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MODELING & CLASSIFIYING RIPARIAN ECOTONES VIA GIS UTILIZING GEOPHYSICAL AND VEGETATIVE INPUTS: A NEW APPROCH

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ABSTRACT: Riparian ecotones are dynamic, transitional ecosystems between aquatic and terrestrial ecosystems with well-defined vegetation and soil characteristics. Development of a geospatial model to delineate riparian ecotones, because of their high variability, is challenging. However, there are two primary factors that all riparian ecotones are dependent on: the watercourse and its associated floodplain. Previous approaches to riparian boundary delineation have utilized fixed width buffers, but this methodology has proven to be inadequate as it only takes the watercourse into consideration and ignores critical geomorphology, associated vegetation, and soil characteristics. Our approach offers advantages over previously used methods by utilizing: the geospatial modeling capabilities of ArcMap GIS; a better sampling technique along the water course to accurately map the 50-year flood plain; the incorporation of National Wetland Inventory (NWI) and Soil Survey Database (SSURGO) data to delineate adjacent areas beyond the 50-year flood plain; and the utilization of National Land Cover Data (NLCD) and Cropland Data Layer (CDL) data. An accuracy assessment is performed to assess the impact of various DEM spatial resolutions, and positional inaccuracies of National Hydrography Dataset (NHD) streams on the delineated riparian ecotone boundary. The result of this study is a robust and automated GIS based model attached to ESRI ArcMap as a toolbox to delineate and classify variable-width riparian ecotones utilizing spatial data readily available from government agencies and geospatial clearinghouses.

KEY TERMS: riparian ecotones, GIS spatial model, variable width riparian buffer, and land use/cover mapping.

INTRODUCTION

Riparius, the original Latin term for riparian means "of or belonging to the bank of a river" (Naiman *et al*., 1997). Across the fields of science and engineering, definitions for riparian areas range from simple to complex. Fischer *et a*l. (2001) mentioned more than 35 terminologies for riparian areas and the vegetation adjacent to aquatic systems. Verry *et al*. (2004) summarized 100 years of definitions and concepts published in the literature. The definitions vary, depending on management agencies, various scientific disciplines and/or functional perspective. Each definition provides criteria to define and delineate the boundary of a riparian area.

Abood *et al*. (2012) developed the second version of the Riparian Buffer Delineation Model (RBDM). This version adopts the riparian definition developed by Verry *et al*. (2004) which states that a riparian zone is "a three dimensional space of interaction that includes terrestrial and aquatic ecosystems that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at a variable width". Also adopted is the term "riparian ecotone", defined as the zone of interaction between an aquatic ecosystem and a terrestrial ecosystem which includes the geomorphology and functional parameters of riparian zones and suggests that a riparian zone boundary is not a fixed distance from the stream but has a variable width (Ilhardt *et al*., 2000).

Utilizing ArcMap, the 50-year flood height, and digital elevation data, this paper presents an overview of the RBDM v2.3, originally developed by Mason (2007) and enhanced by Abood (2011). The expanded model incorporates National Wetlands Inventory (NWI), Soil Survey Geographic Database (SSURGO), and optionally, National Land Cover Data (NLCD) and the Crop Data Layer (CDL) to improve the accuracy and utility of the variable width riparian zones. As Digital Elevation Models (DEMs) have varying spatial resolutions, and there are known positional inaccuracies within the National Hydrography Dataset (NHD), the impact on riparian delineation accuracy is assessed since these data are critical to the model.

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STUDY AREA

Study sites are located in Michigan and Idaho. The Michigan study area is located in Oscoda and Crawford counties and compromised of nine watersheds. The study area is mostly outwash plain with large sandy ground and end moraines located on a high plateau (Albert, 1995). Agriculture is intermixed with deciduous and coniferous forests across the landscape. The Idaho study area, located in Latah County, is comprised of nine watersheds. This study area is a high elevation, complex terrain that reaches a maximum elevation of 1519 meters at Moscow Mountain. Land cover is mostly mixed coniferous forest with a diverse species composition (Falkowski *et al*., 2009). The study areas were selected based on the availability of 1-meter and 10-meter DEMs as well as SSURGO data and provided a variety of diverse landforms in which to evaluate the model.

