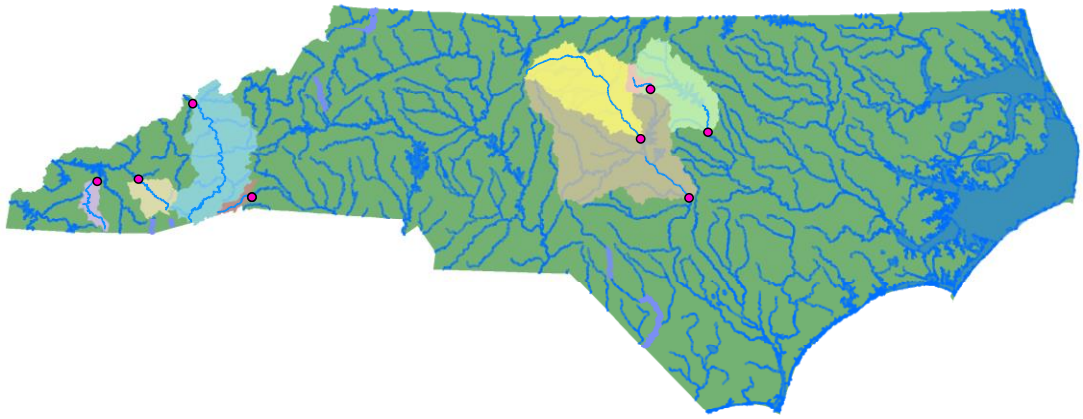
Measuring watershed alteration with land cover data

Using land cover and other data to compare levels of anthropogenic alteration across space and time in eight watersheds in North Carolina



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Introduction

One of the things that attracts people to North Carolina is the lure of outdoor recreation. Whitewater paddling is joining hiking, biking, and fishing as a popular activity among tourists and locals alike (Beedle 2008). The suitability of rivers for paddling by kayakers and canoeists enjoying this growing sport is extremely sensitive to changes in flow regime and water quality. Both of these variables are shaped in part by different human activities that take place within the rivers' watersheds. Just how altered are the watersheds of rivers used for recreation? How has alteration changed over time? This paper will explore the alteration rankings and levels of the watersheds of eight North Carolina rivers popular with paddlers. First, the watersheds, analyzed and ranked based on levels of human alteration. Then, the alteration of the watersheds as seen in land cover data from 2011 is compared with data from 2001 to examine change over time in watershed alteration.

The eight rivers focused on in this paper were chosen from a list of the most popular paddling destinations in the state (Beedle 2008). This paper will examine the Cape Fear, Eno, French Broad, Green, Haw, Nantahala, Neuse, and Tuckaseegee Rivers (see Appendix A for a labelled map). Some of these rivers are quite large, but all watersheds are delineated from a point known to be the most popular place to paddle [American Whitewater]. The points are either at standing waves or water features known as "play holes" or at the takeout of the most commonly paddled section of river.

Spatial Analysis of Watershed Alteration

In order to rank levels of alteration, a method of an ecological study of streamflow was used (Carlisle 2010). In a study to test the accuracy of models for predicting natural streamflow, Carlisle wanted to find only the least altered, most pristine watersheds and see if their actual flow regime matched what the models predicted (Carlisle 2010). In order to find the least altered watersheds, he compiled information on land use, dams, roads, water conveyances, like channels or pipelines, and

major dischargers like wastewater treatment centers. This indicators in Table 1 were calculated for each of the eight watersheds (see Appendix B).

