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## **A Multi-scenario prospection of urban change – the case of urban growth in the Algarve**

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The region of the Algarve in Portugal is often considered as one of the most appealing regions for tourism in the country. Its valuable location and moderate climate have since the mid sixties brought increasing economic prosperity. Associated to the trend of a mass tourism industry, available land-use resources were widely explored to create a cohesive tourism industry.

Economic prosperity has led to an increasing population and growth of infrastructures to cope with the demand from the hospitality sector. These infrastructures however led to high pressures on the coastal areas of the Algarve, as will be discussed and analyzed.

As such, the Algarve, and in a larger extend Portugal and many European regions, have shown an increasing loss of ecosystems resulting from over-growth of urban areas. This has also been accompanied by a significant abandonment of rural areas and hinterlands, leading to loss of agriculture and other rural activities. As a consequence, one may consider that urban growth requires much attention in a context of sustainable development, as often peri-urban areas with fragile ecosystems are becoming increasingly vulnerable and fragile.

In the Algarve, the exploration of a mass tourism industry has been an increasing concern closely linked to decisional processes and policies (especially within the PROT Algarve, the Regional Program of Territorial Administration).

One of the key tools to quantify the changes of land-use and how it effects the regional spatial scope is the multi-temporal inventorying and accounting of land-use change matrices. This paper proposes a dynamic assessment of urban growth in the Algarve based on non-linear complex system modeling by using Cellular Automata. The ancillary data of the CORINE Land Cover (CLC) project, expanding a temporal frame of over 15

years (from 1990 to 2006) will test a novel multi-scenario approach for urban change in the region.

This spatial analysis relates to quantitative methodologies, but also shares important qualitative evaluation processes by assembly of story-lines which articulate traditional scenario approaches. However, the design of story-lines is intrinsically subjective and qualitative, and faces the problem of accuracy in quantifying results. This new methodology articulates quantitative and qualitative spatial results by comparative validation of built scenarios, sharing results for future land-use trends.

In particular, three scenarios will be explored with specific socio-economic paths: the first scenario shares a maximization of urban growth in the area, brought by prosperous economy and continuing exploration of mass tourism. The second scenario is based on the actual indicators of the region in terms of socio-economic activity. The third scenario shows a tendency of increase in rural activity and is equated on the disparities between rural areas and the fringe of the coastal regions.

In order to validate each scenario, a story-line reflects the urban growth in the Algarve and suggests the possible likelihood of land-use change for the region, in a pathway integrating the coherent public policies for a more sustainable future.

Analysis of maximum similarity of the scenarios, allowed to build a future urban growth model for 2020 which was quantitatively assessed, sharing the information of continuing growth for the region of the Algarve within the framework of current policies and regressive spatial trends.

**Keywords:** Urban Growth; Algarve; CORINE Land Cover; Scenario Modelin

## 1. Introduction

Europe has witnessed unprecedented urban change and population increase over the last 30 years and this is expected to continue (Cohen, 2004). Just in 2008, growth in Europe has registered a population increase of 2.1 million people, reflected in the growth of GDP by 0.4%. The European multi-cultural and liberal policies of Europe have directly contributed to the increase of the European Union (EU) making Europe today the strongest world economy (Moravcsik, 1993). However, the downside of this population increase is felt by the rapid land-use cover change (Bilborrow and Ogendo, 1992), especially along the metropolitan areas of larger cities in the EU, or important socio-economical areas (EEA, 2006a).

The European Cohesion Policy (2007-2013) does realize 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 in ameliorating specific impacts of urban sprawl recommending actions for coordination of land use policies. The actions that are chiefly taken into account are related to: challenging structural cohesion of funds and investments between urban and rural areas; delegation of funds within structural fund operational programmes; regulation of EU laws on air quality, waste-water treatment, waste management, water supply and environmental noise; co-financing of activities under the structural funds based on plans that address environmental quality of urban areas in coastal regions (EEA, 2006b).

In the case of Portugal these issues are reinforced at regional level by the existent municipal directory plans, and, framework of the National Policy and Territorial Management Programme (*Programa Nacional da Política de Ordenamento do Território* - PNPOT). The PNPOT depicts the ongoing urban sprawl in the Portuguese region chiefly due to construction of new residencies within less clustered areas, contributing directly to private transportations and increase of urban sprawl in peripheral urban areas and creating a patched urban growth (PNPOT, 2007). At regional level, the PROT (*Plano Regional de Ordenamento de Território* – Regional Plans of Territorial Planning) supports the development of NUT III areas in Portugal within the common framework of

the PNPO sharing specific efforts on sustainable development and environmental quality.

