PATTERNS OF LAND USE CHANGE IN UPLAND AND RIPARIAN AREAS IN THE ETOWAH RIVER BASIN

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Abstract. Streams are influenced by the upstream landscape, but may be differentially affected by conversion of forests in the entire catchment vs riparian areas adjacent to streams. We used geographic information system (GIS) analyses of the stream network and land cover in the Piedmont of the Etowah River basin to assess development patterns in upland catchment and riparian areas of streams. Landsat images (1973, 1987, 1997) were used to determine land cover and land cover change in a 100 m buffer on each side of the stream and the catchment as a whole. Agricultural and urban uses covered a larger percentage of the catchment area compared to the riparian area. Streams exhibited an average 13% decrease in forest cover and 11% increase in urban land cover in the catchments over the 24 year period, with riparian areas changing at a slower rate. Small (~15 km^2) and large (~100 km^2) catchments had similar proportions of buffer vs catchment forest land cover. Although rates of development were less in riparian areas, the continued trends of increased urban and decreased forest cover suggest that current policies may not be adequate at protecting stream ecosystems.

INTRODUCTION

Forested land is being converted to agricultural and urban land uses nationwide (USDA 2000). These land conversions may occur discriminately, based on elevation, geology, or location relative to landscape resources. For example, the function of water as a resource for irrigation, livestock, mining, transportation and land design aesthetics may encourage development adjacent to streams, while increased land losses due to erosion and other negative effects of riparian deforestation may deter development adjacent to streams (e.g., through buffer ordinances or best management practices).

Land cover changes in the catchment can impair water quality and biotic assemblages (Allan and Johnson 1997). Similarly, decreased forest cover in the riparian area adjacent to the stream increases nutrients, temperature, and primary productivity and decreases bed texture and allochthonous inputs (Sweeney 1992). These changes, in turn, can impact biotic assemblages (Jones et al. 1999). Although stream integrity is a function of the entire upstream catchment, the critical location of riparian areas within the landscape may constitute a disproportional influence on aquatic ecosystems (Weller et al. 1998).

We examined patterns of landscape development in the Piedmont physiographic region of the Etowah River basin by directly comparing land cover changes between 1973 and 1997 in riparian areas to those in corresponding catchments. We hypothesized that 1) proportional forested land cover is higher and agricultural and urban land cover are lower in riparian vs catchment areas, 2) trends in land cover change demonstrate less deforestation of riparian vs catchment areas through time, and 3) large streams have higher % forested land cover in riparian areas vs catchment relative to small streams.

METHODS

Sites used in this study were located within the Piedmont physiographic region of the Etowah River basin. For the land cover and land cover change analyses, we conducted a census of all non-nested small streams (10-20 km^2) within this region (n = 83 streams). For the catchment size comparison, 10 streams from 15, 50, and 100 km^2 ± 25% catchments were randomly selected (Leigh et al. 2002).

1973 *Landsat* MSS images (60 m pixels) and 1987 and 1997 *Landsat* TM images (30 m pixels) were used to obtain land coverages (Lo and Yang 2000). Classifications were grouped according to the six class system used in 1973, which included high density urban, low density urban, cultivated/exposed land, cropland/grassland & golf courses, forest land, and open water.

We created a drainage network from Digital Elevation Models (DEMs) which was similar to a 1:24,000 scale stream network. This drainage network was used to create 100 m buffers for the entire extent of the drainage network. For the 30 streams used in size analyses, we also calculated a 100 m buffer for the 1 km reach at the downstream-most portion of the drainage to test whether patterns of riparian land use were locally patchy. Arcview 3.2© was used to tabulate catchment and 100 m buffer areas based on land cover (Environmental Systems Research Institute, Inc., Redlands, CA).

We divided the proportion land cover in the riparian area (100 m buffer) by the proportion land cover in the entire catchment to analyze relative changes in buffer vs catchment. Land cover change variables were calculated for 1973-1987 and 1987-1997. Paired t-tests were used to compare mean differences in change in catchment vs riparian land cover for the 83 streams. A one-way ANOVA was used to compare mean land cover variables among the three stream size classes.