Table 1

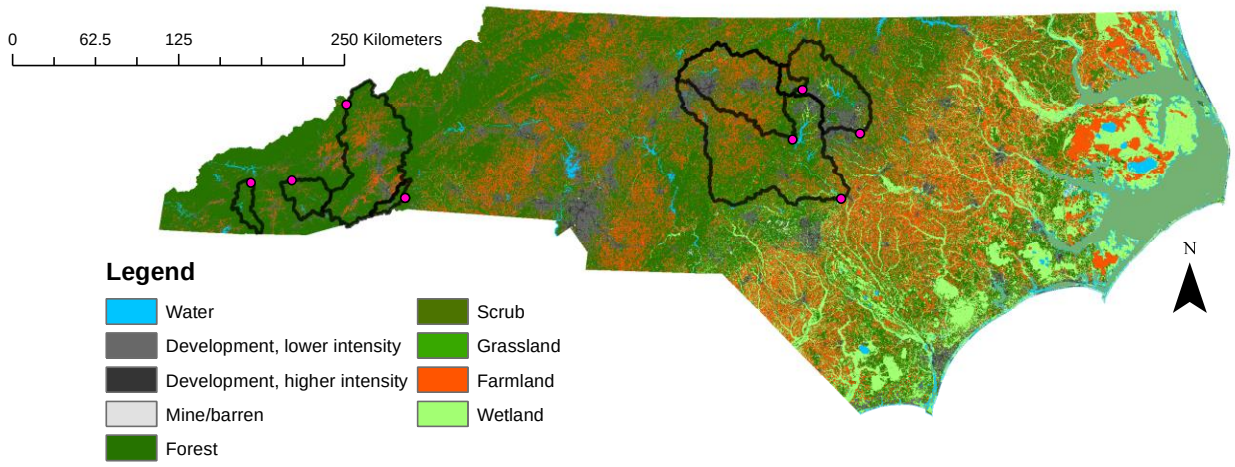
	Indicator
Land Cover	Percent urban, entire watershed
	Percent urban, 600m buffer of main stream
	Percent agricultural, entire watershed
	Percent agricultural, 600m buffer of main stream
	Percent mining/transitional land, 600m buffer of main stream
Dams	Density of dams in basin
	Linear distance from point to nearest dam
	Number of dams divided by mainstream length
Roads	Road density in basin
Water Conveyance	Percent of total streamlength rated “Canal” or “Pipeline”
Dischargers	Linear distance from point to nearest major discharger

The 2011 National Land Cover Dataset was used to determine land uses. Cells with the value 23 (“Developed, medium intensity,” with 50%-79% impervious surface cover) and 24 (“Developed, high intensity,” with 80%-100% impervious surface cover) were considered urban. Cells with the value 81 (“Pasture/hay”) and 82 (“Cultivated crops”) were considered agricultural. The Spatial Analyst Reclassify tool was used to group similar values, and zonal histograms were produced based on the land cover raster’s overlay with the entire watershed and with a 600 meter buffer around the main stream. Alterations within this 600m buffer may have larger effects of the river than alterations elsewhere in the watershed as there is less vegetative and other area between the human activity and the river.

Map 1

North Carolina Land Cover

2011



An Excel file with spatial information about North Carolina's 5,659 dams was retrieved from the NC Division of Land, Energy and Mineral Resources. NC Department of Transportation and Department of Environment and Natural Resources provided data on roads and major dischargers, respectively. The road shapefile was clipped to find the total length in each watershed, but simple the Select by Location function was enough to find the number of dams in the watersheds. Information about water conveyance, like which sections of a stream are through a pipeline or artificial channel, was found in the Feature Type field of the NHDPlusV2 Flowlines data.

After all of the alteration indicators were calculated (see Appendix B), the watersheds were ranked from one to eight, with one indicating the lowest alteration level and eight the greatest. The eleven indicator rankings were added up for each watershed, and the resulting sum was considered each watershed's Alteration Rank, a figure with relative but not absolute significance.

Table 2

Watershed	Nantahala	Tuckasee-gee	Green	French Broad	Eno	Haw	Cape Fear	Neuse
Urban, basin	1	3	2	5	4	7	6	8
Urban, buffer	1	4	2	7	6	5	3	8
Agricultural, basin	1	2	3	4	7	8	6	5
Agricultural, buffer	1	5	3	8	6	7	4	2
Mine, buffer	5	3	1	4	7	2	6	8
Density of dams in basin	1	2	8	3	4	7	5	6
Distance to nearest dam	5	3	7	1	4	2	6	8
Dams/Mainstem	1	2	4	5	3	6	8	7
Road density, basin	1	2	7	5	3	8	6	4
Percent pipeline	8	7	3.5	3.5	3.5	3.5	3.5	3.5
Major dischargers	1.5	7	1.5	4	6	3	8	5
Alteration Rank	**26.5**	**40**	**42**	**49.5**	**53.5**	**58.5**	**61.5**	**64.5**