Urban growth models have shown to be important tools to measure land-use change in peri-urban and rural regions (Tobler, 1970; White et al., 1997; Clarke and Gaydos, 1998; Herold et al., 2003; Mundia and Murayama, 2010) strongly linking decision support systems. Technological development of remote sensing imagery with higher accuracy, has led to the creation of high-resolution spatial imagery which allows to extract more accurate topologic and geomorphologic characteristics (White and Engelen, 2000; Sawaya et al., 2003; Picón-Feliciano, 2009) fundamental for spatial modeling initiatives. Further, recent years have witnessed the construction of elaborate algorithms that manage to filter relevant human information in a context of land-use dynamics. Examples of extraction of such information are industrial areas, urban areas and other artificial terrains which impact land-use, such as Golf courses in the Algarve region. The aggregation of spatial coverage, whether geological or socio-economical, allows complex system dynamics and subsequent spatial land-use analysis. The application regarding the balance of environment and 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 maximization of households triggers location specific amenities which directly or indirectly shape urban regions as pointed out by Straszheim (1987). Prospection of triggers for urban growth may be identified by measurement of externalities which exert 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 analyzed and distinguished at spatial level.

## **2. The Algarve region**

The most southern part of Portugal is the Algarve. With a very heterogeneous geography (Drain, 1989), the region extends a cultural legacy remounting to pre-roman civilizations (Gamito, 1997). Nowadays, Portugal has increased up to 9.2% its Tourism sector over the last couple of years. As pointed out by Correia and Crouch (2004) The Algarve represents Portugal's prime destination for Tourism, substantially due to its beach and climate, being responsible for 42% of all its Tourist activity.

As a consequence of the rapid increase of the tourism sector witnessed in the mid-sixties, urban growth and creation of supporting infrastructures began to emerge, generating high revenues and economic growth for the region and leading to the modernization and generation of infrastructures. Buhalis and Fletcher (1995), question the symbiotic and antagonistic factors that should be considered regarding sustainable development in tourism. One of the reasons for this is the fact that, before the nineties, the distinction between growth and development was quite unclear. Growth was envisioned as a unique driver for economic prosperity. Economic growth however, is long from being enough for sustainable development and of the main consequences of this economic anthropocentric growth perspective has been the depletion of available resources. This has led to a constant pressure on the environment and resulted in environmental changes that may be measured in distinct dimensions of which human impact accounts as the main driver, resulting from factors related to acceleration of the information society, population and urban growth, human impact on carrying capacity of the environment and globalism of environmental deficiencies. (Camhis, 2006)

In the case of the Algarve, the land-use change has been drastic and consequences on the coastal areas of the region have had a direct impact on fragile existing ecosystems such as the *Ria Formosa*. The *Ria Formosa* is a shallow lagoon, classified as a Natural Park due to its important ecological value given the diversity of endemic species which exist in the region. This area supports many different services which benefit the regional economy, such as aquaculture, salt production and tourism. Degradation of this lagoon as analysed by Nobre (2009) is a serious sign of the environmental degradation of the region, and the antagonistic impacts of human impact on ecosystems.

The symbiotic effect of ecosystems in coastal zones is especially relevant due to the high economic value generated by leisure services available within those areas (Costanza et al,

1997). According to Boissonas (2002), 43% of the ecosystem services are provided by coastal environments. However, population increase and related socio-economic aspects generate pressures within those habitats (Meyer and Turner, 1992), putting those coastal ecosystems at permanent risk. Monitoring the *anthroposphere* (that is, the agglomerate of artificial land use, population change and peri-urban growth) brings important information to preserve and manage such habitats. Urban pressure in the region has been shown to be an increasing factor for waste into the outlines of the lagoon and its surroundings. Human impact seems to be the main driver for loss of biodiversity, leading to eutrophication of the fragile ecological habitat of the Ria Formosa (Newton et al., 2003).

### **Land-use maps and urban dynamics**

The CORINE Land Cover (CLC) project started on the 27th June 1985, addressing the following issues at 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 environments and List Natural Hazards (EEA, 1995). According to the European union decision it 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*'.

