LAND COVER AND STREAM MORPHOLOGY INDICATORS OF VARIATION IN RIPARIAN FOREST PATCHES OF THE ETOWAH RIVER BASIN, GEORGIA

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REFERENCE: Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. The goal of this paper is to present useful and simple predictive models that will enable scientists and resource managers to ascertain information about vegetation characteristics within riparian forests without an extensive field effort. Models were developed using land cover and geomorphic variables to predict variation in riparian forest characteristics associated with streams in the Etowah River Basin in north Georgia. Geomorphic factors explained much of the variation among forest patches for trees and for seedlings, saplings and vines. Land cover variables were secondary predictors or had no predictive power over these components of riparian plant communities. However, local and basin scale land cover variables explained differences among sites within the shrub layer. Information about riparian forest characteristics can be used to strengthen assessments of stream integrity and contribute to the appropriate identification of restoration needs.

INTRODUCTION

Within the Etowah River Basin a gradient of development exists. Areas near Atlanta are highly developed while areas in the headwaters remain rural. Using this gradient, a research team at the University of Georgia is working in the Etowah to identify indicators of stream quality. (Leigh et. al., 2001, this volume). Both land cover and geomorphic data are being explored to elicit predictive relationships and develop indicators of biotic integrity of stream ecosystems. As part of this larger research initiative, the purpose of this paper is to develop simple models that will allow for a general assessment of the character of riparian forests (diversity and density of native species and density of invasive non-native species) from geomorphic and land cover data.

A riparian zone is the interface between terrestrial and aquatic systems. These areas perform many functions including trapping sediment, holding and/or removing nutrients and contaminants, stabilizing stream beds and banks, storing flood waters, providing habitat, serving as a corridor for dispersal, and providing nutrient inputs to streams in the form of leaf litter and woody debris (Gregory et. al., 1991).

Often, research examining the influence of riparian forests on stream integrity treats all riparian forests as equal by using such variables as percent riparian forest or riparian forest width. In reality, forest patches can be very different in composition, diversity, and density. For example, in developed areas non-native species can dramatically alter the character of a riparian area (Caicco, 1998). These differences alter the functioning of the riparian area as an interface. This, in turn, is reflected in characteristics of the associated streams.

Stream biota, water chemistry, and physical characteristics have been linked to changes in riparian forest characteristics. This variation has been cited as a cause of changes in shredder communities (Cummins et. al., 1989), fish habitat quality (Roth et. al., 1996), carbon and nitrogen levels (Chauvet and DeCamps, 1989) and stream channel sediment composition (Stevens and Cummins, 1999).

Because of the influence of forests on stream systems, understanding the factors that control variation in riparian forests and predicting forest character from accessible data will contribute to both stream health assessments and stream restoration work.

METHODS

Ten sub-basins with drainage areas of approximately 15 km^2 (±25%) were randomly chosen within the Etowah River Basin (Leigh et. al., 2001, this volume).

Vegetation data

Roughly one hectare of riparian forest was sampled at the drainage outlet of each basin. Three strata of

Table 1. Description and abbreviations of variables

Category	Abbreviation	Description
Vegetation	Diversity of trees	Shannon-Wiener diversity of tree species with DBH > 5cm
	Density of trees	Density of trees (stems/m^2)
	Diversity of shrubs	Shannon-Wiener diversity of native shrub species
	Diversity of ssv	Shannon-Weiner diversity of native seedlings, saplings and vines (ssv)
	Density of privet	Relative density of Chinese privet, a non-native shrub (privet count/total shrub count)
	Density of honeysuckle	Density of Japanese honeysuckle, a non-native vine (stems/m^2)
Land cover		
Recent	Proportion agriculture	Proportion of agriculture within a basin
	Proportion riparian forest	Proportion of forest within 200 meter buffer around 1:24,000 stream network
	Road density	Density of roads within a basin (m/km^2)
	Patch Density	Density of patches for all land cover types within a basin (patches/100 ha)
	93 nonforested local	Proportion of area within a 160 m radius of the sampled forest patch that was not forested in 1993
Historic	38 nonforested local	Proportion of area within a 160 m radius of the sampled forest patch that was not forested in 1938
Geomorphic	Flood frequency	Average recurrence interval for the bankfull flood based on rural flood freq. curves (yrs)
	Relative relief	Maximum height of trunk stream divided by the perimeter of the basin
	Local relief	Elevation range in vicinity of sampling site (m)

