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Watershed Impairment in Buncombe County, North Carolina: Impervious Groundcover Relations to Stream Degradation

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Abstract

Impervious surfaces negatively impact physical and chemical aspects of waterways. Buncombe County, NC has experienced urban growth in recent years and is expected to expand in the foreseeable future. The upper French Broad River (UFBR) watershed (which contains this county) and 14 of its subwatersheds were assessed for threats of water quality impairment based on the extent and rate of expansion of impervious cover in 2006, and the water quality of these systems was projected for 2030. With the use of ArcGIS mapping software, percent impervious groundcover was calculated. It was determined that, by the year 2030, Mud Creek would become degraded and that Hominy Creek, Swannanoa River and UFBR as a whole would become impaired due to the impervious surface cover, which will increase runoff, erosion and nonpoint pollution, harming the aquatic organisms. Further research using data over multiple years, perhaps also examining landuse history, is required to determine if the findings have significance. Management practices to increase forest cover and environmentally friendly urban development planning may help improve impaired streams and prevent environmental degradation in the future. Impervious cover is just one of many aspects of water quality that must be analyzed to determine the health of the whole watershed and could be useful for formulating restoration and preservation strategies.

Keywords: Watershed, Impervious Cover, North Carolina

1. Introduction

The population in Buncombe County, NC is on the rise and is expected to keep climbing in the next fifteen years.[1] Currently, there are estimated to be 258,706 people living in the area, an 8.30% increase in five years, and by 2030, that number is expected to reach 312,373.[1] Thousands are flocking to the county's largest population center, the city of Asheville, now listed as among the Top 20 mid-sized cities in the U.S. for year-over-year growth[2], contributing to a 43.5% increase in total new residential permits since 2014.[2]

While more inhabitants may bring short-term economic gains to the county, this growth negatively impacts the surrounding river basin, the upper French Broad River (UFBR) watershed. As the population rises, development in the area increases, which means greater land coverage by impervious surfaces—roads, buildings, compacted lawns and parking lots.[3, 4] Particularly troubling is that, due to the mountainous terrain in the area, most development is clustered in the less hilly valleys close to rivers and streams, even up to the banks in some areas.[3] When precipitation cannot permeate through the soil, it flows directly into surface waters as runoff. The more land covered by impervious surface, the more stormwater that enters streams.[3] While with natural landcover just 10% of precipitation escapes as

runoff, when 75%-100% of the land is covered by impervious surface that number jumps to 55%.[3] All it takes is 10% impervious surface coverage in a watershed to cause stream degredation.[3]

The objective of this study was to identify subwatersheds projected to have the highest increase in developed land by 2030, as these sites could be at risk for stream degradation in the future and may be in need of restoration and protection now. These findings could promote further research to create conservation strategies and encourage more environmentally friendly urban development projects in the UFBR watershed.

2. Methods

2.1 Study Area

UFBR, the Tennessee River's biggest tributary, cuts north through the Appalachian Mountains, crossing through a landscape comprised of igneous and metamorphic rock.[5] Its clear, cold headwater streams have low levels of productivity.[5] In general, the basin is mostly forested—76% according to NCDENR[3]—while the rest is used for agricultural, urban and industrial purposes, particularly in and around the city of Asheville, NC.[5] The watershed is home to the Federally Endangered Appalachian Elktoe Mussel (*Alasmidonta raveneliana)*, the Federally Threatened Bog Turtle (*Glyptemys muhlenbergii)*, and two Federal Species of Concern, the Hellbender Salamander (*Cryptobranchus alleganiensis)* and the French Broad Crayfish (*Cambarus reburrus*), all of which require clean, clear, stable streams.[3]

In 2014, sections of half the rivers and streams in this study were listed by the EPA as impaired, including Davidson River, French Broad River (FBR) headwaters, Ivy River, Mills River, Mud Creek, Newfound Creek and Swannanoa River.[6] The most common causes of impairment were ecological/biological integrity of the benthos and mercury in fish tissue, which affected 23.9 and 133.8 miles of the UFBR watershed's rivers and streams respectively.[6]

2.2 Study Design

Landuse was examined in UFBR and at 14 sites in the UFBR: Big Laurel Creek, Ivy River, Sandymush Creek, Flat Creek, Reems Creek, Newfound Creek, Swannanoa River, Hominy Creek, Cane Creek, Mills River, Mud Creek, Davidson River, Spring Creek, Little River and headwaters of the French Broad River. With ArcGIS spatial analysis software, UFBR site shapefiles were used to clip landcover information from two other shapefiles of the entire watershed: data collected in 2006 from the National Landcover Database[7] and data projected for 2030 by UNC Charlotte.[8] Both these shapefiles consisted of pixels arranged into three landuse categories: undeveloped (pervious surface), developed (impervious surface), and water (rivers, streams, lakes, etc.). Then, for each site in both shapefiles, the Attribute Table pixel data was exported.