RESULTS

Catchments exhibited a range in 1997 % forest (25-96%), urban (1-67%), and agriculture (3-42%) land cover. Mean forested land cover was higher in the riparian areas than in the catchment, with only six of the 83 sites having lower relative forest cover in the riparian area. Percent urban and agricultural land cover were both lower in the riparian area relative to the catchment. Across all sites, the proportion of open water in the riparian area was double the amount in the catchment (Table 1).

Changes in land cover demonstrated an average 13% decrease in forest (-37% to +4%) and 11% increase in urban land cover (-9% to +47%) in the catchments over

Table 1. Ratio of 1997 riparian to catchment percent land cover in 83 small catchments. Numbers >1 indicate higher percent land cover in riparian vs catchment.

	Mean	St. Error
Total Forest Cover	1.11	0.011
Total Urban Cover	0.73	0.019
High Density Urban	0.70	0.039
Low Density Urban	0.74	0.019
Total Agriculture Cover	0.85	0.018
Cultivated/Exposed Land	0.61	0.041
Crop/Grassland & Golf Courses	0.87	0.018
Open Water	1.99	0.053

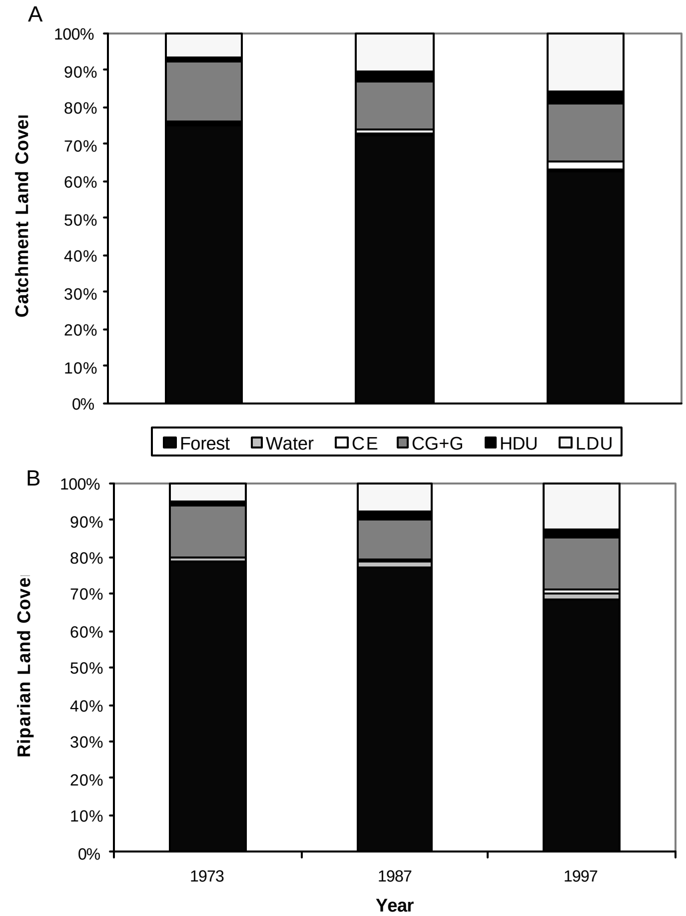

Figure 1. Percent catchment (A) and riparian (B) land cover in 1973, 1987 and 1997. LDU = low density urban, HDU = high density urban, CG+G = crop/grassland + golf courses, CE = cultivated/exposed land.

24 years. Agricultural land cover in the catchments decreased between 1973 and 1987 and increased between 1987 and 1997. Similar trends existed for land cover in the riparian area; however, the changes in forest and urban were smaller in magnitude. Open water increased more in the riparian area (0.8%) than in the catchment (0.4%) through time (Figure 1; Table 2).

