REGIONAL CHANGE IN THE ALGARVE:

A GEOGRAPHIC INFORMATION SYSTEMS APPROACH

by

Eric Moreira de Noronha Vaz

Dissertation submitted to the Instituto Superior de Estatística e Gestão de Informação da Universidade Nova de Lisboa in partial fulfillment of the requirements for the Degree of

Doutor em Gestão de Informação – Sistemas de Informação Geográfica

(Doctor of Philosophy in Information Management – Geographic Information Systems)

Instituto Superior de Estatística e Gestão de Informação

da

Universidade Nova de Lisboa

2011

REGIONAL CHANGE IN THE ALGARVE:

A GEOGRAPHIC INFORMATION SYSTEMS APPROACH

by

Eric Moreira de Noronha Vaz

Dissertation supervised by

Professor Marco Painho

Professor Peter Nijkamp

Instituto Superior de Estatística e Gestão de Informação

da

Universidade Nova de Lisboa

2011

DEDICATION

To joy, laughter, music, and bliss. And most of all, to the two women in my life: my mother and my wife.

ACKNOWLEDGMENTS

This dissertation would have been impossible without the help from so many. My deepest gratitude goes to my advisors, Professor Marco Painho and Professor Peter Nijkamp, who gave me the freedom to think and work enthusiastically on all of my ideas. I am also thankful:

In Cambridge, MA. - Massachusetts Institute of Technology ("*If you don't like the weather, just wait a minute*"): I would like to thank Professor Carlo Ratti and Filippo for having received me at MIT's Senseable City Lab and the rest of the team for their support.

In Vienna - Wirtschaftsuniversität Wien ("*Wien! Mit Freunden, Nusstorten und Oper!*"): I would like to thank Professor Manfred Fischer, for his always continuing support and friendship which I much cherish, and also my friends Tamás, Petra, Alfred, and Sascha.

In Brighton, UK – University of Sussex (*"The best Summer School ever."*): Sigrid and Andy for having organized a fantastic and very inspiring Summer School, where I've made good friends: Matteo, Giacomo, Scott, Doan, Pere, Cristina, Tarik, Rafa, Mari and Anna. In the London School of Economics I would like to thank the interesting experience at the Regional and Urban Planning Studies Masters, especially Professor Nancy Holman for all her support.

In Amsterdam – Free University of Amsterdam ("*travelling on the canals of always exciting projects!"*): My gratitude goes out to Elfie and Jenni, for always supporting me when necessary. Also, Jasper, Henk and Eric and my friend Eveline. Especial thanks to Mrs. Ellman, for her incredible English language editing skills and the detailed and very constructive corrections in so many of my papers.

In Faro – University of the Algarve (*"não há ar que cheire melhor do que o do nosso Algarve."*): I would like to thank Professor Efigénio Rebelo, who believed in my aptitudes as a lecturer for the Universidade do Algarve (the corkscrew still opens many bottles of wine) and my friends at the CIEO: Marlene, Julieta, Andrés and Sílvia.

In Lisbon – Universidade Nova de Lisboa, ISEGI (*"Lisboa, uma das cidades mais bonitos da Europa!"*): André Oliveira, André Barriguinha and my Masters advisors, Professor Pedro Cabral and Professor Mário Caetano, who taught me in the very beginning the tools of the trade. Also my cordial gratitude to the best academic staff in the world: Gisela and Andreia.

My friends: Janete, Bruno, Oscar, João, Eva, Pedro and Sandra Henriques, Jay and Sebastian (may this work also be readable by my godson in two decades: Miguel Maria).

I would also like to thank the Portuguese Science Foundation and Professor João Sentieiro, for having thought me a very valuable lesson: speak up, when you have to - but with understanding.

My wife, again my darling, you have been shortened out on long walks and nice movies, thank you for your love. Most of all, I would like to thank my mother, her infinite love and wisdom, her kindness and tenderness.

The following research of this dissertation was funded by the following institutions:

- *Fundação para a Ciência e Tecnologia* (FCT) – SFRH/BD/44152/2008

- *Programa Operacional Ciência e Inovação* 2010 (POCI 2010)

Ciência.Inovação 2010 Programa Operacional Ciência e Inovação 2010
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

ABSTRACT

The debate on sustainable development has led to an increasing interest covering the effects of the human beings on the natural environment. The development of information and communication technologies (ICT) allowed a better analysis of the drivers of environmental change. With the increase of ICT, especially related to monitoring of sustainable choices, methodologies for analysis of regional and local impact have made a significant contribution to the development of regional strategies at a policy level, but also contributed to the development of regional sciences. One of the main issues has been addressed by the analysis of carrying capacity and availability of scarce resources, resulting from a growing demand, leading to loss of vulnerable natural and historical areas. Much of the work of regional sciences has had a direct relation to space, due to the nature of socio-economic data. This thesis offers an integrated spatial assessment of the results of regional change brought by socio-economic growth. The Algarve region in Portugal is used as a laboratory to understand the current pressures and attempts to provide a framework for the future of socio-economic growth in the region and a systematic analysis of current pressures. While urban sprawl due to increasing tourist activity is an increasing concern, spatial analysis is used as an insightful tool for foresight of future change. Having considered that urban growth is a direct consequence of economic growth our research addresses the consequences of urban sprawl in the coastal region of the Algarve. By building up predictive tools for complex spatial system analysis, cellular automata are used to forecast future urban expansion in the region. The relationship of tourism to urban change is measured to assess what are true costs of tourism for the region. Tourism is then analysed within the duality of socio-economic pressures defining weak and strong sustainability. An integrated strategy considering the historical heritage of the Algarve is offered as a more interesting alternative to the current exploration of the marine environment. Thus, the dissertation expands on the usage of spatial analysis as tools to emphasize the importance of monitoring regional change in coastal environments from a socio-economic perspective. Geographic Information Systems are expressed as ubiquitous systems with unique properties to measure change and to offer relevant solutions for better decision making at local and regional level. An important asset of those tools in the context of information management is further explored in the capabilities of comparing results through spatial data manipulation and visualization of alternative futures for regional development.

*Keywords***:** *Geographic Information Systems, Regional Dynamics, Urban Sprawl, Tourism, Cellular Automata*

RESUMO

O debate sobre desenvolvimento sustentável tem levado a um crescente interesse nos efeitos do ser humano sobre o ambiente natural. O desenvolvimento das tecnologias de informação e comunicação (TIC) tem vindo a permitir uma análise mais cuidada das determinantes de alteração ambiental. Com o incremento das TIC, especialmente em relação à monitorização de escolhas sustentáveis, as metodologias para análise regional e local têm vindo a dar uma contribuição significativa para o desenvolvimento de estratégias regionais a nível das políticas públicas, tanto quanto têm contribuído para um desenvolvimento das ciências regionais. Uma das principais questões abordadas no discurso teórico é a análise da capacidade de carga de recursos que escasseiam de forma crescente como fruto de uma crescente procura e, consequentemente, levando à perca de importantes áreas naturais e históricas. Esta dissertação oferece uma análise espacial integrada dos resultados de mudança regional devido ao crescimento socioeconómico. A região do Algarve em Portugal é utilizada como laboratório na compreensão das actuais pressões, visto proporcionar um contexto particularmente adequado à análise de futuros impactos regionais através de análise sistemática. A crescente actividade turística aumenta a preocupação sobre o crescimento urbano e a análise espacial é utilizada para compreender as alterações futuras deste sector. Tendo-se considerado que o crescimento urbano é uma consequência directa do crescimento económico, o paradigma aborda as consequências do crescimento urbano em zonas litorais. A relação do turismo com a mudança urbana é medida para conseguir compreender melhor o verdadeiro custo do turismo. Assim, o turismo é analisado sob a perspectiva dual de pressões socioeconómicas e o nível de sustentabilidade, mais ou menos forte que ele impõe. Uma estratégia integrada considerando a importância da herança histórico-arqueologica do Algarve é ainda utilizada para oferecer uma visão alternativa sobre a exploração do ambiente lagunar litoral. Assim sendo, esta dissertação pretende expandir conhecimento na aplicação de ferramentas de análise espacial para observação de dinâmicas regionais e sua importância na compreensão das consequências em ambientes costeiros de variáveis socioeconómicos. Os Sistemas de Informação Geográficos são utilizados como sistemas ubíquos com capacidades únicas de medir quantitativamente as mudanças regionais, oferecendo soluções para uma melhor tomada de decisão, até a nível local. Ainda um importante contributo é a utilização da gestão de informação combinada à utilização e manipulação de dados espaciais para visualização de cenários alternativos para múltiplas escolhas, mais ou menos prováveis, de crescimento regional.

Palavras-chave: Sistemas de Informação Geográfica, Dinâmicas Regionais, Crescimento Urbano, Turismo, Autómatos Celulares

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1 - Introduction

1.1. Justification

Unprecedented environmental change has shaped the landscape of our Earth. Most of these changes have been witnessed in the last century and are a consequence of man's behaviour on the environment. Considering that man is one of the youngest species on Earth, humankind managed to modify as no other species the environment to fit its growing demands. These changes brought significant imbalances which led to deterioration of fragile ecosystems and landscapes (Daly and Farley, 2004). The resulting danger of these inequalities were only truly grasped in the 1960s (Meadows et al, 2004), and have gained increasing socio-political attention in the late eighties through the Brundtland Commission. Brundtland's concern came 150 years after the Industrial Revolution, recovering from a long gap regarding awareness about the importance of our natural environment, when both industry and consumers had already created a path of inconsequent behaviours.

In Rio de Janeiro in 1992, nine years after Brundtland, for the first time in history a series of 27 principles were drafted expressing the importance of what may be defined as sustainable development. These principles defined the concept of sustainable development and considered the application of tools for sustainable development drawn from a synergy between stakeholders and decision-makers. A new chapter in the history of sustainable development was unfolded. This vision was shared by the dream of delivering to future generations the inherited wealth which for so long had been taken for granted: our Earth and its available resources. These principles, known as the Rio Declaration on Environment and Development, clearly state the importance of environmental impact assessment (Principle 17): *"Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority."*

The framework of economic growth shifted to economic development, taking advantage of decision-making strategies and a synergy between politicians and scientists.

The 1990s were a fertile ground for the development of new methodologies and tools to monitor environmental changes and understanding the impacts of human on Earth. Although sustainable development still lacks a clear definition (Beckerman, 1994), it is common-sense that it results of direct interactions of social, economic and natural phenomena exerting pressure on the environment (World Commission on the Environment, 1984). As these relations are far from linear, advances of Information and Communication Technologies (ICT) have been important in measuring the changes on our environment. The incorporation of non-linear reasoning, allows the generation of scenarios to understand the dynamics of changes and optimize our choices for sustainable development (Li and Liu, 2008).

In an attempt to minimize the use of non-renewable resources, this dissertation offers a framework of different spatial instruments to understand the dynamics of regional change which are strongly linked to the importance of geographical space. Located in the southern region of Portugal, the Algarve is used as an experimental laboratory to test the concerns of environmental change. Several reasons justify this choice, especially related to a historic, socio-economic and environmental context.

(1) The Algarve is one of the most culturally diverse regions of Portugal. Occupied since the Phoenicians (Neville, 2007), it has offered since antiquity a unique cradle for civilizations, due to its outstanding coastal location to the rest of the World (Strabo, 2008);
(2) Furthermore, the Algarve tells a story of man's ambition and economic growth, as it entails a mass tourism industry since the sixties that to great extend destroyed natural landscapes for economic growth (Vaz and Nijkamp, 2009);

(3) Nowadays, current policy issues and regional planning face a dilemma on coping with economic growth, while maintaining the quality of the environment without compromising the welfare.

1.2. Methodological Tools for GIS and Spatial Analysis

This dissertation uses Geographic Information Systems (GIS) and spatial analysis for interpretation, storage, data convergence and visualization of regional socio-economic and land use changes. Geographic Information Systems become key assets to build-up on the predictive power and creation of tools for interpretation of socio-economic data. These spatial variables are used as explanatory models to understand the parameters of (1) urban growth, (2) tourism propensity and (3) heritage risk. While urban growth models are developed based on transitions of land use, the propensity maps are calculated supported by existing datasets of spatial importance. Modelling of urban growth assumes the integration of complex system theory and takes advantage of the usage of Cellular Automata to deal with non-linearity of urban sprawl. The metrics of tourism propensity are levelled by spatial cluster analysis shedding some light on the patterns of Tourism choices and trends. Much of the heritage risk is followed by the articulation of the sections of urban growth and combined with predictive modelling approaches. Most of the analysis has been carried out in ArcGIS 9.x and Idrisi Andes.

The focus on Geographic Information Sciences (GISc) instead of Geographic Information Systems (GIS) results from the ubiquity of integrating different sciences into the field of study. Following a generic distinction of GISc and GIS, GISc can be seen as the use and study of spatial concepts and analysis methods. GIS on the other hand, is much more related to the collection of Information and Communication Technologies as tools to create solutions for spatial analysis. In this sense, GISc becomes much more holistic within a scientific field of research, and expands on the different methodologies and models that have been integrated in this dissertation. Furthermore, the acknowledgment that sustainable development may be better perceived by a complex system approach, calls for Geographic Information Sciences as a fundamental dimension of tools in the connection of spatial information with socio-economic and natural data. In this dissertation those datasets are integrated into different layers, allowing spatial non-linear manipulation and resulting into the different scenarios of environmental change. As pointed out by Nijkamp and Scholten (1993), GIS share a crucial role in linking land-use management with regional decision making. Combined with non-linear parameters of spatial scenarios, the decision making of the GIS tools lent the possibility of casting future visions for environmental and spatial planning. The combination of GIS, scenarios and modelling approaches, is translated in this dissertation into several different studies on complexity and environmental change in the Algarve. These studies provide an outlook concerning the future of decision making for the region, also sharing the current concern on consequences on land-use and human induced pressures due to economic growth.

1.3. Applied Methodology

The tools for spatial regional assessment of the Algarve are assessed through a series of empirical studies which reflect the main pressures on the region. Thus, the first analysis examines the urban growth in the Algarve. Distinguishing the differences between urban growth and urban sprawl, an urban growth model is explored, leading to a framework of spatial urban assessment through scenario modelling. A novel approach to cellular automata (CA) modelling is carried out for the purpose of understanding the impacts of future urban growth tendencies, given specific pathways adopted by each of three scenarios. The Multi-criteria Evaluation (MCE) methodology related to driving factors weighted by Analytical Hierarchy Processes (AHP) allows to understand the future dynamics of urban growth as well as to recognise which regions are more likely to expand their urban perimeters. The paper concludes that the Algarve is mainly affected by urban growth in the coastal regions, and identifies Tourism as a main indicator for continuous urban pressure on the coastal area. While the paradigm of coastal urban growth has been studied previously by the European Union (EEA, 2006), the co-relation of urban growth with Tourism has been little analysed.