MODEL INPUTS and STRUCTURE

The RBDM data inputs and sources are listed in Table 1. The model utilizes spatial data readily available from government agencies and geospatial data clearinghouses. The NHD is a continuous feature class based dataset formatted as ArcMap File Geodatabases (FGDBs) and includes streams, lakes, and watersheds features. The SSURGO data consists of soil mapping units created from field point samples interpolated by soil scientists. The NLCD is a continuous land cover dataset for the conterminous United States developed from multi-source and multi-layer continuous land use/cover data. The NLCD offers a standardized classification across the United States that is periodically updated and transferable for different users across various scientific and commercial platforms (Homer *et al*., 2004). The CDL is another standardized land use/cover classification with an emphasis on crops types and distribution (Johnson *et al*., 2010). All the inputs in Table 1 must be formatted as ArcMap FGDBs before inputting into the RBDM.

The 50-year flood height is the optimal hydrological descriptor of a riparian ecotone. The 50-year flood height in most cases intersects the first terrace and supports the same microclimate and geomorphology as the moving watercourse and links the valley to its stream through the entrenchment ratio and the belt width ratio (Ilhardt *et al*., 2000). Mason (2007) developed a statistically based methodology to calculate the 50-year flood height utilizing USGS Real-Time Water Data (USGS, 2007). Based on Mason's (2007) methodology the average 50-year flood height for the Michigan study area is 1.0m and 0.9m for the Idaho study site.

Table 1. RBDM Inputs and Sources (from Abood 2011).

Input Data	**Source**
Streams, Lakes, Watersheds (NHD)	USGS National Hydrography Dataset http://nhd.usgs.gov/
50-year Flood Height	Calculated according to Mason (2007)
10m Digital Elevation Model (DEM)	GIS Data Depot http://data.gecomm.com/
National Wetlands Inventory (NWI)	US Fish and Wildlife Service http://www.fws.gov/wetlands/Data/Data-Download.html
Digital Soil Data (SSURGO)	Natural Resources Conservation Service (NRCS) http://soildatamart.nrcs.usda.gov/
National Land Cover Data (NLCD)	Multi-Resolution Land Characteristics Consortium (MRLC) http://www.mrlc.gov
Cropland Data Layer (CDL)	National Agricultural Statistics Service http://www.nass.usda.gov/research/Cropland/SARS1a.htm

The RBDM v2.3 is formatted as an ESRI ArcMap Toolbox (ESRI, 1999-2010). The programming language is Python 2.6. The first processing step prepares selected NHD stream segments utilizing stream attributes (FType or FCode) and also create lake buffers. Second, calculate sample points locations along stream segments. The distance between sample points is 0.75% of the DEM spatial resolution. Third, build transects around sample points. Transects are developed 360^{o} around each sample point to ensure accurate mapping of the riparian areas and capture variations in elevation and changes in stream course direction (Figure 1). The model offers the flexibility of choosing the transect's vector distance (up to 3,000m) from the sample points. The distance between transect points is also 0.75% of the DEM spatial resolution. This minimizes spatial autocorrelation between the sample points along the stream course and the points along the transect (USGS, 1997). Fourth, determine the edge of the variable-width riparian buffer by using the 50-year flood height as a threshold to create the riparian ecotone polygon. Fifth, identify adjacent wetlands features and wet soil areas to create an expanded and contiguous riparian ecotone boundary. According to Palik *et al*., (2004), incorporating NWI & SSURGO data improves the delineation of variable-width riparian buffers since riparian ecotones are not just a function of the floodplain but can extend to other surface waters such as contiguous lakes, adjacent wetlands and soil features which fully encompass the riparian ecotones functional, hydrological and ecological characteristics. Last, if desired, land use/cover can be extracted for the ecotone utilizing the NLCD and/or CDL data (Abood, 2011). The NLCD and CDL provide a standardized land cover/use classification scheme with a synoptic coverage of the United States. Figure 2 is a representative sample of the final continuous riparian buffers around flowing streams in Michigan utilizing the 1.0m 50-year flood height and a 10m DEM.

