Comparing local land use to water quality in Upstate South Carolina

Sadie Perrin

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River Basins Research Initiative

FURMAN

Abstract

In this study, I wanted to determine whether local land use has an effect on water quality. I combined water quality data with the local land use by county, and I used ArcGIS to look for patterns between these factors. I found that there is a marginally significant positive correlation in percent forested land within a watershed and water quality. There are also trends in the increase of pastured or developed land and lower water quality, although this is not demonstrated by a significant correlation.

I. Introduction/Literature Review

Many studies have shown the interactive effects of local land use and water quality, particularly the effects of urbanization on the biotic factors of streams. Freedman et al. (2013) found that the large scale human manipulation of the environment significantly affects watershed health. Biological diversity in river systems is closely tied to the multiple scales of land use (Allan 2004). These scales include small spatial scales, such as individual river or stream channels or the area within a hundred meters from a stream, or larger landscape scales, such as the surrounding topography, geology, or other biotic and abiotic factors (Allan 2004). This large scale views of riverscapes, namely the investigation of the entire watershed, provides a more accurate picture of the overall diversity and local stream conditions in an area (Allan 2004).

Several studies have promoted the idea of using GIS database to compare land use to stream habitat quality in watersheds (Richards and Host 1994; Baker et al. 2001). GIS models can provide information on large scale land use patterns in a form that is easily accessible to a wide audience (Baker et al. 2001).

Water quality can be quantified by a variety of factors, but the Index of Biotic Integrity (IBI), as developed by Karr (1991) has been shown to be one of the most important and all-encompassing factors that determines the health of a stream. This index is a measure of many attributes of the local fish community, including fish species composition and relative abundances. Twelve attributes of fish communities are rated with a number (5,3, or 1), and the sum of these values provides the IBI. These IBI values range from 0-60 with anything over 48 representing a stream with "good" species richness, integrity, and fish abundances. (Karr 1991)

Our study hoped to find patterns between local land use, particularly rural land use, and water quality in upstate South Carolina. We chose to analyze land use and water quality at the watershed level, making the assumption that the water quality tested at one site is influenced by the entire watershed upstream of that point.

II. Methodology

- Used cropland data layers (CDLs) for counties in upstate South Carolina (Abbeville, Anderson, Greenville, Greenwood, Laurens, Pickens, and Spartanburg counties) provided by USDA CropScape (http://nassgeodata.gmu.edu/CropScape/; 2012)
  - CDLs are 30 meter resolution raster layers produced from satellite imagery taken during the current growing season from the following sources: the Landsat 5 TM sensor, Landsat 7 ETM+ sensor, and the Disaster Monitoring Constellation (DMC) DEIMOS-1 and UK2 sensors (Han et al. 2012).
- Used 2012 water quality data provided by Furman RRBI study, collected by Dr. Haney and students
  - Water testing sites were in the upstate of South Carolina and consisted of the following: Broad Mouth Creek (BMC01), Craven Creek (CC02), Martin Creek (MC58), PRS01, Rabon Creek (RA), Turkey Creek (TUC02, TUC03, TUC04), Upper Saluda (SR15A).
- Generated watershed shapefiles from WMS 8.4 for area upstream of each water testing site
- Overlaid watershed shapefiles over CDLs
- Used watersheds as masks to determine the proportion of land use within each watershed
- Correlated land use data to local water quality values for each site and associated watershed
  - Used Spearman's Rank Correlation for non-parametric data

Table 1. Index of Biotic Integrity (IBI) scores and associated attributes of stream (Karr 1991).

Total IBI score (sum of the 12 metric ratings)*	Integrity class of site	Attributes
58–60	Excellent	Comparable to the best situations without human disturbance; all regionally expected species for the habitat and stream size, including the most intolerant forms, are present with a full array of age (size) classes; balanced trophic structure.
48–52	Good	Species richness somewhat below expectation, especially due to the loss of the most intolerant forms; some species are present with less than optimal abundances or size distributions; trophic structure shows some signs of stress.
40–44	Fair	Signs of additional deterioration include loss of intolerant forms, fewer species, highly skewed trophic structure (e.g., increasing frequency of omnivores and green sunfish or other tolerant species); older age classes of top predators may be rare.
28–34	Poor	Dominated by omnivores, tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.
12–22	Very poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.
⋯†	No fish	Repeated sampling finds no fish.

*Sites with values between classes assigned to appropriate integrity class following careful consideration of individual criteria/metrics by informed biologists.

† No score can be calculated where no fish were found.

III. Results and Discussion

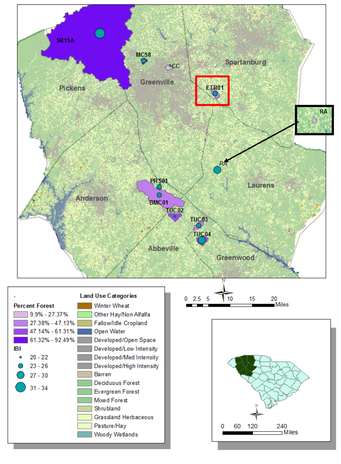

Figure 1. Patterns between the percent of forested land within each watershed (purple areas) and the water quality at each site, measured by Index of Biotic Integrity (IBI) values. See zoomed in land use of ETR01 watershed (red inset) below.