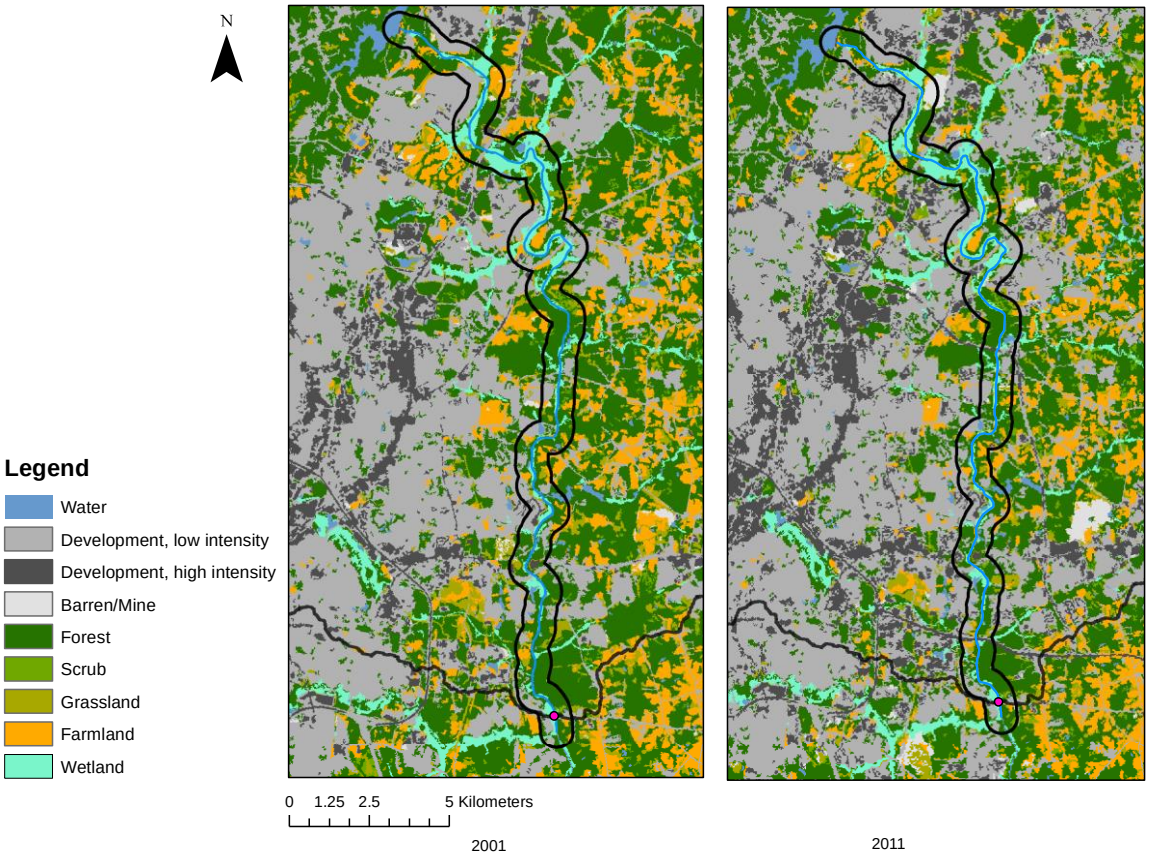
The Nantahala is the least altered, with a score of 26.5, while the Neuse watershed is the most altered at 64.5. These results are not very surprising. The four watersheds with the highest Alteration Ranks are located around North Carolina's Research Triangle, an urban conglomerate of Raleigh, Durham, and Chapel Hill. These watersheds are larger, flatter, and much more urban than the

watersheds of the rivers in the Western mountains of North Carolina. Human activities disturb the watersheds in the Triangle area much more than they do in the quieter Pisgah and Nantahala National Forests in Western North Carolina.

