Ecological Indicators 76 (2017) 71–80

Contents lists available at ScienceDirect

Ecological Indicators

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

Research Paper

Towards sustainable growth? A multi-criteria assessment of (changing) urban forms

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ARTICLE INFO

Article history:
Received 19 September 2016
Received in revised form
31 December 2016
Accepted 10 January 2017
Available online 22 January 2017

Keywords:
Compactness
Sprawl
Morphology
Fractal dimension
Mediterranean city

ABSTRACT

A multi-criteria approach based on descriptive, correlation and multivariate statistics and mathematical morphology was proposed to investigate long-term morphological changes in a metropolitan region (Attica, Greece) representative of the 'Mediterranean compact city' archetype. A total of 33 metrics measured at 6 time points (1948, 1975, 1990, 2000, 2006, 2012) from diachronic land-use maps were used to identify urban phases characterized by variable intensity of growth and reflecting distinct socioeconomic contexts at the local scale. The Attica's urban spatial structure has rapidly changed following Athens' expansion. Fragmentation, dispersion and shape complexity of built-up patches have been continuously increasing over time. Metrics' patterns differed significantly between two time intervals (1948–1990 and 1990–2012), with the highest spatial variability of landscape metrics being observed in the last two decades. Fractal indexes have reached the highest values in 2006 and 2012. Based on critical thresholds of per-capita land consumption, settlement dispersion and patch fragmentation, a Principal Component Analysis has indicated that the Athens' spatial structure of late 1980s and early 1990s was more sustainable than earlier and more recent urban morphologies. Results of this study contribute to a better understanding of long-term form-function relationships in compact and dispersed cities, offering an empirical base to identify sustainable urban forms.

1. Introduction

Recent urban transformations in developed countries have been primarily associated to the expansion of large- and medium-size cities stimulated by population deconcentration and economic decentralization (Kasanko et al., 2006; Longhi and Musolesi, 2007; Schneider and Woodcock, 2008). New spatial structures have emerged based on the assumption that metropolitan regions are becoming increasingly dispersed, central business districts attracting less jobs and new sub-centers emerging at the edge of large cities (Turok and Mykhnenko, 2007).

Urban sprawl has been intended as a key factor causing modifications in the form of compact and dense cities (Schwarz, 2010). Earlier studies suggest that patterns and processes of sprawl well reflect unexplored relationships between urban morphology and socioeconomic functions in cities characterized by mono-centric and continuous settlements (Leontidou, 1990; Bruegmann, 2005; Couch et al., 2007; Salvati, 2014a). The resulting metropolitan structures are becoming progressively more complex and entropic, with increased patchiness and fractal urban landscapes (Paul and Tonts, 2005; Terzi and Bolen, 2009; Chorianopoulos et al., 2010; Serra et al., 2014).

Sprawled development has become a growing concern as regards urban sustainability. Stemming from the idea of 'compact, mixed-use and walkable' cities, the concept of sustainable urban form (Talen, 2011) encompasses the morphological dimensions of density, diversity and nodality, while low-density development is likely to bring about higher infrastructure costs, increased air pollution, uncontrolled growth of land consumption, weakened social connection (Ferrara et al., 2015).

Due to the implications of changes in urban spatial structures for sustainable development, optimal city forms have been investigated in different socioeconomic contexts (Anas et al., 1998). Garcia-López and Muñiz (2013) pointed out that urban structure

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http://dx.doi.org/10.1016/j.ecolind.2017.01.008
1470-160X/

is important for economic growth in an intra-metropolitan context, demonstrating the existence of neighborhood specialization economies and metropolitan localization economies fostering local development. Camagni et al. (2002) indicated polycentrism as a way towards balanced and sustainable territorial development, combining the agglomeration economies typical of compact cities with the reduced congestion of decentralized urban diffusion.

Based on a comprehensive analysis of urban sustainability in European cities, Shaker (2015) has shown that conventional urbanization will continue to disconnect socioeconomic welfare from life-supporting ecosystem services. Dispersed urban growth negatively influences ecosystems both directly (in and near the city) and remotely through land conversion, use of natural resources and generation of emissions and waste (Alberti et al., 2003; Alberti, 2005, 2010; Biasi et al., 2015). Despite soil is a crucial land resource for many ecological processes (Keesstra et al., 2016; Brevik et al., 2015), soil consumption and land degradation usually reflect dispersed urbanization (Beniston et al., 2016). Air pollution is also a relevant outcome of discontinuous urban expansion (Trujillo-González et al., 2016). Fragmentation of priority habitats is also a common process related to urban sprawl (Aguilera et al., 2011; Colantoni et al., 2015), affecting both landscape structure and functions and causing a potential loss of biodiversity (Botequilha-Leitão and Ahern, 2002; Tombolini and Salvati, 2014). Conversely, sustainable urban form and appropriate land-use planning may contain loss of natural habitats and biodiversity (European Environmental Agency, 2006).