The CLC project due to its multi-temporal land-use inventories may be considered a fine methodology to trace and better understand land-use change (Paíño and Caetano, 2006). Especially as the spatial data infrastructures which it supports, maintain a high level of spatial, temporal and thematic information which allows analysis of different phenomena (NCGIA, 2000). In this sense, land-use maps, such as CLC have been witnesses to the depletion of existent resources for tourism, leading to loss of biodiversity and ecosystems, is nowadays easily traceable by land-use maps. A land use / land cover map

allows us to “*assemble far more knowledge about the Earth than is possible on our own*” (Longley et al, 2006).

Land-use maps become witnesses of the indisputable loss of natural habitats, traded for artificial land-uses to allow construction of infrastructures which consider the tourist demand. Comparing urban areas in CLC 90 and 2006, the urban cores have become double the size from CLC 90. This growth is especially perceptible in the surroundings of the major cities of the Algarve, such as Portimão, Albufeira and Faro. The interior of the Algarve has registered insignificant growth, while presenting higher levels of rural abandonment and loss of agriculture. A constant decrease from 44.55% of agricultural land-use in CLC 90 to 41.10% in CLC 00 and reaching to 40.06% in CLC 06 has been registered. The agricultural land loss has been accompanied by an increase in forest areas, prevailing on areas of agricultural loss as indication of rural and agricultural abandonment. Forest has augmented from 50.22% to 52.33% in CLC 06. These changes were mostly felt in rural areas, while peri-urban regions have become more urbanized

The CLC nomenclature has a total of three levels comprising a total of 64 items per level. The first level, indicates the major categories: Artificial surfaces (urban); Agricultural areas; Forests and semi-natural areas; Wetlands and Water bodies. The following Figure (Figure 1) shows the change incurred over the 1986 to 2006 period of the CLC project. While wetlands and water bodies remained somewhat constant with some increase on water bodies – this increase is a result of the loss of coastal area and tidal variations during the survey. Urban surfaces, Agricultural areas and Forest registered the most significant changes. The significant increase of artificial areas as mentioned earlier is mainly related to urban growth around city perimeters and is located mostly on the coastal zones.



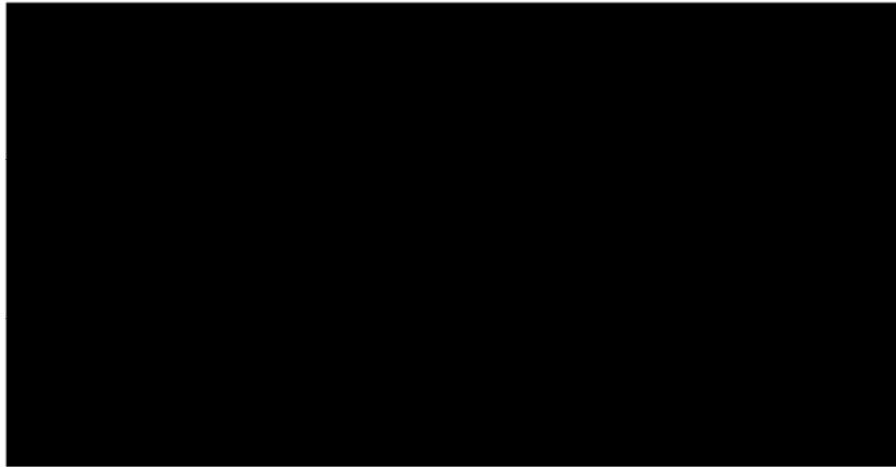


Figure 1 – CORINE Land Cover Classes in CLC90, CLC00 and CLC06

Urban growth showed the most dramatic changes incurred over the period of 1990 to 2006. The initial 1.94% of urban areas from the CORINE Land Cover (CLC) 90 period (1986-1990), doubles to 3.95% in CLC 06. This urban sprawl is felt majorly in the peri-urban regions of the Algarve, especially in the vicinities of coastal touristic areas where services are more abundant (Portimão, Albufeira and Faro). A closer analysis of the urban fabric in the region, allowed assessing the types of artificial land-use that were constructed within the periods of study. During the study period a large tendency for creation of infrastructures prevailed. Previously unregistered road and rail networks were built (a variation of 1.55% within periods of study) as well as sport and leisure facilities (1.181%, increase primarily due to the Euro 2004). These infrastructures are closely linked to the Euro 2004, which supported a total investment of 30.351.354 € for the region. However, as inquired by Pena and Custódio (2007): “(...) *the expectations generated in terms of economic impact on the accommodation industry have not been met. The cause-and-effect relationship between an optimistic forecast of strong growth in demand as desired by the industry agents and its non-fulfillment lead us to conclude that despite the minimized losses in economic terms, Algarve has not been able to capture and take advantage of the range of possible short-term gains associated with the event*”. Despite the not too pessimistic consequences on the regional economy, the generation of infrastructures to support the Euro 2004 have been felt at spatial level. These construction sites have led to the ongoing loss of agricultural land.