Temporal Analysis of Watershed Alteration

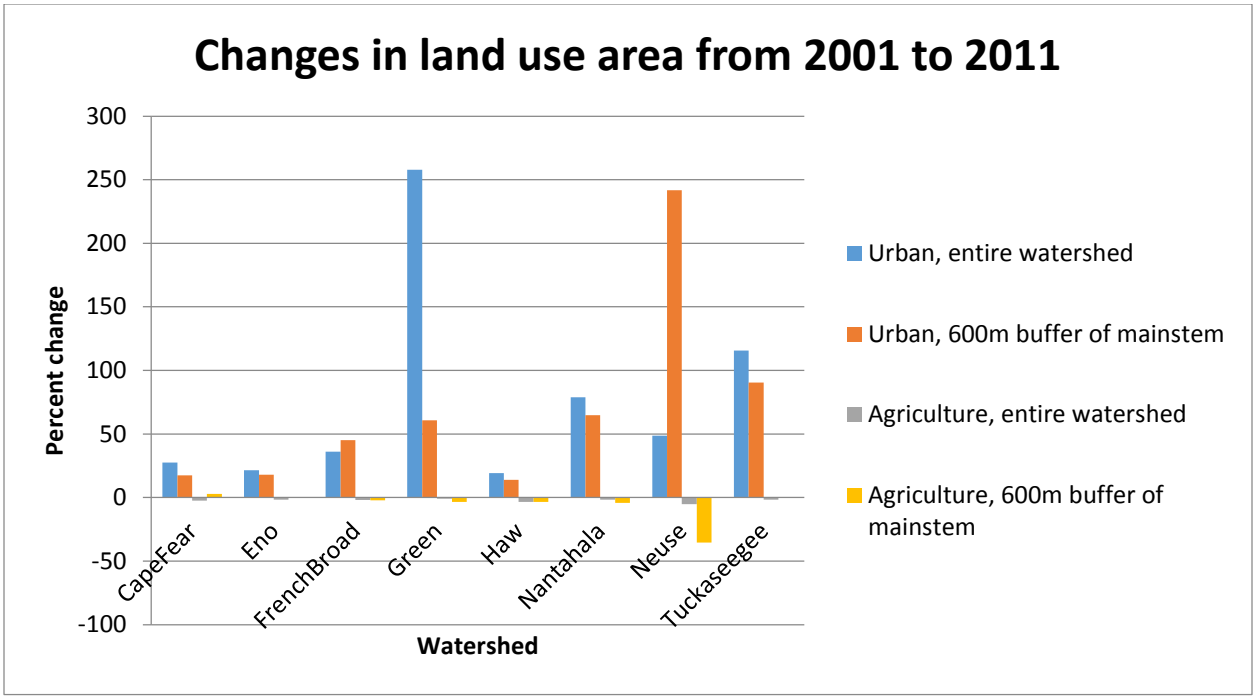
The results of the spatial comparison of the alteration of watersheds are interesting, but somewhat expected and not very helpful in getting the full picture of what is happening in these watersheds. In order to further explore anthropogenic disturbances of these watersheds, the alteration information gained from the 2011 National Land Cover Dataset was compared with the Reclassified results of the 2001 dataset. For example, Map 2 shows the 600 meter buffer area around the Neuse River. There is a notable decline in green cells, indicating forest, scrub, and grassland, and an increase in greys, showing development.

Map 2



The changes in land cover between 2001 and 2011 are even more evident when analyzed quantitatively. The zonal histogram tool was used to find the proportions of each watershed that were composed of specific land uses in 2001. These proportions were compared to the land use proportions in 2011, and the percent change in each proportion was calculated (see Appendix C). The results are also shown graphically in Chart 1.

Chart 1



Discussion

As seen in Chart 1, the trend for urban land use as a proportion of watersheds is up. The biggest increase in proportion urban in the buffer around the main stream is seen at the Neuse River. The area of land there classified as medium and high intensity development increased by 241.7% between 2001 and 2011. The Western rivers, especially the Green River, show large percentage increases in urban land in their watersheds. This does not, however, mean that these areas are being overrun by people and buildings. These mountain rivers, like the Green, had so little developed area to begin with that even small scale development increases, perhaps from rapidly growing nearby Hendersonville, amount to large percent increases in urban land.