2.3 Calculations

In the next phase of the study, Microsoft Excel was used to compare the increase/decrease of the three landuse categories between 2006 and 2030 found in the Attribute Table documents. From these data, increase and percent change in developed land coverage were calculated. Using NCDENR's stream degradation classifications for impervious cover, the sites were categorized based on their level of impairment: "degraded" (>30% impervious cover), "impacted" (10%-30%) and "protected" (<10%).[4] As many of the sites categorized as "protected" had rather high amounts of development (some over 9%) and were therefore more likely to see stream impairment in the future, this group was organized into "moderate risk" (5%<10%) and "low risk" (<5%).

3. Results

Table 1. Percent developed land coverage in UFBR and impairment status—degraded (D); impacted (I); protected, moderate risk (M); protected, low risk (L)—in 2006 and 2030.

	2006 (%)	Determined Impairment Status	2030 (%)	Projected Impairment Status
UFBR Overall	6.94	M	11.30	I
Big Laurel Creek	1.03	L	1.05	L
Davidson River	1.62	L	2.27	L
Flat Creek	10.99	I	13.98	I
FBR Headwaters	0.97	L	1.01	L
Hominy Creek	9.54	M	16.27	I
Ivy River	3.22	L	6.92	M
Little River	1.55	L	1.59	L
Mills River	1.96	L	3.11	L
Mud Creek	22.99	I	37.87	D
Newfound Creek	5.81	M	6.62	M
Reems Creek	6.28	M	9.12	M
Sandymush Creek	1.12	L	1.20	L
Spring Creek	0.35	L	0.38	L
Swannanoa River	8.84	M	15.04	I

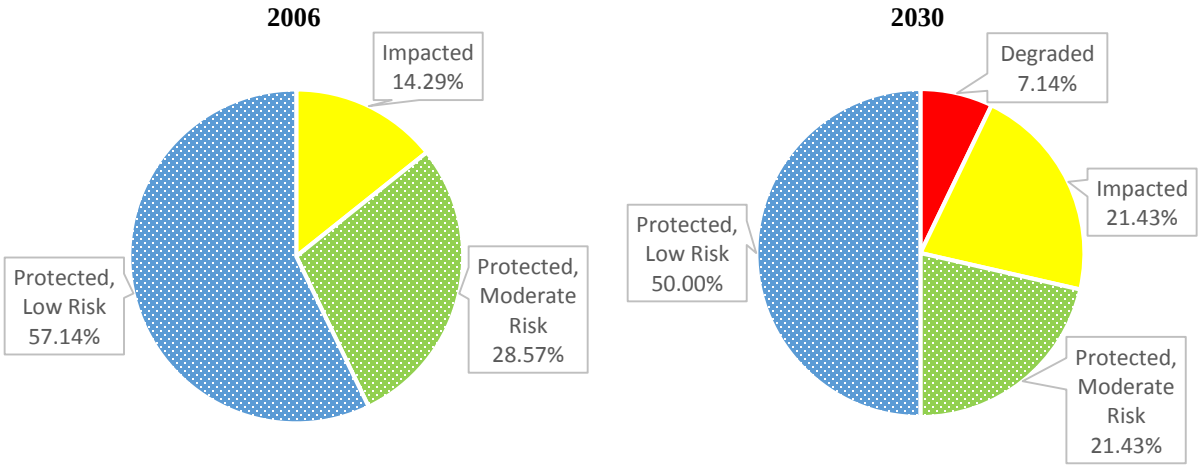

Figure 1. Impairment status of UFBR watershed sites in 2006 and 2030.

Figure 1 compares the impairment statuses of the UFBR sites in 2006 and 2030, illustrating how they changed over the years. Each segment illustrates what percentage of the sites fell into a given impairment category. Statuses include "protected, low risk," "protected, moderate risk," "impacted" and "degraded" (in increasing order of severity).

