Landscape and Urban Planning 104 (2012) 201–211

Contents lists available at SciVerse ScienceDirect

Landscape and Urban Planning

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

A multi-scenario forecast of urban change: A study on urban growth in the Algarve

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ARTICLE INFO

Article history:
Received 23 November 2010
Received in revised form 5 October 2011
Accepted 7 October 2011
Available online 22 October 2011

Keywords:
Urban growth
Algarve
CORINE Land Cover
Scenario modelling

ABSTRACT

The Algarve region in Portugal is often considered as one of the most appealing regions for tourism in the country. Its attractive location and moderate climate have since the mid-1960s brought increasing economic prosperity. As a result of the development of mass tourism, available land-use resources were widely exploited to create an integrated tourist industry. In this area, economic prosperity has led to an increasing population and a significant growth of infrastructures to cope with the demand from the hospitality sector. The far-reaching land-use changes have, however, led to high pressures on the coastal areas of the Algarve. This region has shown an increasing loss of ecosystems resulting from the expansion of urban areas. This paper proposes a dynamic assessment of urban growth in the Algarve based on non-linear complex system modelling by using cellular automata converging on qualitative story lines with quantitative spatial methodologies. This new methodology utilizes both quantitative and qualitative spatial results by a comparative validation of built scenarios, in order to highlight future land use trends. In particular, three scenarios will be explored, each with distinct specific socio-economic paths. Our analysis to identify the scenario with the best fit, based on the evolution of the actual 2006 land cover, enabled us to build a future urban growth model for 2020 which was quantitatively assessed. The outcome suggests a picture of continuing growth for the region of the Algarve within the framework of current policies and regressive spatial trends.

1. Introduction

Europe has experienced unprecedented urban change and population increase over the last 30 years and this is expected to continue (Cohen, 2004). In 2008, the population of the European Union (EU) rose by 2.1 million, resulting in the growth of GDP by 0.4%. Europe's multi-cultural and liberal policies have directly contributed to the expansion of the EU (Barrell, Fitzgeral, & Riley, 2003), making it today the strongest world economy (Moravcsik, 1993). However, the downside of this population increase is reflected in the rapid land-use cover change (Bilsborrow & Ogendo, 1992), especially within the metropolitan areas of larger cities in the EU, or other important socio-economic areas (EEA, 2006a). The European Cohesion Policy (2007–2013) recognizes the complexity of urban sprawl, and proposes a coordinated and integrated approach for sustainable development in urban and rural areas (CEC, 2006). This policy focuses mainly on ameliorating specific impacts of urban sprawl by recommending actions for coordination of land use policies (EEA, 2006b). In the case of Portugal, these issues are reinforced at the regional level by the existing municipal plans, and within the framework of the National Policy and Territorial Management Programme (Programa Nacional da Política de Ordenamento do Território – PNPOT). The PNPOT explains the ongoing urban sprawl in the Portuguese region as being chiefly due to the construction of new residences within less densely populated areas, contributing directly to the growth of private transportation and the increase of urban sprawl in peripheral urban areas, and creating uneven urban growth (PNPOT, 2007). At the regional level, the PROT (Plano Regional de Ordenamento de Território – Regional Plan for Territorial Planning) supports the development of NUTS-III areas in Portugal within the common framework of the PNPOT, including specific efforts on sustainable development and environmental landscape quality. The aim of this article is to combine urban growth modelling with Multi-Criteria Evaluation for the Algarve to help choosing the best strategic development for the region having in mind sustainability and an integration of qualitative decision making within a quantitative analytical approach. Namely, allowing the generation of storylines for the region, based on policymakers sensitivity for the PROT (Plano Regional de

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doi:10.1016/j.landurbplan.2011.10.007

Ordenamento Territorial) this paper generates a multiple scenario approach of possible outcomes on the urban fringe and impacts on the RAN and REN (Reserva Agrícola Nacional and Reserva Ecológica Nacional) having into account the current impacts on the economic recession as well as the stagnating urban sprawl processes in the Algarve due to less economic activity in the region.

