SPATIAL HETEROGENEITY IN URBAN ECOSYSTEMS: QUANTITATIVELY DEFINING A NEW LAND COVER CLASSIFICATION FOR GWYNNS FALLS WATERSHED, BALTIMORE, MARYLAND

MIVELIA ANDIKA
Rutgers University, New Brunswick, NJ 08901 USA

MENTOR SCIENTISTS: DRS. MARY L. CADENASSO AND STEWARD T. A. PICKETT
Institute of Ecosystem Studies, Millbrook, NY 12545 USA

Abstract. The study of cities and their suburbs as urban ecosystems is imperative, as increased human activity and urbanization impacts ecological functions and processes of urban areas. By defining the ecological structure, there will be better understanding of how ecological, physical and socio-economic factors in urban settings relate and change through time- through classification, integration and analysis of the landscape (Band et al Unpublished).

The ecological structure of the urban region of the Gwynns Falls Watershed, Baltimore, Maryland, was defined using a new land cover classification system. Components of spatial heterogeneity of patch types were quantified and compared within and between an urban region (Rognel Heights) and a suburban region (Glyndon) of the Gwynns Falls Watershed. The purpose of this study was to quantify the components of heterogeneity that characterize patch types delineated in a new land cover classification system, serving to further refine this land cover classification system.

Using a new program in Arc View GIS, selected transects (100m length, 1 transect/2 hectares) were randomly distributed over patches and sampled. Segment lengths were used to quantify components, using the variables- relative cover, average segment length and average number of segments. Quantification of heterogeneity within patch types revealed no differences between forest patch types among all variables. There were expected differences in tree density for structural patch types, while tree range and frequency varied between the two regions. The density of structural components for structural patch types was expected, and range and number of structural components were higher in the urban region.

INTRODUCTION

The world's population is expected to double within the next 38 years, and most of the growth will be concentrated in the urban areas of the world (UN 2000). With increased urbanization and human activity, the distribution and abundance of populations, species, and communities of an urban ecosystem will be significantly impacted (Kinzig and Grove 1997). Earlier ecological studies considered their subjects in the absence of humans, with humans as major disturbance factors (McDonnell 1993), or were largely descriptive and examined plants and animals that happened to occur in cities. More recently, studies being done in urban settings have been more quantitative, and consider the ecology *of* urban ecosystems as opposed to ecology *in* urban ecosystems (Hope et al. 2000). The Baltimore Ecosystem Study (BES) is a long-term research initiative studying the urban ecosystem of the Gwynns Falls Watershed, located in Baltimore, Maryland. One of the major questions of the study is how ecological, physical and socio-economic aspects of the urban ecosystem relate to each other and how they change through time (Band Unpublished). As part of the BES, the study presented here focuses on the ecological structure of the contemporary landscape, applying quantification of internal patch composition to qualitative land cover patch delineation.

The structure of the urban landscape is characterized by contiguous, disparate patches, which are made up of spatial components of heterogeneity. Patch delineation is qualitative, categorized by types and densities of components. In order to define the spatial structure of the ecological landscape and compare patch types through patch composition among different regions, quantitative methods are required. A land cover classification and coding system, with patch types delineated for two contrasting regions, provides the base for the quantification of internal patch composition.

The Standard Land Use Classification Manual (SLUCM), developed in the mid-1960s, served as the major standardized land use coding system for the nation (APA 1998). Anderson's Land-Use and Land Cover Classification System, created in 1976, provided more detailed categories than the SLUCM and utilized remote sensing imagery (Andersen 1976). The Multi-Resolution Land Characterization (MRLC) Classification System, created in 1999, also used remote sensing imagery and contained land use and land cover classes conterminous with Anderson's classes (MRLC 1999). Unlike these and other classification systems that qualitatively categorize land based on presence of human constructions (Hope et al. 2000), the new Land Cover Classification System developed by Cadenasso and Pickett (unpublished) is based entirely on land cover. The Cadenasso and Pickett (C&P) system is a qualitative delineation of patches and contains 3 main classes: Forest, Open and Structure. The quantification of internal patch composition serves to refine this classification system, by verifying the composition of patch types and the description of classification codes.

