DISCHARGE DISTRIBUTIONS IN THE SATILLA RIVER: RELATIONSHIPS BETWEEN DISCHARGE METRICS AND LAND USE / LAND COVER

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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. Land use / land cover changes that occur in close proximity to streams are more likely to alter discharge while changes occurring further from the stream are less likely to alter discharge. Our objectives were to: 1) determine if LULC changes in the Satilla watershed are associated with changes in discharge metrics; 2) determine which LULC changes are most closely related to discharge distribution; and 3) determine the spatial scales at which LULC changes are associated with any alterations in discharge metrics.

Positive discharge relationships were found between first quantile discharge and both agricultural as well as forest LULC within 50 m stream buffer. Developed LULC near streams was negatively correlated with first quantile recorded discharge at all spatial scales. Agricultural land use was positively correlated with median discharge at each spatial scale. Developed land use was negatively correlated with first quantile discharge within all buffers. Decreases in first quantile flows associated with increased developed LULC could result from decreased base flow and increased runoff.

INTRODUCTION

Watershed land use / land cover can be a driving factor in river discharge. Watershed land use / land cover (LULC) changes can alter hydrologic stage distribution as well as the water quality of streams. Land use / land cover changes that occur in close proximity to streams are more likely to alter discharge while changes occurring further from the stream are less likely to alter discharge (Yang et al. 2014).

Forest cover and wetlands are generally associated with lower discharges than heavily developed or agricultural watersheds (Booth et al. 2002). Developed and agricultural LULC are generally associated with lower discharges due to reduced baseflow and increased runoff. This also contributes to flashier hydrographs with greater peaks and lower minimum flows (Nejadhashemi et al. 2011).

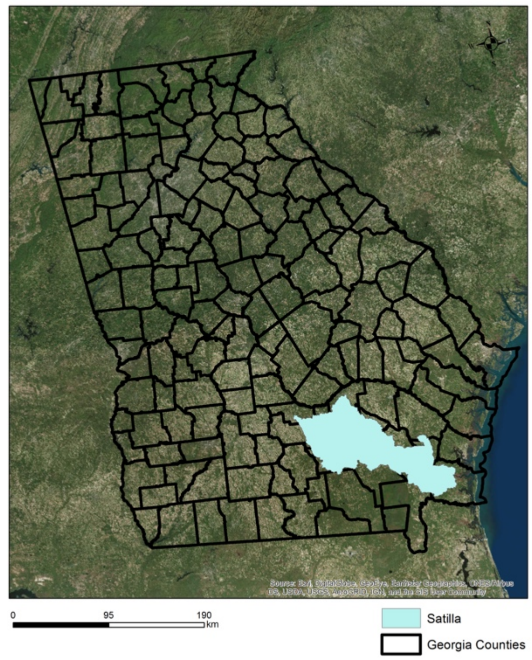

Figure 1. The Satilla River watershed drains over 9,000 km^2 of the coastal plain in southeast Georgia.

The Satilla River Basin is dominated by agriculture and forestry, but the proportion of developed LULC has rapidly increased in this watershed since the 1970's (Alber et al. 2003). Much of the research regarding these LULC changes in the Satilla Basin as well as the adjacent Altamaha River Basin has focused on shifts in: sediment loads, watershed biogeochemistry, and river salinity along the coast (e.g. Li and Pennings 2018, Takagi et al. 2017, Zheng et al. 2004, Zheng et al. 2003). However, discharge relationships with LULC are relatively understudied.

OBJECTIVES

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

METHODS

Satilla River Watershed

The Satilla River covers 9,140 km^2 of the Georgia coastal plain and terminates in the Atlantic Ocean (Alber et al. 2003). This coastal plain river has over 420 km of sinuous channel length extending over 100 km inland from the mouth. As with other regions of Georgia the predominat land use / land covers within this watershed have shifted considerable since the early 1990s (Figure 2).

Spatial Analysis

Land use / land cover data used in this study were provided by the National Land Cover Dataset (NLCD) (1992, 2001, 2006, 2011). Land use / land cover was determined for 50 m, 100m, and 500 m stream buffers to investigate the effects of changes in varying proximities to stream discharge using ArcGIS.

