



Exploring prospective urban growth trends under different economic outlooks and land-use planning scenarios: The case of Athens

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1. Introduction

Changes in land cover and land use are among the most important human made alterations on earth, reflecting a wide range of interactions between society and the environment (Turner II, Lambin & Reenberg, 2007). The rapid transformation of land into artificial surfaces, has rightfully attracted the attention of scholars, planners and policy makers, concerned with the negative environmental implications it entails (Johnson, 2001). Research on the environmental impact of unregulated urban expansion centers on a number of issues, ranging from soil sealing, ecosystem fragmentation and the increased consumption of rural and natural land (Hasse & Lathrop, 2003; Jongman, 2002; Milesi, 2003), to broader concerns regarding the demotion of “urban sustainability” goals (Wilson & Chakraborty, 2013).

In view of these consequences, emphasis in the literature is placed on the capacity of land-use planning to influence the form, degree and direction of urban growth tendencies. Key in the fruitfulness of such efforts - aptly termed “smart growth” policy initiatives (EEA, 2006) - is the availability of two distinct types of information. First, an appraisal of urban growth trends, encompassing the pivotal factors that influence urban expansion. Second, an estimation of the impact of particular spatial planning choices on future land cover patterns (Xiang & Clarke, 2003). In the absence of such insights, spatial planning is insufficiently informed to adequately intervene and regulate urban growth pressures, risking the emergence of sprawl type phenomena (Choriantopoulos, Pagonis, Koukoulas, & Drymoniti, 2010).

Spatially explicit modeling, constitutes a useful tool for conducting computational experiments that quantify the importance of various driving forces of change, contributing to an enhanced understanding of such a complex phenomenon (Veldkamp & Lambin, 2001). Modeling of growth dynamics is meaningful when adopting a two-phase approach. To start with, the history of the place explored has to be comprehensively looked at, part of an attempt to identify the key socio-spatial variables influencing the traits and direction of urban growth. Subsequently, by quantifying the driving forces of local change, a model can be build, capable of predicting possible future growth trajectories in the area under certain scenarios.

Scenario-based analysis has emerged in order to explore variations

for a limited, but consistent, set of model parameters, delineating feasible future development trends under a set of pre-defined conditions (Feng & Liu, 2016; Murray-Rust, Rieser, Robinson, Milicic, & Rounsevell, 2013). The key step in such an attempt is the creation of the so-called transition potential maps, an exercise that draws from an area's recorded trends and performances, to indicate the degree of potential change in the future. This process is based on the change detection outputs of the historical land cover and the quantification of the ways in which the respective driving forces contributed to such changes (Kolb, Mas, & Galicia, 2013).

While, by definition, models cannot replicate complex interactions and nonlinear socio-economic relations, spatial simulation approaches are increasingly being adopted and used. Advancements in geo-informatics as well as in computer capacity triggered the proliferation of modeling techniques (Berling-Wolff & Wu, 2004), the availability of geographic datasets and the methodological achievements in data processing and change detection (Tewkesbury, Comber, Tate, Lamb, & Fisher, 2015). Various approaches have been adopted to model the dynamics of the built-up environment and to explore future scenarios, using regression modeling (Feng, Liu, Chen, & Liu, 2016; Poelmans & Van Rompaey, 2010), agent based modeling (Batty, Xie, & Zhao, 2007), markov chains (Ku, 2016), system dynamics (He, Okada, Zhang, Shia, & Zhang, 2006; Zheng et al., 2012), and cellular automata (CA) (Lagarias, 2012; Vliet, White, & Dragicevic, 2009).

Accounting for the increased interest in CA applications (Sante, Garcia, Miranda, & Crecente, 2010), the literature stresses the capacity of the respective approach to represent stochastic, non-linear processes in a conceptually simple way (Batty, Couclelis, & Eichen, 1997). Additionally, CA are spatially-explicit and application-oriented and therefore fully consistent with Geographic Information Systems (GIS) and remote sensing (Feng, 2017; Feng et al., 2016; Liu & Feng, 2016). Another important advantage of the CA approach is their incorporation in a plethora of modeling frameworks and platforms (Aburas, Ho, Ramli, & Ash'aari, 2016). Examples include, among others, SLEUTH (Clarke, Gaydos, & Hoppen, 1997), Environment Explorer (Engelen, White, & de Nijs, 2003), the MOLAND (Lavalle et al., 2004), IDRISI's CA_MARKOV (Paegelow & Camacho Olmedo, 2005), iCity (Stevens, Dragicevic, & Rothley, 2007) and Dinamica EGO (Soares-Filho,

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Pennachin, & Cerqueria, 2002). However, some of these frameworks and platforms are restricted to certain methodologies, steady schemes and fixed parameters. Instead, Dinamica EGO is a flexible open platform where modelers are able to elaborate and to extend the methodological procedures according to their specific needs. Recently, Mas, Kolb, Paegelow, Camacho Olmedo, and Houet (2014) in a comparative assessment of four modeling frameworks, outlined two key advantages of Dinamica EGO that are crucial for simulating growth dynamics (section 2.2.6).

