Using GIS to Evaluate the Effect of Landuse on the Health of the Upper Trinity River Watershed

Mahendra Mahato

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Dr. Minhe Ji
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Introduction

Humans have caused serious negative impacts on aquatic habitat by both direct and indirect means. In direct ways, humans discharge raw sewage, chemicals, and other industrial effluents directly into water bodies. Indirectly, the landscape surrounding stream channels is modified due to agricultural, recreation, and overgrowth in urban areas. Land use patterns in a watershed influence the delivery of nutrients, sediments, and contaminants into receiving water bodies. Relationship between land use, levels of nutrients, and contaminants and condition of the biotic communities of receiving waters has shown by Allan et al. (1997). They suggested that increased nutrient loads are associated with high levels of agricultural and urban land use. Aquatic biotic communities associated with watersheds with high agricultural and urban land use are generally characterized by lower species diversity, less trophic complexity, altered food webs, altered community composition, and reduced habitat diversity (Fisher and Likens 1973; Conners & Naiman 1984; Roth et al. 1996; Correll 1997). Strong relationships have been reported between freshwater benthic invertebrate community condition and land use (Mangun 1989; Lenat and Crawford 1994). The positive relationship between stream macroinvertebrate community and forested land use has been reported by Richards and Host (1994) and Richards et al. (1996). Studies conducted by Johnston et al. (1990) and Osborne and Kovacic (1993) indicate that at smaller spatial scales, riparian forests and wetlands may ameliorate the effects of agricultural and urban land use

From above literature review, we know that there is very strong correlation between landuse pattern and water quality. GIS permits us to join and overlay all kind of database as well as image files for spatial analysis. Because of that GIS has taken momentum in scientific community to analyze environmental data and relate them with the landuse pattern. The related specific data are widely available through internet and can be downloaded for free. Since several researchers have shown relationship between landuse pattern and water quality, in this present project available date from upper Trinity River watershed area were analyzed to see if there is a relationship. My hypothesis was that as shown by other researcher in various watersheds, this upper Trinity River watershed will also show some short of relationship between water quality and land use pattern.

Methodology

Study Area:

This project was conducted on the upper Trinity River watershed catchment area. The Trinity River watershed begins in north central Texas and extends southeast into Galveston Bay on the Gulf of Mexico. There are several sections to the upper Trinity River. The main channel begins at the confluence of the West and Elm Forks in Dallas. Origination of the watershed and most densely populated region, the Dallas-Fort Worth Metroplex (pop. 3.5 million) lies within the upper portion of Trinity River. The detail map of the watershed is presented in Figure 1. The hydrograph within the Metroplex is controlled by local watershed runoff during storm events, wastewater treatment plant discharge, and releases from reservoirs. The latter two are the dominant influences during all periods. The Trinity has been described as a “mythological river of death” in the past. Sixteen fish kills have been documented downstream from the Metroplex since 1970, the last occurred in 1991 (TNRCC, 1996). Because this portion of the watershed accommodates both urban and agricultural land uses, it presents a very unique opportunity to study water quality. Improvements in wastewater treatment in the past twenty years have positively impacted water quality. However, surface runoff, insufficient treatment of wastewater effluent within the Metroplex and the use of fertilizers and pesticides continue to have negative impacts on the water quality and biota of the Trinity River (Dickson et al. 1992; Land and Brown 1996).

The effects of landuse on watershed health was analyzed using ArcGIS (ESRI, 2001). Trinity River basin boundary, counties within the study area, streams, and landuse data were downloded from North Central Texas Council of Governments (NCTCOG) web site (http://www.gis.dfwinfo.com) and elevation DEM shapefiles of these area were downloaded from USEPA Office of Water web site (http://www.epa.gov/ost/basins). Elevation DEM shapefiles were polygonal representations of the original USGS DEM raster files resampled to a 300m x 300m cell size. Water quality data were obtained from recent thesis research work conducted here at UNT (Stephenson 2000, Csekitz 1999). Sampling sites of their water quality study are presented in Table 1.