For the purposes of our analyses, agricultural land use types, developed land use types, forest land cover types, and wetland land cover types were aggregated respectively.

Discharge

Stream discharge data were downloaded from the USGS Water Watch program (station 02228000). Discharge data was selected for 5-year windows centered on the year of each NLCD LULC dataset. For example: discharge data associated with the 1992 LULC was selected from a window that began from the start of the 1990 calendar year – to the end of 1994 calendar year.

Statistical Analysis

Minimum, median, first & third quantiles, and peak recorded discharge were selected as focal discharge metrics. These metrics were determined for each 5-year discharge dataset. Subsequently, correlations between each discharge metric and aggregate land use / land cover were calculated at each buffer scale. All statistical analyses were conducted using the R statistical analysis software (R Core Team).

RESULTS

Forest and agricultural LULC both decreased from 1992-2011 within each buffer distance (Figure 2, Table 1). Developed land increased rapidly during this period.

First quantile flows were positively correlated to agricultural and forest LULC at the 50 m buffer (Table 1, Figure 3). Developed and wetlands LULC were negatively correlated with first quantile flows at all buffer scales. Agriculture was positively correlated with median flows at all buffer scales.

Table 1. LULC within each focal stream buffer distance.

Year	Agricul-ture (ha)	Devel-oped (ha)	Forest (ha)	Wetland (ha)
50 m buffer				
1992	5633.73	340.02	21016.8	20217.42
2001	3160.17	1876.14	7134.3	35895.6
2006	3139.02	1915.65	6837.39	35874.36
2011	2937.51	1922.85	6330.78	35910.45
100 m buffer				
1992	16121.88	701.46	41854.32	34343.1
2001	11182.05	4135.32	19716.84	57840.75
2006	11136.87	4217.4	18767.34	57814.2
2011	10508.31	4234.86	17398.89	57882.24
500 m buffer				
1992	112435.11	3586.59	159342.84	78487.11
2001	83991.33	23664.6	107477.55	123270.12
2006	83678.13	24050.88	100061.28	123125.22
2011	80233.92	24173.37	91971.18	123302.88

Table 2. Select relationship between land use and discharge statistics (* $p < 0.05$)

LULC	Metric	r	p
50 m Buffer			
Forest	1st Quantile	0.958	*
Developed	1st Quantile	-0.961	*
Agriculture	1st Quantile	0.955	*
Wetland	1st Quantile	-0.967	*
Agriculture	Median	0.954	*
100 m Buffer			
Developed	1st Quantile	-0.961	*
Wetland	1st Quantile	-0.967	*
Agriculture	Median	0.956	*
500 m Buffer			
Developed	1st Quantile	-0.962	*
Wetland	1st Quantile	-0.968	*
Agriculture	Median	0.955	*