The purpose of this study was to further refine the C&P Classification system through rigorous definition of patch types, allowing improved comparisons of patch types among regions to be made 1) within an urban and suburban region and 2) between an urban and suburban region. I hypothesized that: 1) components of heterogeneity within a patch differed by patch type, 2) components of heterogeneity of a patch type would be the same among different study regions, and 3) components of heterogeneity of different patch types would differ within the same region.

Study Area

Two contrasting regions of the Gwynns Falls Watershed in Baltimore, Maryland, Glyndon and Rognel Heights, were studied. Patches for the Gwynns Falls Watershed reflect a gradient of urbanization as the stream flows from Glyndon in the upper northwest region to Rognel Heights, in the lower southeast region. Glyndon, located in the outskirts of Baltimore City, is a new developing suburban area comprised of residential, commercial and agricultural fields. Rognel Heights, located in Baltimore City, is an older, urban and commercial area. Each study region is approximately 18.5 square kilometers.

METHODS

Internal patch composition was spatially quantified through transect analysis in Arc View GIS. High-resolution infrared aerial photos, with leaf on, taken in October 1999, were used as the base layer in Arc View for the Gwynns Falls Watershed. Patches that had been delineated for the regions of Glyndon and Rognel Heights were layered over the air photos. A specific patch type to be examined was selected by query and saved as shape files in Arc View. A new software program, Arc Trcs, specifically designed for BES, was used to sample transects, which allows specific length and density of transects to be chosen (Tenenbaum et al. in review). Transects were randomly scattered across a selected patch type (shape file) with a length of 100m and density of one transect per 2 hectares. As sampling was done along the length of each transect, each spatial component of heterogeneity, represented as segments, was classified into their primary and secondary class (Table 1). Components along the transect but outside the patch boundaries were classified as 'Outside' and not included in the data analysis. Segment lengths by component class were continuously recorded in Arc View. Field verification was done during mid-July to verify patch type and component interpretations on the landscape, due to resolution limitations of aerial photos.

After all data had been collected and recorded in Arc View, the segment tables for each classification type were acquired and imported into an Excel spreadsheet. Every combination of primary and secondary classes for components was listed, along with their segment lengths. Using segment lengths for each unique combination, the number of transects, number of segments and total segment lengths were calculated.

For quantification of components and comparisons among different regions, relative variables were used, due to the diverse sizes and quantities of patch types:

Relative cover gives the cover or density of a specific component relative to the entire sampled area.

$$\frac{\text{Total length of segments}}{\text{Total length sampled}} \quad x100$$

The average segment length gives the length or range of a specific component measured across each 100m transect.

$$\frac{\text{Total length of segments}}{\text{Number of segments}} \quad x100$$

The average number of segments per 100m transect is the distribution or frequency of a specific component relative to the entire sampled area.

$$\frac{\text{Number of segments/100m transect}}{\text{Total length sampled}} \quad x100$$

Transect sampling and data collection was done for six patch types in both study regions (Table 2). Each selected classification combination had a common component of the same type and density, and another component of the same type but contrasting density. The component of heterogeneity contrasting density was used to compare patch types within and between the regions of Glyndon and Rognel Heights (Table 2). All data was analyzed using SAS.

RESULTS

Results will be discussed using the patch IDs (Table 2).

101vs. 102: Within Glyndon and Rognel Heights, there was no significant difference in the relative cover of trees for these two patch types. Comparing between Glyndon and Rognel Heights, the relative cover of trees in these two forest types was nearly the same (Figure 1). There were no significant differences in average segment lengths or average number of segments within and between the regions of and Glyndon and Rognel Heights for 101 and 102 (Figures 2 and 3).

3106 vs. 3108: Relative cover of trees was significantly greater in 3108 within Glyndon (39%) and Rognel Heights (58%) compared to 3106. The relative cover of trees was higher for 3106 and 3108 in Glyndon than Rognel Heights Heights for both 3106 and 3108 (Figure 5). The average number of tree-covered segments was higher in Glyndon for 3106 than 3108 and higher in Rognel Heights for 3108 within and between both regions (Figure 6).

