RELATIONSHIPS BETWEEN DISCHARGE AND LAND USE / LAND COVER IN THE ALTAMAHA RIVER WATERSHED

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Abstract. Watershed land use / land cover (LULC) changes can alter hydrologic stage distribution as well as the water quality of streams. LULC changes that occur in close proximity to streams are more likely to alter discharge and while changes occurring further from the stream less likely to alter discharge. Our objectives were to 1) determine if LULC changes in greater the Altamaha Watershed and the Upper Oconee Sub-watershed are associated with changes in discharge metrics; 2) determine which LULC changes are most closely related to discharge distribution; and 3) determine spatial scales at which LULC changes are associated with any alterations in discharge metrics. In the greater Altamaha watershed first quantile discharge was positively with forest land cover at the 50 and 500 m stream buffer. Third quantile discharge was negatively associated with wetland land cover at the 50 m buffer. In the Upper Oconee Sub-watershed, agricultural and forest land use were well correlated with the median, 3rd quantile and minimum recorded discharge at the 50 and 500 m stream buffers. Developed and wetland land use cover near streams was negatively correlated with minimum recorded discharge. Within the 100 m stream buffer wetland LULC was negatively correlated with discharge at the minimum, median, and 1st and 3rd quantiles of recorded discharge. Both developed and wetland land use were negatively correlated with minimum recorded discharge within the 500 m stream buffer as well. Associations between LULC and discharge metrics in the immediate vicinity of the stream (50 m) and within (500 m) of the stream are stronger than those within the intermediate distance (100 m).

INTRODUCTION

Water quantity and quality within a watershed are driven by both climate and land use / land cover (LULC). The latter can be further divided into LULC types: Developed, agricultural, forested, and wetland. Each type can contribute to changes in discharge within a watershed. Decreases in forest cover often lead to loss in evapotranspiration and an increased overall discharge (Bosch and Hewlett 1982, Price 2011). Increases in agricultural land use however are thought to increase evapotranspiration and thus increase baseflows (Price 2011). With regard to urbanization, increases in population density have been shown to decrease discharge (Takagi et al. 2017).

The influence of LULC on streamflow dynamics is further dependent on spatial arrangement and watershed size. For example, King et al. (2005) demonstrated that the percent probability that macroinvertebrate assemblage composition will be altered by LULC is dependent on both the percentage of developed land and the distance from the impacted stream. The study further showed that correlations between cropland and stream nitrate concentrations vary depending on watershed size (King et al. 2005). Coupled with further analyses on hydrologic connectivity, these studies have important implications for watershed policy and management practices.

In Georgia, the Altamaha River Watershed has been studied with regard to the driving effects of climate, water use, and land use on stream biogeochemical dynamics (Schafer and Alber 2007, Takagi et al. 2007). However, the spatial relationships between LULC and discharge are relatively understudied.

OBJECTIVES

Our objectives were to 1) determine if LULC changes in the Altamaha watershed are associated with changes in discharge metrics; 2) determine which LULC changes are most closely related to discharge distribution; and 3) determine spatial scales at which LULC changes are associated with any alterations in discharge metrics.

METHODS

Altamaha River Watershed

The Altamaha River Watershed encompasses five sub-watersheds (The Altamaha, Ocmulgee, Little Ocmulgee, Oconee, and Ohoopee) and covers 35,000 km^2 (Figure 1). The upper watershed (made up of the upper Oconee and upper Ocmulgee watersheds) is located in the Northern Piedmont physiographic province whereas the lower watershed is in the Coastal Plain. The watershed drains into the Altamaha River Estuary and Sound before going out to the Atlantic Ocean (Georgia EPD 2004).

The part of the upper Oconee sub-watershed focused on in this study is HUC 03070101. It encompasses the headwaters of the North Oconee River and the Middle Oconee River that join to form the Oconee River just south of Athens, GA (Georgia EPD 1998).

