestao de Bacias Urbanas. *Proceedings of AbrhSIG*. Sao Paulo, 2005.

Saaty, T. L. 1995. Transport planning with multiple criteria: the analytic hierarchy process applications and progress review. *Journal of Advanced Transportation*. Vol 29, 81–126.

Sadasivuni, R., O'Hara, C.G., Nobrega, R. and Dumas, J. 2009. A transportation corridor case study for multi-criteria decision analysis. *Proceedings of American Society of Photogrammetry and Remote Sensing Annual Conference*, March 11-14, 2009, Baltimore-MD.

Sader, S., D. and Ahl, W. 1995. Accuracy of Landsat-TM and GIS rule-based methods for forest wetland classification in Maine. *Remote Sensing of Environment*. Vol 53 (3), 133-144.

Saunders, S. C., Mislivets, M, R., Chen, J. and Cleland, D. T. 2002. Effects of roads on landscape structure within nested ecological units on the Northern Great Lakes Region, USA. *Biological Conservation*. Vol 103, 209-225.

Schiewe, J., Tufte, L. and Ehlers, M. 2001. Potential and problems of multi-scale segmentation methods in remote sensing. GIS – *Zeitschrift für Geoinformationssysteme*. Vol 6, 34-39.

Spellerberg, I. F. 1998. Ecological effects of roads and traffic: a literature review. *Global Ecology and Biogeography Letters*. Vol 7, 317–333.

TownshendWalker, J. R.., Huang, G., Kalluri, DeFries, N. V. and Liang, S. 2000. Beware of per-pixel characterisation of land cover. *International Journal of Remote Sensin*g. Vol 21, 839– 843

Wheeler, A. P., Angermeier, P., Rosenberguer, A. 2005. Impacts of new highways and subsequent landscape urbanization on stream habitat and biota. *Reviews in Fisheries and Science*. Vol 13, 141-164.