These increases in the amount of urban land in the watersheds of the Nantahala, Tuckaseegee, French Broad, and Green Rivers are not good news for paddlers or anybody who wants to keep the less altered watersheds as natural as possible. However, a high percentage of the area of these watersheds is classified as “managed areas.” This land can be federally, state, or privately owned tracts and parks,

and a main goal of the land's management is conservation. For example, over 76% of the land in the watershed of the Nantahala River is part of the Nantahala National Forest, the Southern Appalachian Highlands Conservancy Tract, or some other managed area. Managed land does not mean that a watershed will necessarily stay unaltered; the US Forest Service does engage in some logging and other extractive activities that could affect land cover and the watershed. However, thanks to the protection of managed land ownership and easements, we are unlikely to see the vast areas of impervious surfaces that we get in the watersheds around the more urban region around Raleigh.

The results of this paper could be of interest to whitewater kayakers, paddling groups like the Carolina Canoe Club, and to other outdoor recreation groups with conservation aims, like American Whitewater. Such information about past and current watershed alteration could potentially be useful as one input for model that computes watershed restoration suitability, like the work John Lovette has done. This estimation of watershed alteration has been limited because a ranking system rather than a specific formula that weights different concrete variables. The "Alteration Rank" is purely relative, not absolute, and cannot be compared to anything outside of this small study. Another weakness of this paper's approach is the heavy reliance on Landsat images from the National Land Cover Database. This kind of data shows relatively permanent anthropogenic structures like high density of buildings, but does not reflect the human behaviors in a watershed that might also disturb it. The addition of information about population densities and the rates of usage of roads and other spaces would improve alteration estimates.

Future research building on this investigation of rivers important for recreation could include predicting natural flow regimes of these rivers; calculating the optimal conditions for paddling each major river; investigating the local economic impacts of recreational paddling; and researching the short and long term plans of dam operators, park managers, and municipalities vis a vis watershed development.

Knowledge gained from these areas could be used to formulate and suggest a feasible plan for land and water management that consider the interests of the paddling and outdoor recreation community.

Conclusion

Of the eight North Carolina rivers most popular with paddlers, the Neuse River has both the greatest degree of watershed alteration and the biggest increase in urban land near the main stream. Watersheds of rivers in the western part of the state- Nantahala, Green, Tuckaseegee, and French Broad- are less altered in terms of land cover, dams, roads, dischargers, and water conveyance than their counterparts in the Piedmont- watersheds of Cape Fear, Eno, Neuse, and Haw. Proportion of urban land in the watershed and the area near the main stream increased for all of the watersheds between 2001 and 2011. Overall, the watersheds of these rivers are being shaped by human activity, and further research with advanced models will be necessary to quantify for each watershed the effects on flow and water quality of these anthropogenic influences.

Sources

Beedle, Jennifer. (2008). Paddle Tourism Study *North Carolina State Trails Program*. North Carolina State University.

Carlisle, D.M.; Falcone, J.; Wolock, D.M.; Meador, M.R.; Norris, R.H. (2010). Predicting the natural flow regime: Models for assessing hydrological alteration in streams. *River Research and Applications*, 26:2 118-136.

Dam Inventory: NC Division of Energy, Mineral, and Land Resources

Discharger dataset: Planning Branch of the Division of Water Quality of the NC Department of Environment and Natural Resources