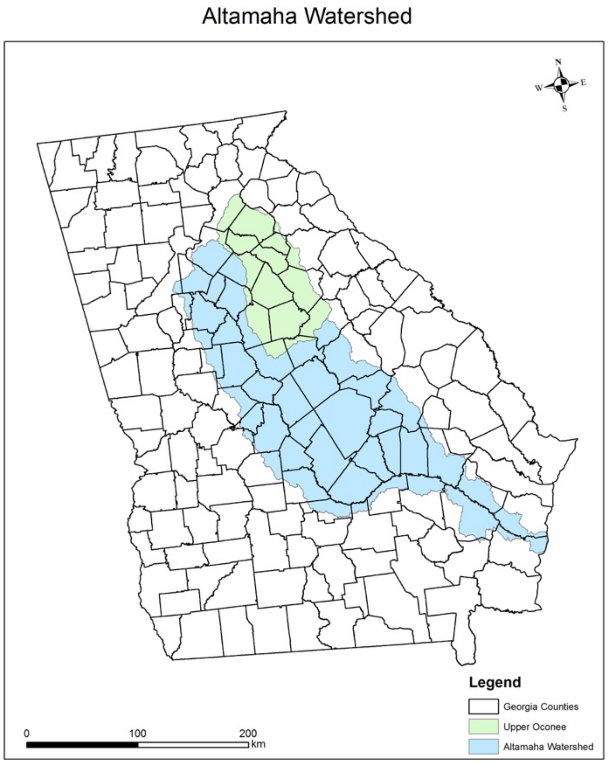

Figure 1. The Altamaha River watershed drains approximately 35,000 km^2 of Georgia. The Upper Oconee is one of seven distinct sub-watersheds for this major river basin.

Spatial Analysis

The National Land Cover Datasets for 1992, 2001, 2006, and 2011 were downloaded and analyzed. LULC was determined within the Altamaha River basin for stream buffers of 50 m, 100m, and 500 m using ArcGIS. Additionally, a subwatershed (Upper Oconee) was also analyzed using stream buffers of the same stream buffers. The purpose for investigating the Upper Oconee was to determine if differences could be expected between greater watersheds and their subwatersheds. Agricultural land uses, forest covers, developed land uses and wetland cover types were aggregated for our analysis.

Discharge

Stream discharge data were downloaded from the USGS Water Watch program (station 02225000). Discharge data was selected for 5 year windows centered on the year of each NLCD LULC dataset. For example: discharge data used associated with the 1992 LULC was selected in a window from the beginning of 1990 calendar year – to the end of 1994 calendar year.

Statistical Analysis

Minimum, median, first and third quantiles, and peak recorded discharge were selected as focal discharge metrics. These metrics were determined for each five-year discharge dataset and subsequently correlations between each discharge metric and aggregate LULC were calculated at each buffer scale. All statistical analyses used the R statistical analysis software (R Core Team).

RESULTS

At the greater watershed scale, significant positive correlations were found between forest LULC and discharge at the 50- and 500-m stream buffers. A significant negative correlation was also found between the wetland cover and third-quantile flow at the 50-m buffer (Table 1).

In the Upper Oconee Watershed, discharge metrics were positively correlated with agricultural and forest LULC types at both the 50- and 500-m stream buffers (Table 2). Discharge metrics were negatively correlated with the wetland LULC type at all stream buffers and negatively correlated with the developed LULC type at 50- and 500-m stream buffer (Table 2).

DISCUSSION

Greater Altamaha Watershed

Forest land cover was associated with greater discharge minimum and first quantile discharge in the greater Altamaha basin. This could potentially be due to greater infiltration and subsequent baseflow. Therefore, increasing forest cover within 500 m of streams could be used to increase discharge during low flow conditions.

Wetland cover was negatively associated with third quantile discharge which could be due to wetlands functioning to moderate discharge conditions at high flows. Accordingly, efforts to manage high discharge conditions could focus on wetland restoration / creation within a narrow buffer around streams.

Upper Oconee Sub-watershed

LULC classes within our selected buffers were more frequently related to discharge at the Upper Oconee scale than the greater Altamaha scale. Forest and agricultural LULC were both positively associated with minimum and median flows at both the 50-m and 500-m buffers. This could potentially be the result of these covers increasing infiltration relative to less permeable developed cover.

Additionally, wetlands were associated with decreased minimum, median, and third quantile discharge at all buffer scales. Interestingly, wetlands were the only land cover associated with our focal discharge statistics at the 100-m buffer.

Management of discharge within the Upper Oconee may depend on LULC within both narrow (50-m) and broad (500-m) buffers around streams. Wetlands appear to moderate discharge at all buffer scales while increasing forest use could potentially mitigate the effects of increased developed land use.

Table 1. Select relationship between land use and discharge statistics for the greater Altamaha river.

LULC	Buffer	Metric	r	p
Forest	50	1st Quantile	0.965	< 0.05
Wetland	50	3rd Quantile	-0.954	< 0.05
Forest	500	Minimum	0.964	< 0.05
Forest	500	1st Quantile	0.970	< 0.05

Table 2. Selected correlations of aggregate LULC and stream discharge metrics in the Upper Oconee sub-watershed.