This leads to the second empirical study which assesses the direct relation of urban growth with Tourism. By filtering the spatial tourism attributes within their proximity to urban areas, Euclidean distances are weighted from urban centres and a relative weighting factor for Tourism in the Algarve becomes clear. Tourism is assessed as the main driver for economic prosperity in the Algarve, but also shown to be the main responsible negative externality as sink of sustainable regional development. The carried out spatial analysis, shows that it is important to find a different kind of approach for Tourism in the Algarve, which, although still an important driver for economic growth, should restrain from using the coastal area as main Tourism product. The application to sustainable tourism becomes a turning point of the spatial debate and spatial assessment, offering a solution of integrated tourism taking advantage of historical heritage as driver for economic development in the Algarve.

Within the context of strong and weak sustainability (Cabeza Gutés, 1996) an interpretation of the consequences of the asymmetries of rural versus urban areas in the Algarve is carried out. Expanding on the notion of spatial relations of urban areas and loss of agricultural regions, an additional study is carried forth to understand the current trends of loss of agricultural land. This study not only allows assessing the current and increasing loss of agricultural productive areas, but shows that the Algarve is suffering from a cyclical process of land loss, strongly linked to the lack of application of long term strategies at regional level that should enable a better protection of rural areas in the Algarve. The environmental law system is pointed out as one of the factors which could influence on a better management of rural regions in the Algarve. However, some faults in the legislative process hinder the possibilities of better management of hinterlands and rural regions, translated in the continuous loss of the National Agricultural Reserve (*Reserva Agrícola Nacional*).

An interesting opportunity to avoid the asymmetries of the Algarve is found by fomenting sustainable tourism; however, sustainable tourism depends on the exploration of resources which are renewable. Supporting the issue of renewable resources, the Algarve has been a region of vast historico-cultural interactions, which could be an interesting opportunity for a better Tourism industry. Thus, the next study integrates the analysis of Archaeological vestiges from the Roman period in the Algarve, in an attempt to understand the Archaeological dynamics of the region. By creating a Logistical Regression Model (LRM) within the application of Archaeological Predictive Modelling (APM) it is assessed that the Algarve shows a vast potential for Archaeological Tourism, especially in the interior, where the region is far from overburdened, and sustainable Tourism could easily be incorporated. Lastly, a further study is developed based on overlaying information on propensity for urban growth and Archaeological industry. The consequences of urban growth on archaeological regions, and the drivers of Tourism are incorporated within what becomes defined as an opportunity for historico-cultural endangerment (HCE) from urban growth. The dissertation proposes a final reflection on the dynamics of urban growth as a result from massive tourism industry and socio-economic growth.

Table 1 – Expected resulting publications and published materials

Title	Authors	Journal / Book	Publisher
A Multi-scenario prospection of urban change – the case of urban growth in the Algarve	Vaz, Caetano, Nijkamp, Painho	Landscape and Urban Planning	Elsevier
Crossroads of Tourism – a complex spatial analysis of tourism and urban sprawl	Vaz, Nainggolan, Nijkamp, Painho	Journal of Sustainable Development	Inderscience
Impacts on environmental law and regulation on agricultural land-use change	Vaz, Brito, Painho, Nijkamp	European Planning Studies	Taylor and Francis
Past Landscapes for the Reconstruction of Roman Land Use: Eco-history Tourism in the Algarve	Vaz, Bernardes, Nijkamp	Ecotourism: Management, Development and Impact	NOVA Publishers
Urban heritage endangerment at the interface of future cities and past heritage	Vaz, Caetano, Cabral, Painho, Nijkamp	The Annals of Regional Science	Springer
Historico-cultural sustainability and urban dynamics: A Geo-Information Science approach	Vaz, Nijkamp	Enhancing the City: New Perspectives for Tourism and Leisure	Springer

1.4. Assumptions

The dissertation proposes a symbiotic approach of theoretical and empirical analysis constructing a base for an integrative complex system approach. In this system, four assumptions are considered:

1. The systemic approach: Environment may be considered as a system, in which the different parts interact as a whole.
2. The dynamic approach: Scenarios and predictive modelling allow the analysis of temporal change.
3. Spatial representation: Spatio-temporal representation of reality is possible with spatial modelling where hypothesis are created that allow interpretation of environmental systems. Urban modelling and GIS are key-players for observation and spatial data analysis.
4. Uncertainty and prediction: The complex relations of integrative approaches in complex systems are quite complex and often fuzzy. Non-linearity in system analysis yields uncertainty which is unavoidable. However, prediction still creates important structural pathways which facilitate decision making.

1.5. Objectives

One of the major concerns regarding sustainable development is land-use change, brought largely from urban growth, and asymmetric socio-economic strategies (Koomen et al, 2007). The socio-economic factors of land-use change, are often linked to policy-makers and should comply with more assertive strategies, as to create better decision support systems for sustainable development (Sanchez-Marre et al., 2008), resulting in better management, without compromising either economic activities or the preservation of biodiversity and heritage.

In this sense, the main objective of **PART A** of this dissertation is to understand the intrinsic relations of sustainable development by considering the different backgrounds brought by economic, social and natural aspects dealing with the issue of carrying capacity of the environment and tools that support such analysis (Figure 1). Underpinned by the importance of Complex System theory, the discussion brings to light the importance of scenario based modelling approaches to accurately measure and predict change. This part embodies two sections (**Chapter 2** and **Chapter 3**) in a sequential deductive approach, offering macroscopic vision of the different dimensions of sustainable development. As such, **Chapter 2** focuses on the critical backgrounds of the social, economic and natural dimensions and discusses the importance of a joined effort in which spatial analysis modelling and applied complex systems are discussed. While this chapter represents a critical view of the state-of-the-art of the spatial sustainable development, **Chapter 3**, describes the necessary tools to allow better spatial decision making. Analysing the applicability of Urban Growth Models (UGM), this next chapter draws further on the non-linear toolsets. This is the case of Cellular Automata (CA) to assess the propensity for environmental change and as well as the state of predictive modelling based on endogenous and exogenous variables.

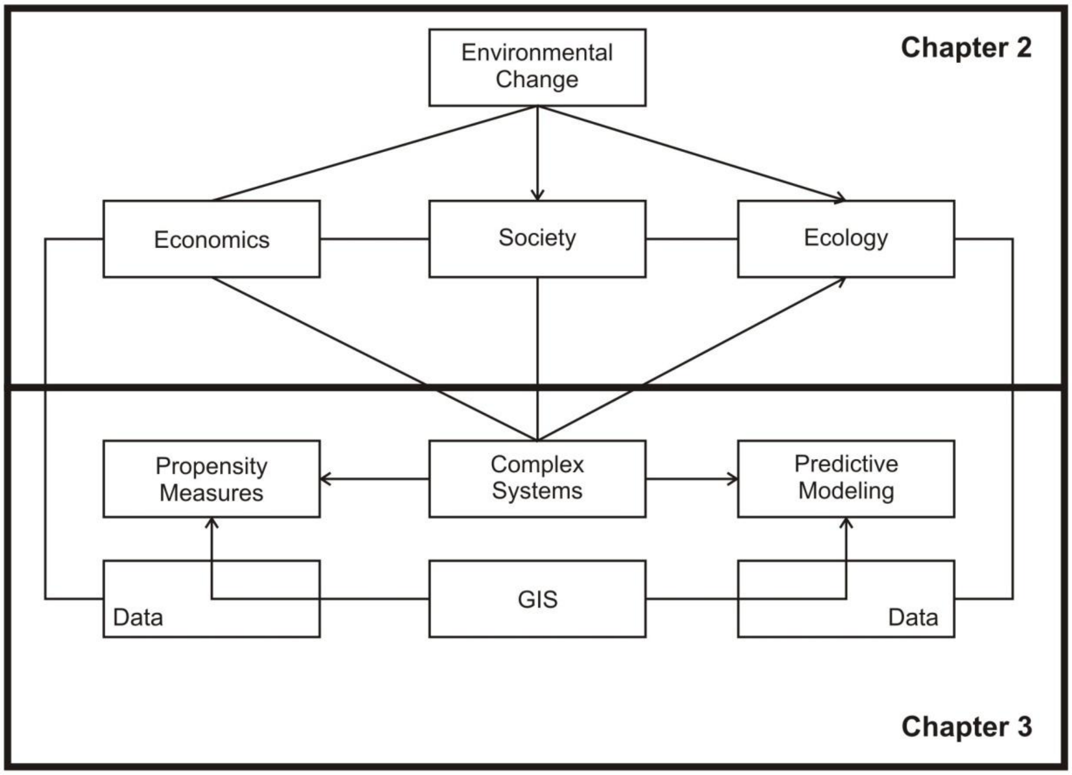


Figure 1 – Diagram of Part one

PART B of this dissertation uses the Algarve as a laboratory of analysis of the different aspects of regional environmental change and sustainable development. Epistemologically, this part, divides into three main studies which are the core of the empirical evidence of the dissertation (Chapter 4, Chapter 5 and Chapter 6 as presented in Figure 2). The Empirical material (Study 1, Study 2 and Study 3) corresponds to international peer-reviewed publications, which shed light on the different aspects and interconnections of the identified key issues: urban growth and future of sustainable cities (Study 1), socio-economic pressure brought by unsustainable economic activities (Study

2) the dimensions of environmental law and regional impacts (Study 3). **PART C** offers a solution using heritage to regain the balance of existing regional asymmetries. Focusing on sustainable Tourism and critically evaluation Tourism as an opportunity for economic growth in the Algarve, an assessment of the historico-cultural potential of the region is assessed. The results of the main studies may lead to inquiries and interesting analysis which will allow scientific work to be carried out in the near future (some of the inquiries and analysis are reported on Figure 2)

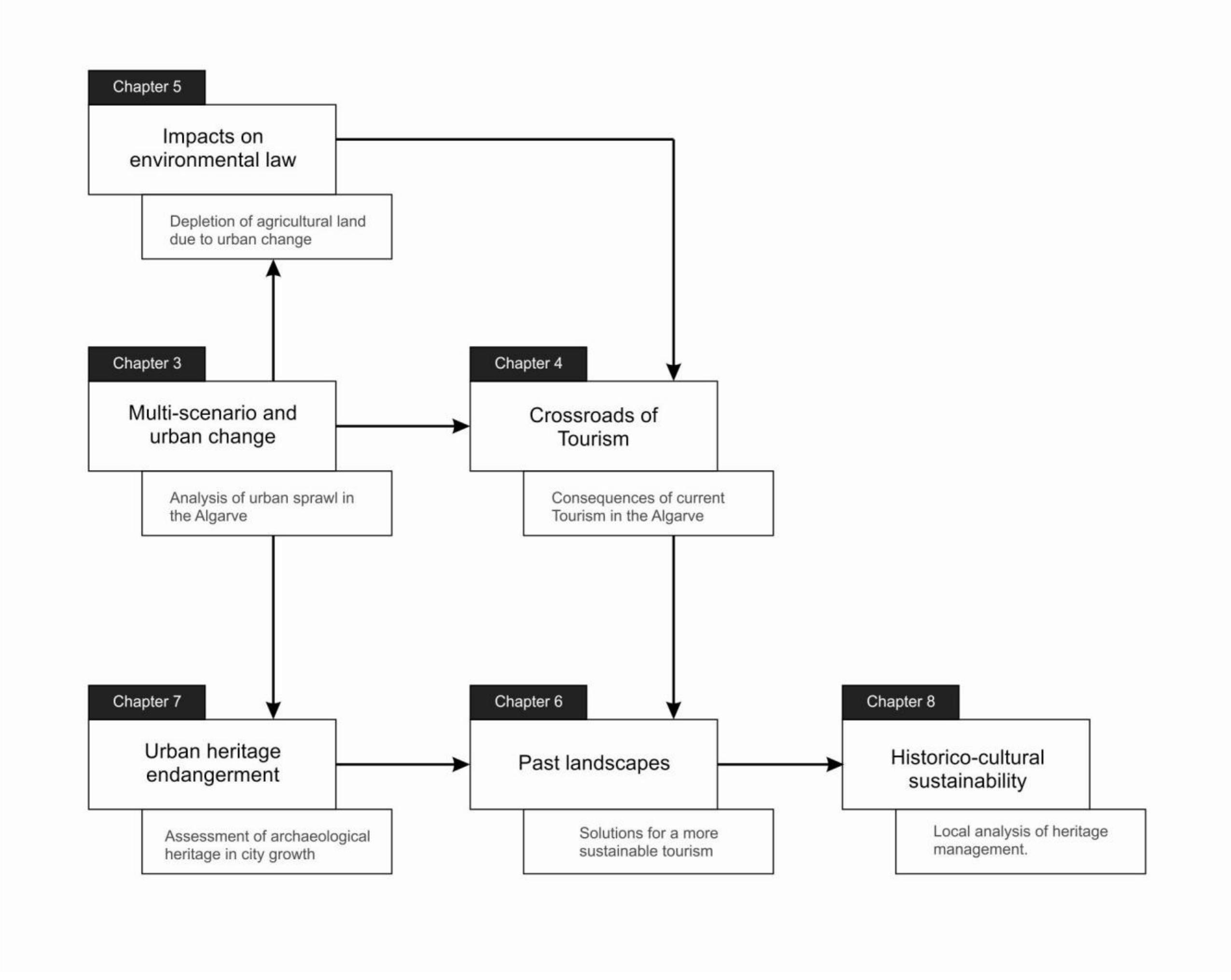


Figure 2 - Relation of studies

.The existing archaeological landscape, offers a genuine attraction which rectifies the existing excess of economic activity along the coast fringe. While the Archaeological landscape is tested in Study 4, Study 5 shows the intricate relations endangering continuous urban growth on this unique landscape. Finally, Study 6 emphasises on the concept of regional sustainable development based on the existing historico-cultural sustainability, as a novel opportunity for coastal equilibrium in similar situations.

1.4. Hypothesis

The next figure (Figure 3) shows the intricate relationship of all the different Chapters and Parts. Furthermore, while the different parts summarize the organic structure of the dissertation, a series of Hypothesis are tested along the study. Thus, the diagram also responds to the different Hypothesis which is validated for each of the study within specific frameworks in an attempt of defining sustainable development and carrying capacity.

These Hypotheses are directly related to the development of the studies. Some of the Hypothesis arise from the relationship of one study-case to the other, as many of the questions may not be answered isolated, but rather, are a result of the interaction of different elements.

The following Hypotheses were discussed regarding each of the papers and will be tested during this investigation.

1) Multi-scenario and urban growth:

    1. Hypothesis 1 Cellular Automata related to GIS allow accurate visualization of future landscapes within the region of the Algarve.
    2. Hypothesis 2: Urban growth has a direct consequence on environmental ecological sustainability in the Algarve region.

2) Crossroads of Tourism:

    1. Hypothesis 3: It is possible to relate spatial information with tourist attractors and land-use vulnerability.
    2. Hypothesis 4: Tourism industry if not correctly managed may damage the fragile ecosystems.
    3. Hypothesis 5: Land-use vulnerability within touristic attractors shed information of future urban growth and land-use change tendencies.

3) Urban Heritage Endangerment:

    1. Hypothesis 6: Archaeological Predictive Models are important tools to measure cultural heritage for the Algarve.
    2. Hypothesis 7: The historico-cultural landscape is successively becoming destroyed due to human impact on the environment.

