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Forest and the city: A multivariate analysis of peri-urban forest land cover patterns in 283 European metropolitan areas

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ABSTRACT

Heterogeneous definitions of urban areas and poorly homogenized forest data at the country scale have hampered the comparative assessment of peri-urban forest structure in developed countries. The present study investigates selected landscape characteristics of peri-urban forests in 283 metropolitan areas in Europe controlling for the role of the local context and regional suburbanization trends. Using landscape metrics derived from Urban Atlas maps (a Copernicus/GMES initiative providing a comprehensive land-use assessment of European cities >100,000 inhabitants), significant differences in peri-urban forest structure were detected under five European regions. Specific class metrics (percent forest area, mean patch size, perimeter-to-area ratio) were correlated with urban morphology, landscape and territorial indicators. On average, forest cover is larger in northern and southern European metropolitan areas. Forest patch size increases from western to eastern Europe, with more regular patch shapes in central and eastern regions and less regular shapes in the rest of Europe. Forest class area increases with the area of discontinuous, medium-density settlements. Forest patch size increases with the average patch size of discontinuous dense urban fabric. Our evidence outlines a 'sprawl model' shaping fringe landscapes characterized by discontinuous urban settlements mixed with fragmented – but possibly well protected – forest patches.

1. Introduction

Urbanization is increasingly affecting environmental quality and ecosystem patterns at the global scale (Piorr et al., 2011; Wu, 2013). Changes in the use of land depend on place-specific factors shaping the spatial organization of metropolitan areas and are in turn influenced by the socioeconomic and planning context, at both national and regional scales (Hall and Hay, 1980; Couch et al., 2007; Turok and Mykhnenko, 2007). For example, Europe in the industrial age was characterized by a small number of urban centres dominating (more or less) vast rural areas (European Environment Agency (EEA), 2006a). In the past century, cities grew mainly along the access routes, railroads and waterways (Antrop, 2004).

After World War II, with the growing use of cars, cities expanded into rural areas, creating dispersed settlements and fragmenting natural and agricultural landscapes. Especially during the last three decades, European landscapes have been experienced drastic transformations impacting soil, water, biodiversity and rural communities (Zitti et al., 2015). According to Piorr et al. (2011) more than a quarter of land in Europe is affected by urbanization. The expanding Wildland-Urban Interface (WUI) reflects the growing anthropogenic pressure on fringe land where cities, agriculture and forestry are competing for space (European Environment Agency (EEA), 2006a; Tavares et al., 2012).

Forests and green areas surrounding cities have been considered key components of urban ecosystems, being managed for centuries especially in central Europe. Public green spaces were considered an appropriate response to the decreasing quality of life in expanding industrial cities (Konijnendijk et al., 2006). The notion of 'urban forest', originally proposed in the United States, appeared for the first time in Europe at the end of the 1970s (Ricard, 2005). This

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concept refers to the structural elements of green areas and their urban/suburban location, considering the benefits of natural vegetation to urban ecosystems (Escobedo et al., 2011). However, the concept of 'urban forestry' – often referred to a space situated 'in (and around) urban area(s)' – seems to be rather vague especially in Europe (Gomez-Baggethun and Barton, 2013), where the diversity in urban cultures and landscapes is remarkable and the definitions of 'urban area' and 'metropolitan area' vary largely among countries (Wu, 2014). Furthermore, the term 'municipal forest' is often used to distinguish vegetated areas included in private property from public urban forests.

Forests have been subjected to different management techniques along the urban gradient (Tyrväinen et al., 2005), notwithstanding the multiple ecosystem services and socioeconomic benefits they provide according to spatially-varying local contexts (Bowler et al., 2010; Fares et al., 2015). The practice of managing forests or groups of trees in (and around) urban areas, the so-called 'Urban and Peri-urban Forestry' (UPF), is a relevant issue contributing to the sustainability of urban environments (Konijnendijk et al., 2006). Research has investigated the role of peri-urban forests in the mitigation of climate change (Gomez-Baggethun and Barton, 2013; Nowak et al., 2008; Niemelä, 2014), improvement of well-being (Lachowycz and Jones, 2013; Wolch et al., 2014), biodiversity conservation (Wu, 2013), increasing land value (Zygmunt and Gluszak, 2015) and high-quality drinking water (Abildtrup et al., 2013) providing multiple benefits to different population segments (Wang, 2013). Further investigation is needed to refine approaches to assess urban sustainability (Grimm et al., 2008; Salvati et al., 2013) by developing innovative frameworks that improve knowledge in social and ecological systems (Wu, 2014; Niemelä, 2014; Childers et al., 2013).