woody species were sampled; (1) trees (DBH> 5cm), (2) seedlings, saplings and vines, and (3) shrubs. The tree layer was sampled in 10 randomly located circular quadrats (80 m^2). Seedlings, saplings and vines were sampled in quadrats (10 m^2) sharing the same center point with the tree plots. All sampling occurred within 40 meters of the stream bank.

Shrubs were sampled using the line-intercept method with transects running perpendicular to the streams. This method was employed because of the occurrence of the non-native shrub, Chinese privet (*Ligustrum sinense*) at several sites. The growth habit of this multi-stemmed shrub makes it difficult to define an individual, a step necessary in most quadrat methods.

Table 1 summarizes the variables used in this study. The Shannon-Wiener diversity index was determined for the three vegetation layers using only native species data. Densities were derived for trees and the two notable non-native species in the area, Chinese privet (*Ligustrum sinense*) and a woody vine, Japanese honeysuckle (*Lonicera japonica*).

Stream morphology

Geomorphic data was collected by Dr. David Leigh (Department of Geography, University of Georgia) during the summer of 1999. To ascertain flood frequency estimates the stream morphology variable used in this study is the average recurrence interval (in years) of bankfull floods for the surveyed channel reach. This is derived in reference to the rural flood frequency curves published for Georgia (Stamey and Hess, 1993) by modeling discharge in the bankfull cross section with the Manning equation for average flow velocity. Values greater than two indicate an enlarged channel capacity, because rural streams typically have a 1 to 2 year recurrence frequency of overbank flooding. Urban streams will inherently have a relatively high value compared to rural streams, because their flood discharges have increased due to more impermeable surfaces in the basin, leading to greater runoff. Also, streams with enlarged channel capacities due to incision into alluvium deposited in streams from past erosive land use practices (i.e. intensive agriculture) will have relatively high values.

Relief morphometry variables were obtained from elevations on USGS topographic maps (1:24,000 scale). Relative relief was computed as the elevation range of the trunk stream in the basin divided by the perimeter of the basin. Local relief is the elevation range that represents the height to the nearest upland interstream divide along a line perpendicular to the valley where the sample site is located.

Land cover

Basin scale land cover variables were derived from the 1993 Multi-Resolution Land Characterization (MRLC) dataset for Georgia, reclassified into four land cover categories; open water, forest, agriculture and urban. FRAGSTATS (McGarigal and Marks, 1994) spatial pattern analysis program was used to determine patch density for the basins.

Using rectified aerial photography, local land cover was determined for both 1993 and 1938. Sampling sites were buffered with a circle having a radius four times the width of the sampled forest patch (approx. 160

meters). This buffer generally included several property lines which allowed for the incorporation of adjacent land cover types due to changes in land ownership. Land cover types were delineated within the circular buffer. Land cover was classified as either forested or non-forested.

Analysis

Standard least squares regression analysis and forward stepwise multiple regression analysis were used to determine predictive models. Two variable pools were used to produce the models. The first dataset included geomorphic variables, and recent and historical land cover variables. The variables were chosen based on initial correlation and regression analysis, as well as, ease of data collection. The second dataset contained only current land cover data which can be derived entirely from accessible remotely sensed data.

RESULTS AND DISCUSSION

Several useful models for predicting riparian forest characteristics within the Etowah River basin resulted from multiple regression analysis. The strongest models were created using the full variable set including geomorphic data and land cover data (Table 2). Models derived from only recent land cover variables explained a significant amount of variation in vegetation characteristics but R-squared values were lower (Table 3).

Density of honeysuckle, diversity of seedlings, saplings and vines, and diversity and density of trees were explained by geomorphic factors; basin relief and flood frequency. Diversity and density of the seedlings, saplings and vines layer and the tree layer increase with disturbance due to flooding, a factor identified as the overriding influence over the distribution of riparian plant species in the eastern United States (Hupp and Osterkamp, 1996). Greater relative relief indicates greater elevation changes over shorter distances and results in higher diversities and densities in the same two vegetation layers, except in the case of the non-native honeysuckle, which decreases in density with greater relief.