4) Future works (Spatially articulated Social, Economic and Natural Model):

    1. Hypothesis 8: Dynamic complex system modelling within a framework of spatial models, allows sharing crucial information of environmental global change at regional and urban level – The beginning of a research agenda for postdoc.

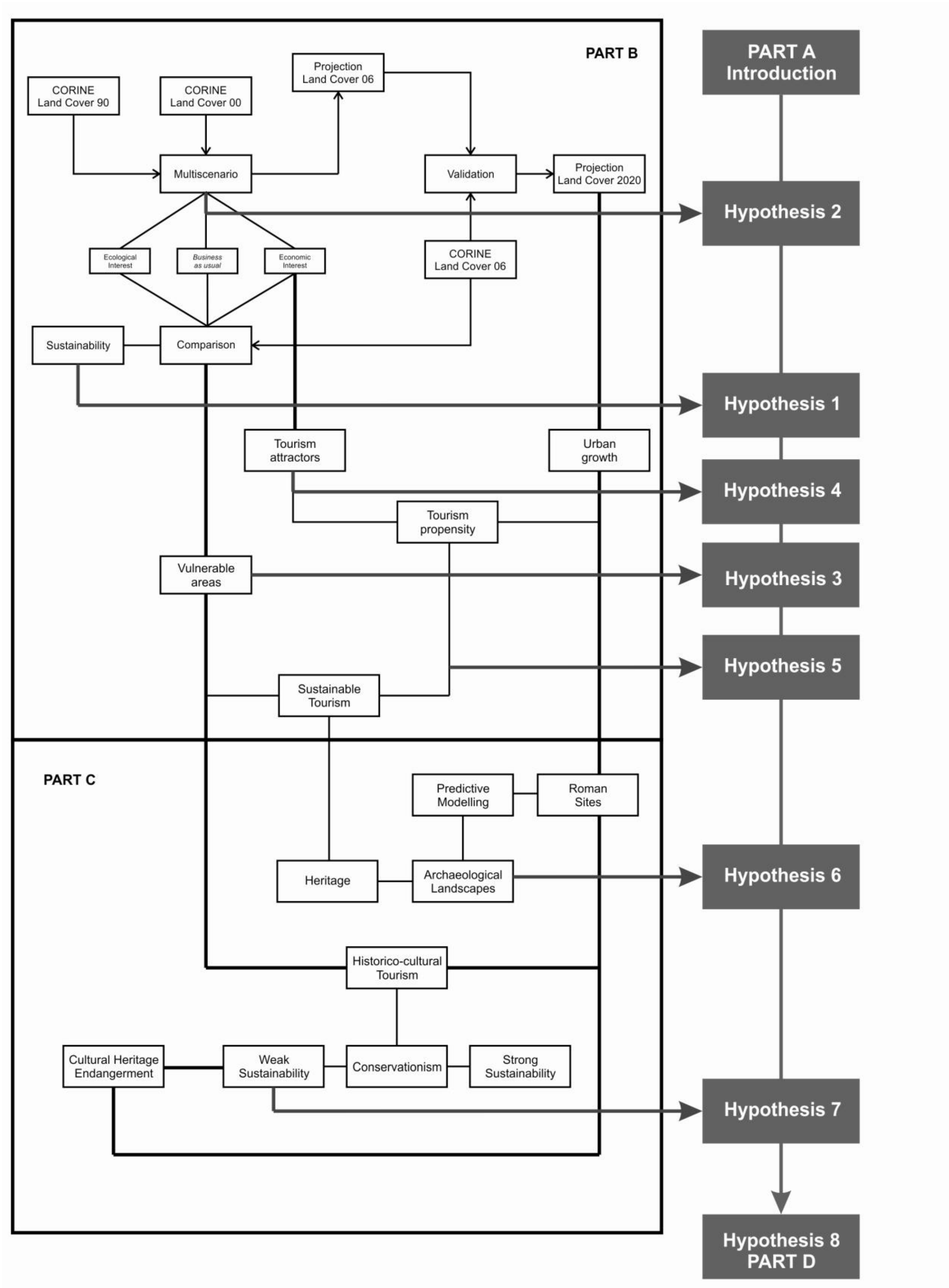


Figure 3 - Overall structure of the empirical approach and related Hypothesis

Chapter 2 –Economic, Social and Natural Factors in Regional Change

2.1. Complex Systems and Scenarios

The objective of this chapter is to understand the global dynamics that lead to environmental change from a spatial perspective. Three distinct and relevant dimensions have been considered in regional sustainable development: economic, social and ecological (van den Bergh, 1996; Haughton and Counsell, 2004). The intricate relation of those dimensions in space allows the application of spatial analysis to calculate the consequences of the carrying capacity on the physical environment. Human being has had a large impact on these different, systematically integrated dimensions, generating unpredictable spill-over effects.

The recent advances in systems theory facilitate the disaggregation of the complexity resulting from human transformation of the natural environment. In this process the spatio-environmental perspective is a key dimension of better understanding the complex relationship of environmental degradation driven by human behaviour.

The origin of complex system theory is strongly linked to the importance of coping with multiple aspects of intertwining realities of measurable and reliable data. System theory originated from Bertalanffy's work as a biologist (Bertalanffy, 1950), in an attempt to abridge the different aspects of the dynamics and transactions within a system. Although the relations of complex systems were first explored within biological micro-simulation of small systems, the understanding of system theory in general, presupposed the possibility of a wider range of application within different domains of science (Meadows, 2008). Thus, complex systems as an attempt of understanding the consequences of a holistic approach to complexity of different parts within a system have been an interesting solution to generalize and formalize several aspects of change dynamics.

Complexity as such is better understood if cause-effect sequences among the elements of the system are defined, establishing more or less constant relationships among them able to be extended in time. These dynamic aspects of complex systems are of great importance to foresee the possible structural change and create probable outcomes which are named scenarios. Scenarios are strongly stimulated by the possibility of understanding the consequences within systems to assess future change in ‘what if’ relationships established between different agents. The convergence of the formal knowledge of complex system theory, related to scenario modelling, allows generating non-linear outcomes of future events which may combine the economic, social and natural dimensions of environmental change (Allen, 2001).

As recently defined by the United Nations Environment Programme (UNEP, 2007) development and wellbeing depend largely on biodiversity and ecosystems. Yet, as a result of multiple pressures – mostly human induced (CBD, 2003) - ecosystems are becoming more and more vulnerable (Millennium Ecosystem Assessment, 2005). The complexity of understanding the dimension of sustainable development may be limited to a set of questions that argue qualitative options (Gale and Cordray, 1994) namely: (1) what is sustained, (2) why sustain it, (3) how is sustainability measured, and (4) what are the politics involving the sustainability process. As those questions scope a more specific aspect of sustainable development, these qualitative assessments do not consider alternative possibilities for future outcomes of different political choices. Therefore, although sustainability indicators may provide important information, they do not provide a toolbox with direct application. However, such results may be achieved by a combination of qualitative assessment of environmental indicators. Combining relevant environmental information may help to explore future outcomes based on socio-economic tendencies. These consequences are of social importance (Dunlap and Catton, 1979) and permit an interdisciplinary research approach (Dickens, 2001) in which the environment has a clear role in the construction of future scenarios.

Uncertainty however, is high and the relation towards scientific evidence (or truth) is often unrelated, and therefore complex (Figure 4a). It is through the convergence of creating scientific hypothesis that combine information accurately, that uncertainty may be reduced and lower complexity levels achieved. The intellectual property of such venture asserts in a synergy among exact and human sciences, as information and knowledge can only be relevant if considered as a whole and not as a sum of its different parts (co-constructivism). Thus, a relation among quantitative evidence and empirical evidence will forge a direct relation for understanding truth, embedded by the multiple criteria in speculative scenarios. As represented in Figure 4b and defined by the paradigm shift of human and exact sciences, the complex science brings the capability of joining human and exact science in a single framework. This adds on the possibility of finding more robust explanations to certain phenomena which exist within social and behavioural sciences.

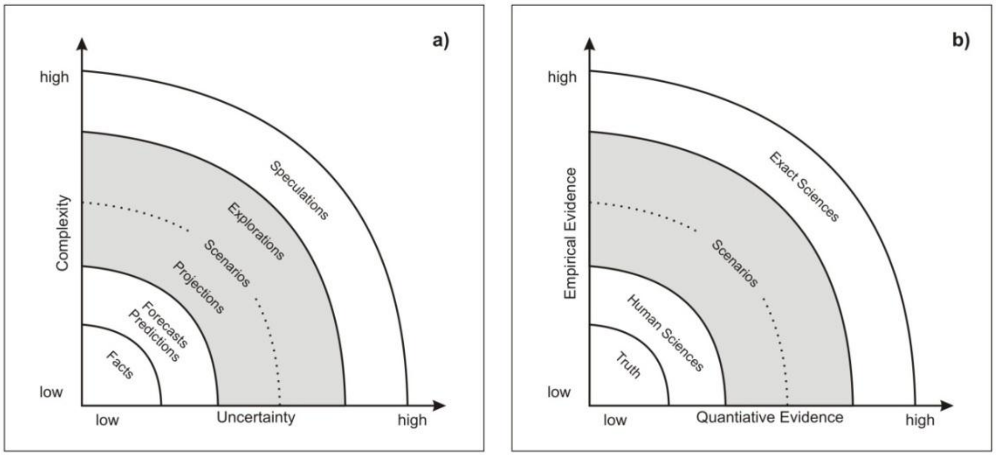


Figure 4 - Central role of scenarios (Alcamo and Heinrichs, 2009) and (b) paradigm shift of human and exact sciences

The empirical (and quantitative) evidence nowadays may be included into the scenario perspective through intelligent systems. In considering the dynamics of actors as agents, multi-agent based models allow assessing the behaviour within a transdisciplinary approach of different environmental change behaviours. By computer simulation of ecological factors, as well as of spatial relations between the different anthropomorphic result related to land-use degradation and environmental endangerment may be observed. An interesting evolution of a similar field of development in the spatial analysis and predictive modelling approaches, are Cellular Automata (CA) where transitions of a cell state to another may be considered as a cellular form of independent and thus, intelligent agents transitioning from one state to another based on a set of user-defined rules.

2.2. Economics and Environmental Change

The relationship between resources and commodities is inherently quantitative in nature and its analysis allows a structured understanding of a system. Human kind depends on natural environment to anticipate demand created for (Hussen, 2004): *(a) the extraction of non-renewable resources (such as iron ore, fossil fuels, etc.) and the harvest of renewable resources (such as fish of various species, agricultural products, forest products, etc.) to be used as factors of production; (b) the disposal and assimilation of wastes; (c) the consumption of environmental amenities (such as bird watching, canoeing, hiking national park trails, observing a morning sunrise or an evening sunset, etc.).* From an economic perspective, those variables may easily be integrated in a circular flow model (Figure 5), constructing a restrictive relation with the environment.

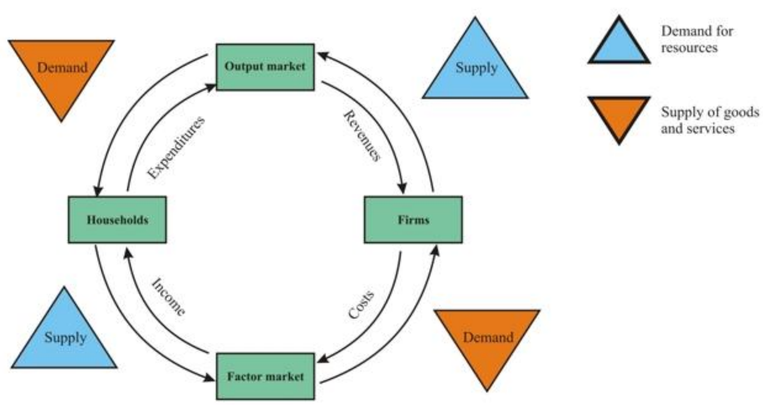


Figure 5– Circular flow model (adapted from Daly and Farley, 2004)

Scarcity of resources is the major assumption the economic science leading to a dichotomy of the possibilities to maintain current market stability while coping with increasing demand from several sectors and not having often the capacity to develop the resources necessary. This consequence of development has lead over the coming years to a collapse of natural and environmental landscapes as well as societal rivalries which become a consequence of uncertain production choices and production regions.

O'Neill and Kahn (2000), explain how economic development is dependant of ecological conditions in which human being may be considered as a keystone species, whose role is that of fostering and controlling ecological environment, rather than an aliened species from the natural ecological system. The result of economic instability is heating on-going debates on functionality of economic models and the recent financial recession has witnessed unprecedented economic uncertainty. Although the resources of economic interest are absolutely dependent on natural resources within any part of the product cycle, still the classical economic thought is regarded as a closed system not allowing key players such as organizations, institutions and enterprises to cope with a more abridging phenomenon in which also natural resources may suffer from scarcity. As a result, the market tends to ignore the importance of ecosystem dynamics and a new view of economic interdependencies has been brought to scene by environmental economics and ecological economics. This heterodox approach of economic thought understands the economic system rather as an open system of circular nature, in which all of the inherent parts of ecological characteristics as well as the economic factors are underlined in a general system of equilibrium among resources and goods (produced or consumed).

In fact, the balance needed for environmental sustainability is a direct consequence of ecological and economic efficiency. Nevertheless, the existence of non-renewable resources marked by the carrying capacity of the environment which is directly related to a growing demand of production due to population growth jeopardizes sustainability and queries therefore limits to growth (Meadows et al., 2004). Mainly, this problem is intrinsically related to the amount of pollutants thrown into the ecosystem which is naturally associated to a strong economic growth and a tendency of spatial aggregation, and over time, this paradigm of population growth and pollutants has grown into an issue addressing the technological aspect of coping with by-products of population increase and demand.

Development and its relationship to environment may be understood in a context of environmental degradation depicted by spatial models with economic analytics. The Kuznets curve for example, reflects the relationship between various indicators of environmental degradation and the existent income per capita. Nevertheless, the reduced form the Environmental Kuznets Curve (EKC) (Figure 6) tends to limit information on policy choices (Stern et al, 1996) which are of utmost importance for decision making process concerning sustainability as well as not reflect the scarcity of resources.

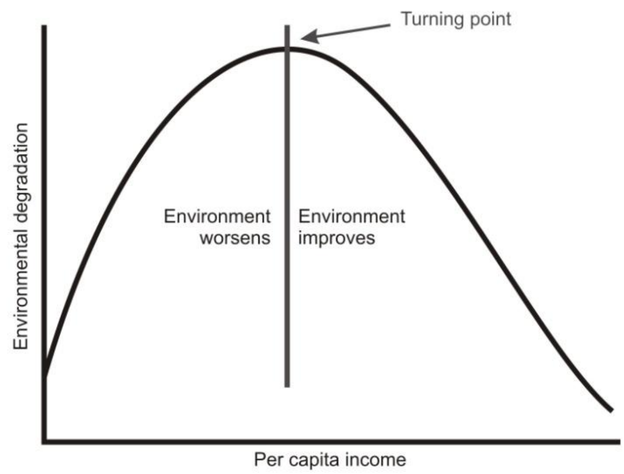


Figure 6– Environmental Kuznets Curve

As seen, economic analysis connected to spatial information, may allow the understanding of more causal relationships which fragment the complexity of the environmental-economical relation and may synthesise accurately the more complex relation of environmental economics which “*(...)undertakes theoretical or empirical studies of the economic effects of national or local environmental policies around the world, including effects on pollution, research and development, physical investment, labour supply, economic efficiency, and the distribution of real income. Particular issues include the costs and benefits of alternative environmental policies to deal with air pollution, water quality, toxic substances, solid waste, and global warming*.” (National Bureau of Economic Research).