(Figure 4). The average tree-covered segment length was significantly greater in 3108 within both regions and greater in Glyndon than Rognel 3103 vs. 3111: Within Glyndon and Rognel Heights, the relative cover of structures was slightly greater for 3111 in Glyndon but there was no difference between 3103 and 3111 in Rognel Heights. Glyndon had a lower relative cover of structures for 3103 than Rognel Heights and relative cover of structures did not vary significantly for 3111 between Glyndon and Rognel Heights (Figure 7). Within Glyndon, the average segment length was the same for 3103 and 3111. Within Rognel Heights, the average segment length was greater for 3103 than 3111. There was no difference among regions for either 3103 or 3111 (Figure 8). The average number of segments was significantly higher for 3111 within Glyndon and Rognel Heights, but did not vary significantly for 3103 and 3111 between regions (Figure 9).

DISCUSSION

The degree of spatial heterogeneity of components varied considerably among patch types within and between Glyndon and Rognel Heights. Patch types 101 and 102 were very similar in cover, segment length and average number of segments. The component of heterogeneity quantified for these two patch types was tree cover. Because both 101 and 102 are forested patch types, it is not surprising that they both exhibited almost 100% tree cover. The feature distinguishing patch type 101 from 102 is the maturity of the trees as exemplified by crown size. Therefore, canopy size may have been a more appropriate variable to measure.

Patch types 3106 and 3108 were distinguished from each other by the greater density of trees in type 3108 than 3106. This difference is illustrated by the greater tree cover in 3108 than 3106 in both Glyndon and Rognel Heights. However, tree cover was greater in Glyndon for both patch types than in Rognel Heights. The average length of tree cover, as measured by segment length, was greater in 3108 compared to 3106 for both Glyndon and Rognel Heights. This result is consistent with the greater tree cover. Therefore, where there is more tree cover, the length of tree cover is also greater. The average number of segments of tree cover in Glyndon does not follow this same trend. There are more tree cover segments in patch type 3106 than 3108. This indicates that though there is less tree cover in 3106, the cover that is there is in smaller pieces. Alternatively, patch type 3108 has greater tree cover and the cover is more continuous as indicated by the larger average segment length and the smaller average number of segments. In Rognel Heights patch 3108 has greater tree cover, longer segment lengths on average, and more segments.

Patch types 3103 was distinguished from patch types 3111 by the density of structures, which was greater in 3111. In Glyndon, the relative cover of structures was indeed greater in 3111 compared to 3103 but no difference was found in the cover of structures between patch types in Rognel Heights. In Glyndon, the lower cover of structure in 3103 is reflected in the smaller average segment length and in the fewer number of segments occupied by structures than 3111 patches. In Rognel Heights, though the cover of structures did not differ between patch types, the average number of segments occupied by structures in 3111 patches was greater and average segment length shorter than in 3103 patches. This indicates that structures in Rognel Heights are arrayed in a more scattered fashion in 3111 patches than in 3103 patches.

CONCLUSION

Quantification of internal patch composition improves the means to more accurately assess and compare spatial heterogeneity of patch types on the landscape, enabling refinement of the classification system. Due to time limitations for this study, only representative samples of patch types of the classification scheme were chosen for quantification. Future research is needed for quantification and comparison of other patch types within these regions and other study regions.

Using a classification system based on land cover enables understanding of the ecological structure of the urban landscape. It can be used for further ecological research or other objectives. Based on structural and vegetative cover, it can be applied to other urban areas that have variable densities and types of components, in which comparisons can be made among different regions within an urban ecosystem. It is hoped that patch delineation, classification and quantification of internal patch composition will be completed for two other regions, McDonogh and Oregon Ridge, and eventually for the entire Gwynns Falls Watershed. Together, the four study sites will represent the urban core, residential and suburban fringe, which are fundamental components of urban ecosystems (Band, Unpublished). Collaboration with a Baltimore group studying the socio-economic factors of the structural landscape through patch delineation will enable a strong linkage in the future, to understand the relationship between the ecological, socio-economic as well as physical processes and functions occurring on the urban landscape.