## **Multi-scenario Modeling of the Algarve**

Natural and socio-economic variables may be seen as spatio-temporal drivers especially when related to urban systems (Han et al., 2009). Sensitivity maps based on variables of urban change share a scale of propensity for built-up environments and are relevant tools to assess the dynamics of land-use change over a given period. As pointed out by Pontius and Schneider (2001) the drivers are subset of factors and constraints, calculated for the area of study and combine the visualization of urban change in time. However, combination of variables to measure change dynamics, is dependent on the drivers at regional level, justifying the importance of multi-criteria approaches on stochastic analysis of urban change scenarios. The calculation of a Multi Criteria Evaluation (MCE) suitability index relied on the physical, socio-economic and regional characteristics prioritized through a Analytical Hierarchy Process (AHP) leading to three scenarios with different pair-wise quantification. The main advantage of AHP is related to the structural thinking of decision making, in which several values along a range of different scales may be compared. This comparison generates quantifiable priorities of different variables. It is therefore, a qualitative structural decision process that rather than quantifying a best decision aggregates a range of different values for decision making.

The transition matrix from the land-use inventories allowed the spatial assessment of the proposed scenarios. One of the main advantages of this methodology is the capability to combine of qualitative assessments from multi-scenario with quantifiable spatial analytics. This permits to assemble a propensity for urban growth embedded with Multi-Criteria Evaluation (MCE) and with an outlook to economic, social and physical variables. The figure below (Figure 2) summarizes the methodological approach of AHP / Scenario / Markov transition process to build spatial enabled models for urban propensity.

The three scenarios may be defined as: (i) Agricultural Maximization: Responsible planning and auto-sufficiency by development of agricultural activities along the interior

of the Algarve. Higher development of rural sectors of economic activity for traditional production and with specialized market strategies. Road networks are of some importance, but public transportations should play a central role. Coastal proximity is less significant, and should be avoided as not to overburden the already endangered coastal regions. (ii) Business as usual: continuing exploration of tourism industry along the coastal region of the Algarve, taking advantage of reduced costs in further urban growth in peri-urban areas while benefiting from good road networks. Population density plays a significant role in the main cities of the regions such as Faro, Portimão, Loulé and Albufeira. (iii) Economical maximization: maximization of traditional economic growth through creation of more infrastructures to support mass-tourism industry. Continuing urban growth in urban perimeters especially within areas with larger population density while generating more revenues which allow the service sectors to prosper.

As projected in Figure 2, story-lines of each scenario may be defined through the AHP process as different circles, in which the size of each circle (agriculture, urban proximity, road networks, coastal proximity and population density) represent the weight-factor used for each scenario (i, ii, iii). The size of those circles is compared through each of the scenarios and originated the bottom right table of relative weights of the qualitative criteria. An urban propensity for urban growth occurrence is calculated through the weights attributed for each value in each scenario. This results later on in the possibility to discern a Markov transition rule for location of urban sprawl.