2. Theoretical framework

Urban growth models have proved to be important tools to measure land-use change in peri-urban and rural regions (Clarke & Gaydos, 1998; Herold, Goldstein, & Clarke, 2003; Mundia & Murayama, 2010; Tobler, 1970; White, Engelen, & Uljee, 1997) in strong connection with decision support systems. The technological development of remote sensing imagery with higher accuracy has led to the creation of high-resolution spatial imagery which makes it possible to extract more accurate topological and geomorphological characteristics (Picón-Feliciano, Vásquez, González, Luvall, & Rickman, 2009; Sawaya, Olmanson, Heinert, Brezonik, & Bauer, 2003; White & Engelen, 2000), which are fundamental for spatial modelling experiments. Furthermore, in recent years elaborate algorithms have been constructed that manage to filter relevant human information in a context of land-use dynamics. Examples of the extraction of such information are: industrial areas, urban areas and other man-made land cover which have an impact on land use, such as golf courses in the Algarve region. The aggregation of spatial coverage, whether geological or socio-economic, allows complex system dynamics and subsequent spatial land-use analysis. This application of spatial models to achieve a balance between the environment and the management of scarce resources (Goudie, 2006) supports the adequate decision-making strategies. One of the key elements within the context of socio-economic land-use change is that within the inherent complexity of environmental change, man-induced change is fundamentally self-organized (Moussaïd et al., 2009). From a classical perspective, the multiplication of households triggers location-specific amenities which directly or indirectly shape urban regions, as pointed out by Straszheim (1987). Possible triggers for urban growth may be identified by the measurement of externalities which exert an impact on land-use change. As long as externalities are spatially explicit, the socio-economic dimension of land-use becomes a ubiquitous phenomenon which may be analysed and distinguished at a spatial level.

2.1. Land-use maps and urban dynamics

The CORINE Land Cover (CLC) project started in 1985, and addressed the following issues at the spatial level: state of individual environments; geographical distribution and state of natural areas; geographical distribution and abundance of wild fauna and flora; quality and abundance of water resources; land-cover structure and the state of the soil; quantities of toxic substances discharged into the environment; and a list of Natural Hazards (EEA, 1995). According to a European Union decision, the CLC may be seen as (85/338/EEC, Council Decision 27/6/1985) *an experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community*.

Because of its multi-temporal land-use inventories, the CLC project may be considered a very suitable methodology to trace and better understand land-use change (Paínho & Caetano, 2006). The combination of socio-economic data and thematic information aids in the interpretation and analysis of land change. Valuable information can be extracted when change is analysed over time. Meanwhile, land-use maps have become witnesses of the indisputable loss of natural habitats, as a result of artificial land uses to enable the construction of infrastructures which relate to the tourist demand. In the next point the importance of this instrument will demonstrate a combined approach of assembly of cellular automata in context of decision making theory for the study area. Cellular automata may be defined as discrete models, useful in complexity science to understand spatial dynamics of change over time. The cellular spaces formed between iterations of cells in a given state, allow such models for explanatory models for assessing possible outcomes of urban change. Tobler (1970) introduced cellular automata in a context of geography. The applications of CA to urban growth specifically, have gained an increasing importance as urban areas have increasingly expanded and spatial data becomes further available for empirical research to be carried forth. While cellular automata for urban growth maintain usually similar frameworks regarding assembly, testing, validation and calibration, some conceptual issues arise regarding the modelling techniques used. One of the advantages in using Markov transition-chains noted by these models rarely cited is, the efficiency of using multiple land use types within the iteration of the cell, conditioning the stochastic outcome of the cell type not only to a non-urban or urban state, but also most importantly: to a conditioned state of land use depending on the vicinity of the neighbourhood types of existing cells. This is a characteristic of utmost importance, framed in a Markov Cellular Automata model, allowing in the case of Portugal a more accurate outcome regarding future urban classification as surrounding land-types are more heterogeneous, contrary to other regions of the world, such as the USA, where other urban growth models have also largely been applied.

2.2. Cellular automata for urban growth forecasting

The usage of cellular automata for urban growth forecasting has been increasingly linked to the possibilities of understanding land use change from a policymaking perspective (Pontius, Shusas, & McEachern, 2004). The accumulative usability and ease of use, have allowed a ubiquitous application in the assembly and data generation of these models. CA, applied to urban growth, rely on the iteration of a given dimensional cell based on supporting socio-economic and geographical data, to change into urban or non-urban form within a given time-frame. The simplicity of the model allied to the possible complexity of intertwining variables make this approach of especial interest to understand regions where rapid change in urban patterns has been witnessed. This has been in the last decades the case of Portugal, where several models have been built to understand urban change in the last decades (Cabral & Zamyatin, 2009; Petrov, Lavalle, & Kasanko, 2009). Although relatively easy to assemble, urban growth models need the availability of multi-temporal data in at least three time frames that generate a cohesive vision that may be validated of future urban outcome. The data should have the same criteria regarding its spatial resolution and match a similar (if not equal) data inventory where the different technical details of data collection, integration and inventorying shared common targets. Petrov et al. (2009) shared important results regarding the existence of urban change in the Algarve, within the MOLAND framework. However, as the authors claim, the unavailability at the time of generation of the urban growth model of CORINE Land Cover, could lead to differed results within the accuracy of the calibration period. Nowadays, the availability of CORINE Land Cover and the unaddressed issue of the economic recession in Portugal, have brought unprecedented consequences on the stagnation of urban regions in the Algarve, affecting the decision making process and the landscapes that were expected to occur in the Algarve three years ago. Furthermore, the existence of the CORINE Land Cover dataset showed a decrease in the type of urbanization in the region. The Algarve, expanding