Neoclassical economic theory understands a maximization of utilities from part of individuals, while firms shall maximize their profits. This basic principle deduces that the economic flow will necessarily have an anthropocentric perspective, in which man’s wellbeing is the decisive goal. This concept brings forth the mentioned EKC, as direct reflection is a result of evolution of income. In a neoclassical concept, environmental degradation therefore, only becomes relevant when directly affecting human welfare. Environment, by those means, is faced as a quantified product and sustainability is necessarily a reflex on environmental consequences which resources may be enhanced and therefore provides a better capitalization of its initial resources.

Neoclassical economists recognize the structural importance of empirical research (Illge and Schwarze, 2009) brought by the strong background based on processes of evaluation and testing, which allow quantitative conclusions. And, in this sense, environmental economics from a neoclassical perspective becomes more *macroeconomic*, justifying the demand flows at a definite scale for choices made upon the environment and creation of economic welfare. On the other hand ecological economy is centred not necessarily on the welfare of man, but rather, on the welfare of an ecological metabolism that attributes value to nature itself, not as a resource. In this context, both differ deeply: Contrary to neoclassical reasoning that forfeits environment as an externality (positive if the benefits surpass the cost of maintenance, negative in the other case), ecological economy considers man as the externality to the environment.

Land-use is a by-product of any economic activity, as it directly affects in a measurable form the production process. For example, agricultural production, will necessarily affect the exploration of land-use related to types of crops which will influence land cover. On the other hand, increase of population may have an effect on urban growth subdued by the Gross Domestic Product (GDP) and existence of employment, which may reflect on which areas may become urbanized.

Leontief's input-output model "describes and explains the level of output of each sector of a given national economy in terms of its relationships to the corresponding levels of activities in all the other sectors. (…)" while "(…) [permitting] to explain the spatial distribution of output and consumption of various goods and services and of their growth or decline—as the case may be—over time." (Leontief, 1986, p.241). Traditional economic models, as the input-output model, may adapt themselves at the regional scale. The consequence is a plausible regional scope of analysis, which addresses spatial uncertainty of economic aggregates. Regional and urban economics, explore largely the spatial dimensions entailing the possibilities of predicting outcomes given indexed values of economic throughput, scarcity of resources and sectors of economic activity. In this sense, regional economics may be defined as the "*Regional Economics analyses the spatial dispersion and coherence of economic activities.*" (Nijkamp and Mills, 1987).

Supported by, "*Conceiving space as a grid system has the advantage of explicitly presenting a map of spatial activities to any desired level of detail (…)*" where "*Similarly, economic regions may be constructed according to socio-cultural or historical criteria or by using such economic variables as industrial structure, rates of unemployment, and per capita income. Or, economic regions may be delineated according to the intensity of economic exchange via commodity exchange and factor mobility. Administrative or political regions may be delineated according to the above mentioned criteria or* *according to historical or political phenomena.*" (Siebert, 1993). This representation of detailed space, allows a better perception of the dimension of local economic, social and natural change, leading to a better decision making and analysis of local/regional trends, manifesting the importance of human behaviour in an environmental context (Isard, 1956).

2.3. Society and Environmental Change

Society has changed drastically over the last 200 years. From a chronologic perspective, the anthropocentric role of social factors has been questioned increasingly by a broad number of scholars justifying a new social paradigm related to a society with less structured values, characterized by a lack of clear concepts and ideals. Society today is living according to scholars in a postmodernist era that gained expression over the sixties in western societies. A key trait of postmodernism from a social perspective, is the questioning of values established since the enlightenment and modernism, and contrary to modernism ideologies, defies current values on a constructive, often anthropocentric rationale leading towards a strong criticism of pre-established values.

Extending the postmodernist criticism not only in the domain of the arts and on iconic symbolism of cultural background in modern societies, postmodernism sets nowadays new standards for a critic of an inconsequent and sometimes obsolete capitalistic model. Example of this is the trend of following a paradigm shift, from a society established in the idea where the key concept should be limitless production, driven by limitless consumption to a level of a *future shock* (Toffler, 1970) where technological development may have a crucial outcome in the management of the society and economy.

In fact, the Enlightenment allowed establishing an ideological shift of a man centred role in the universe and the Modernism further extended the anthropocentric role to a scientific conglomeration of human and exact sciences. Today's Postmodernism defies the boundaries of science, articulating new transversal areas of study in which human and technology integrate to fit elegantly in framework of new scientific directions.

Geographic Information Systems (GIS) may be considered one of such recent scientific areas of study. Reaching an important role for analysis of spatial related phenomena, recent years have shown an on-going increase of GIS as tools for social sensitizing and knowledge diffusion. Spatial information, as such, seems to replace the traditional information system by associating the spatial perception to analyse different kinds of visual information and aiding in the forecast of human and natural trends.

Recent applications of software such as *Google Earth*™ and *Microsoft Virtual Earth*™ that, offer a spatial visualization of geographic environmental and topographic characteristics of cultural, social and ecological phenomena, enhancing the way we perceive reality. The impact of generalized and long term use of such visualized information at a social level may have important results on the diffusion of existing environmental change awareness.

By usage of spatial modelling and GIS, it has become possible to envision the consequences of urban change and inform stakeholders of more sustainable decisions. Nowadays, spatial information ventures even further, and the appearance of the phenomena such as *web 2.0* have led to a more social role of information transition. Modelling of future land use scenarios at a regional context is thus, an important evolution for the possibilities of analysing future change and social awareness of environmental fragility.

Over 45 years ago, Roger Tomlinson conceived the first Geographic Information System (GIS) as a tool for land use planning for the Canada land inventory (Thill, 2000). It would not be expected, that a few decades later GIS would transcend in so many aspects the traditional knowledge of regular mapping tools. Meanwhile, GIS have become complex systems of interconnected parts constituted by information products, software, data, hardware, procedures and people (Tomlinson, 2003). It is surprising that this vision would have 40 years earlier, the same notion of complexity and arguments of the intricate parts that form the complexity of a GIS. Thus - although the vision has not changed in time - perspective on technological evolution did, and as a consequence issues that GIS couldn't handle forty years ago due to technological limitations, are now solvable. Thus, the role of GIS by the use of new tools, some yet to be further developed leads to a new paradigm regarding the role of those tools, nest outreaching spatial possibilities. Not only have GIS become tools for static land monitoring, but also, with the technological advance of high spatial resolution satellites and of repetitive observation of spatial properties over time, it has become possible to assess dynamic spatial models, prompting effects on spatial change. GIS have evolved into very adequate instruments for spatial quantification depending rather on the creativity of the user. Thus, rather than becoming a simple spatial analysis toolbox, GIS are increasingly seen as a science (Geographic

Information Science). Attending elementary properties related to GIS related technologies (Goodchild, 1990) GIS permits the creation of a new discipline, with considerable depth, focusing on the richness of the challenges brought by scholars (Mark, 2003).

As a result from these different dimensions, Geographic Information Science (GISc) is an expanding discipline of study, the National Centre for Geographic Information and Analysis (NCGIA) defined quite early five key topics of research in its field of study in 1987: (1) Spatial analysis and spatial statistics, (2) Languages of spatial relations, (3) Visualization, (4) Artificial intelligence and expert systems (5) Social and institutional issues.

These different scopes of interest represent a reflection of the importance of the different fields of study directly proposed by GISc, but the fifth topic underlies the need and the importance of Social awareness.

Examples of applications of the social dimension of GIS and web phenomena are incitingly being coined with the appearance of Web Geographic Information Systems (Web GIS) as well as the development of a more sociocentric instead of a technocentric web. An example of some of the latest applications may be found by usage of GPS with GIS embedded devices for monitoring of car-jacking activities, or GIS as proactive tools for cataclysm management. Also considering the needs of knowledge diffusion for scientific evolution, GIS have shown vast importance in information dissemination. This is the case of for example, with the recurrent use of satellite imagery and spatial information with metadata to reproduce ecological, geographical, natural and cultural phenomena.

Within a framework of spatial science, relevant investigation has been applied to understand economic, social and natural change:

1) In a European context, where existent asymmetries among an expanding Europe. Such circumstances seem to indicate the need for a generic scope definition confined by divergent policy choices and environmental decisions.
2) Also, the legislation for land use change for instance, is a reflex of economic activity and consequence of regional production as well as market outputs in a context of growth. Affecting employment, migration patterns and life quality, the understanding of land-use patterns in a context of temporal land change, creates the needs of planning issues at national, regional and local scales.
3) The relationship between land use cover and environment are of biogeochemical nature, and the consequences of not maintaining the most adequate land use, may easily jeopardize the stability of ecosystems, natural habitat and life support. Examples of this are the monitored spatial land changes of effects of deforestation, with dire consequences on the CO2 emissions. On the other hand, Europe has witnessed an unprecedented urban expansion having a direct consequence on hinterlands and rural areas (Vaz et al, 2009) as well as peripheries of cities, leading to often degraded urban and ecological landscapes.

The symbiotic nature of land-use and environmental sustainability has had a rising interest since the publication of works such as Rachel Carson's "Silent Spring" [1] (Carson, 1962), in which the criticism of man-made technologies (pesticides) showed an increasing baleful effect on environment. The awareness of the role of man as a driving force upon the environment became further obvious in "The Limits to Growth" (Meadows and Meadows, 1972) where from a pragmatic perspective, understanding of the consequences of population growth showed the dreadful results of an ever increasing world population given the scarcity of available resources. Nevertheless, mentioned both volumes had a certain number scepticism attached, often related to the uncertain nature of quantitatively consequences of prediction as well as relation to human welfare in general. In fact, environmental issues brought to general public from the very beginning of its origins, despite best intentions, had always had a certain burden of scientific community which tended to argue on the media as a shallow understanding of real quantifiable scientific methodologies. Both books became outstanding bestsellers and have decades later inspired many views on social sciences and on individual behaviour. Also, the scientific community brought a larger recognition of the importance of social cogitation on the disastrous consequences on environment. Forty years later, the role of society regarding environmental change remains unclear while vastly assimilated as a key player by the media. As policies become a consequence in developed countries of democratic legislation, the *vox populi* may have an important role in coping with sustainable development and environmental change. Recent articles such as in the National Geographic of March 2009, "Saving Energy starts at Home" (Miller, 2009), concluding

[1] Regarding "Silent Spring", the consequences of DDT would avoid outbreaks of Malaria

with the final remark of "*what do we have to lose*", clearly shows the possibility of a social, although still unrefined, role of generic society and mass media to intertwine social environmental awareness.

Predictive modelling of future environmental scenarios may help to create a generalized awareness of environmental change stimulating social behaviour in the context of avoiding future endangerment and sensitizing a more adequate behaviour regarding the usage of public transportations, electric appliances, recycling etc., among many other aspects which may easily be incorporated in daily life. Thus, spatial information becomes a major task in the agenda of knowledge diffusion, for which predefined spatial databases may have an important role to create conditions to model environmental spatial change.

The willingness of civil society to absorb knowledge via new Information and Communication Technologies (ICT) is very significant and has increased of almost 11 times to 353.3 million in July 2005 compared to 1998 (Internet System Consortium, 2006) from the internet hosts, it is clear that the last decade has witnessed an unprecedented technology and form of communication, changing the form people communicate and transmit information and how information may have a dynamic role in a context of environmental change. Geo-information allows establishing a relation between spatial data and information dissemination of spatial attributes. Usage of such technologies and development of integrative spatial support systems via internet, have recently allowed the development of so-called cloud computing. Application of cloud computing share a new wealth of technological advances within Geographic Information Systems consolidating opening to a wider range of products and services in which GIS may be directly applied. The application of Geographic Information Systems thus, is of utmost importance for socio-economic sciences from a perspective of understanding and manipulating spatial data as to understand the spatio-temporal dynamics. The creation of scenarios with spatial attributes allows decision makers and society in general to be more aware of global, regional and local problems, and thus integrate more informed solutions to environmental issues.

Chapter 3 – Material and Methods: GIS and Spatial Analysis to Evaluate Environmental Impact Assessments in the Algarve

The region of the Algarve comprises a total area of 4899 km^2 which is 5,5% of continental Portugal (Pena and Cabral, 1997) and is the farthest region to the south of Portugal. Bathed by the Atlantic Ocean to the south and west to the north, a massive mountain range, the *Serra do Caldeirão*, separates the Algarve from the Alentejo. This encapsulated morphology of the region, has had influence on a more temperate microclimate than the rest of Portugal, as well as some vegetation and wildlife particularities which make this area a unique habitat for many different species. From a geomorphologic perspective, the Algarve shows three distinct layers of singular cultural, vegetative and ecological aspects.

The location of the Serra do Caldeirão is circumscribed by a mountain range, and is known as the *Barrocal*, while the region to the south of the *Barrocal* is the *Interior* and the overly populated region is coastal, and known as the Litoral. Inexistence of commutes has avoided the pressure in the Interior and Barrocal and has maintained its unique edaphic and climatic particularities as well as its unique vegetative coverage (Malato-Beliz, 1986), while the coastal region has been affected by a mass tourism industry since the sixties, which has led to an uncontrolled urban sprawl within the coastal zone of the Algarve.

Understanding the dynamics of spatio-temporal change has been a persistent effort for regional and urban planning purposes. Evaluation of socioeconomic effects on the environment has been combined with the consequences of land-use change to propose better strategic tools to cope with change processes.

A relevant initiative in the Algarve has been the implementation of the PROT Algarve (*Plano Regional de Ordenamento do Território do Algarve* transl. Regional Plan for Territorial Management in the Algarve). The PROT Algarve converges within the Municipal Directory Plans part of the framework of the National Policy and Territorial Management Program (*Programa Nacional da Política de Ordenamento do Território* - PNPOT). PNPOT sets a series of guide rules for sustainable development of the Portuguese territory which may be summarized as (PROT Algarve, 2008):

a) Preserve and valorise biodiversity, landscape as well as natural and cultural heritage, as well as sustainable usage of geology and energy resources while hindering and minimizing damage.

b) Reinforce national territorial competitiveness within the Iberian, European, Atlantic and global context.

c) Promote the polycentric development of territories as well as reinforce infrastructures supporting integration and territorial cohesion.

d) Assure territorial equity by providing infrastructures and collective equipment while maintaining universal access to services of generic interest, stimulating social cohesion.

e) Expand information and communication channels as to provide a crescent usage of such services citizens, institutions and stakeholders.

f) Reinforce the quality and efficiency of territorial management by encouraging the informed participation of citizens and institutions.