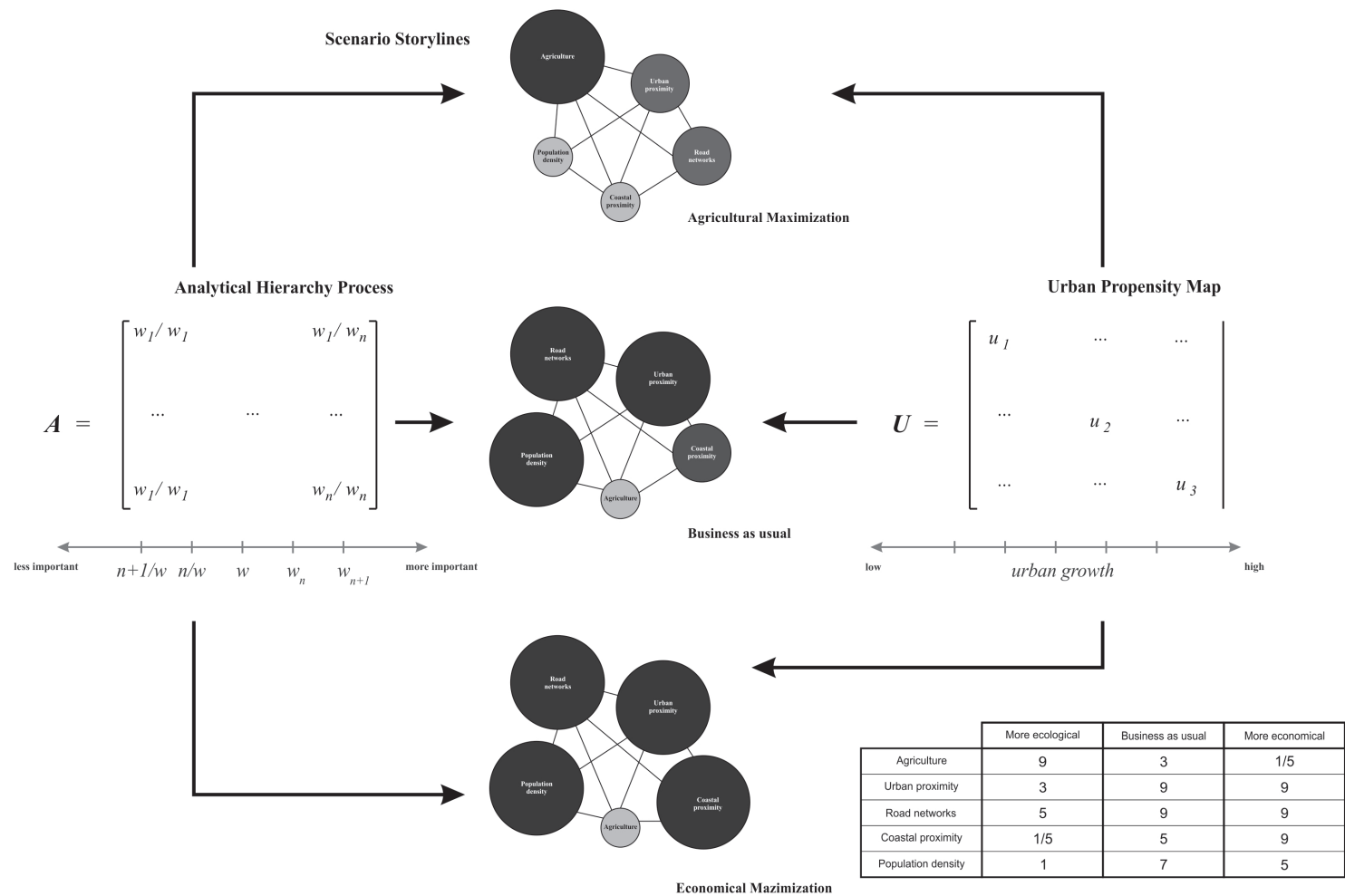


Figure 2 – Methodological conceptualization of integrated Multi-scenario Modeling approach

## Projecting and comparing urban growth in the Algarve – From 2006 to 2020

Combination of the different subset of drivers with originated a cohesive sensibility map of future urban growth sensitivity for the Algarve. The overall scale is reflected from 0-255 while the maximum propensity for urban growth was found in economical maximization and business as usual scenarios (Figure 3a, b). This corresponds to the propensity resulting from the integration of the Analytical Hierarchy Process combined to the weights for each storyline.