Jabareen (2006) identified multiple design concepts related to urban morphology (compactness, sustainable transport, density, mixed land-use, diversity, passive solar design and greening), proposing four types of sustainable urban forms: the neo-traditional development, the urban containment, the compact city, and the eco-city. Compact cities, characterized by high population density, mixed land-use and spatially-concentrated economic functions (e.g. in a Central Business District) have been proposed as one solution for sustainable urban planning (Westerink et al., 2013; Qureshi and Haase, 2014; Salvati, 2014b). However, the applicability of a more compact setting to expanding already dense cities remains questionable (Redman and Jones, 2005). Critical debate on the compact city includes crucial questions of the environmental benefits accruing to compaction, and its acceptability to local communities (Breheny, 1997; Burgess and Jenks, 2002; Frey, 2003; Colantoni et al., 2016). Major doubts are raised about the economic, political and technical dimensions of compaction and particularly the unacceptability of higher densities to many urban residents (Williams et al., 2000; Dovey and King, 2011; Jenks et al., 2013). Essential to the decision-making is a deeper understanding about the relationship between urban compactness and the sustainable performance of growing cities (Holden, 2004).

Urban sustainability indicators play an important role helping policy-makers to ensure the continued success of their metropolitan regions (Tan et al., 2005; Chen et al., 2008; Ioannidis et al., 2009). Land saving is critical to long-term sustainability of urban expansion and is considered a target criterion informing policies that reduce the environmental impact of sprawl (Zitti et al., 2015). Efficiency in the use of land is a widely accepted concept in the analysis of urban sustainability (Munafò et al., 2013), providing relevant information on land consumed by specific forms of urban expansion (Grădinaru et al., 2015). Although polycentric development has been hypothesized to contribute to more sustainable (spatially-balanced, economically depolarized and socially mixed) spatial structures than mono-centric urban expansion, it has been demonstrated that a polycentric metropolitan growth may consume a higher rate of non-urban land than cities dominated by a central core and with suburbs expanding radio-centrically (Munafò et al., 2010).

Urban morphology is spatially measurable through metrics, supporting studies on sustainability of urban forms (Burton et al., 2003). Tsai (2005) proposed four dimensions to evaluate urban structures at the metropolitan level: city size, activity intensity, the degree that activities are evenly distributed, and the extent that high-density sub-areas are clustered. Formulation of new indicator systems and quantitative approaches to the identification of sustainable urban forms in both compact and dispersed metropolitan areas is a relevant issue in regional planning and urban studies. Multivariate approaches analyzing diachronic land-use maps may help identify a set of working indicators of sustainability in a given urban structure, possibly replacing traditional, univariate metrics (Westerink et al., 2013). Comparing different spatial configurations of a given metropolitan region with multi-criteria approaches (e.g. based on a wide set of morphological indicators) may provide a relevant contribution in the identification of more (or less) sustainable urban forms (e.g. Carlucci et al., 2016). Sustainable urban forms can be evaluated comparatively on the same (expanding) city over time or among different cities at the same time.

The present study illustrates an original, multi-criteria framework assessing conditions for sustainability of different urban forms. To fill the gap between theory and practice and to overcome vague definitions of urban sustainability, we identified relevant conditions appropriate to evaluate urban forms based on few target indicators (Keirstead and Leach, 2008). Subsequently, we have expanded the analysis considering a wide set of indicators representative of 4 themes (urban concentration, spatial expansion pattern, patch fragmentation/fractal dimension, landscape complexity). The approach was used to evaluate the sustainability of different settlement morphologies in the light of land-saving processes of urbanization by investigating changes in the form of a compact and mono-centric metropolitan region (Athens, Greece) throughout six years (1948, 1975, 1990, 2000, 2006, 2012). By displaying one of the lowest amounts of per-head sealed land in the European capitals (Salvati, 2016), Athens is a paradigmatic example for the identification of sustainable urban forms alongside its long-term expansion.

2. Methodology

2.1. Study area

The investigated area encompasses the Athens Metropolitan Region (AMR) which extends nearly 3000 km^2 in the Nuts-2 administrative region of Attica, central Greece (Fig. 1). All mainland areas and the island of Salamina were considered in this study being administered by 115 municipalities on the base of the 'Kapodistrian' administrative asset in force during the study period. The AMR mostly consists of mountains bordering a flat area known as 'Lekanopedio Attikis' [water basin of Athens] and hosting Greater Athens, a compact urban area extending nearly 400 km^2 and being administered by 58 municipalities. Three coastal plains (Messoghia, Marathona, Thriasio) are situated in the Attica region outside the Greater Athens' area. The climate is semi-arid since land received nearly 400 mm rainfalls (30-years average) with a mean annual temperature above 19 °C. Since the early 1990s, the city was aiming to attract investments to sustain peri-urban growth (Delladetsima, 2006). The 2004 Olympic Games have positively impacted the city's economic background attracting investments and promoting the construction of new infrastructure (Chorianopoulos et al., 2010). Later on, the economic crisis has reduced building activity by more than 50% over few years (Salvati, 2014a).