Supporting the territorial dimension is therefore a key aspect which leads to a more competitive region, sharing impacts at social, economic and natural level. It is the combination of those key aspects that allow the equitable assessment of spatial sustainable development, within a policy framework for Portugal. PROT Algarve (2008) advances with a territorial analysis of these factors for the Algarve. One of the key aspects of the territorial dimension of sustainability, are the physical consequences of land-use change, largely visible over the last decades in the Algarve. Urban growth, has been one of the key characteristics of the region. Under the European umbrella, several spatial data infrastructures and Programmes have been created to evaluate land-use change and urban growth. The INSPIRE initiative, attempts to create a joined effort of "*fully compatible and integrated databases without restrictions on reuse of data, facilitating access to geographic information assets held by a wide range of stakeholders. Widespread implementation of SDIs will bring substantial economic, social and environmental benefits*" (Masser, 2007). Several urban growth models have addressed the issue of land-use change regarding physical territorial sustainability. Most of them, take advantage of non-linear processes, predicting up to a certain level of accuracy the consequences of urban change (Benenson, 2004).

Determination of impact on the regional environment of the coastal Algarve and the interior areas preceding urban growth, land-use change and cultural heritage fragility, is an important step for understanding the dynamics of sustainable development. The information retrieved from the papers, share the urban dimension, touristic dimension and the cultural heritage dimension, which combined report the importance of a dynamic spatial complex system. The conceptualized GIS-based model, calls forth regarding the urban growth propensity to the urban growth models used largely to understand urban sprawl. The combination of CORINE Land Cover bring relevant land-use characteristics and integrate the dynamics of spatio-temporal change for 1990, 2000 and 2006, permitting to advance with an urban growth scenario for 2020. As discussed earlier, within an empirical framework, the spatial georeferenced data allows for a combined inquiry of different factors which express evidence of non-linear scenarios based on the dynamics of overstrained areas and derive additional information concerning the carrying capacity of the environment (Figure 7).

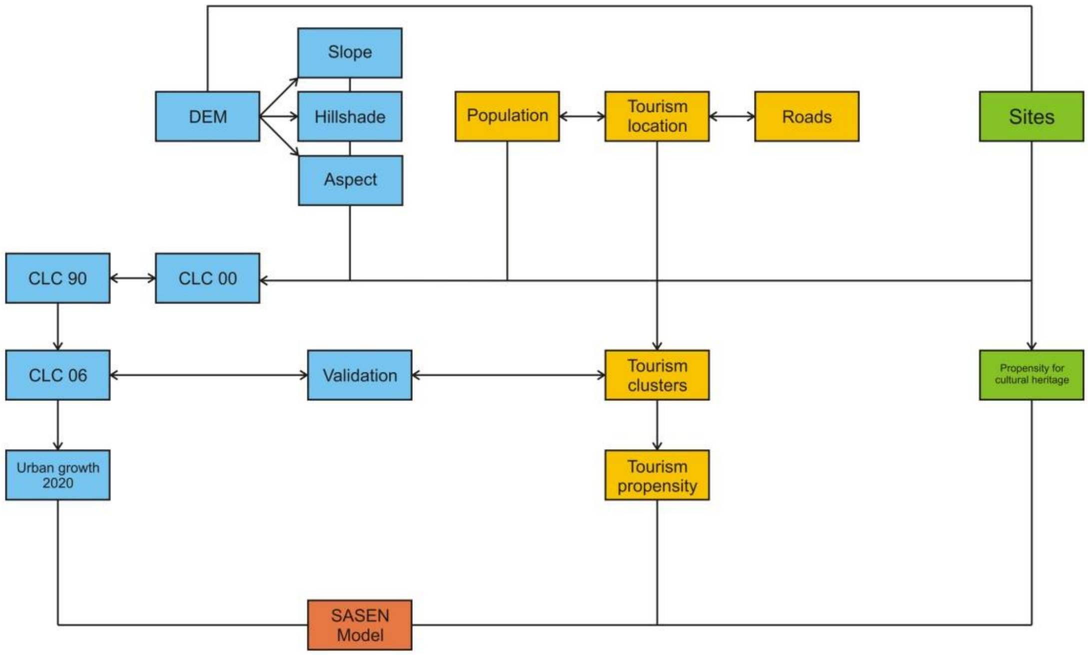


Figure 7 - Methodology

As a first step, a regional database of a Digital Elevation Model (DEM) is used to combine geomorphologic characteristics important to combine for socio-economic dynamics. From this DEM factors such as slope, hill shade and aspect are calculated. Combination of urban weight which is stochastically measured for the different temporal periods, shall allow the generation of a propensity map for urban growth. The calculated propensity runs under a cellular automaton which generated a future outcome of urban growth underlying decision rules of Markovian transition matrixes. Once the information is validated based on the cellular automaton iterations for 2006, a projection for future urban growth is generated for 2020.

Social information on population density, as well as the existence of touristic infrastructures and knowledge of their spatial location, shall approach the relationship of urban propensity within touristic areas, answering the question whether tourism is a driver of urban growth for the Algarve. The answer to this question poses the agenda of resilience for regional decision making, and allows retrieving further crucial information for carrying capacity in the region. This information is also spatially explicit, and will convey into a tourism propensity map which measures with a reliable degree of accuracy due to a jack-knife sampling technique, the relation of tourism infrastructures and urbanity.

Combination of agglomerated propensity data – from the urban propensity map and tourism propensity map alike – will be combined with the conditions driven by the third driver which undertakes the question of heritage protection, defined as a key factor for sustainable development. Those are discussed in the papers in the subsequent chapter, and may be understood as the relationship of urban growth to physical land use change, tourism attractors and cluster analysis of propensity for unsustainable areas and predictive modelling of historico-cultural heritage for sustainable choices. This shall allow an interaction of reciprocal influences among different agents (Legrand, 1991).

Time is a central component that deals exactly with the dynamics of change of the cell in a temporal context. Thus, the models that allow the creation of such cells and the context that allows studying their patterns must be a consequence of the so-called dynamic models, in which the temporal factor represents a crucial factor to allow the study of the dynamic and its motion. Hence, Cellular Automata (CA) are the logical step to combine dynamic models with intuitive agents that relying on a set of variables allow prediction of certain types of behaviours. These types of models have their branches in the areas of computational sciences and find a vast use in many different areas. As they are capable of reflecting quite clearly the behaviour of groups and biological variables, they have extensively been used in the social sciences after all in this circumstances *"computers offer a solution to the problem of incorporating heterogeneous actors and environments, and nonlinear relationships (or effects)."* (Lansing, 2002). Cellular Automata are thus, discrete mathematical models that consist of a grid of cells that allow interaction of variables along the designated system, involving the variable time, representing as a consequence a dynamic system in which patterns of behaviour may be observed. Due to their intrinsic nature (grid based system with specific number of cells) they are quite adaptable to a Geographical Information System (GIS) environment, given the necessary software and programming experience or attachable models, one can adapt CA easily to the context of a GIS and do predictive multi-temporal dynamics of change on a spatial basis.

To allow the interaction of a Cellular Automata, a few logical presuppositions are necessary. Those presuppositions are basically the programmers or the user's premises which define the behaviour of the Cellular Automata. In a GIS context, the set of premises that define specific rules may very well be the following:

- External Factors: Land Use, Elevation, Slope etc.
- Internal Factors: Number of Iterations possible for CA

- Distance Factors: Existing distance between CA and Objects (Tobler's Law)

It is in the interaction between external, internal and distance factors that the CA defines a set of logic rules (e.g. should slope be higher than x, urban construction is not feasible) and complexity of those rules that lies the capacities of predictive powers of the CA. In other words, though more rules define logical behaviours of the automata and though more data is made available, the better the CA is calibrated to reach accuracy in its predicted power.

The spatial relation between cellular automata, rules and interaction is defined in a common system of matrix value: That is for instance, a given spatial location is converted into a grid in which each cell represent a specific aggregate with a common size and unique weight. The result is a so-called raster, which mathematically can be understood as a raster. Having understood this, we may consider that a CA is a cell within the spatial grid which interacts among the values we have defined (in our set of established rules) optimal for action. Thus, a CA generates random behaviours based on the set of rules and number of iterations allowing the observer to assess a predicted model. The necessity to calibrate the model to understand the accuracy of spatial models using CA is an inherent feature: The automaton is calibrated based on a known moment and alternative rules are defined on a surface (e.g. suitability map) to assemble the dynamics of its interactions.

Figure 8, shows an example of rules set in cellular automata of aggregation and non-aggregation. This is a simple example, and it should be clear that rules are much more complex then shown. A simple Cellular Automata is behaving in function of its proximity. The rule defined is trivial: Should distance between the blue cells be less than 6 (that is, should less than 6 cells separate from the two blue cells), the cells transform aggregate into a single cell. On the other hand, should distance be greater than 6 cells, cells disperse from each other. This fundamental relation shows some contiguity in Tobler's law of distance and proximity which for spatial analysis is of extreme importance and is recurrently used in cellular automata.

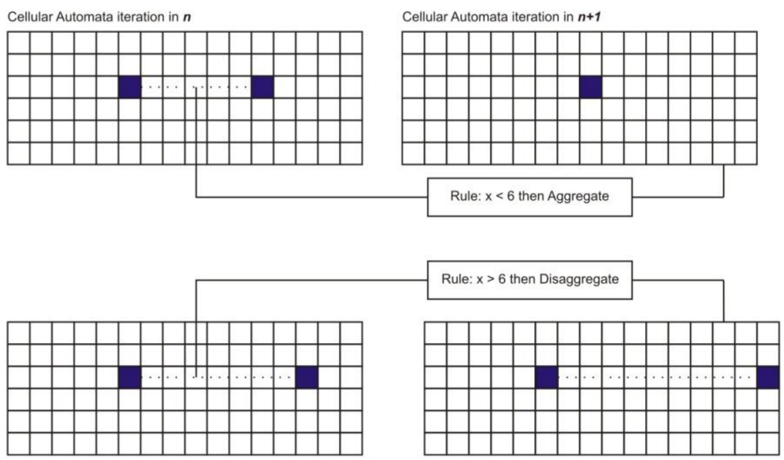


Figure 8 - Example of CA rules and projection in n+1

One can conclude, that CA are based on a set of principle rules which allow the analysis of complexity. In this context, although the sense of complexity is difficult to grasp philosophically, we will try to understand complexity as the result of an enough large amount of rules that define a transition of behaviours. That is, a system is defined as complex, if enough interactions take place leading to the possibility of different and not as obvious results. Also, predictability is a result of a linear equation with fundamental sets of rules that may be clearly assessed and help us shed some light on future spatial behaviours.

Though true this may be, we have to understand the following clearly: A system, as linear complex as it is, is not accurate due to its intrinsic nature. Unpredictability therefore is a constant that *complicates* the fusion of future cognition in predictive modelling approaches. This limitation is avoided elegantly by assuming that the model has a probabilistic contiguity of occurrence. Probability of occurrences assumes therefore a given error margin, and as a result, forecasting of future scenarios is support options of within an expert panel, or such as of Multi-Criteria Evaluation or even using different hypothesis.

It is through the convergence of creating scientific hypothesis that combine information accurately, that we may reduce uncertainty and lower complexity. The intellectual property of such venture, asserts in a synergy among exact and human sciences, as information and knowledge can only be relevant if considered as a whole and not as a sum of its different parts (co-constructivism). In an attempt to fortify the role of scenarios within environmental change, the European Environmental Agency (EEA) developed a causal framework called Driving Forces-Pressures-States-Impacts-Responses (DPSIR). Originating from a Pressure-State-Response framework proposed by the OECD, the DPSIR permits the intervention of different key players while regulating and responding to the demands of articulated planning. Intervention of different key players at regional level allows the gathering of a vast amount of multi-level information which becomes spatially relevant, allowing the composition of such information to composite indexes through computational procedures (Salvatti and Zitti, 2008).

From Omann et al. (2009) the following definitions are considered:

1. Driving forces are changes in the social, economic and institutional systems (and/or their relationships) which are triggering, directly and indirectly, Pressures on biodiversity. Pressures are consequences of human activities (i.e. release of chemicals, physical and biological agents, climate change, extraction and use of resources, patterns of land use, and creation of invasion corridors) which have the potential to cause or contribute to adverse effects (impacts).

2. The state of biodiversity is the quantity of biological features (measured within species, between species and between ecosystems), of physical and chemical features of ecosystems, and/or of environmental functions, vulnerable to (a) pressure(s), in a certain area.

3. Impacts are changes in the environmental functions, affecting (negatively) the social, economic and environmental dimensions, and which are caused by changes in the State of the biodiversity.

4. A response is a policy action, initiated by institutions or groups (politicians, managers, consensus groups) which is directly or indirectly triggered by [the societal perception of] Impacts and which attempts to prevent, eliminate, compensate, reduce or adapt to them and their consequences.

A causal pathway is established based on the previous definitions for Land degradation (pressure) and alternative scenarios (Figure 9). Originating from driving forces the impacts given alternative scenarios regarding socio-economic calibration of indicators is demonstrated.

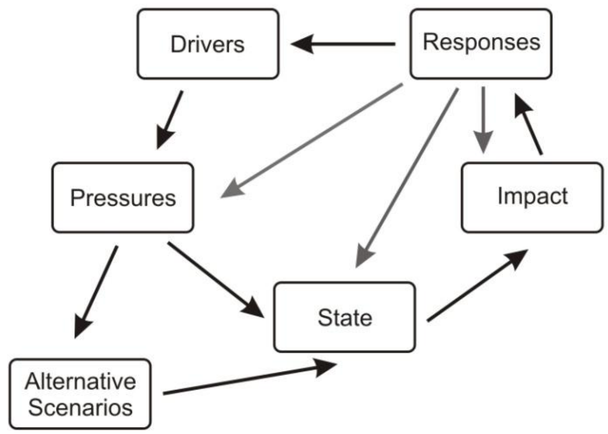


Figure 9 - Simplified DPSIR framework with alternative scenarios

Land degradation is dynamic and reflected on the role of natural, economic and social variables, as discussed earlier. The consequences of land degradation are established by the intervention of initial drivers (Driving Forces related to political economy) which are essential to welfare and may hinder sustainable development (Blaikie and Jeanerenaud, 1997) and representing loss of biological and economic productivity (Brandt et al., 2003). Therefore, policy choices must be taken in account carefully, as not to affect negatively climate change, agricultural development, and increase of population.

Chapter 4 - A Multi-Scenario Forecast of Urban Change: A Study on Urban Growth in the Algarve

4. 1 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 has also been accompanied by a significant abandonment of rural areas and hinterlands, leading to loss of agriculture and other rural activities. Clearly, urban growth needs considerable attention in the context of sustainable development, as often peri-urban areas with fragile ecosystems are becoming increasingly vulnerable. This paper aims to develop and apply key tools to quantify the changes of land use and how this affects the regional spatial scope by using multi-temporal inventorying and accounting of land-use change matrices. The paper makes a dynamic assessment of urban growth in the Algarve based on non-linear complex system modelling by using Cellular Automata. The ancillary data of the CORINE Land Cover (CLC) project, which covers a temporal frame of over 15 years (from 1990 to 2006) will be used to test a novel multi-scenario approach for urban change in the region.