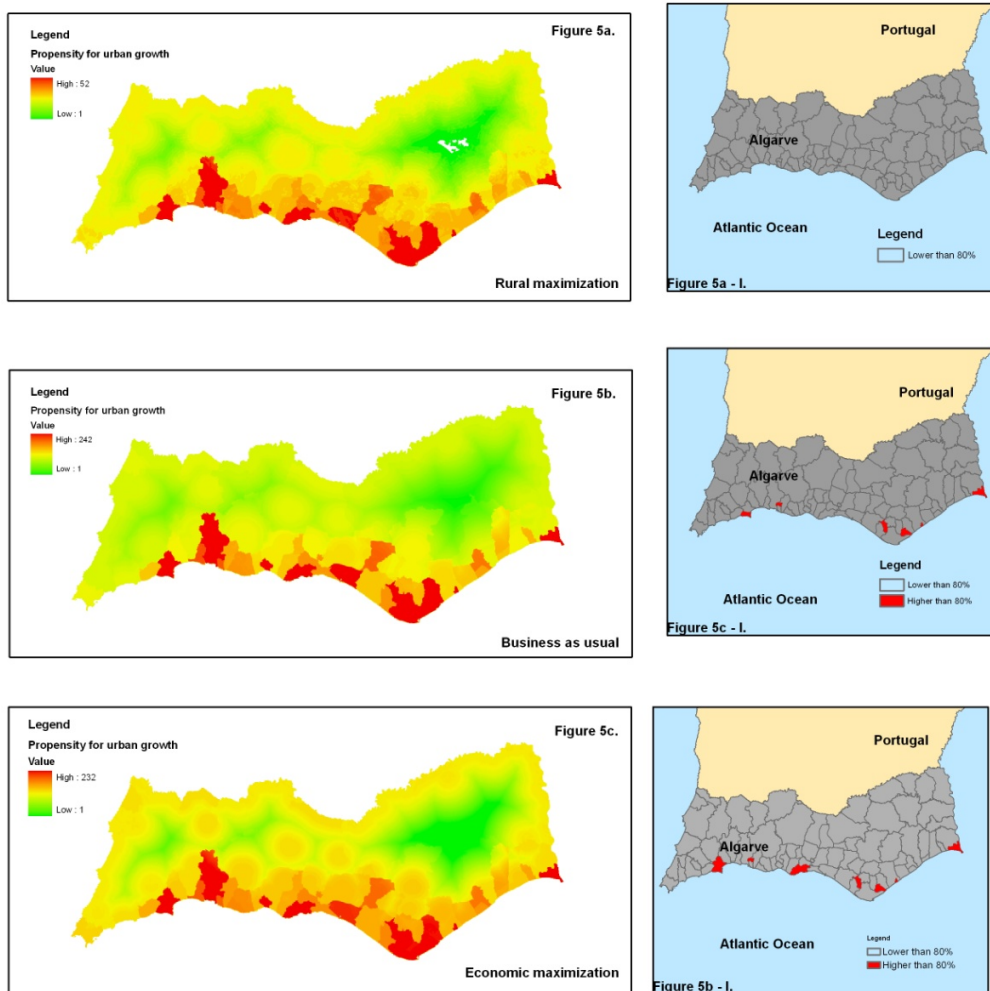


Figure 3 – Comparative urban sensitivity of multi-scenarios

The more rural scenario (Figure 3a.) showed no increase of urban areas on the fringe of the coastal regions. Also, for this specific scenario, the propensity reported a maximum likelihood of 54 out of 255 of transforming into urban, almost less than one fifth of the maximum registered in the Economical maximization scenario. Another interesting aspect of the different propensity map results is reflected in the figures on the right (Figure 3a-I, 3b-I, 3c-I). These maps represent the areas which are more volatile for occurrence of construction sites. The calculation of those sites was assessed on the resulting AHP combined to a probability indicator of higher propensity than 50%. As expected, the rural maximization output did not register municipalities with high propensity of further urban development. This may be interpreted as the shift to a more eco-balanced activity allowing using existing resources, without overburdening carrying capacity. Also, as areas become used for agricultural activity, the intensity of carrying capacity on the coastal regions becomes less. While the Economical Maximization (Figure 3c-I) shows a higher growth on similar parishes as the Business as usual scenario (Figure 3b-I), more urban sprawl is registered. Finally the Business as usual scenario shows the most extension for construction. These extensions of construction are a result of urban sprawl, rather than urban growth, resulting from mixed policies that do not have a significant focus of decisional objectives and lack of the use of agglomeration economies. These comparative results suggest that the business as usual scenario is less efficient, both in terms of ecological impacts and socio-economic effects. On one side, the agglomeration of cities shows that the city, as a loci where cumulative learning may exist, allows knowledge spillovers and learning spaces (Capello and Nijkamp, 2004) which may be less endangering to the sustainable environment. On the other side, the rural maximization demonstrates the possibility of rebalancing agricultural efficiency which limits urban growth as rural activities do not rely on the construction of as many infrastructures. However, this model is less probable, as it calls out for a much too radical shift of the economicentric growth paradigm which combines physical proximity to population dynamics with economic prosperity. Most constraining for the environment are the residues of urban sprawl which are current trends within the region as it affects much more volatile territory than either of the other scenarios.