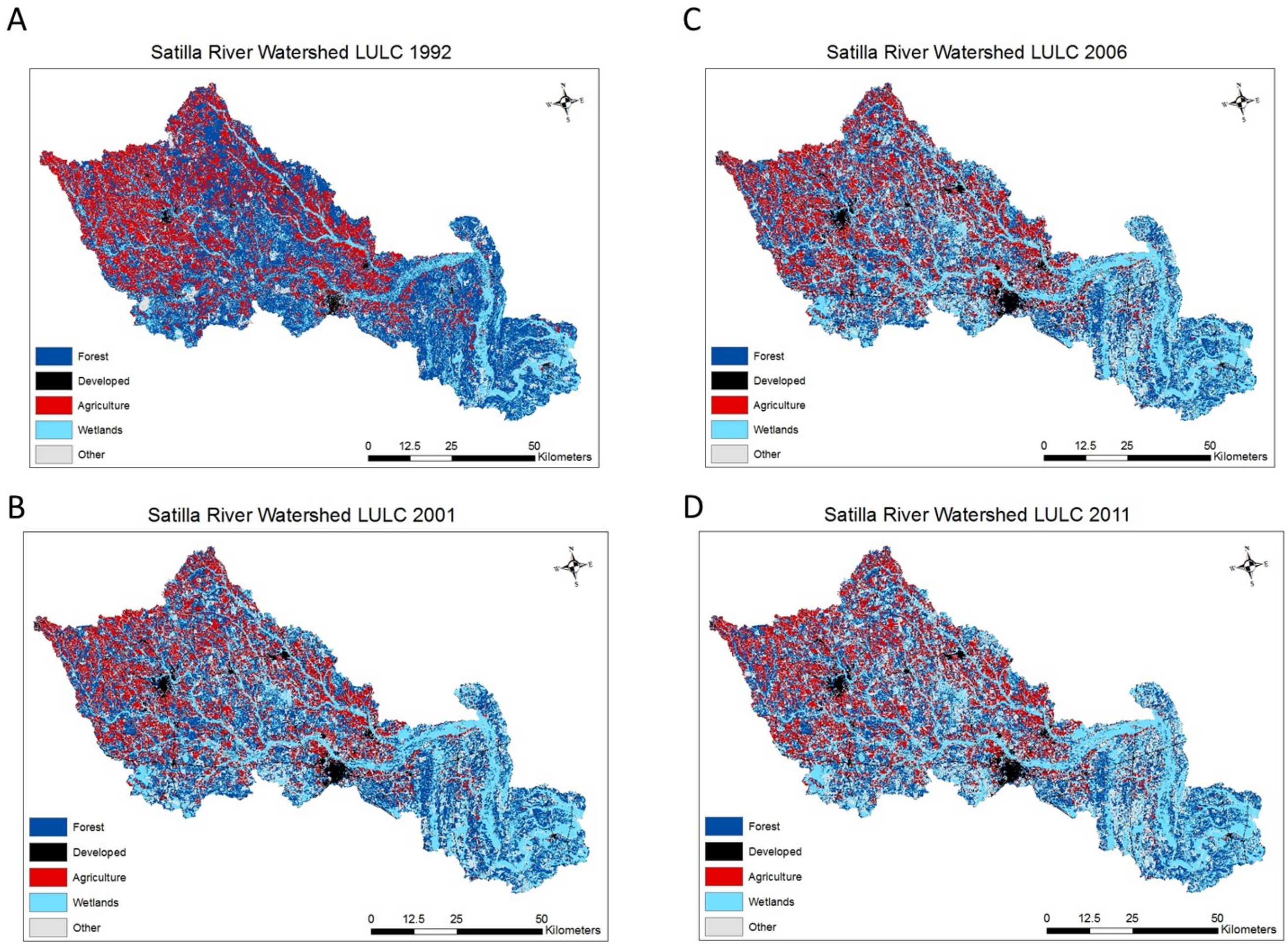

Figure 2. Satilla river basin NLCD LULC data for 1992 (A), 2001 (B), 2006 (C) and 2011 (D).

DISCUSSION

Our findings indicate that land use / land cover is more often related to our focal discharge metrics in the immediate vicinity of the stream (50 m) than at greater spatial scales. In particular, forest cover and agricultural land use were strongly correlated with first quantile flows at this scale but not at other scales. This implies that in the Satilla Watershed, management of these two LULC types in a narrow stream buffer may be sufficient to maintaining historically observed lower flow discharge than managing wider buffers.

However, strong relationships between first quantile flows and developed land use as well as wetland land cover were observed at all buffer scales. This could indicate that the Satilla is more sensitive to increases or losses of these two LULC classes within the greater watershed context rather than in areas immediately adjacent to the river.

Agricultural land use was also strongly correlated with median flows at all spatial scales. Which could indicate that this LULC type influences near stream runoff processes as well as potentially allowing for greater infiltration and subsequent baseflow than other LULC types.

One limit to our analysis is that we did not investigate the timing and duration of our discharge metrics. Future analyses will include comparisons of discharge metric timing as well as the duration of flows at each discharge metric.

From a management perspective these results can be applied to managing rivers beyond conventional minimum flow methods. Watershed development decisions should include discharge analyses that are specific to LULC type and proximity to streams/ rivers. This can aid in maintaining effective discharge distributions.

