Forest Riparian Buffers and Water Quality

The role of forest riparian buffers on water quality is a topic that I am interested in as I pursue my training as a hydrologist. Access to portal water and sanitation is essential for life; the importance of this is reflected in its adoption in a UN Human Rights Council Resolution in 2010. Prior to the ratification of this international resolution, individual countries have had their own legislation, such as the Clean Water Act in the U.S or regional legislation like the EU’s Water Framework Directive, that protect water resources. It is for this reason that 6 journal articles from different countries, namely USA (2), Canada, Brazil, Austria and Trinidad were selected to investigate how GIS and Remote Sensing are used in forest management. It was decided to focus on riparian forest buffers to due abundance of research regarding their abilities to mitigate non point source pollution and thus improving water quality. Another equally important purpose that these buffers also have is habitat conservation; they increase the diversity of aquatic and plant species as well as the animals that shelter in trees.

There were similarities in the use of geo spatial data in the reviewed articles. Firstly, the most common recurring theme is using GIS and Remote Sensing to make accurate maps of land use and land cover. As the saying goes, a picture speaks a thousand words. For example, in their case study investigating conflicts in land use between timber harvesting and conservation, Greene et al. (2010) called the use of geo referenced data geo visualization. Using Landsat imagery, ArcGIS and MCDAS (an application developed using Microsoft Visual Studio 2008 with C# programming language that works on the ArcGIS platform), were used to produce maps in order to decide where to harvest time based on ecological, social and economical factors. These factors are also known as the triple bottom line. They are equal components of an Ecologically Based Management (EBM) plan as it would not be sustainable to focus on ecological conservation and ignore the other two criteria or vice versa. Multiple Criteria Decision Analysis System (MCDAS) is like a site suitability study, it was used to evaluate a range of considerations in order to decide where to best harvest timber. The factors considered include stand age, height, species composition, and distance to production site, accessibility as well as other constraints such as protect areas and riparian zones.

In this particular case study, the decision making process involved representatives from the community, conservation groups, natural resource management agencies, and the timber industry. They ranked areas that they thought were priority, and based on the scores from ecological, social and economical importance, user friendly maps were produced that showed were timber could be harvested. Similar to a traffic light, green was use to so most suitable areas, orange areas that could be harvested with caution, and red for areas to avoid. This case is highlighted here because GIS & Remote Sensing were used to make accurate maps of a large area covering thousands of acres that facilitated communications between different land users. However, it should be noted that other journal articles also document the benefits of GIS/Remote Sensing to produce maps of land cover and land use which can be overlaid on top of each other. Overlays reduce the need for several paper maps and also save trees. Aerial photographs are also widely used in map production; they are scanned and classified into raster images, then converted into GIS vector data sets. Both Wine and Zou (2010) and Juman and Ramewak (2013) provide good examples in their studies of using aerial photographs to detect changes in land use and land cover.
The second common use of GIS and Remote Sensing revealed in the journal articles is modeling. Perhaps the example is from the journal article by Poepl et al. (2012). They used 1m resolution LiDAR-DTM and ArcGIS to produce sediment models of sediment overland flow paths. This concurs with what Chen (2000) described more than a decade earlier as a paradigm shift in hydrological modeling: using maps to show environmental attributes instead of using mathematical equations to show environmental process. Without modeling, it would have been difficult to effectively show how forest riparian buffers trap sediment.

Last but not least, all the journal articles illustrate how GIS and Remote Sensing are used to carry out a wide range of analyses such as calculating slope, distance, area, post-classification change detection, sediment flow and connectivity. Pie charts and bar graphs can be produced from these calculations. The benefits of doing multiple analyses over a large area, sometimes spanning several decades, are well documented by all the researchers.

I believe that we will see an increase in the use of GIS and Remote Sensing in forest management and watershed hydrology. Increase in population worldwide is putting pressure on land use and affects our most critical resource; water. Spatial analysis data is vital to produce sustainable management plans that balance conflicts in land use between ecological, social and economical needs. Half of the journal articles concluded that more research is needed to fully understand the impact of forest riparian buffers on water quality. There is no one size fits all buffer. Although regulations specify how far from the river and how wide buffer zones should be, more research is needed into their functionality. One of the problems with regulated riparian buffer zones is that they don’t take into account the heterogeneity of the landscape. In my opinion, GIS and Remote Sensing will be used to produce functional forest riparian buffers, by analyzing factors such as slope and species composition of the trees, which fit the needs of the end user instead of relying legally mandated forest riparian buffer zones that may not serve the needs of end users.
Annotated Bibliography


This paper focuses on how Landscape Ecology can help manage Nonpoint Source Pollution (NPS) in order to improve drinking water quality. NPS pollutants are difficult to manage because they are diffuse and they occur over a range of spatially heterogeneous landscapes. Although NPS pollutants can be natural, Chen is interested in human induced NPS pollutants because they make up the majority of NPS pollutants. In order to understand this, she investigates the interaction between people, land, and water. Since NPS pollutants are found across the entire ecosystem, information acquired at a fine scale in the field cannot be easily applied to a broader scale. This is how Landscape Ecology can assist in monitoring and controlling NPS pollutants: by showing how environmental systems interact across the heterogeneous landscape over time and space. Chen reviews how Landscape Ecology enhanced nonpoint source assessment by focusing on the implication of hierarchy theory on NPS monitoring and modeling. I particularly like the pioneering approach to hydrologic modeling by championing spatial hydrology (using maps to show environmental attributes) instead of the traditional approach (using mathematical equations to show environmental process). Chen shows that knowledge of environmental systems can be combined with GIS as part of a management strategy to reduce Nonpoint Source Pollution.