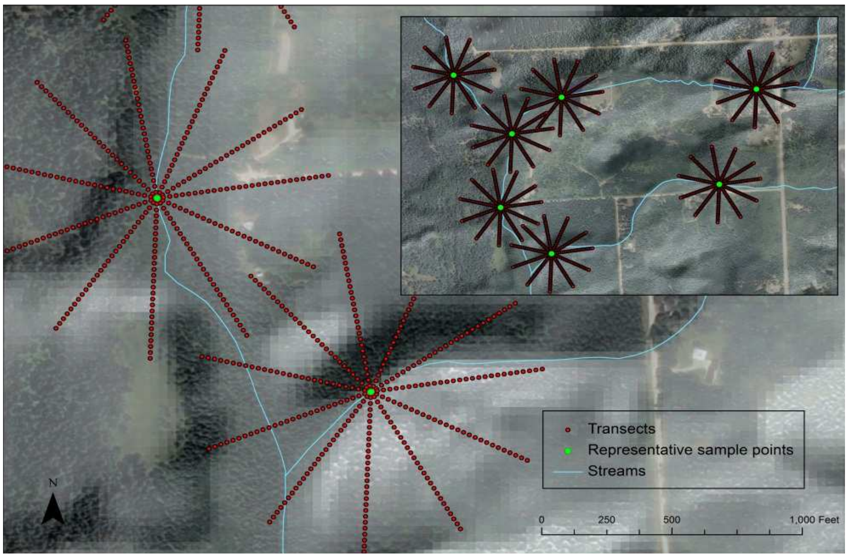

Figure 1. Transects generation around representative sample points from Michigan study area (from Abood, 2011)

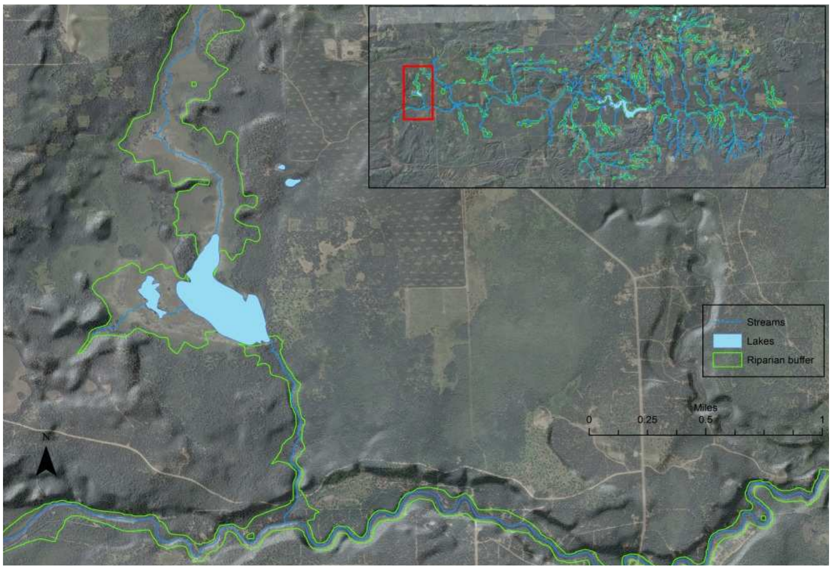

Figure 2. Representative riparian buffer utilizing 1m flood height & 10m DEM in Michigan.

RESULTS

Figure 3 shows a portion of the Latah County, Idaho study area and illustrates that the RBDM accurately delineates riparian ecotone boundaries in a narrow valley flood plain. It supports the statistical assessment results by Mason (2007) for the initial study sites in Minnesota and Michigan and Abood *et al*. (2012) for the additional study sites in Michigan that the RBDM is not impacted by landform. The figure also shows steam positional inaccuracies (shown in blue) when compared to streams mapped by the ArcMap Hydrology Toolset (shown in red). NHD streams where found mapped on hillsides and in one instance flowing across the top of ridge. The RBDM identifies these stream inaccuracies by generating a "pipeline" riparian buffer (Abood, 2011).

Figure 4 presents the expanded riparian ecotone from incorporating NWI and SSURGO data as inputs into the delineation process. The model incorporates adjacent wetlands that share a common boundary with the calculated riparian buffer. Soils polygons are added to the buffer based on the recommendations by Palik *et al*., (2004) if they are characterized as flood plain, wetland and/or frequently flooded. These two additional parameters increased the riparian ecotones area that extended outside the flood plain in a complex landform due to glaciation.