There were no differences in mean % urban, forest, or agricultural land in the riparian vs catchment across stream size classes (Table 3). The 1 km reach had higher variability in riparian land cover relative to the catchment compared to the riparian area calculated for the entire upstream network. For example, percent forest was higher in the riparian area vs catchment in 27 of the 30 sites based on buffering the entire stream, but half of the sites had lower percent forest in the riparian area vs catchment when considering only the 1 km reach (Figure 2).

Table 2. Mean (SE) of riparian, catchment, and riparian/catchment ratio (R/C) for change in land cover from 1973-87 and 1987-97 for the 83 streams. Sign (+/-) indicates direction of change. Significant differences between catchment and riparian land cover are indicated (paired *t*-test); * = *p*<0.001, ** = *p*<0.01.**

	1973 to 1987 % Land Cover Change				1987 to 1997 % Land Cover Change			
	Forest***	Urban***	Agriculture	Water***	Forest**	Urban***	Agriculture	Water***
Catchment	-3.10 (1.00)	+5.42 (0.96)	-2.35 (1.02)	+0.03 (0.03)	-9.57 (0.83)	+5.71 (0.70)	+3.52 (0.71)	+0.34 (0.05)
Riparian	-1.31 (1.12)	+3.71 (0.84)	-2.63 (0.95)	+0.24 (0.06)	-9.02 (0.81)	+4.79 (0.65)	+3.70 (0.61)	+0.53 (0.06)
R/C	+0.03 (0.00)	-0.06 (0.04)	-0.05 (0.04)	+0.50 (0.09)	+0.03 (0.00)	+0.01 (0.03)	+0.06 (0.02)	-0.07 (0.06)

DISCUSSION

In the Piedmont portion of the Etowah basin, loss of forest cover is occurring faster in the catchment than the riparian area. This may be a result of statewide protection of riparian buffers, although only 25 ft (~8 m) is protected under Georgia's Erosion and Sedimentation Control Act (OCGA 12-7). Perceived problems associated with developing in riparian areas along with increased knowledge of the benefits of having a forested riparian area may also be contributing to higher percent forest cover in riparian areas.

Although the proportion of development is less in riparian areas, there has been an increase of 8.5% urban and a decrease of 10.3% forest in riparian areas in the last 24 years. If these trends continue, 94% of small streams will have >10% urban in their riparian areas (vs 43% in 1997) and 87% of small streams will have >15% urban in upland catchments (vs 39% in 1997) by 2021. These high levels of urbanization typically correspond to impaired stream ecosystems (Paul and Meyer 2001). Thus, current policy may not be adequate at protecting streams from land cover change.

This pattern of higher forest in riparian areas relative to catchment is not consistent for all areas of the US.

Table 3. Ratio of 1997 percent riparian land cover (within 100 m buffer on 1 km reach and entire extent stream network) to percent catchment land cover in small (15 km²), medium (50 km²) and large (100 km²) catchments for 30 sites. F and *p* values are from a one-way ANOVA based on log(x+1) transformed data.

	15 km²	50 km²	100 km²	F	p
Urban					
1 km	0.74 (0.19)	0.83 (0.24)	0.51 (0.17)	0.91	0.41
entire	0.73 (0.05)	0.77 (0.02)	0.73 (0.03)	0.90	0.42
Forest					
1 km	0.81 (0.12)	1.02 (0.11)	1.00 (0.09)	1.31	0.29
entire	1.14 (0.02)	1.11 (0.02)	1.11 (0.02)	0.68	0.52
Agriculture					
1 km	1.44 (0.26)	1.72 (0.61)	1.36 (0.40)	0.04	0.96
entire	0.76 (0.05)	0.85 (0.04)	0.89 (0.04)	1.84	0.18

A study in the Blue Ridge physiographic region of Georgia indicated a trend of *higher* deforestation in the area relative to the catchment (riparian/catchment ratio 0.91 vs 1.11 in Piedmont). Of the 30 sites sampled in that study, 24 sites had lower forest land cover in riparian vs catchment, presumably due to the higher ease of developing in valleys adjacent to streams (Kundell et al. 2002). These contradictory patterns in location of land development offer an excellent opportunity to understand relations between development patterns and stream ecosystem quality.