### **Cellular Automata for Urban Growth prospection**

Based on the CORINE Land Cover (CLC) and information of its main classes, a transition matrix was assembled based on Markov transition probabilities. Such a matrix permits the interoperability of changes from one state to another. This commutes very well for land-use change analysis, especially when combined with cellular automata iteration rules, which allow the transition probabilities to become spatially explicit. The conditional probabilities of changing from one state to another are then assembled within a given set of socio-economic constraints. The following transition probabilities were obtained (Table 1).

		<i>Probability of changing to:</i>				
		Urban	Agriculture	Forest	Wetlands	Waterbodies
<i>Lan dcla ss</i>	Urban	<b>0.83</b>	0.06	0.07	0.03	0.01
	Agriculture	0.07	<b>0.77</b>	0.15	0.00	0.01
	Forest	0.04	0.11	<b>0.83</b>	0.00	0.01
	Wetlands	0.03	0.01	0.10	<b>0.84</b>	0.02
	Waterbodies	0.03	0.01	0.09	0.05	<b>0.82</b>

Table 1 – Transition Matrix of Markov Chains from CLC00 based on CLC90

A couple of interesting points are stressed from the stochastic comparison of probability transition: (i) the class of most occurring change expected from agricultural transition to urban. (ii) Forest areas have registered the highest probability of changing into Agricultural soil and finally (iii) a correlation exists between the possible evolutions of wetlands to areas considered as coniferous forests.

The previous relations explore the ecological transitions of the ecosystem of the Algarve quite well: Agricultural abandonment is leading to the increasing of Forest areas, while these areas are more likely for urban growth, due to their physical and geographical characteristics. The wetlands in the Algarve are mostly found in the coastal perimeters, and have shown to be areas of enormous environmental pressure. Methodological refinements have been experimented: the

figure below represents the approach for validating and projecting land-use change within the multi-scenario approach (Figure 4).

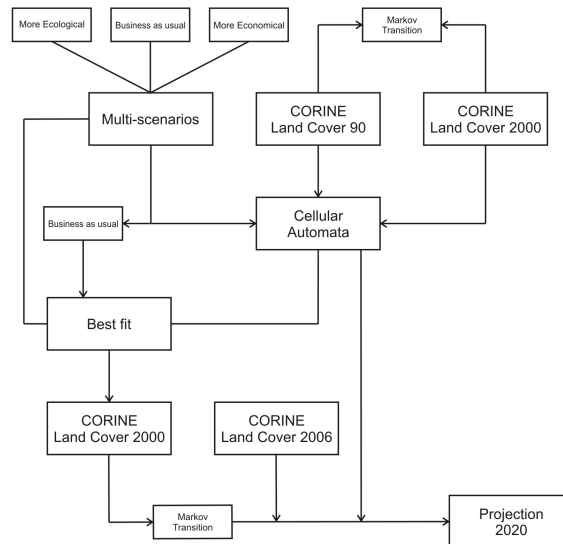


Figure 4 - Diagram of validation and projection

The first steps corresponded to connecting the different scenarios with the base land-covers from CLC 90 and CLC 00. The calculated values of Markov transition chains from the five different classes (Urban areas, Agriculture, Forest, Wetlands and Water bodies) are assessed by means of a Cellular Automata algorithm which relates the spatial properties of the Markov transition matrixes.

The three generated outcomes are compared with the base dataset of CORINE Land Cover 2006 via the generation of a statistical Kappa, showing the margin of error for each of the calculated scenarios. As may be seen, the ‘Business as usual’ corresponds to the most likely scenario as it shows the clearest similarity to the CORINE Land Cover 2006. Two conclusions are in order from this comparison: Our Cellular Automata approach, allowed a stable analysis of real transformation of land-use, suggesting that Markov propensities related to CA approaches have interesting capabilities for land-use change analysis. Furthermore, the comparison of the results from land-change in the other scenarios, prompt for important results on the differentiation of strategies for policyholders regarding the choices of different strategies.



The most deviated results were found in the Ecological model, not envisioning the trend of urban growth which has occurred up to 2006. The best-fit analysis comprehends the comparison of each class of each calculated scenario in its amplitude value related to the CLC 06 projection.