ACKNOWLEDGEMENT

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LITERATURE CITED

American Planning Association, Research Department. 1994. Land Based Classification Standards. www.planning.org/lbcs.index.html

Anderson, J., Ernest, H., Roach, J., and Witmer, R. 1976. A Land Use and Land Cover Classification System For Use With Remote Sensor Data. USGS.

Band, L., A. Berkowitz, G. Brush, W. Burch, J. Carerra R. Costanza, R. Foresman, R., P. Groffman, J. Grove, D. Nowak, S. Pickett, R. Pouyat, and W. Zipperer. *Unpublished.* Human Settlements as Ecosystems: Metropolitan Baltimore, Maryland, from 1797 to 2100.

Hope, D., K. Knowles-Yanez, and N. E. McIntyre. 2000. Urban Ecology as an interdisciplinary field: differences in the use of "urban" between the social and natural sciences. Urban Ecosystems **4**:5-24.

Kinzig, A. and J. Grove. 2001. Urban-Suburban Ecology. Encyclopedia of Biodiversity **5**:741.

McDonnell, M. J., S. Pickett , editors. 1993. Humans as components of Ecosystems. Springer-Verlag, New York.

Multi-Resolution Land Characterization (MRLC) Consortium. 1999. National Land Cover Data. United States Geological Survey.

Tenenbaum, D. E., M. L. Cadenasso, L. E. Band, and S. T. A. Pickett. *In Review.* ARCTrcs - ARCView Transect Characterization System. Journal of Geographical and Environmental Modelling.

United Nations. 24 Mar 2000. World population growth will occur in urban areas of the world. People's Daily. www.peopledaily.com.cn

APPENDIX

TABLE 1. Components of heterogeneity within patch types, broken down into primary and secondary classes.

Primary Class	Secondary Class
Herbaceous	mown lawn, unmanaged field
Pavement	walkway, driveway, parking lot
Road	<= 2 lanes, > 2 lanes
Structure	pitched, flat, equipped roof
Water	swimming pool, pond, lake
Woody	deciduous, mixed stature, shrub

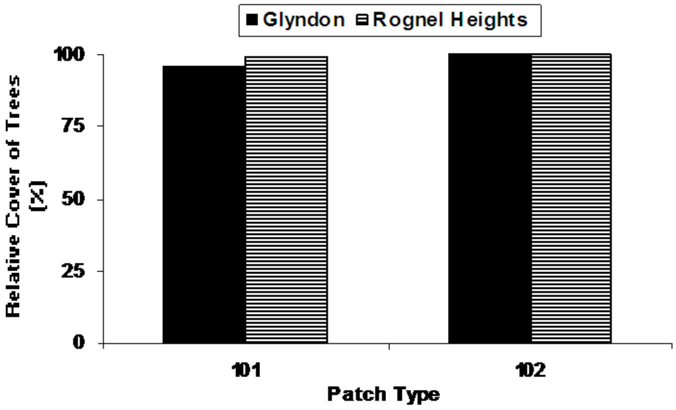

FIGURE 1. Relative cover (%) of tree components for forest patch types 101 (mature forest) and 102 (young forest).

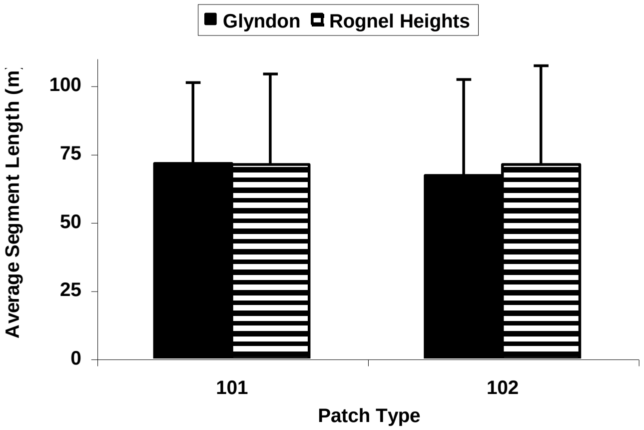

FIGURE 2. Average segment length (meters) (±SE) for forest patch types 101 (mature forest) and 102 (young forest).