Table - 1

Site	Description
5	West Fork of Trinity River @ Old Randol Mill Road, Arlington
6	West Fork of Trinity River @ Precinct Line Road, Arlington
7	Elm FORK OF Trinity River @ West Beltline Road, Carrolton
8	West Fork of Trinity River directly below Trinity River Authority WWTP, Arlington

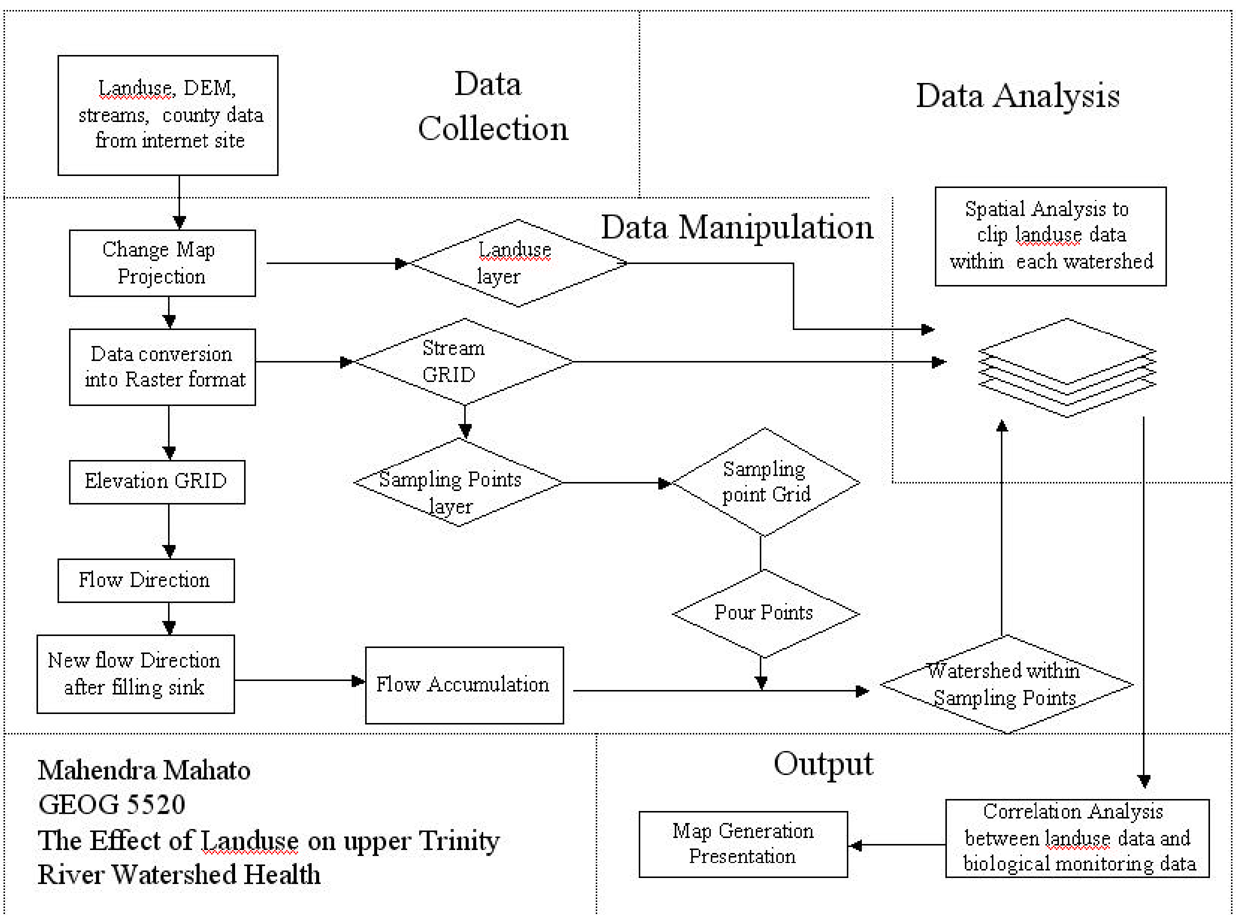
9	Trinity River @ South Loop 12, Sleepy Hollow Country Club, Dallas

All downloaded data were unzipped and projected according to the information presented in accompanied metadata. Later all files were projected into NAD 1983 UTM region 14 coordinate system. The detail steps of the data collection, conversion, process, and analysis process is presented in attached flow chart. First of all upper counties which includes Upper Trinity River Basin were selected from county layer of Texas. From this selection new county layer was created. This layer was used to clip stream layer from Texas stream shape file. Clipped stream was saved as a new stream layer and from this layer upper Trinity River was selected by using select by attribute function and was saved as new layer.