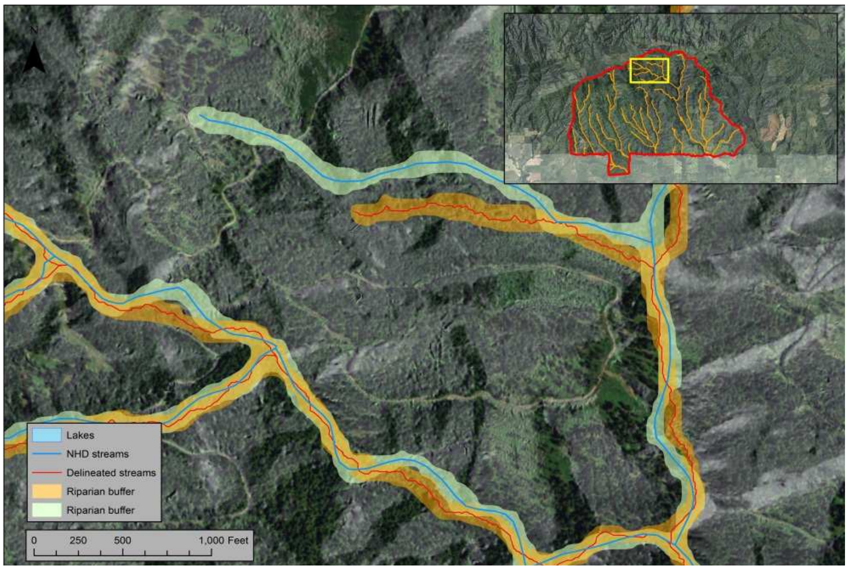

Figure 3. Representative sample of delineated riparian buffer utilizing 0.9m 50 flood height, 1m DEM, Idaho.

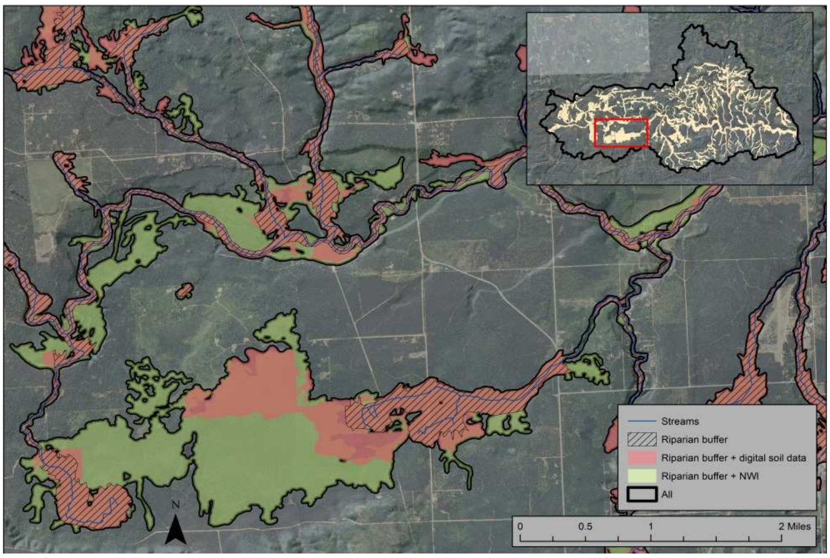

Figure 4. Example of expanded riparian ecotone in Michigan utilizing 1m flood height, SSURGO and NWI data.

Land use/cover, such as the NLCD or CLD, may be extracted if desired. Figure 5 shows the application of NLCD and CDL data to produce a times series analysis of changes in land use/cover within a riparian ecotone for 2001, 2006, 2007, 2008, 2009, and 2010 (Abood, 2011). All common NLCD and CDL classes are used. The CDL detailed crops classes were merged into the NLCD cultivated crops and pasture/hay classes as appropriate.