The spatial analysis does not only employ conventional quantitative methodologies, but also covers important qualitative evaluation processes by the assembly of story-lines which articulate traditional scenario approaches. However, the design of story-lines is intrinsically subjective and qualitative, and has to deal with the problem of accuracy in quantifying the results. 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 specific socio-economic paths: the first scenario envisages a maximization of urban growth in the area, brought by a prosperous economy and the continuing development of mass tourism. The second scenario is based on the actual indicators of the region in terms of socio-economic activity while, the third scenario shows a tendency of rising rural activity and addresses the disparities between rural areas and the fringe of the coastal regions.

In order to validate each scenario, a story-line, based on different proportions of economic, socio-economic and natural variables, is used to map out a possibility for urban growth in the Algarve, and suggests the possible likelihood of land-use change for the region, in a pathway that integrates public policies designed to achieve a more sustainable future. 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.

4. 2. 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 per cent. Europe's multi-cultural and liberal policies have directly contributed to the expansion of the EU, 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 and 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. The actions that are chiefly taken into account are related to: challenging the distribution of the structural cohesion funds and investments between urban and rural areas; delegating of funds within structural fund operational programmes; regulations of EU laws on air quality, waste-water treatment, waste management, water supply and environmental noise; and co-financing 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 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 on-going 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 quality.

Urban growth models have proved 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) 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 (White and Engelen, 2000; Sawaya et al., 2003; Picón-Feliciano, 2009), 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 artificial terrains 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.

4.3. The Algarve Region

The most southern part of Portugal is the Algarve. With a very heterogeneous geography (Drain, 1989), the region has a cultural legacy that goes back to pre-Roman civilizations (Gamito, 1997). Over the last few years, the Portuguese tourist sector has increased to a 9.2 per cent share of GDP. As pointed out by Correia and Crouch (2004), the Algarve is Portugal's prime destination for tourism, mainly due to its beaches and climate, and accounts for 42% per cent of Portugal's tourist activity.

The rapid increase of the tourism sector in the mid-1960s led to urban growth and the creation of supporting infrastructures, generating high revenues and economic growth for the region and resulting in 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 that, before the 1990s, the distinction between growth and development was quite unclear. Growth was envisioned as a unique driver for economic prosperity. Economic growth however, is far from being sustainable and one of the main consequences of this economic anthropocentric growth perspective has been the depletion of available resources. This has led to constant pressure on the environment and resulted in environmental changes that may be measured in terms of several dimensions of which the human impact represents the main driver, resulting from factors related to acceleration of the information society, population and urban growth, the human impact on the carrying capacity of the environment, and the globalization of environmental deficiencies. (Camhis, 2006).

In the case of the Algarve, the land-use change has been drastic, and the consequences for 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, designated as a Natural Park because of its important ecological value, given the diversity of indigenous species which exist in the region. This area supports many different services which benefit the regional economy, such as aquaculture, salt production and tourism. The degradation of this lagoon, as analysed by Nobre (2009), is a serious sign of the environmental degradation of the region, and of the antagonistic impacts of human behaviour on ecosystems.

The symbiotic effect of ecosystems in coastal zones is especially relevant because of the high economic value generated by leisure services available within those areas (Costanza et al., 1997). According to Boissonnas and others (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 combination of artificial land use, population change, and peri-urban growth) provides important information to preserve and manage such habitats. Urban pressure in the region has been shown to be an important factor for the increasing pressures on the shores of the wetlands and its surroundings. Human impact seems to be the main driver for the loss of biodiversity, leading to eutrophication of the fragile ecological habitat of the Ria Formosa (Newton et al., 2003).

4.4. 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 and 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.

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. When comparing urban areas in CLC 1990 and 2006, it can be seen that the class of urban land use has become double the size from CLC 1990. This growth is especially noticeable in the surroundings of the major cities of the Algarve, such as Portimão, Albufeira and Faro. In contrast, 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 per cent of agricultural land-use in CLC 1990 to 41.10 per cent in CLC 2000 and reaching to 40.06 per cent in CLC 2006 has been registered. The agricultural land loss has been accompanied by an increase in forest areas, which are the prevailing land use on areas of agricultural loss as an indication of rural and agricultural abandonment. Forest has increased from 50.22 per cent to 52.33 per cent in CLC 2006. 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 with a total of 64 items per level. The first level, includes the major categories: Artificial surfaces (urban); Agricultural areas; Forests and semi-natural areas; Wetlands and Water bodies. Figure 10 shows the change which has occurred over the period 1986-2000 of the CLC project. In comparison wetlands and water bodies remained somewhat constant with some increase of 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 in the coastal zones. Urban growth showed the most dramatic changes over the period 1990 to 2006. The initial 1.94 per cent of urban areas from the CORINE Land Cover (CLC) 1990 period (1986-1990), doubles to 3.95 per cent in CLC 2006. This urban sprawl is observed mainly in the peri-urban regions of the Algarve, especially in the vicinity of coastal tourist areas where services are more abundant (Portimão, Albufeira and Faro).

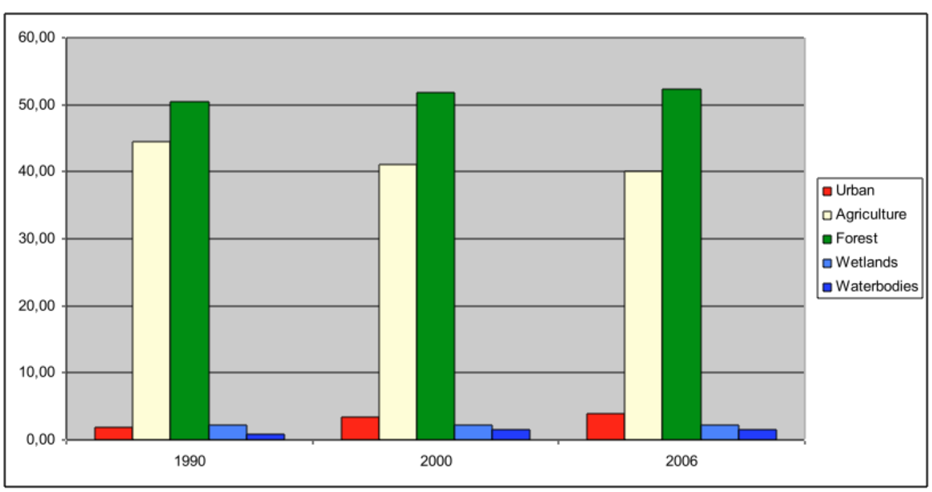


Figure 10– CORINE Land Cover Classes in CLC 1990. CLC 2000 and CLC 2006

A closer analysis of the urban fabric in the region enabled us to assess the types of artificial land use that were constructed within the study period. During this period there was a marked tendency for building infrastructures. Previously unregistered road and rail networks were built (a variation of 1.55 per cent within study periods) as well as sports and leisure facilities (1.181%, increase primarily due to the Euro 2004 football championship). These infrastructures are closely linked to Euro 2004, which stimulated a total investment of 30,351,354 € in the region. However, as pointed out by Perna 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-fulfilment 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". The generation of infrastructures to support Euro 2004 has been felt at a spatial level, and these construction sites have contributed to the on-going loss of possible agricultural arable land.

4.5. Multi-scenario Modelling of the Algarve

Our approach is based on recent advances in geo-science modelling. 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 have a scale of propensity for the existence of built-up environments, and are relevant tools to assess the dynamics of land-use change over a given period. As indicated in a foresight analysis by Pontius and Schneider (2001), the drivers are a subset of factors and constraints, calculated for the area of study and which when combined enable the visualization of urban change in time. However, the combination of variables to measure change dynamics is dependent on the drivers at the regional level, which justifies the importance of multi-criteria approaches to the stochastic analysis of urban change scenarios. Our calculation of a Multi-criteria Evaluation (MCE) suitability index relies on the physical, socio-economic, and regional characteristics, which are prioritized by means of an Analytical Hierarchy Process (AHP) (see Saaty, 1990) which led to the design of three scenarios with different pairwise quantification. The main advantage of AHP is related to the structural conceptualization of decision making, in which several values in a range of different scales may be compared. This comparison generates quantifiable priorities attached to different variables. It is therefore, a qualitative structural decision process that, rather than quantifying just one best decision, aggregates a range of different values balanced for decision making in a proper space-time context.

Next, a Markov transition matrix from the land-use inventories in our information system allows the spatial assessment of the proposed scenarios. One of the main advantages of this methodology is the capability to combine qualitative assessments from multi-scenarios with quantifiable spatial analyses. This permits us to calculate a propensity for urban growth embedded within a Multi-criteria Evaluation (MCE) framework on the basis of forecasting economic, social and physical variables. Figure 11 below summarizes the methodological approach of the AHP / Multi-scenario / Markov transition process to represent the spatial dynamics of land-use by designing models which can predict the propensity for urban development.

The three distinct scenarios may be conceptualized as follows:

(i) Ecological Interest:

- Responsible planning and self-sufficiency through the development of agricultural activities in the interior area the Algarve;

- Greater development of rural sectors of economic activity for traditional production and with specialized market strategies;

- Road networks are of some importance, but public transport should play a central role.

- Coastal proximity is less significant, and should be avoided whenever possible, so as not to overburden the already endangered coastal regions.

(ii) Business as Usual:

- Continuing development of the tourist 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;

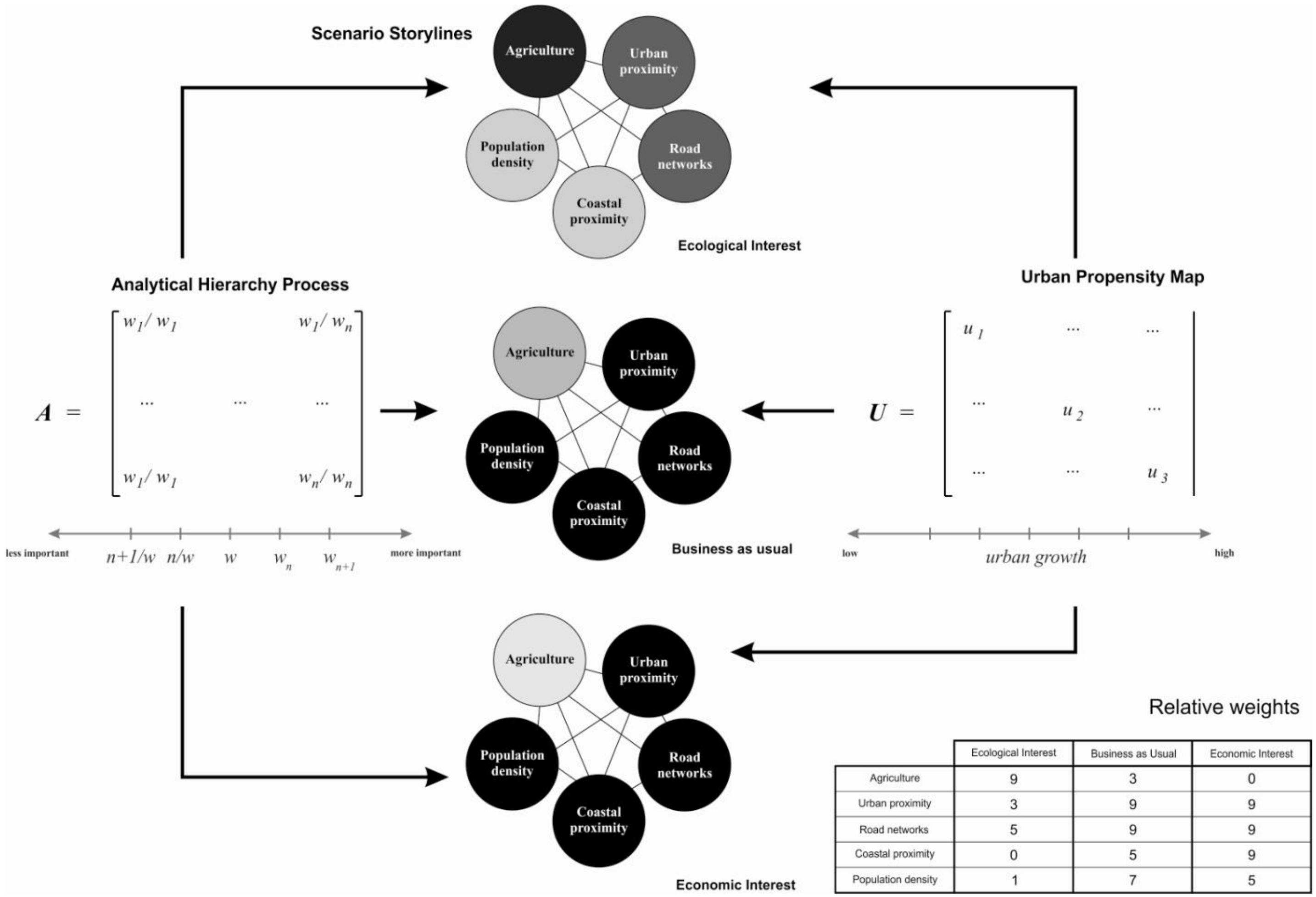
- Increasing population density plays a significant role in the main cities of the regions such as Faro, Portimão, Loulé and Albufeira;

(iii) Economic Interest:

- Maximization of traditional economic growth through the creation of more infrastructures to support the mass-tourism industry;

- Continuing urban growth in urban perimeters, especially within areas with a high population density while generating more revenues in order to allow the service sectors to prosper;

As projected in Figure 11, the elements of the story-lines of each scenario of urban growth 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) represents the weighting used for each scenario (i, ii, iii). The size of those circles is compared within each of the scenarios, and this forms the basis of the table of the relative weights of the qualitative criteria, located in the bottom right-hand corner of the Figure. The propensity for urban growth is calculated by means of the weights assigned to each value in each scenario. Eventually, this results later in the possibility to discern a Markov transition rule for the geography of urban sprawl. This framework model will for multiple scenario foresight analysis will now be applied to the Algarve region.



	Ecological Interest	Business as Usual	Economic Interest
Agriculture	9	3	0
Urban proximity	3	9	9
Road networks	5	9	9
Coastal proximity	0	5	9
Population density	1	7	5

Figure 11– Methodological conceptualization of integrated Multi-scenario Modelling approach

4.6. Projecting and Comparing Urban Growth in the Algarve – From 2006 to 2020

The combination of the different subset of drivers enabled us to produce a series of maps showing the future urban growth sensitivity for the Algarve. The proportion of each colour (red and yellow and green) was controlled by a saturation of values ranging from 0-255. So, if maximum propensity should be found, saturated colour is maximized in red (255), while yellow and green are discarded. Middle ranged values of the distribution show a higher saturation of green, while low range saturation, that is, lowest propensity for urban development are saturated in the spectre of green. The resulting propensity for highest occurrence was established by creating a relative percentage of the 0-255 scale. The regions with highest values for urban growth (that is, with more saturation in red) were found in the Economic Interest and Business as Usual scenarios (Figure 12a, b). This corresponds to the propensity resulting from the integration of the Analytical Hierarchy Process (AHP) with the weights for each story-line.