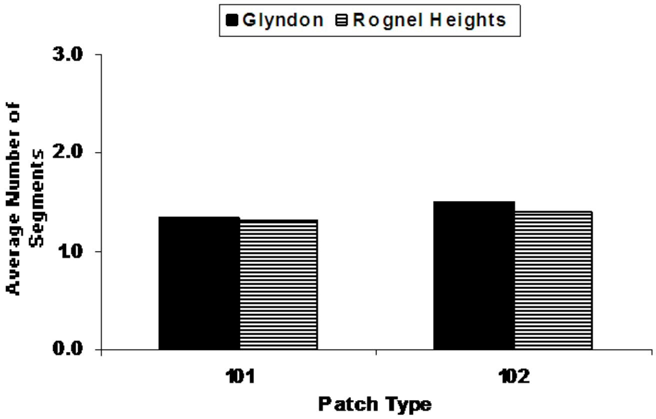

FIGURE 3. Average number of segments of tree components for forest patch types 101 (mature forest) and 102 (young forests).

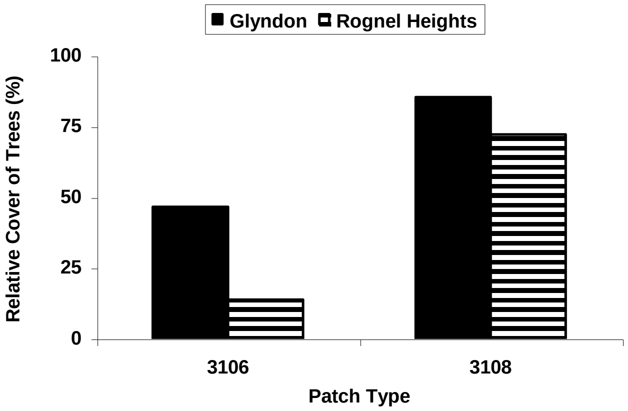

FIGURE 4. Relative cover (%) of tree components for structural patch types 3106 (lower tree density) and 3108 (higher tree density).

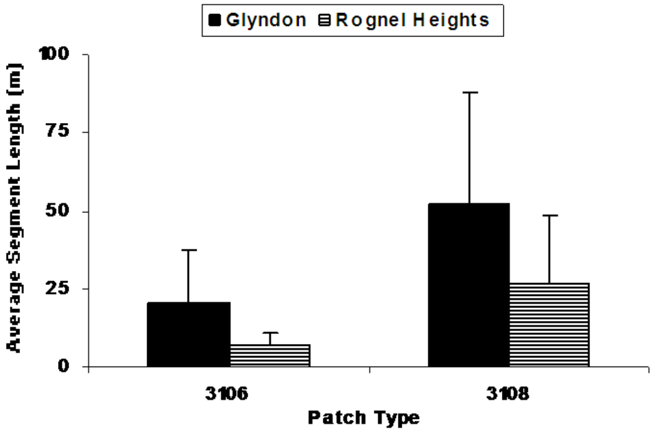

FIGURE 5. Average segment length (m) (±SE) of tree components for structural patch types 3106 (lower tree density) and 3108 (higher tree density).

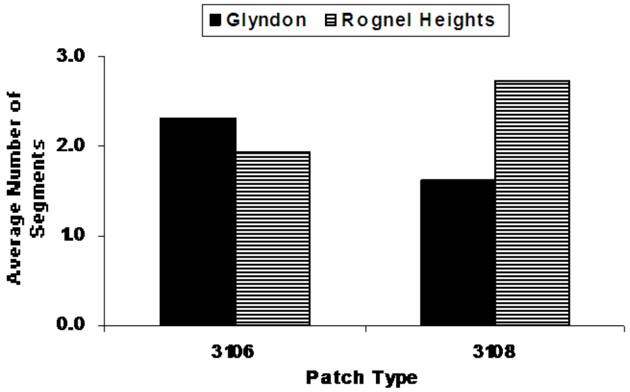

FIGURE 6. Average number of segments of tree components for structural patch types 3106 (lower tree density) and 3108 (higher tree density).