Table 2. Increase in developed land coverage in UFBR from 2006 to 2030, descending order.

	Increase in Developed Land Cover (%)
UFBR Overall	4.36
Mud Creek	14.88
Hominy Creek	6.73
Swannanoa River	6.20
Ivy River	3.71
Flat Creek	2.99
Reems Creek	2.84
Mills River	1.15
Newfound Creek	0.82
Davidson River	0.65
Sandymush Creek	0.08
FBR Headwaters	0.04
Little River	0.04
Spring Creek	0.03
Big Laurel Creek	0.02

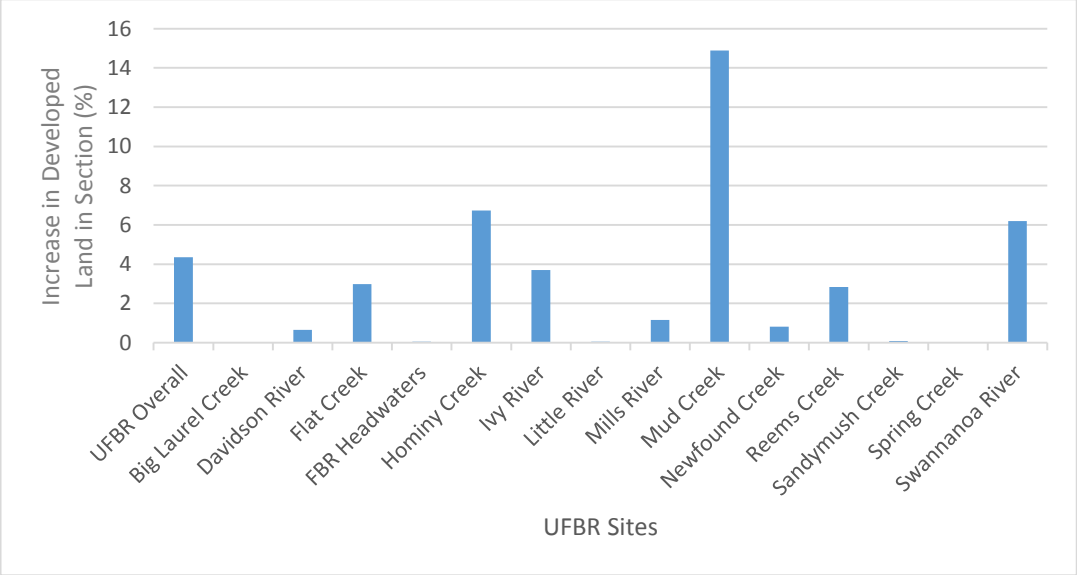

Figure 2. Increase in developed land coverage in UFBR from 2006 to 2030.

Figure 2 provides a visual display of the data presented in Table 2 above, illustrating how coverage of developed land in each section increased. Some percentages are too small to appear in the graph.

Table 3. Percent change in developed land coverage in UFBR from 2006 to 2030, descending order.

	Percent Change (%)
UFBR Overall	62.81
Ivy River	115.27
Hominy Creek	70.47
Swannanoa River	70.11
Mud Creek	64.74
Mills River	58.68
Reems Creek	45.19
Davidson River	40.02
Flat Creek	27.20
Newfound Creek	14.03
Spring Creek	9.00
Sandymush Creek	7.49
FBR Headwaters	4.56
Little River	2.66
Big Laurel Creek	1.98

