Landscape and Urban Planning 108 (2012) 28–38

Contents lists available at SciVerse ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research paper

Landscape structure, zoning ordinance, and topography in hillside residential neighborhoods: A case study of Morgantown, WV

Jinki Kim*, Xiaolu Zhou

University of Illinois, Department of Landscape Architecture, Fine & Applied Arts, 611 Taft Drive, Champaign, IL 61820, United States

HIGHLIGHTS

- ▶ Landscape structures are significantly associated with lot attributes governed by zoning ordinance.
- ▶ Zoning requirements for smaller minimum lot size and lot frontage result in more vegetation but also cause more fragmentation.
- ▶ Geographic slope influences landscape structure in hilly residential neighborhood.

ARTICLE INFO

Article history:
Received 23 January 2012
Received in revised form 17 July 2012
Accepted 24 July 2012
Available online 11 August 2012

Keywords:
Landscape structure
Zoning ordinance
Geographic characteristics
Single-family parcel
Landscape fragmentation

ABSTRACT

The purpose of this study is to investigate the relationship among landscape structure, zoning ordinance, and geographic attributes in Morgantown, West Virginia. Two residential areas zoned by different standards, but with similar development history and socioeconomic status were examined.

Aerial photography was digitized into woody and non-woody areas and the landscape structure was quantified with six core landscape metrics related to fragmentation. Computer aided design (CAD) map and digital elevation model (DEM) were used for the calculation of building footprint and geographical characteristics respectively.

The findings indicate that differences in zoning requirements result in distinct landscape structure. Zoning requirements for smaller minimum lot size and lot frontage result in more vegetation but also result in more fragmentation than requirements that call for greater minimum lot size and lot frontage. Although building footprint is weakly associated with landscape structure, lot size and lot perimeter are strongly related to vegetation abundance, fragmentation, and dominance. Slope is associated with vegetation patch size, especially in hilly residential neighborhoods.

This study provides a better understanding of how human and environmental factors are related to residential landscape structure at different scale. Providing numerous quantitative metrics is useful for understanding social and ecological benefits. The results of this study will help planners, landscape architects, and administrators for planning and designing more ecologically and socially sustainable neighborhoods.

1. Introduction

It is widely recognized that urban vegetation provides a variety of important benefits, which can be summarized as follows: (1) social, such as improving social cohesion (Kweon, Sullivan, & Wiley, 1998) and neighborhood vitality (Sullivan, Kuo, & DePooter, 2004); (2) economic, such as improved property values (Tajima, 2003); (3) psychological, such as promoting psychological health and well-being (Shin, Yeoun, Yoo, & Shin, 2010); (4) environmental, such as mitigating the urban heat island effect (Yuan & Bauer, 2007), enhancing carbon sequestration (Jo & McPherson, 1995; Nowak & Crane, 2002), providing important habitats for wildlife (Young, 2010), increasing local biodiversity (Kong, Yin, Nakagoshi, & Zong, 2010), and improving air quality (Nowak, Crane, & Stevens, 2006); and (5) physical health, as evidenced by improved health indicators (De Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003).

Swanwick, Dunnett, and Woolley (2003) likewise concluded that the presence of green spaces has multiple benefits, such as providing social support and helping maintain urban sustainability and facilitate urban renewal.

Urban vegetation structures have been studied in many different ways. Schmid (1975) found that the composition and configuration of vegetation are important in the urban setting. Schmid investigated urban vegetation in Chicago residential areas and found that biomass, species composition, and arrangement of plants varied significantly among neighborhoods with different physical and

* Corresponding author. Tel.: +1 217 244 8658.
E-mail addresses: jinkikim@illinois.edu (J. Kim), xzhou11@illinois.edu (X. Zhou).

0169-2046/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.landurbplan.2012.07.011

social fabrics. Urban vegetation structure has also been proven to be associated with bird fauna distributions (Murgui, 2009), while land cover composition and configuration were shown to affect land surface temperature in urban areas (Zhou, Huang, & Cadenasso, 2011).

Within the last two decades, combining ecological and socioeconomic methods has been essential to studies of urban and rural areas (Grove & Burch, 1997; Grove et al., 2006b; Iverson & Cook, 2000; Martin, Warren, & Kinzig, 2004; McDonnell & Pickett, 1990; Troy, Grove, O'Neil-Dunne, Pickett, & Cadenasso, 2007; Zipperer, Sisinni, Pouyat, & Foresman, 1997). A common finding is that household income and level of education are positively correlated with amount of vegetation cover (Grove & Burch, 1997; Grove et al., 2006a; Iverson & Cook, 2000; Troy et al., 2007) and a diversity of urban vegetation (Martin et al., 2004).

Iverson and Cook (2000) found wealthy regions have higher tree cover than poor regions. Troy et al. (2007) found a positive relationship between the percentage of African American families and tree canopy cover in an area. Martin et al. (2004) found that vegetation richness in a neighborhood has a strong positive correspondence with socioeconomic status (SES)––that is, neighborhoods with a high SES are more likely than low-SES neighborhoods to have rich vegetation.