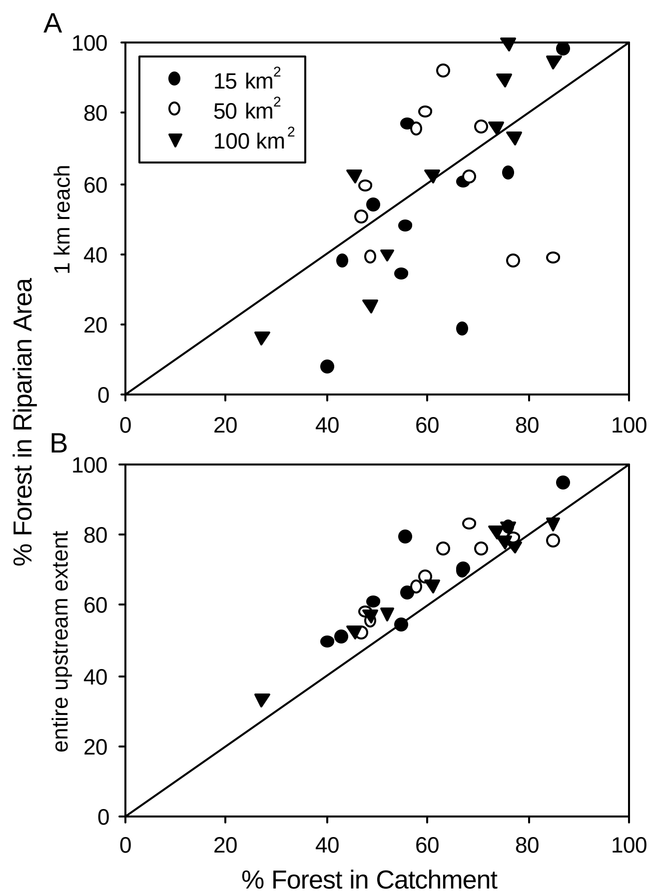

Figure 2. 1997 Percent forested riparian land cover (100 m buffer) for 1 km reach (A) and entire upstream extent (B) vs percent forest in catchment for ten small (15 km²), medium (50 km²) and large (100 km²) catchments. Line indicates 1:1.

We hypothesized that larger streams would have a more intact riparian area relative to the catchment because of higher protection afforded to larger streams and that larger streams are more of a public resource (i.e., small streams often transect properties while large streams border property lines). However, we found no evidence of differences across stream catchment size. Such a pattern may exist with even smaller streams (e.g., <10 km^2) that have fewer landowners. Further, the scale of the stream network (1:24,000) used in this study may be too large to detect land uses occurring on very small streams (Meyer and Wallace 2001).

All size streams had highly variable land cover within the 1 km buffer, indicating that that forested riparian land cover is extremely spatially patchy. Studies suggest that the degree of patchiness may be related to stream quality. For example, Jones et al. (1999) showed a significant relationship between the length of deforested riparian patches and fish assemblage changes. Because gaps in riparian areas may dictate water conduits in the landscape, the number and extent of deforested reaches, rather the proportion of deforestation within riparian areas may be more related to stream quality (Weller et al. 1998).

Many regulations give higher protection to larger streams relative to smaller streams. For example, the Metropolitan River Protection Act (OCGA 12-5-440 to 12-5-457) mandates wider buffer protection along the main stem of the Chattahoochee River than on smaller tributaries. This discrimination based on catchment size seems unwarranted, as a larger percentage of the catchment is in closer contact with small streams. Since stream quality is a function of all upstream uses, equal protection of large and small streams is recommended (Meyer and Wallace 2001).

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