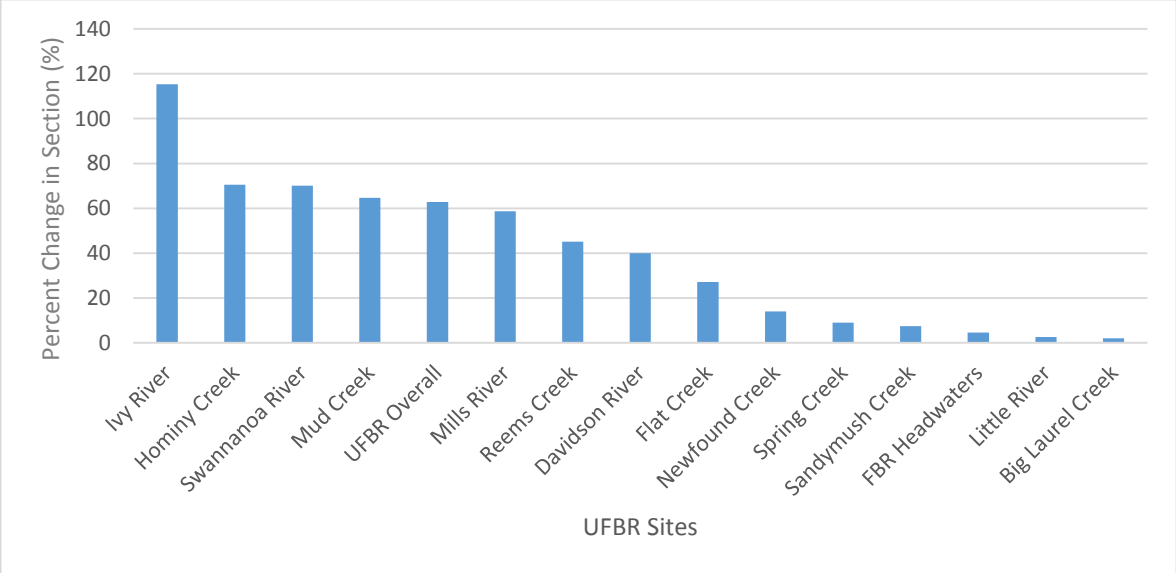

Figure 3. Percent change in developed land coverage in UFBR from 2006 to 2030, descending order.

Figure 3 provides a visual display of the data presented in Table 3 above. It illustrates the predicted change in developed land coverage expected for each site.

The data revealed that impervious cover increased at all of the sites. As shown in Table 1, in 2006, Flat Creek and Mud Creek had between 10% and 30% impervious surface landcover, qualifying them as impacted streams. Hominy Creek, Newfound Creek, Reems Creek and Swannanoa River had less than 10% impervious cover thus were protected, but with greater than 5% impervious cover, they are at moderate risk for impairment in the future—particularly Hominy Creek (9.54%) and Swannanoa River (8.84%). With 6.94% developed landcover, UFBR is also protected but

at moderate risk. By 2030, the number of impaired subwatersheds doubled (see Figure 1). As noted in Table 1, the impacted list is predicted to include the Swannanoa River and Hominy Creek in addition to Flat Creek, and at 37.87% developed landcover, Mud Creek will be upgraded to degraded. Ivy River will be protected at moderate risk along with Newfound Creek and Reems Creek (which, at 9.12% impervious cover, is most vulnerable). Overall, 11.30% of UFBR is predicted to be covered by impervious surface in 2030.

By 2030, UFBR is projected to see a 4.36% increase in developed land coverage from 2006 (Table 2 and Figure 2), a 62.81% change in a 14 year period (Table 3 and Figure 3). All UFBR sites showed a rise in development, with impervious landuse increasing on average by 2.97%. As shown in Table 2, the sites with the highest predicted increase in developed land were, in increasing order, Mills River, Reems Creek, Flat Creek, Ivy River, Swannanoa River, Hominy Creek, and Mud Creek—which, with a 14.88% increase, was over double that of the second and third highest increasing sites Hominy Creek (6.73%) and Swannanoa River (6.20%). (In ascending order) Davidson River, Reems Creek, Mills River, Mud Creek, Swannanoa River, Hominy Creek, and Ivy River had the greatest percent change (see Table 3). Ivy River was of particular concern, which, at a 115.27% predicted change in developed land coverage, more than doubled between 2006 and 2030.

4. Discussion

The data revealed that at least half of the sites at the UFBR watershed are in threat of becoming impaired in the next fifteen years, with four high risk sections predicted to be impacted or degraded and three others at moderate risk for impairment. Mud Creek, one of the two 2006 impacted sites, was predicted to become degraded. Half the moderate risk subwatersheds—Hominy Creek and Swannanoa River—had the second and third highest increases in impervious cover and percent changes respectively, and both were projected to be impaired by 2030. At the rate urban areas in UFBR (also moderately at risk) are expanding, the UFBR watershed as a whole is forecasted to be impaired within the next fifteen years as well. Though Ivy River had less than 10% impervious cover, because it had the highest percent change of all the sites and was listed as impaired by the EPA in 2014, efforts should be taken to restore and protect it, along with the sites mentioned above.