LULC	Metric	r	p
50 m Stream Buffer			
Developed	1st Quantile	-0.978	0.0218
Agricultural	Median	0.981	0.0191
Forest	Median	0.967	0.0326
Wetland	Median	-0.994	0.0061
Agricultural	3rd Quantile	0.979	0.0210
Forest	3rd Quantile	0.955	0.0445
Wetland	3rd Quantile	-0.987	0.0128
Agricultural	Minimum	0.991	0.0092
Developed	Minimum	-0.980	0.0198
Forest	Minimum	0.999	0.0002
Wetland	Minimum	-0.987	0.0129
100 m Stream Buffer			
Wetland	1 st Quantile	-0.952	0.048
Wetland	Median	-0.964	0.036
Wetland	3rd Quantile	-0.964	0.036
Wetland	Minimum	-0.989	0.011
500 m Stream Buffer			
Agricultural	1st Quantile	0.953	0.047
Developed	Median	-0.953	0.047
Agricultural	Median	0.962	0.038
Developed	Median	-0.962	0.038
Forest	Median	0.956	0.044
Wetland	Median	-0.993	0.007
Agricultural	3rd Quantile	0.963	0.037
Developed	3rd Quantile	-0.961	0.039
Wetland	3rd Quantile	-0.986	0.014
Agricultural	Mean	0.902	0.098
Agricultural	Minimum	0.989	0.011
Developed	Minimum	-0.991	0.009
Forest	Minimum	0.999	0.001
Wetland	Minimum	-0.989	0.011

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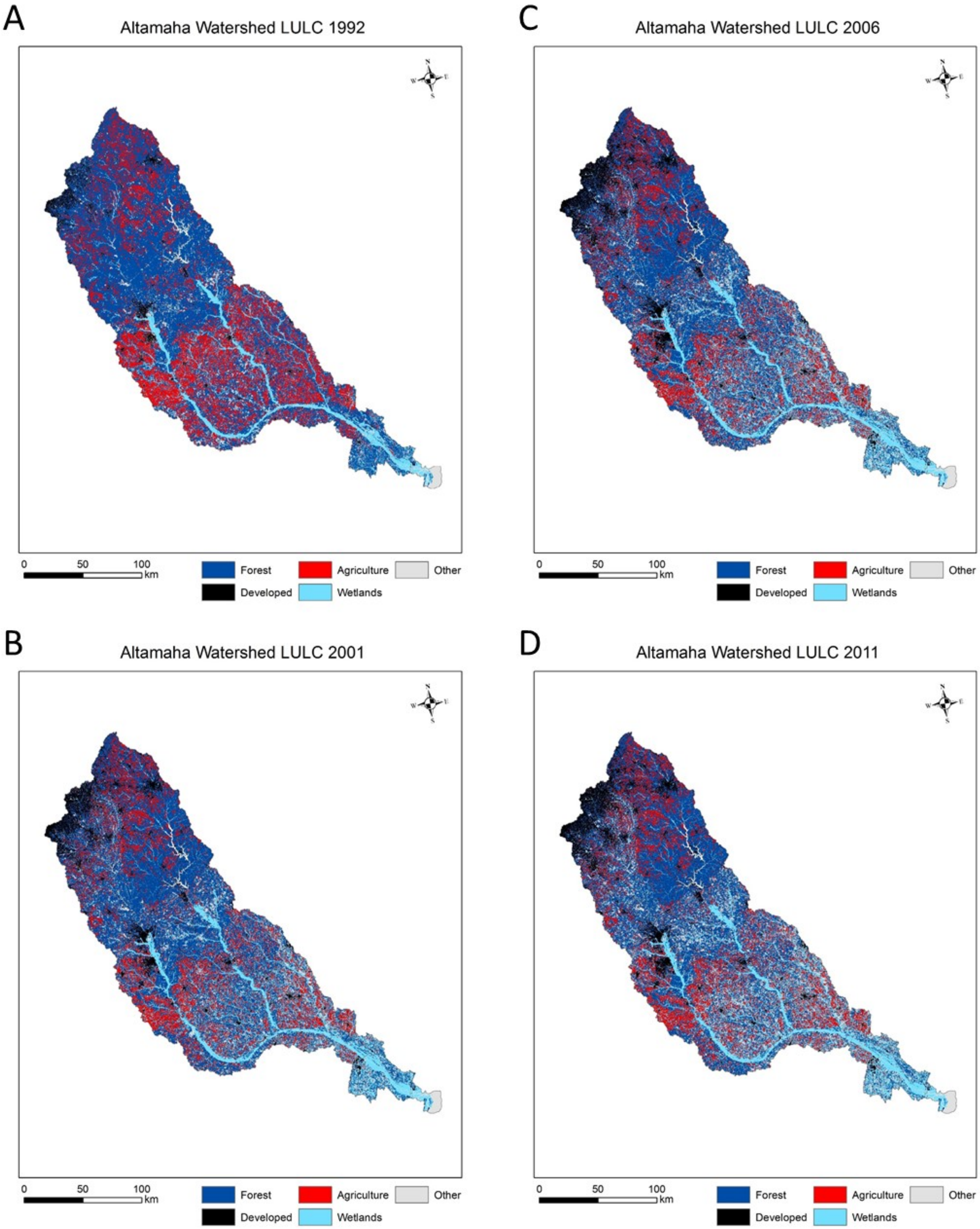

Figure 2. Altamaha watershed NLCD LULC data for 1992 (A), 2001 (B), 2006 (C) and 2011 (D).