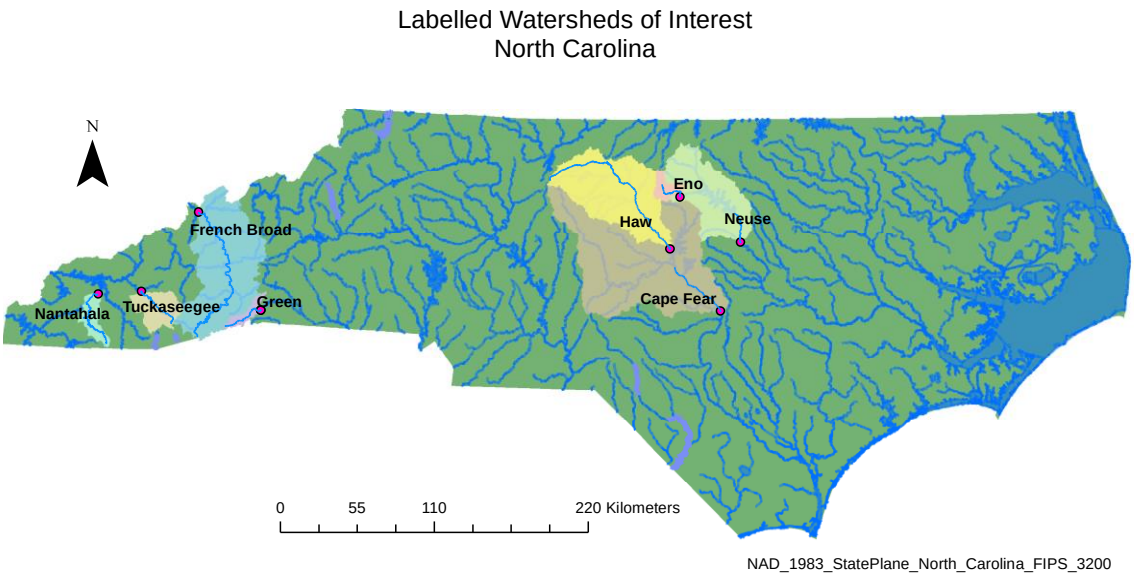
NHDPlusV2

NLCD 2001 and 2011: www.mrlc.gov

Road Characteristics Arc Shapefile Format: www.ncdot.gov

Appendix

A


Labelled Watersheds of Interest
North Carolina
N
French Broad
Nantahala
Tuckaseegee
Green
Eno
Haw
Neuse
Cape Fear
0
55
110
220 Kilometers
NAD_1983_StatePlane_North_Carolina_FIPS_3200

B

Alteration Indicators

Alteration Indicator	Cape Fear	Eno	French Broad	Green	Haw	Nantahala	Neuse	Tuckaseegee
urban area/basin area	0.026	0.013	0.013	0.002	0.035	0.000	0.043	0.002
urban area/buffer area	0.006	0.013	0.017	0.002	0.008	0.001	0.043	0.007
ag. area/basin area	0.216	0.216	0.126	0.076	0.272	0.006	0.143	0.038
ag. area/buffer area	0.059	0.085	0.265	0.050	0.176	0.009	0.043	0.080
mining area/buffer area	0.004	0.004	0.002	0.000	0.000	0.002	16761.000	0.001
Density of dams	0.093	0.074	0.064	0.148	0.130	0.014	0.122	0.039
distance (km)	3.266	4.489	6.179	3.151	5.078	3.361	2.682	4.947
# of dams/mainstem km	17.625	0.657	1.449	0.868	438/147.309	0.077	10.728	0.471
road length (km)/basin area (km^2)	1.508	1.048	1.243	1.537	1.701	0.413	1.093	0.793
length canal/total streamlength(km)	0.000	0.000	0.000	0.000	0.000	0.035	0.000	0.012

C

Change in Alteration Indicators between 2001 and 2011

River	% change urban, entire watershed	% change urban, 600m buffer of mainstem	% change agriculture, entire watershed	% change agriculture, 600m buffer of mainstem
CapeFear	27.5	17.4	-2.4	2.9
Eno	21.4	17.9	-1.6	-0.1
FrenchBroad	36.2	45.2	-1.9	-2.2
Green	257.9	60.7	-1	-3.4
Haw	19.1	13.9	-3.5	-3.4
Nantahala	78.9	64.8	-1.7	-4.3
Neuse	48.7	241.7	-5.3	-35.4
Tuckaseegee	115.6	90.5	-1.6	-0.1