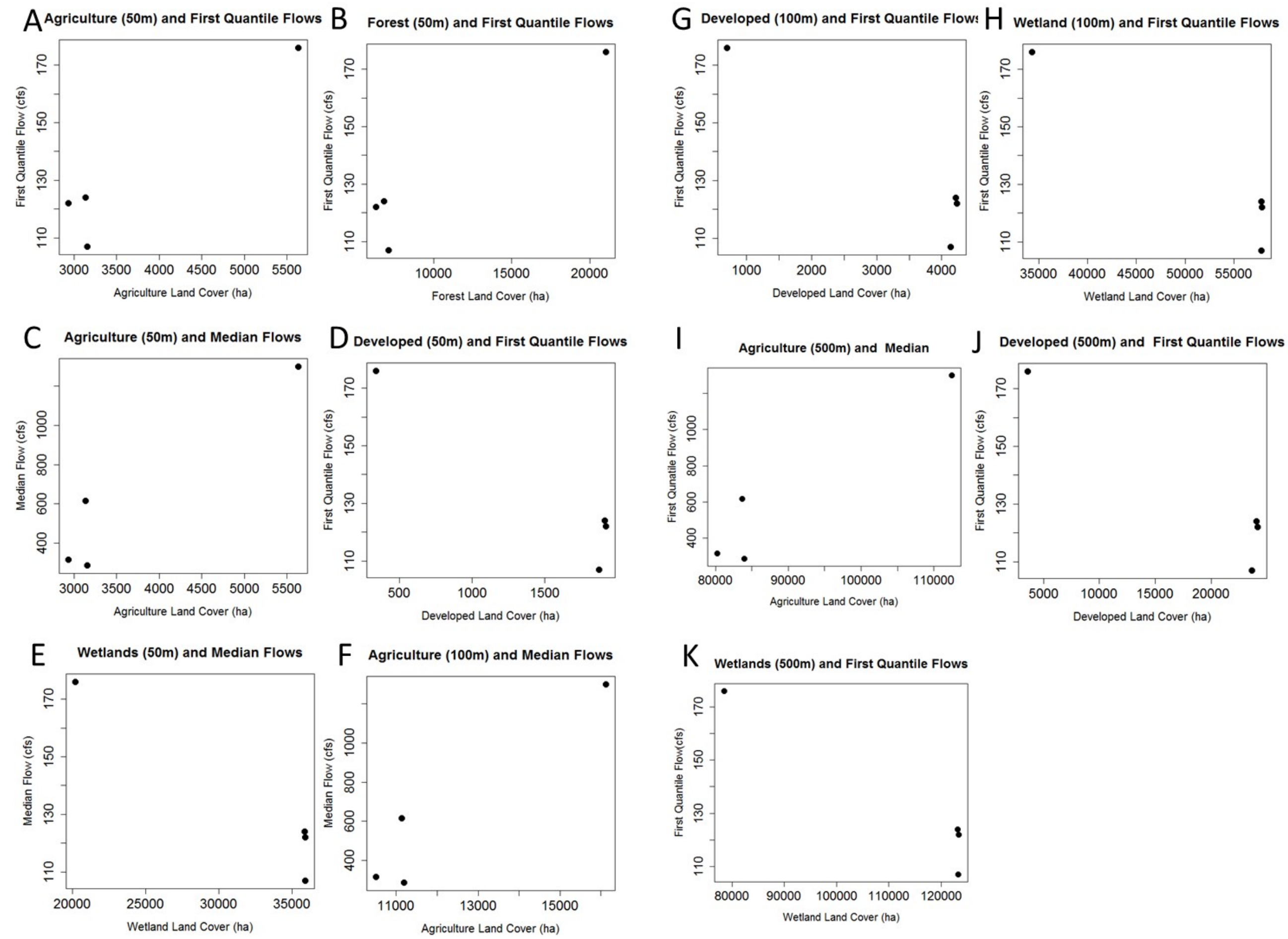

Figure 3. Select relationships between LULC and discharge metrics at 50 m buffer (A, B, C, D, E), 100 m (F, G, H), and 500 m (I, J, K).

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