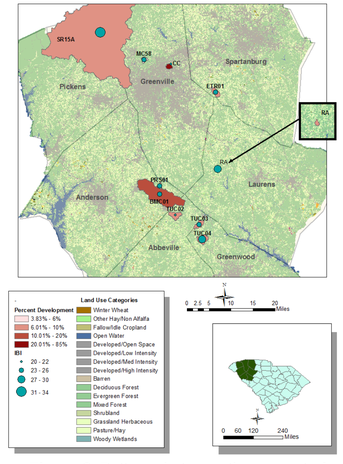

Figure 2. Patterns between the percent of developed land within each watershed (red areas) and the water quality at each site, measured by Index of Biotic Integrity (IBI) values.

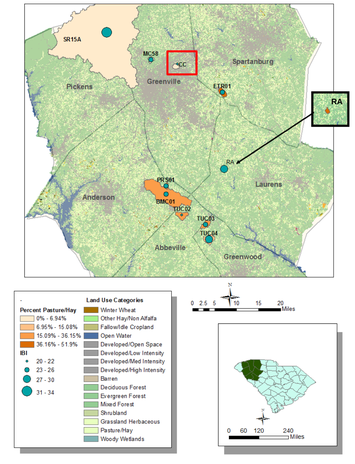

Figure 3. Patterns between the percent of pasture/hay land within each watershed (orange areas) and the water quality at each site, measured by Index of Biotic Integrity (IBI) values. See zoomed in land use of CC watershed (red inset) below.

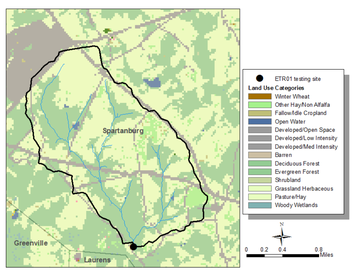

Figure 4. Local land use within Enoree Tributary watershed (ETR) upstream of water testing site (ETR01). This represents a watershed with a high percentage of pasture. IBI value: 22

Streams with forested land cover (top) and pasture land cover (bottom)

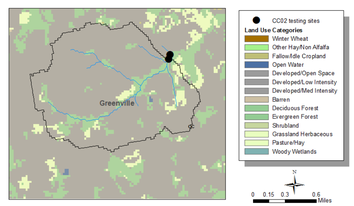

Figure 5. Local land use within Craven Creek watershed (CC) upstream of water testing site (CC02). This represents a watershed with a high percentage of developed land. IBI Value: 20

Site	IBI	% Developed	% Cropland	% Hay/Pasture	% Shrubland/Grassland	% Water/Wetland	% Forest
BMC01	22	11.65	1.56	29.53	9.44	0.69	47.13
CC01	20	84.77	0.02	3.20	1.37	0.12	9.90
ETR01	22	9.13	0.37	50.78	2.67	0.33	36.72
MC58	22	3.83	1.30	0.83	1.04	0.52	92.49
PRS01	26	6.87	2.63	24.04	14.54	0.56	51.37
RA04	20	6.95	0.96	51.90	12.83	0.00	27.37
SR15A	34	6.48	0.13	6.94	5.62	1.31	79.52
TUC02	20	7.52	1.78	28.06	9.41	0.28	52.95
TUC03	26	8.44	0.15	36.15	10.48	0.29	44.49
TUC04	28	7.28	0.07	15.08	16.17	0.10	61.31

Table 2. Index of Biotic Integrity (IBI) and percentage of local land use of surrounding watershed for each water quality testing site.

IV. Conclusion

- There is a marginally significant positive correlation between the percentage of forested land within a watershed and the local stream IBI (ρ=0.5547; p=0.0960).
  - This positive correlation is further shown by the patterns between higher percentages of forested land within a watershed and high IBI values shown by our land use model (Figure 2).
- There is no significant correlation between pasture or developed land use and water quality (p>0.01).
  - However, both of these tests show a negative trend of the data; as developed or pastured land increases, IBI often decreases.
  - Our maps also demonstrate the patterns between high percentages of pastured or developed land within a watershed and low IBI values (Figure 1 and 2).
- Our data also demonstrates the overall poor water quality of streams in Upstate South Carolina. All IBI values are less than or equal to 34, placing them in the "poor" or "very poor" categories for stream health and diversity. This fact alone should prompt landowners and environmental organizations to protect the remaining forested land within watershed areas.

V. Future Research

- Further studies could compare the trends in land use and water quality across time, comparing current land practices to historical land practices. The particularly low IBI values we found may be the result of not only present-day land use but of intense farming in years past.
- Further studies could also compare local water quality to other abiotic factors, including soil types.
- Due to the effects of pastured land on water quality, further studies could also investigate the types of farm animals raised in these areas. The production of cattle, poultry, or hogs may have alternate effects on water quality.

VI. Acknowledgements

I would like to thank the following for help on this project: River Basins Research Initiative, Dr. Dennis Haney, David Brendle, Megan Chapman, and Mike Winiski.

VII. Data Sources

- **Figure 1-5 Data Sources:** 1) USA County shapefile from ESRI and US Census Bureau, 2) 2012 Cropland Data Layers for each county from USDA CropScape (http://nassgeodata.gmu.edu/CropScape), 3) Water testing sites and stream layers provided by Dr. Haney and David Brendle, created for RBRI studies, 4) Watershed shapefiles created using WMA 8.4 by Dr. Haney and David Brendle, 5) 2012 water quality data provided by Dr. Haney and David Brendle from RBRI study

***All maps created with Environmental Systems Research Institute (ESRI) ArcDesktop 10.1.

VII. References

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