The more rural oriented scenario (Figure 12a) shows no increase of urban areas on the fringe of the coastal regions. Also, for this particular scenario, the propensity score indicates a maximum likelihood of 54 out of 255 of transforming into urban, less than one fifth of the maximum registered in the Economic Interest scenario. A calculation of those sites was assessed on the resulting AHP combined with a probability indicator of higher propensity than 50 per cent. As expected, the Ecological Interest scenario output did not register any municipalities with a high propensity for further urban development. This may be interpreted as the shift to a more eco-balanced activity allowing using existing resources to be used, without overburdening the carrying capacity. Also, as areas become used for agricultural activity, the intensity of pressure on the carrying capacity of the coastal regions becomes less. While the Economic Interest scenario shows a higher growth in similar parishes as in the Business as Usual scenario, more urban sprawl is registered. Finally, the Business as usual scenario shows the most extension of construction. These extensions of construction are the result of urban sprawl, rather than urban growth, resulting from mixed policies that do not have a significant focus on decisional objectives and a lack of the use of agglomeration economies. These comparative results suggest that the Business as Usual scenario is the least efficient, in terms of both ecological impacts and socio-economic effects. On the one hand, the agglomeration of cities shows that the city, as a locus where cumulative learning may exist, allows knowledge spill overs and learning spaces (Capello and Nijkamp, 2004) which may be less endangering to the realisation of a sustainable environment.

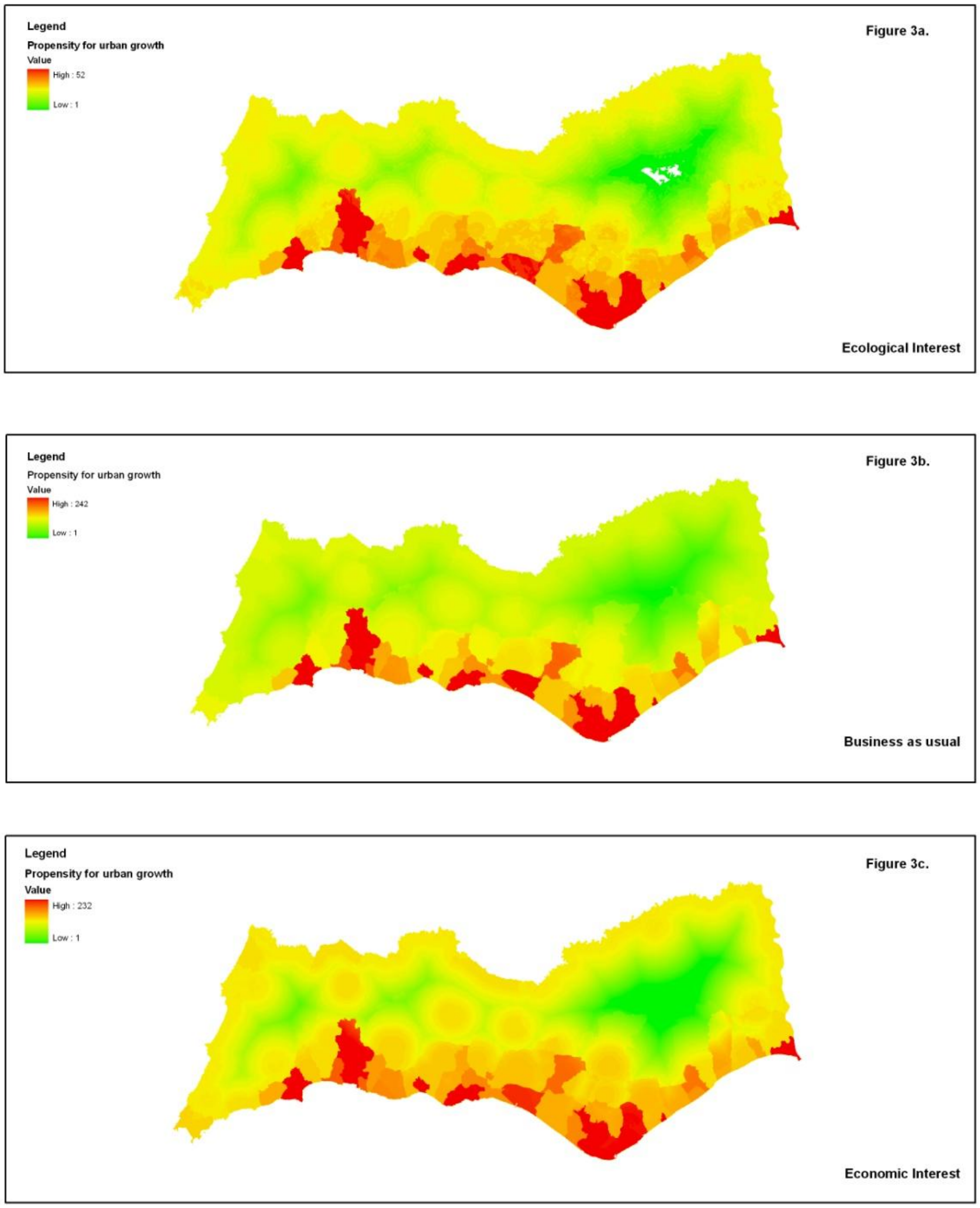


Figure 12– Comparative urban sensitivity of multi-scenarios

On the other hand, the Ecological Interest scenario demonstrates the possibility of stimulating agricultural efficiency which would limit urban growth, as rural activities do not rely on the construction of so many infrastructures. However, this model is less probable, as it calls for a much too radical shift of the economy-centred 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 they affect much more volatile territory than either of the other scenarios.

4.7. Cellular Automata for Urban Growth Forecasting

Based on the CORINE Land Cover (CLC) and the information on its main classes, a transition matrix was compiled, using Markov transition probabilities. Such a matrix indicates the likelihood of changes from one state to another. This is very suitable for land-use change analysis, especially when combined with cellular automata iteration rules, which allow the transition probabilities to become spatially explicit (Barredo et al. 2003). 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).

Table 2 – Transition Matrix of Markov Chains from CLC00 based on CLC90

		Probability of changing to:				
		Urban	Agriculture	Forest	Wetlands	Water bodies
Land class	Urban	0.83	0.06	0.07	0.03	0.01
	Agriculture	0.07	0.77	0.15	0.00	0.01
	Forest	0.04	0.11	0.83	0.00	0.01
	Wetlands	0.03	0.01	0.10	0.84	0.02
	Water bodies	0.03	0.01	0.09	0.05	0.82

A couple of interesting points are apparent from the stochastic comparison of probability transition: (i) the class of most occurring change is expected to be the transition from agricultural to urban land use; (ii) forest areas register the highest probability of changing into agricultural land; and finally (iii) a relationship exists between the possible evolution of wetlands to areas anticipated to be coniferous forests.

The previous relations reveal the ecological transitions of the ecosystem of the Algarve quite well: Agricultural abandonment is leading to an increase of forest areas, while these areas are then more likely to be used for urban growth, due to their physical and geographical characteristics. The wetlands in the Algarve are mostly found in the coastal perimeters, which are known to be areas of enormous environmental pressure. We experimented with a number of methodological refinements: the figure below represents the approach for validating and projecting land-use change within the multi-scenario approach (Figure 13).

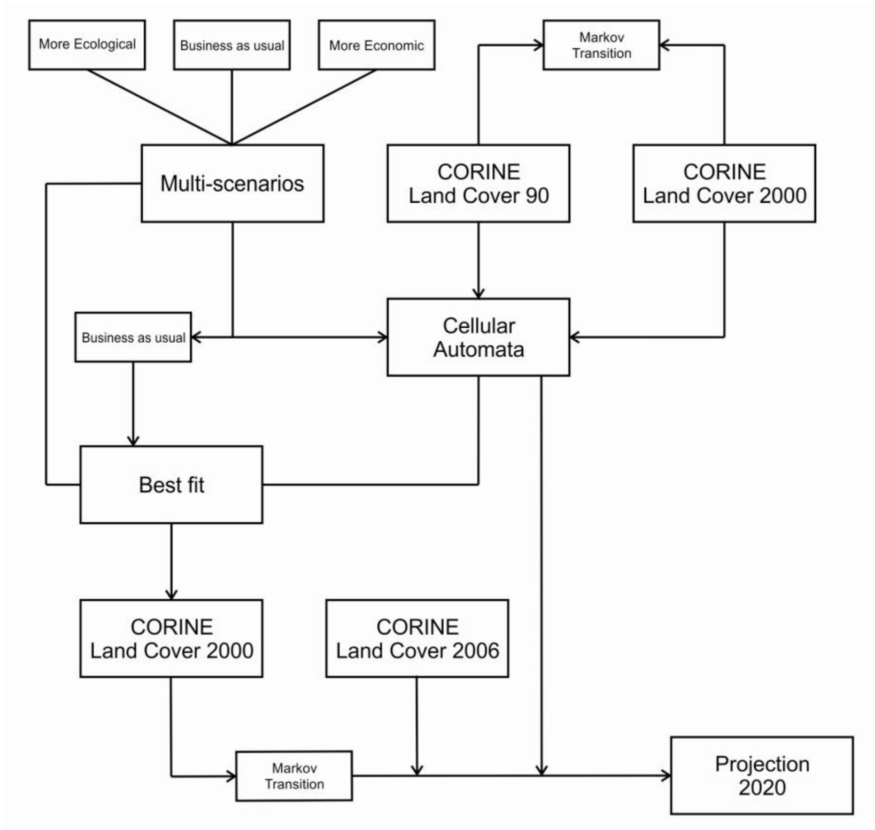


Figure 13- Diagram of validation and projection

The first steps involved connecting the different scenarios with the base land covers from CLC 1990 and CLC 2000. The calculated values of Markov transition chains from the five different classes (Urban areas, Agriculture, Forest, Wetlands and Water bodies) were assessed by means of a Cellular Automata algorithm which represents the spatial properties of the Markov transition matrices.

The three generated outcomes are compared with the base data set 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 scenario is the most likely scenario as it shows the clearest similarity to the CORINE Land Cover 2006. Two conclusions can be drawn from this comparison: Our Cellular Automata approach allowed a stable analysis of the real transformation of land use, suggesting that Markov propensities related to Cellular Automata approaches have interesting capabilities for land use change analysis. Furthermore, the comparison of the results from land changes in the other scenarios, lead to important results on the differentiation of strategies for policymakers regarding the choice of different strategies.

The most deviant results were found in the Ecological Interest model, which did not envision the trend of urban growth which has occurred up to 2006. The best-fit analysis involves the comparison of each class of each calculated scenario in its amplitude of change value related to the CLC 2006 projection:

$$x = \quad s_a - l_n \cong 0,$$

where x is the best fit of the amplitude of propensity for urban change most similar to the original land-cover class; and s_a corresponds to the scenario and each representing class and l_n 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:

Table 2 – Results from the best-fit analysis

	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

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 2006 land cover, with CLC 1990 and CLC 2000 as reference.

4.8. Conclusions

The iterations of the cellular automata related to similar Markov transition rules, enabled us to generate the future urban growth scenario for the year 2020 (Figure 14). While urban growth seems to be increasing along all the coastal regions of the Algarve, the region between Albufeira, Portimão and Faro, Olhão is of most concern. Similarly, former agricultural land is being converted into urban areas around Portimão.

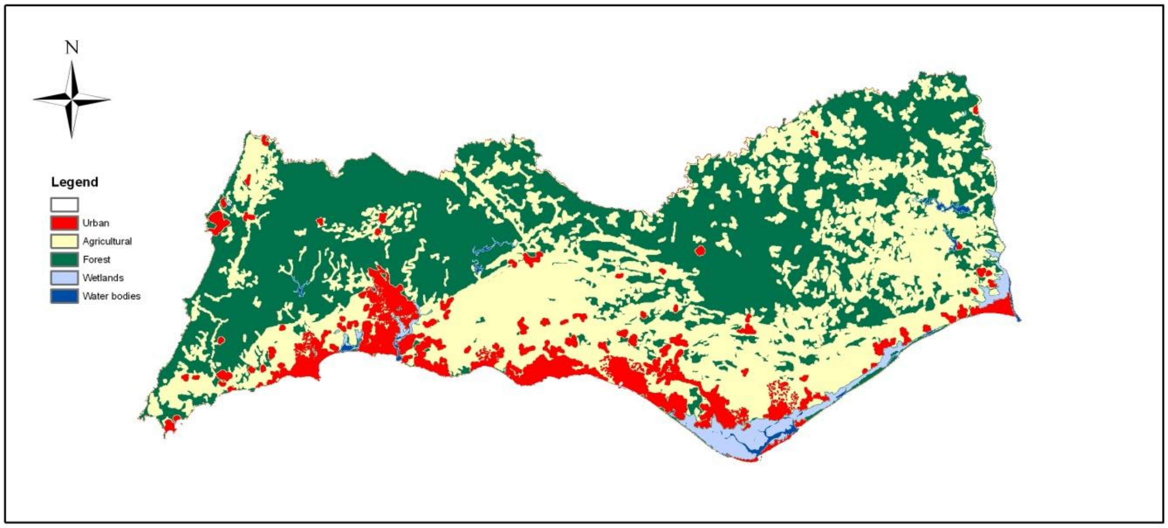


Figure 14– Urban growth projection for 2020

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 the coastal areas. The analysis of the central region of the Algarve between Faro and Portimão shows that the existing road networks play an important role in urban growth. Also, an agglomeration of artificial land use is visible in the coming years, especially in and around the district capital of Faro and in the vicinity of different parishes which during the 1990s did not report significant urban growth tendencies. Another concern is noticeable in the form of rural abandonment, witnessed by an unprecedented increase of coniferous forest areas, and accompanied by loss of agricultural sectors. The divergence between the urban scene and rural regions is becoming more accentuated over time, showing lack of integration of policies designed to achieve sustainable development in the coming years.

The results for the Algarve suggest that the region should focus on the diversification of sectors of economic 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 the creation of infrastructures wisely, especially regarding their distribution, so as not to overburden the carrying capacity of the natural environment, caused mainly by urban sprawl and rural abandonment.

This paper has proposed a new methodology, which combines different tools for the spatial analysis of future urban land-use scenarios. The use of Cellular Automata within qualitative modelling approaches produced novel results for scenario modelling of alternatives for future urban design trends. The handling of such scenario-modelling approaches may involve a broad range of land-use analysis and strongly suggests future areas of study. The novelty of this methodology is that it produces very interesting results regarding the gap between qualitative analysis and quantitative outputs, especially when related to spatial decision-making support systems, in which combined methodologies may have a leading role in better decision-making.