Peri-urban forestry is seen as a powerful tool mitigating the negative effect of urbanization on environmental quality and ecosystem functions that guarantee human well-being (Nowak and Walton, 2005; Zhang et al., 2013). The conversion rate of natural land to urban use has progressively increased in Europe, with either rising or declining population (Salvati and Carlucci, 2015; Zitti et al., 2015). Recent urbanization is characterized by dispersed and low-density expansion, resulting in a progressive fragmentation of cropland and forests (Johnson, 2001; Ferrara et al., 2014) and impact on carbon storage (Sallustio et al., 2015). Moreover, residential settlements are getting closer to shrubland and woodland, resulting in an increased risk of forest fires (Ferrara et al., 2014; Corona et al., 2015). Urban agglomerations expanding into more distant land from central cities usually impact negatively forest structure and functions (Bruegmann, 2005; Poelmans and Van Rompaey, 2009; Salvati and Sabbi, 2011), altering ecosystem patterns and processes in the long-term (Zipperer, 2002; Salvati and Ferrara, 2013).

With urbanization being a key process in the fragmentation of rural landscape (Yang and Liu, 2005; Tang et al., 2006; Gonzalez-Abraham et al., 2007), regional planning is increasingly required to foster provision and maintenance of ecosystem services (Tavares et al., 2012; Childers et al., 2013; Kelly et al., 2015). Managing peri-urban forests should take into account key planning issues such as institutional fragmentation and the heterogeneity of local actors (Ricard, 2005). The hypothesized mismatch between planning and practices at the local scale requires substantial efforts integrating urban development policies and environmental protection measures (Kline et al., 2004). Permanent assessment of peri-urban forests carried out at both central and decentralized levels of territorial governance is recognized as a crucial task in the European policy agenda (European Environment Agency (EEA), 2006b) and multi-criteria approaches are required to inform cooperation between scientists, planners and urban dwellers (Tress et al., 2005). In this sense, forest monitoring provides basic information to regional planning and sustainable land management (Corona et al., 2012; Weissert et al., 2014).

This study investigates differences in peri-urban forest structure between European regions under different suburbanization trends, using a unique geo-database which allows a comparable and detailed analysis of the spatial distribution of land-use and land cover types (Seifert, 2009). A comparative framework using high-resolution land-use maps and data mining was applied to 283 cities classified under five European regions. An exploratory multivariate data analysis was run on three landscape metrics (forest class area, mean patch size, perimeter-to-area ratio) allowing for a comprehensive investigation of peri-urban forest structure with respect to (i) landscape composition, (i) structure and spatial configuration of urban and agricultural land-use classes, (iii) settlement density, (iv) city size and (v) suburbanization trend. To highlight the influence of urban form and configuration of agricultural landscape on peri-urban forest land cover patterns in European cities provides basic information for assessing and planning forest ecosystems in the (expanding) metropolitan areas.

2. Materials and methods

2.1. Study area

The present study investigates 283 metropolitan areas located in 27 European countries (Fig. 1) whose boundaries are delineated according to the Urban Atlas (UA) initiative aimed at collecting homogeneous land-use data for European cities >100,000

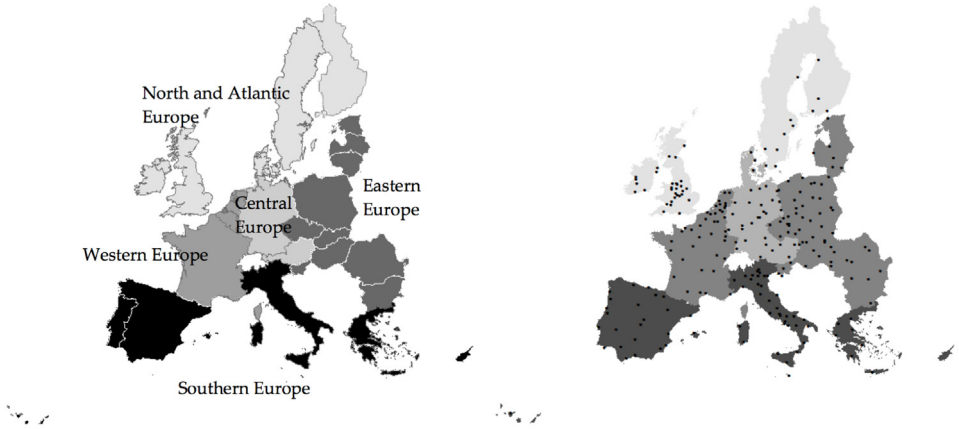

Fig. 1. Maps of the European countries and the five regions investigated in the present study (left) and the spatial distribution of the 283 cities (right).