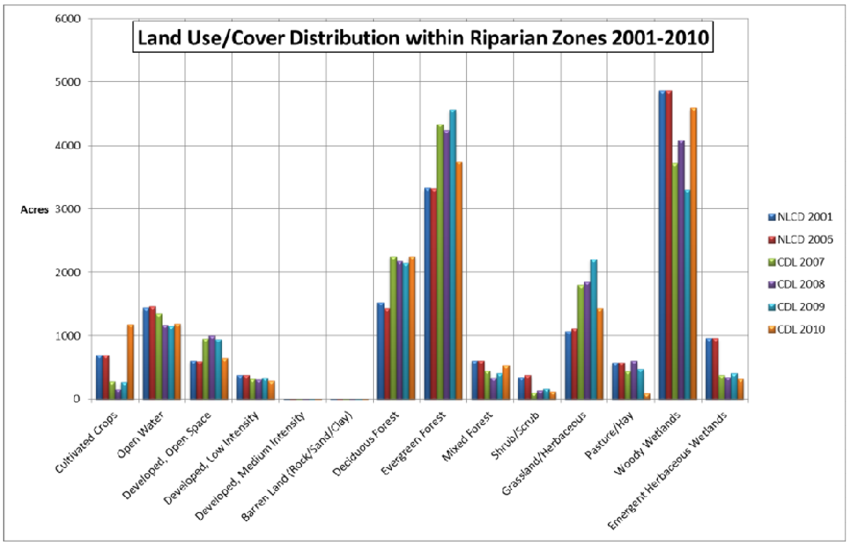

Figure 5. Land use/cover time series analysis within riparian ecotones boundary for the Michigan study area (from Abood, 2011).

DISCUSSION

The RBDM v2.3 can utilize up to nine inputs with three being required (50-year flood height, NHD streams and a DEM). Two inputs have a significant impact on riparian boundary delineation- the DEM spatial resolution and NHD positional accuracy. An accuracy assessment of varying DEM spatial resolutions (1m, 3m, 5m, and 10m) for the watersheds in Idaho shows an increase in riparian area as the DEM spatial resolution becomes larger with the 50-year flood height held constant (Table 2). The NHD reports a 40ft (13.3m) positional accuracy for its high resolution NHD streams layer (USGS, 2011). However, this does not hold true for all areas.

Two riparian ecotones are mapped utilizing the 50-year flood height (0.9m) and 1m DEM but with different stream networks, NHD streams versus delineated streams using ArcMap Hydrology toolset, for nine watersheds in Latah County, Idaho. An increase in riparian ecotones area is noted with NHD streams compared to streams produced via ArcMap Hydrology toolset (Figure 3) due to two factors. First, positional inaccuracies mean a wider range of elevations are included in the riparian delineation process along the stream course which reduces the impact of the 50-year flood height as a riparian hydrological descriptor. Second, the NHD streams were not delineated using a 1m DEM; hence the stream course is not as detailed or accurate. Therefore NHD streams positional inaccuracies are not reflecting the natural meandering nature of free flowing streams and rivers (Rosgen, 1996).

Table 2. Changes in riparian area for the nine watersheds in Idaho with varying DEM spatial resolutions.

	1m DEM	**3m DEM**	**5m DEM**	**10m DEM**
Overall Riparian ecotones, Acres	6176.75	7328.13	7550	836684
% of watershed area	7.65	9.07	9.35	10.36

CONCLUSIONS

The RBDM v2.3 is a robust automated GIS model attached to ESRI ArcMap as a toolbox that delineates riparian ecotones accurately. New enhancements from the RBDM v2.0 developed by Abood *et al*., (2012) are introduced. Selecting specific streams by attributes optimizes the delineation process of the riparian buffers and decreases the computational time. Increasing the transects vector distance to 3000m increases the area sampled around the stream and increases the accuracy of mapping extended riparian ecotones especially in lowlands and agricultural areas.

Utilizing the NWI data and digital soils data (SURRGO) as additional parameters takes into consideration that adjacent wetlands and riparian soils can extend outside of the floodplain boundary and need to be included in the mapped area.

Incorporating land use/cover data such as NLCD and the CDL produces a riparian ecotone with additional attribute information to assist resource managers and decision makers in monitoring land practices within the ecotone.

The current model has a variety of inputs and variables that can affect mapping accuracy. Two important variables that impact the final delineated riparian ecotone are the DEM spatial resolution and the NHD streams positional accuracy. The model can incorporate DEMs with a high spatial resolution such as those generated from LIDAR. An assessment of NHD streams positional inaccuracies shows the impact of inherited error on the final delineated riparian ecotone boundary and must be taken into consideration.

The updated model introduces a new delineation approach. This approach recognizes the dynamic and transitional nature of riparian ecotones by accounting for hydrologic, geomorphic, and vegetation data as inputs in the mapping process of riparian zones or ecotones boundary. Furthermore this approach incorporates land use/cover data, if desired, within the mapped riparian boundary to help decision makers in monitoring and conservation efforts within riparian ecotones.

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