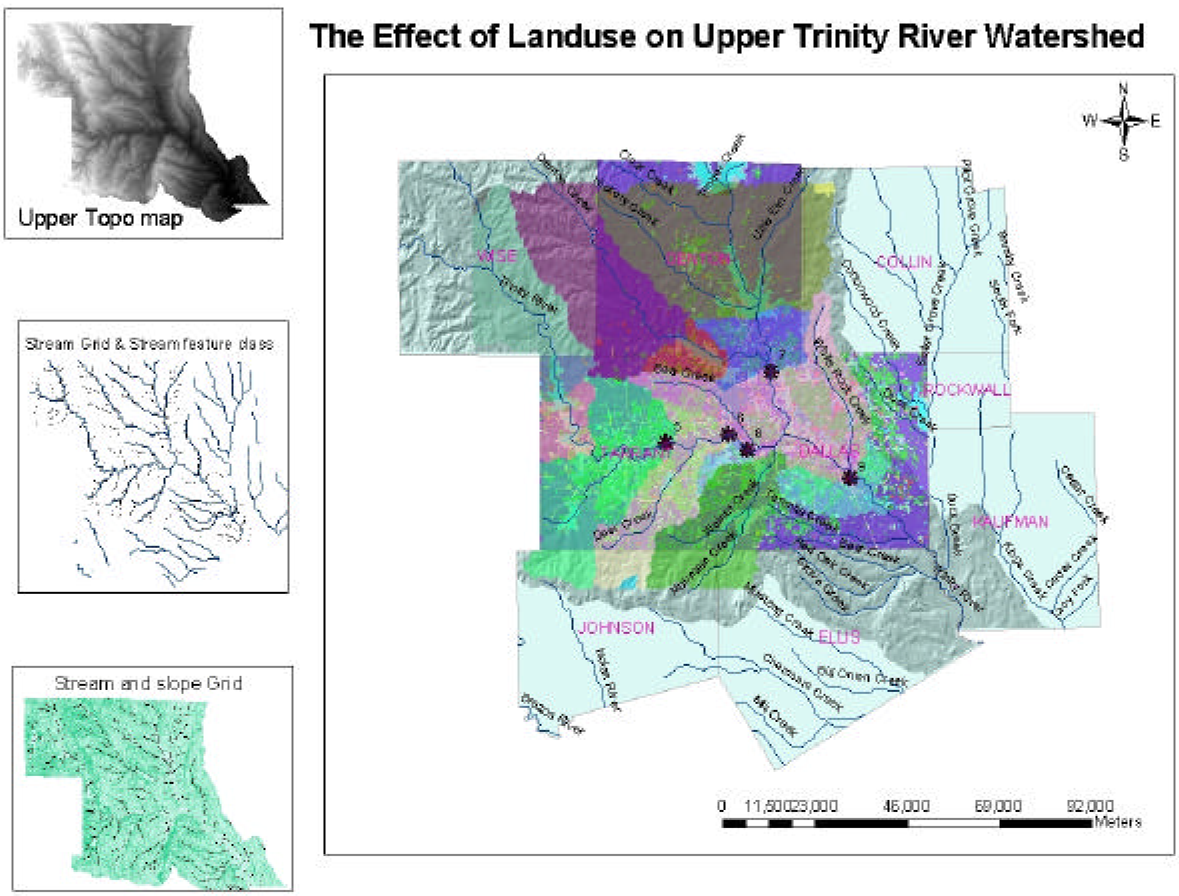
A new shapefile was created and sampling points were added in that file by using UTM coordinate information for each site on activated Trinity River layer. Coordinate values were obtained from USGS 7.5 Quad maps. Since all sampling sites were within Denton, Dallas, and Tarrrant counties, only land use data from these counties were downloaded from the Internet to make it smaller in size. These three shape files were merged in one file by using geo-processing tool. These land use shape files had only land use categories code, which was generated in 1995. A separate table was generated for these codes and their descriptions from the information obtained from metadata and were spatially joined with land use layer by using code key.

Similarly, several elevation DEM shape files for all upper forks of Trinity River were also merged by using same method and was saved as a new layer. Later upper county layer was used to clip this layer to trim out side data to make it small file. This trimmed layer for elevation and land use layer were later converted into raster for watershed and flow length processing and map presentation respectively.