In this paper, Greene et al. used a case study from Corner Brook, a timber harvesting area in the province of Newfoundland & Labrador, Canada, in order to show how GIS can be used to resolve conflicts in land use between conservation and ecological development. From their study, I learned that Ecosystem Based Management (EBM) can also be applied in other situations where there is a conflict in land use because it fuses ecological, social and economic objectives. As well as presenting the advantages of using Landsat imagery and ArcGIS to produce overlays of maps to decide where to harvest timber in a forest that is thousands of acres, similar to a site suitability study, they also demonstrate how spatial analysis is under used. I like the solutions that they produce to increase the use of GIS: involve all stakeholders (communities, conservation groups, natural resource managers, and businesses) in the decision machining process and the development of user friendly analysis tool sets that do not require expert GIS training.


In this study, Wine & Zou analyzed a series of aerial photographs from different time periods, 1938, 1954, 1974, and1995, to create a mosaic of photographs in order to quantify landscape change. This was a cheap way of connecting changes in land cover to streamflow records since the data is publicly available. They reclassified these photos in order to ascertain if the expansion of forest riparian buffers led to a decrease in base flow. GIS analyses were performed on the historical aerial photos to monitor Land Use Land Cover changes in conjunction with USGS 10m resolution Digital Elevation Models (DEMs).
The photos were first scanned, and then maximum likelihood classification was used to show cells that were either forested or non-forested. These classified raster images were then converted into polygon vectors using ArcGIS 10.0. The researchers also used 2006 National Land Cover Dataset to produce accurate maps. Using a color ramp is an effective way to show forest cover changes in the study area, Council Creek Watershed, Payne County, Oklahoma. It is interesting to note that contrary to expectations, in this particular watershed an increase in riparian forest buffers did not result in reduced base flow. Although the study didn't validate the researchers’ hypothesis, it shows that more research is needed regarding the function of forest riparian buffers. Other factors, such as the gradient of the landscape and the species composition of the forest, need to be considered.


This is an extensive research investigation on the role of riparian forest buffers on sediment connectivity between the catchment area and river channel. Riparian forest buffers acting as sediments sinks is a very topical subject. According to the USDA, sediment is the most common and most easily recognized of the non point source pollutants. The authors take a complex problem, and address it step by step to answering key questions? How does vegetation cover type influence sediment entrapment? What are the biogeomorphic processes involved? The answer these questions using a combination of field studies and GIS analyses. Soil Erosion models, such as Water Erosion Prediction Model (WEPP) are used to analyze the effect of vegetation on sediment transport. The catchment area was delineated using Arc Hyro Tools 1.4 in ArcGIS from a 1m resolution LiDAR-DTM. Although they created conceptual models of sediment entrainment, transport, and accumulation, adding actual photographs from their field visits helps the reader connect the conceptual model to a real world context. Perhaps the greatest use of GIS and Remote Sensing in addition to carrying out a range of calculations, such as connectivity and slope, is producing maps modeling sediment overland flow paths. This is a comprehensive study of how forest riparian buffers and their roots act as sediment sinks thus improving water quality.


This paper examines Land Use Land Cover changes in a catchment in Trinidad spanning 65 years and highlights the importance of wetlands. This is a further example of how an increase in population leads to conflict in land use between conservation and balancing the needs of urbanization and economic development. Juma and Ramsewak used aerial photographs, satellite imagery produced by Ikonos and Landsat, and change detection analysis to create accurate maps. They used ER Mapper 7.0 to create a mosaic of aerial photos from different time periods: 1942, 1957, 1986, 1994, 2003, and 2007. It needs to be noted that a research study like this covering several decades covering a larger area couldn’t have easily been done without GIS and Remote Sensing. ArcGIS 9.3 was used to produce shape files of land cover class boundaries. These can be overlaid to visually see changes over the years. The spatial statistical function in ‘Spatial Analyst’ was used to calculate the area of each land cover class from the different time periods. This would be time consuming without GIS. The authors explain clearly a complex problem: rice cultivation and canals in the past diverted fresh water away from the wetlands which has resulted in the expansion of mangrove forests in marsh vegetation due to the intrusion of salt water. Although we can’t change past land uses, the study illustrated that the problem is human induced and provides an opportunity for further use of spatial analysis. It would be interesting to see if
GIS and Remote Sensing are part of the management tools for this catchment and if cost-benefit analyses are carried out unlike in the past.


Of all the papers reviewed, this paper had the least amount of GIS and Remote Sensing involvement. Although GIS was used to produce a map of the study area, it could have been used more extensively. For example, remote sensing imagery could have been used to produce more accurate maps of forest cover, especially since LiDAR has sub meter accuracy for elevation, and attribute tables in GIS can store a wealth of information about forests, such as species composition, stand age, height, etc. Nevertheless, the authors carry out a thorough investigation of riparian vegetation (which is widely researched) and riparian forest structure (which is under researched) and their impact on water quality. There is a clear break down of the water quality parameters that they used, such as electric conductivity, pH, dissolved oxygen, nitrate-N, ammonium-N, total N, total and dissolved phosphorus. They used spatial regression models in order to see if there was a relationship between stream habitats and water quality parameters. The study revealed that heterogeneous forest riparian buffers yield better water quality, it would be interesting to see if adding DEMs or LiDAR data will shed light on how slope affects the functions of these forested buffers.