Land cover accounted for most of the variation recorded in the density of privet, and the diversity of native shrubs. Road density can be considered a surrogate for anthropogenic disturbance (e.g. agricultural and urban development, timber harvest) and serves as a dispersal corridor for non-native species (Trombulak and Frissell, 2000). As road density increased, privet increased in density. High densities of privet caused a decline in the diversity of the native shrub community (R^2= 0.64, p= 0.01). Because of the strong influence of privet on the shrub community and the influence of land cover disturbance on the densities of this invasive non-native

Table 2. Multiple regression models derived from all geomorphic and land cover. Models significant at p= 0.05 unless otherwise noted

Response	Explanatory variables with regression coefficients	R^2
Diversity of trees	0.08 +1.73(Relative relief)	0.71
Density of trees	0.02 –0.12(Flood frequency) +1.24(Relative relief)	0.61
Diversity of ssv	0.25 –0.12(Flood frequency) +1.71(Relative relief)	0.72
Diversity of shrubs	0.51 –0.0002(Road density) +0.44(93 nonforested local)	0.82
Density of privet	0.02 +0.0004(Road density)	0.32 (p=0.08)
Density of honeysuckle	8.94 –14.13(Relative relief)	0.62

Table 3. Multiple regression models derived from recent land cover. Models significant at p= 0.05 unless otherwise noted

Response	Explanatory variables with regression coefficients	R^2
Diversity of trees	0.94 –0.0003(Road density) +0.70(93 nonforested local)	0.59
Density of trees	No significant model	
Diversity of ssv	No significant model	
Diversity of shrubs	0.51 –0.0002(Road density) +0.44(93 nonforested local)	0.82
Density of privet	0.02 +0.0004(Road density)	0.32 (p=0.08)
Density of honeysuckle	1.19 +12.47(Proportion agriculture)	0.49

species, it seems that the influence of land cover factors over the shrub layer masks any geomorphic influence that may exist.

In the absence of geomorphic data, the density of honeysuckle, and diversity of trees can be predicted by land cover variables illustrating that land cover is a secondary constraint for these variables. However, no significant model was produced for diversity of seedlings, saplings and vines or tree density based on land cover alone.

CONCLUSIONS

In summary, the geomorphology of a basin is a better predictor of riparian forest characteristics than land cover factors. However, a key exception exists when describing variation in the shrub layer due to the nature of the dispersal and establishment of privet and the influence this shrub has over the native shrub community. Variation in the shrub layer is best accounted for by land cover variables. This illustrates the importance of incorporating variables from more than one aspect of the landscape. Variation in riparian forests is best accounted for using both land cover and geomorphic data.

In the absence of geomorphic data and historical land cover data, a significant amount of information about the character of riparian forests can be determined from recent land cover data. This provides an efficient way to describe riparian forests relying on available remotely sensed data rather than extensive and resource intensive fieldwork. There are several drawbacks that are worthy of note; (1) predictive power decreases with this restricted dataset, (2) results leave the interpreter with an incomplete idea about the mechanisms that define riparian forest characteristics and, (3) this restricted view could be detrimental to the success of restoration efforts.

Ultimately, information about riparian forest characteristics can be used to enhance attempts to assess stream biotic integrity and restoration work because of the many ways that riparian vegetation influences the physical, chemical and biological components of streams. Extensive in-stream data has been collected in the streams adjacent to the sampled forest patches by the researchers involved in the larger Etowah initiative. The next step of this research will be to determine the strength of the relationships between riparian forest vegetation and stream characteristics.

ACKNOWLEDGMENTS

This research was funded by a STAR grant from the U.S. Environmental Protection Agency (EPA# R826597-01-0) and the University of Georgia Research Foundation, Inc. Special thanks to Julie Mathes for her knowledge and support in the field. I would also like to extend thanks to Kenny Peavy and Peter Esselman for volunteering their time and to all of the collaborators on this grant for their knowledge, ideas and support.

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