In this paper we employ and elaborate this particular methodology to explore a challenging example of a dynamically growing peri-urban area. The case in point is the Messoghia plain in Athens, Greece. Since the early 1980s and for the following two decades, Athenian urban growth was channeled towards Messoghia, initiating a rural to urban transformation process with marked environmental implications. During this time, land use planning controls were not in place, as unregulated built-up expansion was approached as a shortcut to economic growth (Chorianopoulos, Tsilimigkas, Koukoulas, & Balatsos, 2014). Environmental deterioration, however, triggered a belated planning response (2003), aiming to curb emergent sprawling tendencies. Built-up expansion has also been affected by the insolvency crisis the country is facing since 2010. The Messoghia plain, therefore, is an area that faces strong development pressures that have only been temporarily weakened as a result of extreme economic circumstances. In fact, the area's strong development potential is underscored and encouraged in the city's revised Master Plan (2014), shaping a pro-growth policy trajectory for the forthcoming decade (GGN, 2014).

In this paper we argue that estimating the future growth traits in the area in light of different economic performance realities and land-use planning contexts and choices, is a prerequisite in any attempt to address the undesirable consequences of unregulated urban expansion. From this perspective, we attempt to delineate the future growth dynamics in Messoghia under four different economic and spatial policy scenarios and to illustrate accordingly the respective the urban scenery in the medium (10 years) and the long (30 years) term. With regard to key concepts of reference, urban land is defined in respect to all human-constructed elements, such as continuous or discontinuous residential areas (hereafter called urban fabric) and industrial, commercial, infrastructure and transport units (hereafter called artificial non-urban areas).

The paper is organized in four parts. In the first part, we look at the case study area, contextualizing the research exercise. In the second part, we outline the research methodology followed for imagery processing, classification and change detection along with the 20 factors description and processing, including the calculation of the Leap-frog development index. Accordingly, we present the sequence of methodologies for the transition potential modeling, the scenarios development, the model calibration and the projection of results to the future. In the third part of the paper, we illustrate and discuss in detail the results obtained. In the concluding section, we revisit the area's prospective futures, highlighting the relevance of our approach to the quest for effective planning responses and sustainable urban development trajectories.

2. Material and methods

2.1. Study site

The Messoghia plain is located eastwards of the Athens conurbation (Fig. 1). Until the early 1980s the area retained at large a rural character, escaping the rapid urbanization wave that transformed Athens in the postwar years. The main reason for this particularity is the Hymettus Mountain, a physical barrier separating the plain from the city that obstructed accessibility and delayed the development of an adequate transportation network. Since the mid-1980s, however, the area displayed notable urban expansion signs, associated in the literature

with the sprawling tendencies of Athens; a congested city with rapidly deteriorating environmental conditions (Leontidou, Afouxenidis, Korliouros, & Marmaras, 2007). In the succeeding decades, change in Messoghia was swift and multifaceted, a turn of events bringing to the foreground the fundamental antagonism between economic growth preoccupations and regulated urban expansion goals. The key developments that altered the area's features are hereafter discussed and categorized for methodological purposes in four distinct chronological frames of reference.

- 1985–1995: In the mid-1980s, and in light of urban expansion tendencies noted in the region, the planning authorities decided to intervene. The introduction of the Master Plan of Athens (1985) was expected to guide urban growth in the region via the launch of detailed land-use plans. In the case of Messoghia, the Master Plan was geared towards the protection of the area's rural character. This, however, did not happen. In a parallel trajectory, the decision to relocate the Athens international airport in Messoghia was taken, cancelling de facto the respective Master Plan directions. Consequently, the implementation of the spatial planning framework for Messoghia was indefinitely postponed, enabling the unobstructed continuation of the sprawling tendencies noted in the area.
- 1995–2006: In the mid-1990s, the national authorities put Athens forward as a candidate city for hosting the 2004 Olympic Games. The bid was successful (1997), and a number of large scale physical infrastructure projects were expeditiously initiated in Messoghia, including Olympics' related venues (Equestrian Centre, Shooting Centre) and transportation networks of metropolitan importance (ring road, suburban railway). Investment in transportation infrastructure, in particular, enhanced Messoghia's accessibility, triggering a population influx and a concurrent increase in urban land-uses. The inflexible deadline of the 2004 Olympics resulted in the prioritization of development planning goals over the spatial planning ones (Souliotis, 2013). The land-use zoning scheme that was supposed to guide growth in Messoghia, for instance, was put into force as late as in 2003. In the intervening period, rural to urban transformation in the region proceeded apace.
- 2006–2010: The post-Olympics era is characterized by the relative soundness of the economy, displaying annual growth rates that exceeded, on average, three per cent of the GDP (Bank of Greece, 2014). Alongside, the long awaited land-use planning scheme for Messoghia was finally in place. This period of stability, however, was cut short by the impact of the global financial crisis (2008) on the state of public finances.
- 2010–2015: In the wake of the global financial crisis, the general government deficit and the public debt stretched respectively to 15.4 and 126.8 percent of Gross Domestic Product (GDP). As the state practically lost access to the international financial markets, and in order to avoid a solvency crisis, the government agreed a series of loans with the European Commission, the European Central Bank and the IMF. The loans were conditional upon Greece implementing an adjustment programme including, amongst others, the introduction of steep austerity measures and the privatization of state owned assets (Eurogroup, 2015). As a result, between 2008 and 2015 the economy lost a cumulative 27 percent of its GDP (Bank of Greece, 2016). The relevance of these developments for Messoghia are twofold. First, by reason of the economic depression, transactions in the real estate market in the region fell by 78 percent, grinding the built-up expansion trend to a halt (Municipality of Athens, 2014). Second, the ownership and, hence, the fate of key state owned real estate properties in Messoghia (land and structures) was transferred to a privatization fund, the sales of which aim to reduce the government's debt burden. The future usage of these sites is not regulated by the area's planning framework, arresting in practice the effectiveness of the respective land use planning scheme

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