Elevation raster layer was analyzed for hillside, slope, aspect, and flow direction by using spatial analysis. From flow direction raster layer sinks were calculated by using raster calculator. Later sink depth was calculated by following series of steps and the maximum sink depth was used to fill the sink and to calculate new flow direction raster. This procedure was done by using Arc. Flow direction is often used to analyze accumulative impact along the river channel. This new flow direction was used along with aspect to calculate flow length which is often used to create distance-area diagrams for hypothetical rainfall/runoff events using the aspect as an impedance to movement downslope.



Similarly this new flow direction was also used to calculate flow accumulation. As suggested Djokic and Zichuan of ESRI, the highest flow accumulation value was divided by 500 to get the threshold flow accumulation value. This value was used to calculate stream grid. Later watershed raster grid was calculated by following series of steps. However this watershed layer was not used for comparison. Since I had water quality data from specific points, these points were used as the pour points to create watershed for those sampling points. In order to accomplish this task, I converted sampling point shape file into raster grid. Later sampling site point was snapped to flow accumulation grid. The snappour function in raster calculator was used to snap sampling point with the flow accumulation grid. This function is used to ensure selection of points of high-accumulated flow when delineating drainage basins using the watershed function. Snappour code searches within snap_distance around the specified pour points for the cell of highest accumulated flow, and move the pour point to that location. I used 2000 as a snap distance. This new grid was used as a pour point grid to calculate watershed grid. This new watershed raster grid was later converted into feature class. This new feature layer was used to clip landuse layer for that specific watershed by using intersection function in geo-processing tool. Clipped landuse feature layer was specially joined with sampling point feature layer by using spatial location function. From attribute tables land use data for each sampling site was exported to each individual database. This extraction was done by using select by attribute function. Later percent of each landuse categories was calculated. Total area of major land use categories were used to do correlation coefficient analysis to compare with biological monitoring data to see any relationship between them. The buffering method of sampling site was not used. Since buffer is a ring around sampling point, for this kind of analysis buffer method is not applicable. Because in streams water quality is impacted by upstream condition but not with downstream condition. Also other disadvantage of using buffer zone is that by changing the buffer area surrounding the water body may alter land use compositions in subcatchments and regional catchments and may affect study results.



Results

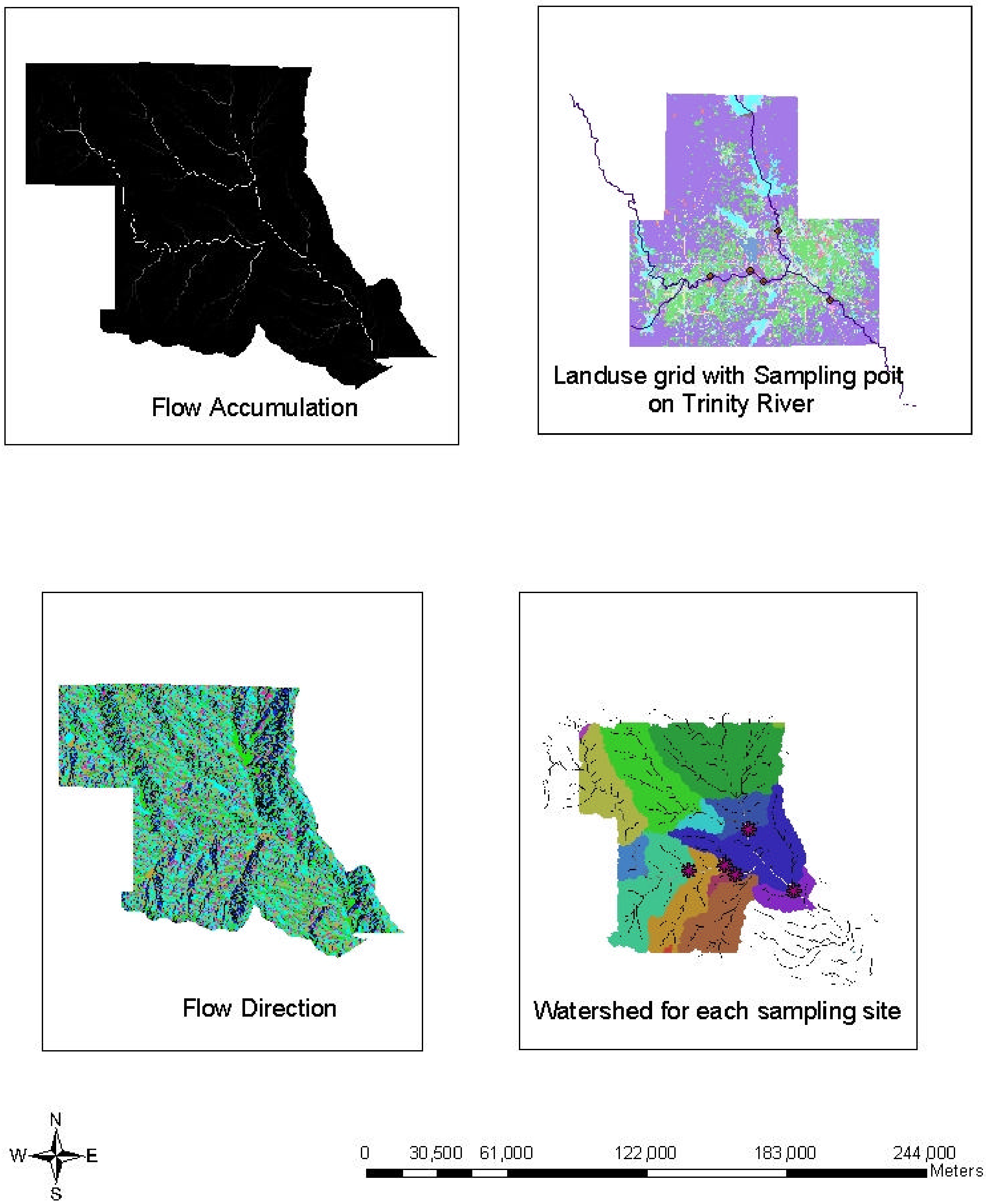
Water quality and benthic bio-monitoring data obtained from above mentioned thesis are presented in Tables 2.. This tabulated data indicate no particular trend or relationship between water quality data and biological data. Site 8 and 9 were located just after west water treatment plant but had higher corbecula mass gained and shell growth than other sites. It was also noticed that many different kind of organisms were present at site 7 and 8 than others.