As urban landscape development policies and codes become more prevalent, studies on the relationship between regulations and vegetation patterns are being conducted. Landry and Pu (2010) found that land development codes were associated with protection of urban forests in residential areas. Robinson and Brown (2009) evaluated land-use development policies on forest cover. Results showed that large lot-size zoning policies led to greater sprawl and increased forest cover. Zhou and Wang (2011) found that the existence of green space policies or regulations had an impact on the process of green space change. Kim and Ellis (2009) found that an ecologically planned neighborhood exhibited a less fragmented forest pattern and that restrictive development guidelines resulted in more ecologically sound environments. Sung (2012) evaluated the efficacy of tree removal permits and found that communities requiring tree removal permits had trees taller than those in communities without such permits.

Landscape ecology outlines important principles of green space organization related to the theory of island biogeography (MacArthur & Wilson, 1967). In essence, large patches, high connectivity, and proximity foster species diversity and ecosystem functions. These spatial concepts have been widely adopted in urban landscape architecture and landscape planning projects (Goldstein et al., 1982/1983).

Landscapes are distinguished by spatial relations among component parts and can be characterized by both composition and configuration (Turner, 1989). Landscape structure is determined by the flow of materials, animals, energy, and water through the landscape elements of patches, corridors, and matrix. Factors such as patch size and shape, corridor characteristics, and connectivity work together to establish the pattern and process of the landscape (Forman, 1995). Configuration is how the spatial arrangement of patches accounts for their position in relation to the dispersal of individuals through an entire network of patches. Patch geometry describes the attributes of patches such as area, perimeter, and heterogeneity (Borthagaray, Arim, & Marquet, 2012). We use the term "landscape structure" to describe the spatial configuration and geometry of tree canopy in this study.

Despite the regulations and socioeconomic factors that shape urban landscape structure, we know relatively little about the relationship between landscape structure and design attributes such as lot size, setback line, ground floor area of buildings, and streets governed by zoning ordinances. Recently, a few studies have considered these aspects, such as street pattern (Conway & Urbani, 2007; Stone, 2004), lot size and frontage (Stone, 2004), and zoning class (Wilson, Clay, Martin, Stuckley, & Vedder-Risch, 2003), and found that these attributes are related to urban vegetation conditions.

A further dimension that is not well understood but influences landscape structure is the geographic characteristics such as slope, aspect, and elevation. A few studies have been conducted on the relationship among plant communities, landforms, and geomorphic surfaces. Parker and Bendix (1996) examined geomorphic influences on vegetation patterns at the landscape scale and found that the geomorphic processes most strongly linked with vegetation patterns operate. Wondzell, Cunningham, and Bachelet (1996) observed that the correlation of plant communities to landforms and geomorphic surfaces resulted from differences in the redistribution of water and organic matter between landforms. Similarly, Hope et al. (2003) found that elevation is a significant predictor of variation in plant diversity, and Lowry, Baker, and Ramsey (2012) found that neighborhood age is an important covariate that influences how the human and environmental factors relate to the abundance of neighborhood tree canopy.

Even though many factors, such as socioeconomic status, geographic condition, built environment, and development regulations, have been used as a means to understand urban vegetation, few comprehensive studies of residential landscape structure have been conducted. This gap in understanding hinders the ability to predict the impacts of future residential development and to design planning strategies that might mitigate negative impacts. We hypothesize that subdivision design attributes governed by zoning and geographic characteristics, however, may exert influence on neighborhood landscape structures along with socioeconomic status and the built environment. Providing numerous quantitative metrics is useful for understanding social and ecological benefits and designing sustainable landscapes, particularly in the urban context, where land resources are limited.

Different social groups can derive different social and ecological benefits from the same landscape. The resultant trade-off between benefits of urban vegetation and the issue of safety and management may place a constraint in residential landscape structure. However, the benefits of urban vegetation to residents and to urban-dwelling species are significant; therefore, comprehensively identifying the factors that influence and shape landscape structure in urban areas is thus pivotal.

The purpose of this study, therefore, is to investigate a broad range of factors related to residential landscape structure in Morgantown, West Virginia––more specifically, to provide a better understanding of how zoning ordinances and geographic characteristics are related to landscape structure in a hilly residential area at two levels: community and block. The study utilized a core set of landscape metrics that are considered the most useful and relevant for landscape planning and management. A quantitatively robust study to better understand how human and environmental factors are related to residential landscape structure at different scales will provide planners and landscape architects with accurate information they can use to improve neighborhood design and to manage neighborhood landscape more efficiently.

2. Study area

West Virginia is located within Appalachian region that follows the ridge of the Appalachian Mountains from southern New York to northern Mississippi. The state is primarily mountainous, with the average elevation at 457 m above sea level, which is the highest of any US state east of the Mississippi River. Most of the smooth surface areas are near large rivers such as the Ohio River or Monongahela River. Extremely irregular in boundary,