$x = \sum |x_{ij} - y_{ij}| = 0$  where,  $x$  is the best-fit of the amplitude most similar to the original land-coverclass and  $y_{ij}$  corresponds to the scenario and each representing class and  $x_{ij}$  the quantified results per class on the land-cover, whose value for best-fit equals the value closest to zero. The following results were obtained:

	Scenario		
	Ecological	Economical	Business as usual
Urban areas	0.94	5.12	3.88
Agricultural areas	7.68	2.98	1.81
Forests	8.29	7.63	2.06
Wetlands	0.16	0.18	0
Water bodies	0.49	0.65	0.01
best-fit	17.56	16.56	7.76

Table 2 – Results from the best-fit analysis

As the best-fit was found in the ‘Business as usual’ scenario, the projection of land-use change for 2020 is done in a similar manner through iterating values based on our CLC 06 land-cover, having CLC 00 and CLC 06 as reference.

## Conclusions

The iterations of the cellular automata related to similar Markov transition rules, permitted to generate the future urban growth scenario for the year 2020 (Figure 5). While urban growth seems to be increasing along the coastal regions of the Algarve, the region between Albufeira,

Portimão and Faro, Olhão are of most concern. Similarly, prior agricultural land is converted into urban areas around Portimão.

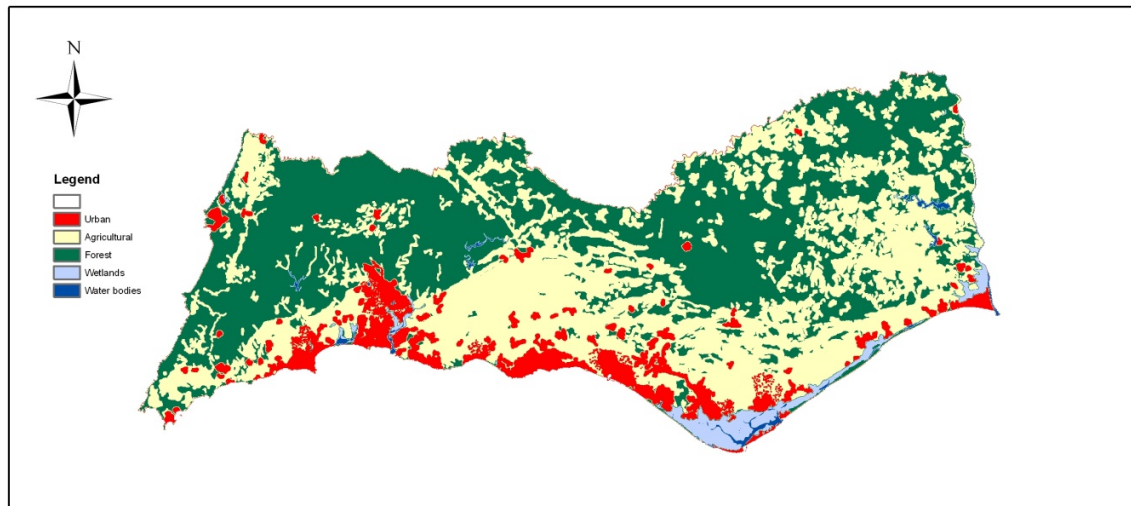


Figure 5 – Urban growth projection for 2020

The overall assessment of land-use change in the coming years given the current strategies for development, will lead to growing cities which remain very close to coastal areas. The central region of the Algarve between Faro and Portimão shows that existing road networks play an important task in urban growth. Also, an agglomeration of artificial land-use is visible in the coming years, especially along the districts capital of Faro and in the vicinities of different parishes which during the nineties did not report significant urban growth tendencies. Another concern is noticeable through the rural abandonment, witnessed by unprecedented increase of coniferous forest areas, and accompanied by loss of agricultural sectors. The divergence between the urban reality and rural regions become more accentuated over time, showing lack of integration of policies that lead to sustainable development in the forthcoming years.

The results for the Algarve, suggest that the region should focus in a diversification of sectors of activity, offering new solutions for the regions, other than tourism. Although Tourism is an important economic activity for the Algarve and Portugal as a whole, it is of utmost importance to use creation of infra-structures wisely, especially regarding the distribution as not to

overburden the carrying capacity on the natural environment, translated mainly by urban sprawl and rural abandonment.

This paper proposed a new methodology, which combines different tools for spatial analysis of future urban land-use scenarios. The usage of Cellular Automata within qualitative modeling approaches, shared novel results for scenario modeling alternatives for future urban design trends. Handling of such scenario-modeling approaches may have a broad scope of land-use analysis and strongly suggests future areas of study. The novelty of this methodology, shares very interesting results regarding the gap of qualitative analysis and quantitative outputs, especially when related for spatial decision making support systems, in which combined methodologies may have a leading role for better decision making.

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