Watershed generated from GIS manipulation for all sampling sites are presented in Figure 2 and 3. Land use clip data for each watershed were extracted in database. These extracted land use categories were converted into percentage for site and are presented in Table-3. Data from this table indicate more than 50% land as a vacant category at site 5 and 6, These sites are located north east of Fort Worth Metropolitan area. Site 7 has very low percentage of family housing area. Total area of land use by different categories is presented in Table-4. Even though relatively higher percentage of industrial area was within site 7 and 8 watersheds, actual area is smaller because of larger watershed area. Species richness was higher in those sites than any other sites. Since vacant, housing, and industrial landuse categories represented higher percentage of landuse category, these data were used in correlation coefficient analysis with biological monitoring data and the results are presented in Table 5. Data indicate higher negative correlation for species level richness and diversity indices for all three landuse categories.

Table 5 Correlation Coefficient for major land use categories

	Vacant	**Housing**	**Industrial**
Shell Lenth Growth	0.37	0.41	0.27
Shell Width Growth	0.38	0.44	0.27
Mass Gained	0.42	0.44	0.33
Density	0.18	0.17	0.16
Richness (Genus)	0.72	0.68	0.74
Richness (Species)	0.8	0.81	0.76
Diversity (Genus)	0.64	0.64	0.56
Diversity (Species)	0.8	0.87	0.69

Effect of Landuse on Upper Trinity River Watershed



Discussion

Recently GIS has been widely used in watershed monitoring research work. As discussed in introduction section, in some study scientist have found association between biological data and land use pattern and some studied no association was found. I used Csekitz (1999) and Stephenson (2000) water quality and biological data to perform watershed analysis. They used a 500-meter radius from sampling site to get land use data and they did not find any association. I took different approach. I used DEM file and created stream, flow direction and flow accumulation and used sampling points as a pour points to create watershed. In my approach there was negative correlation between major landuse pattern and species richness and diversity. Higher the area of vacant land, urbanization and industrial area lower the species diversity and richness.

Conclusion

Watershed created by GIS analysis for investigated sampling sites to clip land use data did show some association between land use and biological monitoring data. It looks like watershed approach makes more sense than using buffer area around sampling sites. The original data collector used buffer approach and they did not find any association but in my watershed approach association was detected.

I had also downloaded stream data from internet and tested with streamline created from DEM layer. They did not exactly overlap on each other which is also presented in one of the figure. Sampling points were created on stream layer and was later snapped in flow accumulation layer. So I am not sure which streamline is correct.

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