EFFECTS OF FOREST FRAGMENTATION AND URBANIZATION ON STREAM CONDITIONS—THE DEVELOPMENT OF RELEVANT LANDSCAPE PARAMETERS AND SOURCE DATASETS FOR EFFECTIVE MONITORING

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Urbanization and associated fragmentation of forestland have been shown to adversely affect stream water quality and ecological health. Accurate land cover data of sufficient resolution are needed to identify effects of landscape alterations on stream ecosystems. Landscape data from photointerpretation is generally most accurate, but is not widely available and can be expensive to obtain. Satellite data sets, although more widely available, do not necessarily provide the accuracy and resolution needed to characterize critical features of the urbanizing landscape. In this study, we link USDA Forest Service (USFS) investigations of forest fragmentation and urbanization with U.S. Geological Survey (USGS) stream studies in the Delaware River Basin (New York, New Jersey, and Pennsylvania), conducted as part of the National Water Quality Assessment Program, in order to: (1) describe how streams in the study area respond to urbanization of their watersheds, (2) identify what types of landscape characteristics are related to the identified stream ecosystem responses, (3) evaluate the effect of landscape data source on interpretations of effects of urbanization effects on streams, and (4) devise a correction for widely available satellite data so that it can be effectively used in monitoring landscape changes that affect water quality.

Biological, physical, and chemical data were collected during 2000 and 2001 from 43 wadable streams in the Piedmont and Appalachian Plateau physiographic regions of the Delaware River Basin. Sites were selected to provide a gradient of urban intensity (as initially indicated by road density) while avoiding known point sources of contaminants and minimizing variation in natural factors, such as stream size, gradient, and channel type. Photointerpretation of the subbasins produced a set of landscape variables, including basinwide land cover percentages, buffer zone (200 m strip centered on the stream) land cover percentages, and statistics and indices that quantify land cover distribution and forest fragmentation. Finally, stressor-response patterns elucidated through analysis of photointerpreted data were compared with those identified by using National Land Characteristics Dataset (NLCD) 1992 and 2000 satellite-derived data sets, and with a modified version of NLCD 1992 after applying a proposed correction.

Stream responses that were found to be related to urbanization (as indicated by their correlation with road density) included (1) increasing (in spring baseflow) total nitrogen concentration (Spearman *rho* 0.56, p<0.001), (2) increasing (in spring baseflow) chloride concentration (*rho* 0.69, p<0.0001), and (3) increasing (in late summer baseflow) potential toxicity of the mixture of pesticides detected in the water column (*rho* 0.78, <0.0001). Increasing road density was also related to a decline in the number of sensitive macroinvertebrates, as indicated by metrics such as EPT richness, or the number of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa (*rho* -0.82, p<0.0001). In addition, road density was significantly correlated (*rho* 0.67, p<0.0001) with a change in macroinvertebrate community structure, as indicated by site scores on a Detrended Correspondence Analysis (DCA) axis I (eigenvalue 0.33).

An iterative process of Principal Components Analysis (PCA) and correlation analyses of landscape variables resulted in the reduction of the large number of landscape variables to a smaller number of landscape variables for further analysis. The two key types of landscape variables identified were (1) the relative quantity of forested or urban land in the subbasin (PCA axis I, eigenvalue 0.47), and (2) forest "patchiness" (PCA axis II, eigenvalue 0.40). Multiple regression with forward selection of key landscape variables was used to model invertebrate community structure (i.e. DCA axis I site scores). A model $R^2$of 0.86 ($p<0.01$) was achieved with a combination of three variables: percent forest in the basin, percent commercial or industrial land in the basin, and percent urban land in the buffer zone. Total nitrogen concentration in springtime base-flow samples was best predicted (model R^2 0.83, $p=0.004$) by a combination of percent forest in the basin, basin-wide contagion and percent commercial or industrial land in the basin. Subbasin percentage of forested land was the most important variable in both cases (R^2 0.77 and 0.68, respectively).

Use of the NLCD1992 dataset instead of the photointerpreted land use data to examine relations between stream ecosystem response and landscape characteristics resulted in substantially different patterns, such as differences in rate of response, differences in locations of apparent thresholds, and, in some cases, complete absence of response. These differences were due, in part, to the substantial underestimation of the extent of developed land use in basins at the lower end of the urbanization gradient by the NLCD1992 dataset – typically caused by a misclassification of urban areas with substantial tree cover as forestland. Application of a coarse "correction" to the NLCD1992 dataset, using neighborhood road density, improved basin land use estimates considerably, and resulted in some stressor-response patterns that more closely approximated those generated from photointerpreted data. Investigation of NLCD2000 data (available for the Piedmont region of the study area) is currently underway.

The adverse effects of land disturbance on water quality make monitoring of the amount, character and spatial distribution of forest and developed land essential. Results from this study indicate several landscape characteristics that are of particular importance to measure and monitor accurately with respect to their effect on water quality. The amount of forest land in subbasins was clearly a key factor underlying stream ecosystem responses. In addition, measures of spatial distribution of forest and disturbed land, and information regarding the type of developed land may be important to include in studies of effects of urbanization on water quality. In this study, using photointerpreted data was necessary to clearly depict the form of the relation between ecosystem responses and landscape characteristics, and for determining those factors of urbanization and fragmentation that may be management and planning-relevant. However, monitoring of urbanization and fragmentation over larger areas will still require the use of the more broadly available satellite-derived datasets, and the limitations of these source datasets must be considered.

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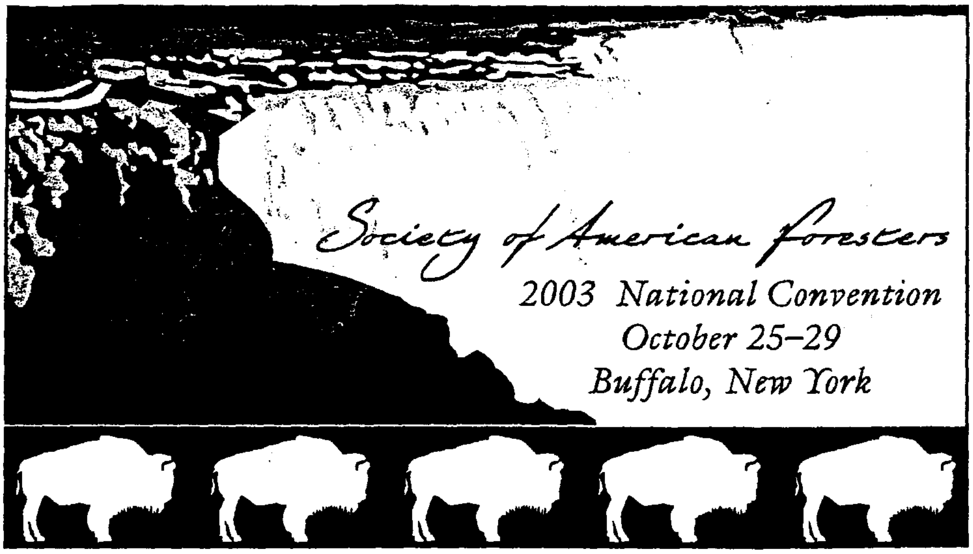

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