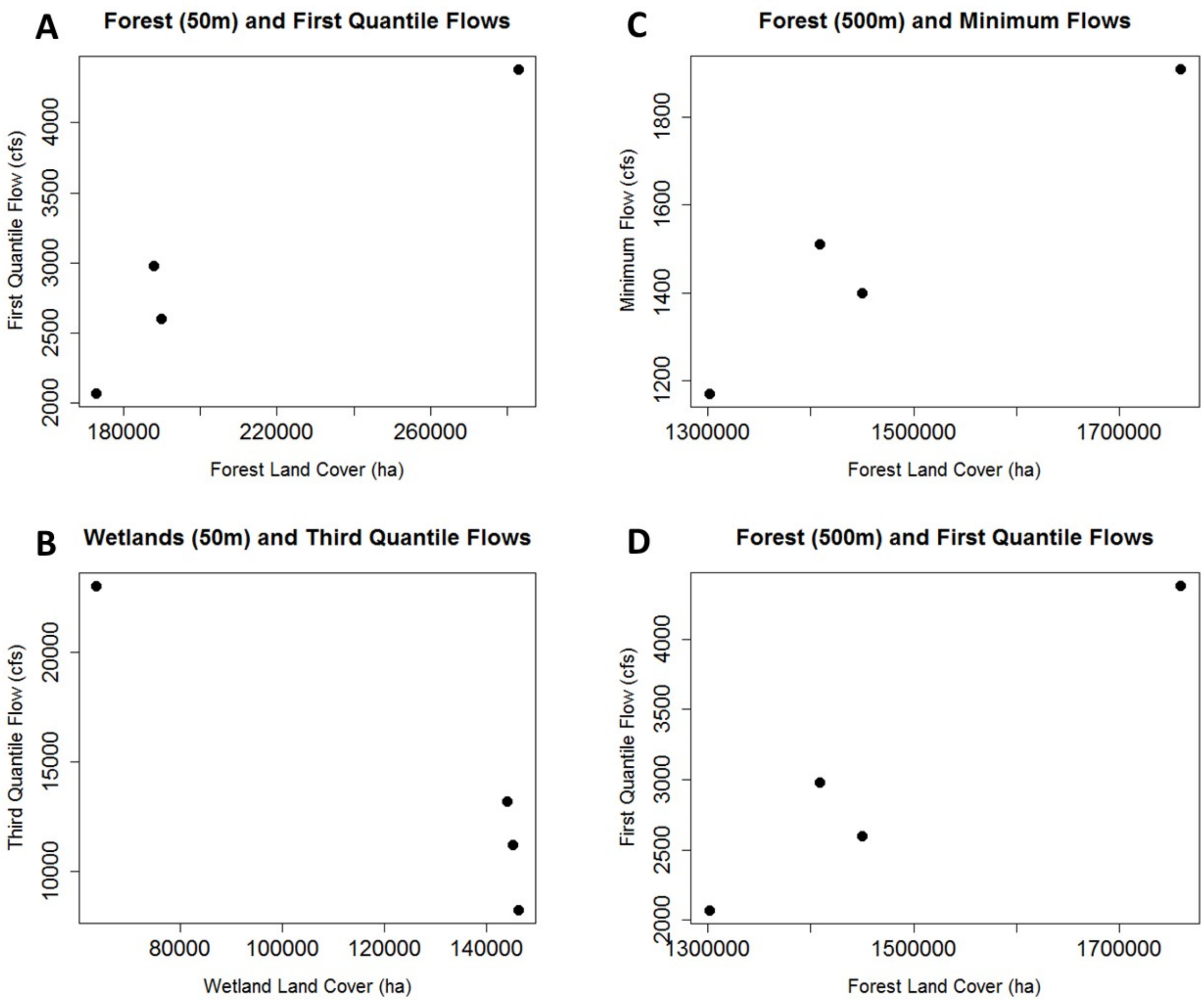

Figure 3. Select relationships between discharge statistics and LULC in the Altamaha river. At the 50 m buffer scale forest cover was positively associated with first quantile discharge (A) and wetlands were negatively associated with third quantile discharge (B). Forest cover was associated with and minimum flows (C) and first quantile (D) at the 500 m buffer scale.