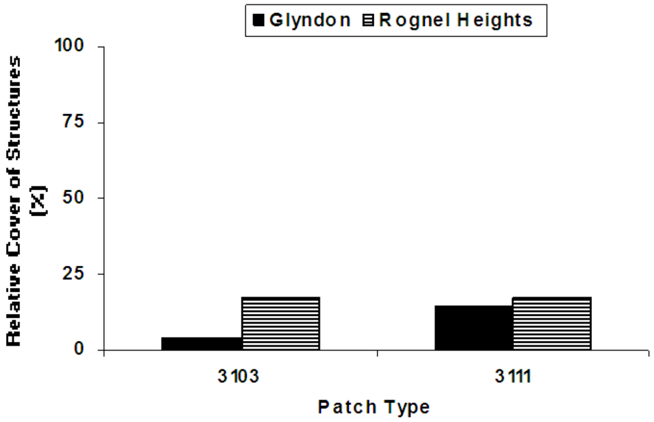

FIGURE 7. Relative cover (%) of structural components for structural patch types 3103 (lower structural density) and 3111 (higher structural density).

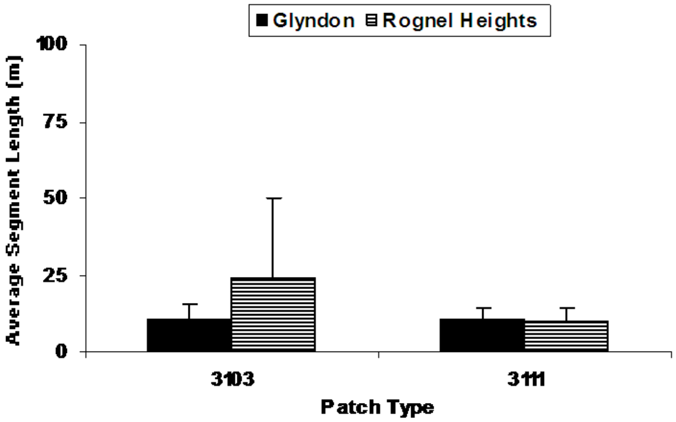

FIGURE 8. Average segment length (m) (±SE) of structural components for structural patch types 3103 (lower structural density) and 3111 (higher structural density).

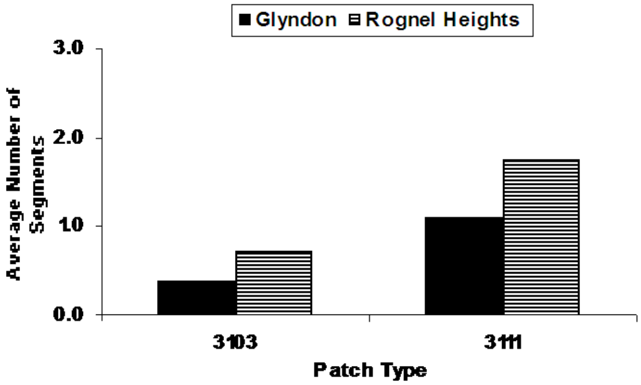

FIGURE 9. Average number of segments of structural components for structural patch types 3103 (lower structural density) and 3111 (higher structural density).

TABLE 2. Patch types sampled in Glyndon and Rognel Heights study regions and the component of contrasting density.

Patch ID	Patch Description	Component of contrasting density
101 **102**	(mature deciduous) vs. (young deciduous)	Trees
3106 **3018**	(single bungalow medium density, w/ low density of high vegetation) vs. (single bungalow medium density, w/ high density of high vegetation)	Trees
3013 **3111**	(single bungalow low density, with medium density of high vegetation) vs. (single bungalow high density, with medium density of high vegetation).	Structures