Studies have shown that the rate and sprawl of urban development are positively correlated with increased runoff volume.[9] This elevates flooding during rainstorms and reduces available groundwater during droughts.[3] Not only does more stormwater enter streams and rivers, but the quality of the water is also progressively degraded with increased impervious cover.[9] Pollutants such as nutrients, oil, grease, and heavy metals collect on impervious surfaces and wash into waterways during rainstorms.[9] Runoff also escalates erosion of stream channels and river banks, intensifying turbulence in waterways.[3] When stream and river habitats are physically and chemically transformed by these factors, this can be highly detrimental to endemic aquatic plants and animals, particularly to sensitive, threatened organisms.[3]

It is important to note that NCDENR's impairment classifications and the groupings of protected waters are merely guidelines for preventing stream degradation. To monitor the watershed as a whole, it is essential to examine pH levels, fecal coliform concentrations, and benthic macroinvertebrate assemblages along with other stream health factors to get a more accurate assessment of stream and river health that impervious cover alone cannot reveal. For instance, though the Davidson River, FBR Headwaters, Ivy River, Mills River and Newfound Creek—over a third of the sites—were listed as impaired by the EPA in 2014, none of them are projected to have 10% impervious cover by 2030, and Flat Creek had over 10% developed landcover in 2006 yet was not listed as impaired. Factors other than impermeable surface can contribute to impairment—perhaps the impairment of Davidson River may be due to recurrent sanitary sewer overspills at the area's collection stations.[3]

As the total number of pixels for the UFBR shapefile in 2006 (5,371,644) differed from the total in 2030 (4,987,189), it is clear that different measurements were used in the two studies. For the 2006 shapefile, each pixel represented 30 m^3, but the measurements for the 2030 projections were not provided. Having this information would allow for comparisons of the total difference in area between the sites, developing a clearer image for how much land is being developed. To determine whether or not the findings were statistically significant, data must be studied over a longer period of time. Additionally, looking at landuse history over the years may make for an interesting UFBR study in the future as changes in landuse type and intensity have been shown to affect water quality.[10]

A major reason impervious cover causes so many environmental problems in watersheds is due to the expansion of towns and cities impinging on the natural landscape, reducing forests and degrading habitats. Deforestation, forest fragmentation, and other land cover alterations have all been shown to reduce biodiversity in watersheds, particularly in endemic species.[11] Additionally, the less forest coverage in an area, the greater the erosion and runoff, resulting in nutrient loading in streams.[12]

One way to restore and preserve watersheds is to implement best management practices (BMPs) that apply urban forestry in riparian and street buffers.[13] Studies have shown that increased forest cover in watersheds leads to higher water quality,[14] and areas that have undergone reforestation have seen decreased nitrate and phosphate loading[12] as well as decreased sedimentation and runoff in their rivers and streams.[13] Additionally, BMPs revitalize groundwater and help the watershed adjust to harsh conditions like pollution and flooding.[12] Another way to protect watersheds would be to implement greener urban planning such as smart growth. This technique fosters condensed, environmentally sound development, and city-planning strategies like this helps reduce impervious surfaces in the watershed.[9]

The sites predicted to experience the most development should be managed and protected, as their ecosystems are likely to be the most impacted. These include Mud Creek, Flat Creek, Swannanoa River, Ivy River, Newfound Creek, Reems Creek and Hominy Creek. Additionally, recently impaired sites, Flat Creek and Mud Creek, should undergo habitat restoration to prevent them from becoming degraded in the future. On the other hand, sites with little development are at low risk for impairment, including Big Laurel Creek, Davidson River, Mills River, Sandymush Creek, Spring Creek and FBR headwaters, so restoration may not be necessary. Additionally, people must educate development organizations and the public about the effects of impervious surface on the watershed so they can consider the future impact of their actions and make more environmentally sound decisions for the future.

5. Conclusions

Upon first glance, terrestrial and aquatic environments may appear to be separate entities, but in actuality the two systems are intimately linked. The condition of one directly affects the condition of the other. Thus, it comes as no surprise that urban development contributes to a number of environmental problems in watersheds. The expansion of towns and cities impinges on the natural landscape, reducing forests and degrading habitats. Not only does this harm the environment, but it threatens society's modern lifestyle. Healthy streams are essential for safe plumbing and drinking water, and if waterways are not protected, then people run the risk of ruining favorite water recreation sites and losing the wildlife they fish, hunt and enjoy observing. In order to preserve watershed ecosystems in this area, development in watersheds must be examined to understand impacts on biota and water quality in the rivers. Not only will this preserve particular stream sections, but it will help to protect the entire UFBR watershed in the long run.

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