Chapter 5 - Crossroads of Tourism – Thoughts on Complex Systems and Spatial Analysis Within a Framework of Urban Sprawl in the Algarve

5.1. Abstract

In recent decades, Europe has experiences an unprecedented urban growth affecting fragile ecosystems and natural habitats. Urban development in coastal zones, combined with city expansion, has led to irreversible adverse consequences for land use and to environmental degradation. The delicate balance between stability in urban areas and biodiversity, in both urban and rural areas, relates in essence to sustainability and economic development. This economic development in southern Europe is especially affected by service industries such as tourism. Preventing land-use degradation and environmental change is of the utmost importance for land-use management. This is particularly necessary in coastal zones, where contributing factors of a human (e.g. land-use change, pollution) or natural (e.g. erosion, changes in sea level) kind require important strategies to be designed for regional and urban planning. As the basic objective of sustainability and coastal management is the transmission of environmental assets to future generations, it is imperative to take into consideration the dimension of urban change and its impacts on the landscape in relation to socio-economic driving forces. The application of the spatial realities of land use within temporal dynamics allows the ex-ante assessment of spatial planning policies. Such impact assessments have become important tools for the supervision of decision making within land-use dynamics. The combination of economic, social, and natural consequences questions the application of complex systems theory within spatio-temporal dynamics in supporting regional decision making. In this context, Geographic Information Systems (GIS), combined with

spatial data inventories, can provide a more accurate representation of the dynamics of urban change as within land-use dynamics as part of complex systems. This paper proposes an analysis of the impact of tourism as an attractor of urban growth, leading to the loss of rural agricultural land use. By using spatial data inventories retrieved from the CORINE Land Cover Project in 1990, 2000 and 2006, this paper analyses urban sprawl tendencies associated with coastal tourist attractors. Mass tourism is defined in terms of weak and strong sustainability, depending on the distance of urban sprawl to tourist points of interest. While the ecological objective is to recognize the importance of balancing urban and rural choices within spatially sustainable land use, from an economic perspective, the lack of equilibrium in urban tourist choices underlines the need for better management of the service sectors in coastal regions.

5.2. Complexity and Urban Growth: a Reflection

'Complexity' has become a buzz word as an alternative way of looking at and researching contemporary environmental issues, especially where social and ecological processes are simultaneously at work (see, e.g., Newman, 2005; Reggiani and Nijkamp, 2009). This terminology has been used alongside other vocabularies such as study, research, science, and theory (e.g. Ruth and Coelho, 2007; Baynes, 2009). The concept of complexity is, however, still evolving, and no consensus has yet been achieved regarding its definition. That said, in general, complexity examines phenomena of concern in the context of evolving, multi-agent and non-linear dynamic systems. Nevertheless, the notion of complexity in this sense should not simply be regarded as meaning `complicated´ (Cilliers, 2005; Stewart, 2002). Cilliers (2005) further warns that complexity theory is far from prescriptive in terms of the specific methods that can be used to study complex systems; instead it offers a useful framework to approach the phenomena of interest from a more holistic perspective. It is noteworthy that the foundations of complexity theory in the social sciences were already laid by Nobel laureate Herbert Simon in 1958.

Complex systems constitute heterogeneous agents linked with one to another and with the environment where they are situated by various interdependent relationships and interactions (Taylor, 2005). Such interdependencies are dynamic in nature both spatially and temporally, underlie non-linear processes and mechanisms with feedback loops shaping the systems, and collectively result in identifiable patterns at the macro- or aggregate level (Taylor, 2005; Newman 2005). The resulting observable patterns are contingent on the historical trajectory of the systems and do not readily lend themselves to conventional predictive techniques (Berkes et al., 2003; Axelrod and Cohen, 2000).

Both the social and biological components of the systems, together with the interdependencies and processes driving these systems, are embedded in "hierarchical, nested structures" (Parker et al., 2003). Consequently, each individual agent or component contributes to the whole dynamics of the systems and is affected by others at different spatial scales (Parker et al., 2003). In fact, one of the most important characteristics of complex systems, in addition to their capacity to self-organize, is that the outcome patterns surfacing at the aggregate level do not simply mirror the elements of the systems added together, a characteristic known as "emergent properties of complex systems" (Baynes, 2009). Since interactions between the diverse components are so important, complex systems cannot therefore simply be decomposed into their constituent components and associated behaviour, each to be examined in isolation (Urry, 2005). In short, complex systems are distinguishable from others, in that these systems are characterized by several critical features, including non-linearity, uncertainty, emergence, multiple scales, and self-organization (Anderson, 1972; Bertalanffy, 1950; Berkes et al., 2003).

The directions towards which complex systems are heading are determined by how strong the dynamic relationships are that exist between the components (agents and environment) that make up the systems. It is important to note that complex systems may entail not a single equilibrium but often multiple equilibria. Stable or equilibrium states are likely to emerge from strong relationships, temporarily changing but with persistent patterns of organization, and are normally associated with systems that have moderate relationships. At the other end of the continuum, systems that have weak relationships tend to be vulnerable to disruption and, in turn, the effects are not easily observable (Parker et al., 2003).

Given the nature of complex systems, it has been increasingly advocated that conventional analytical and statistical methods alone will not suffice to investigate such systems (Parker et al., 2003; Baynes, 2009). Alternative tools are becoming available which have the capacity to explore the processes underlying the complex systems under examination and to identify patterns resulting from such processes. In other words, these are tools that can be used to both understand the non-linear behaviours of complex systems and the observable patterns that emerge from such behaviours. The ability of the tools to capture both spatial and temporal complexities thus becomes imperative. Increasingly fashionable are those tools that can be used not only to reconstruct past phenomena and to understand the present situation but also to explore future spatial possibilities. The latter, in the presence of many risks and uncertainties inherent in almost all complex systems, arguably has a unique place in both academic and applied arenas. Promising alternative tools include, among others, network analysis, system dynamics, cellular automata modelling, agent-based modelling, and multi-agent system modelling (Baynes, 2009). The last three approaches are gaining increasing acceptance and popularity among researchers dealing with complex systems that involve both social (human) and ecological interactions because of the capacity of the tools to capture human decision rules and to represent the interactions and the resulting phenomena in spatially explicit ways at various temporal scales (see also van Leeuwen et al. 2007).

Reflecting on the brief discussion on complexity and complex systems above, urban growth can be viewed as both a process and the resulting patterns of complex systems. Various characteristics of complex systems are self-evident when one closely examines the phenomenon of urban growth (see also Batty, 2007). To begin with, urban growth involves heterogeneous agents (policy makers, business players, residents – to name a few) that are interdependent, and whose dynamic interactions over time at multiple scales make what a given urban area looks like today. An array of factors influence and shape urban growth ranging from biophysical constraints, existing infrastructures, technological advancement to the conflicting social, economic, and political interests of different agents (stakeholders). As these three elements continuously change (especially human aspiration), managing these in the long run may become problematic, and complexity theory has something to offer (Ruth and Coelho, 2007). As Zahra and Ryan (2007) put it, complexity theory offers "a language" that can be used not only to examine the components but also any changes involved. In similar vein, by embracing complexity theory it is possible to even link the notions of both space and place in geographical studies (Portugali, 2006). On the other hand, a growing body of insights from urban studies has further refined complexity theory (Reggiani and Nijkamp, 2009; Wilson, 2006).

Micro-level interactions between the heterogeneous agents and with the environment result in patterns of expanding urban areas following particular rules – in this paper, for example, these rules are linked with the presence of focal points of tourism attraction and the associated infrastructures. By carefully exploring processes that underpin urban growth, it is possible to generate insights into what forces drive urban growth from the past to the present, and into the likelihood of future trends by using spatially-explicit cellular-automata-based models (see, e.g., Silva and Clarke, 2005). The aim of this paper is to illustrate the importance of complexity concepts by presenting the findings from a spatial dynamics exploration of the impact of tourism in the Algarve in Portugal as an empirical case.

5.3. The Algarve Region – From Past to Present

The southern region of Portugal, known as the Algarve, shares unrivalled geographical and topological characteristics, recognized since pre-Roman civilizations (Gamito, 1997). Since Antiquity, the Algarve has been a trading route to the Mediterranean and Northern Africa, enabling a diversity of cultures to develop within the region (Strabo, 2007).

With an advanced cultural Neolithic presence (Nocete et al., 2005), as well as the existence of several Bronze Age settlements, the Algarve has aroused interest from archaeologists from the beginning of the XIX century onwards. One of these was Estácio da Veiga who very actively reported a huge amount of findings which were the basis of an important regional archaeological volume called "Antiguidades Monumentaes do Algarve" (Veiga, 2005).

The Roman period in the Algarve is quite well documented and even today is represented by certain Roman villas and sites, as well as by the many *cetarias* (fish-salting tanks) abundant in most of the coastal areas. Roman Algarve, in fact, still continues to intrigue archaeologists who are attempting to better understand the importance of the Algarve in the context of the former area of Lusitania, which prospered greatly at the time of Augustus until the end of Antiquity.

Known Roman cities such as Ossonoba, Baetica and Balsa, as well as the ruins of Milreu, show a very high level of cultural and social development, most probably directly related to the economic prosperity of those times, which is also observable in the richness of the Roman mosaics that are abundant in this area.

Nowadays, diverse tourist attractions are at the heart of the historico-cultural and natural narrative of the region where urban sustainability must be considered (Vaz and Nijkamp, 2009). The Algarve is bathed by the Atlantic Ocean in the South, and a well- defined mountain range in the North separates it from the region of the Alentejo.

The study area is in the Southern part of the Algarve, and comprises the farthest south-eastern part of the Portuguese mainland (Figure 15). This coastal area borders the Atlantic Ocean to the South, and to the East it is separated from Spain by the River

Guadiana. To the West, the limits of the study area are defined by the location of one of the most popular tourist cities of the Algarve, the city of Portimão, whose tourist activity has greatly expanded over the last 30 years.

Figure 15 – Location of study area

5.4. Urban growth, Tourism and Sustainable Challenges

In the early 1960s, poor legislation and inadequate urban planning led to uncontrolled mass tourism industry in the Algarve, where to meet the demand, hundreds of new tourist infrastructures (e.g. hotels) were built, generating considerable revenues for this region. However, these infrastructures were poorly planned, and often located within coastal areas to increase the spatial proximity to areas of tourist interest. As a result, there has been an increasing concern about mass urbanization in the Algarve, especially in the region of Faro, where at present an International Airport facilitates a massive influx of tourists from northern Europe, which, in the peak summer period, is as much as ten times greater than it is in the winter season.

The circular flow model proposed by Tribe (2005) shown in Figure 16 clearly focuses on the consequences of tourism and the use of sinks/sources relating to environmental capacity. The circular-flow model shows the consequences of permitting the accumulation of wealth from the production of goods and services and the exploitation of resources.

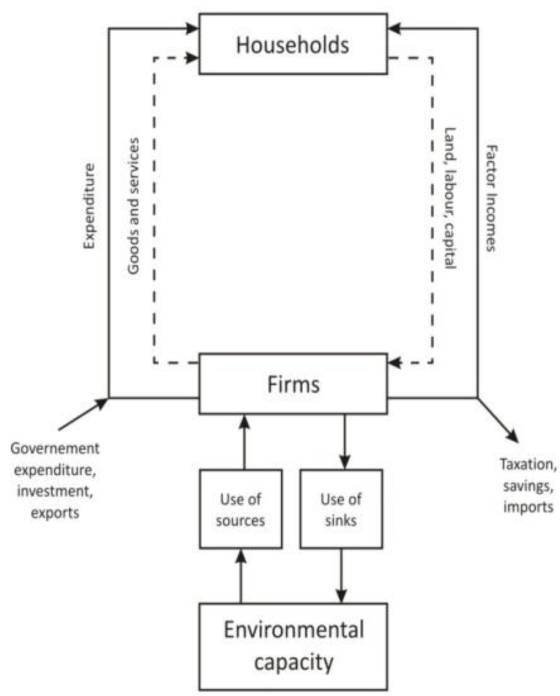


Figure 16 - Environmental capacity circular-flow model

The relationship between the production of goods and services and the utilization of resources necessary for this, combined with the scarcity of resources, defines the resilience of the environment. Such economic activity inevitably leads to land-use change, pollution, and the vulnerability of ecosystems, and thus sustainability becomes unavoidably compromised.

The vulnerability caused by land-use change and generated throughput from economic activity within the tourist industry is jeopardizing natural landscapes and ecological habitats, resulting in a number of worrying consequences for the social and natural dimensions of the Algarve. Although the Portuguese PROT (Plano Regional de Ordenamento do Território – Portuguese Regional Territorial Plan) designates the use of specific areas only for tourists, existing urban areas are located within specific protected areas such as the *Parque Natural da Ria Formosa* (the Formosa estuary Nature Park), an ecological lung for the wildlife of the very fragile wetland bio-habitats. Population increase and infrastructures generated in response to tourist activity may therefore pose serious dangers for future land sustainability in the medium/long run, if no measures for more sustainable choices – such as ecotourism – are taken. Clearly, the argument for tourism within a regional planning perspective involves the utilization of sustainability strategies in which both weak-sustainability and strong-sustainability options should be considered.

In this context, and given the problems of land-use sustainability that the Algarve is currently facing, GIS-based research may help to shed some light on future planning strategies, by combining available tourist information within implicit land-use change models. The spatial complex systems literature applied to land use change models

(Clarke and Hoppen 1997, Syphard et al., 2004) strongly recommends the use of Euclidian distance factors (urban proximity, road proximity), as well as morphological characteristics (slope, land use) for predicting urban growth, which is stochastically assessed. As tourism seems to be a key growth factor in the Algarve region (Guerreiro et al., 2008), distance from the International Airport of Faro was also taken into account. Social leverage was analysed using Census data per municipality. Table 3 illustrates the data inventories used for the creation of our urban growth model. These data inventories are separated into different layers which allow the weighting process within a known spatial projection.

Table 3 – Spatial data for the urban growth model

Data Layer	Source	Original Projection	Used for
ENVIRONMENTAL DATA			
Algarve DEM 90m resolution	SRTM (Shuttle Radar Topography Mission - NASA)	UTM	For creation of slope
Slope	SRTM (secondary data)	Lisbon Hayford-Gauss	Significant Layer for APM
Portuguese Administrative Chart	Portuguese Geographic Institute	Lisbon Hayford-Gauss	Definition of Municipality and *Freguesias* Boundaries
Land Use for Portugal	Requested from Portuguese Environmental Institute, belonging to CORINE Land Cover 90 and 2000 Project.	Lisbon Hayford-Gauss	Significant Layer to understand land use / land change between CLC 90 and CLC2000
Roads	Digitized on screen from Carta de Portugal Digital 1:500000 scale – Portuguese Geographic Institute	Lisbon Hayford-Gauss	Road distance is critically analysed as an important factor for network proximity between Faro and Olhão
SOCIAL DATA			
CENSUS 1991 and CENSUS 2001	National Institute of Statistics (INE)	No Projection	Used to balance weight factors among *freguesias* and tendencies of growth

5.5. Land-cover map and Urban Growth in the Algarve

A land-use/land cover map enables us to "assemble far more knowledge about the Earth than is possible on our own" (Longley et al., 2006), Such a map provides a large quantity of information which can be regarded as a spatial data infrastructure, that supports the spatial, temporal and thematic data sets which represent the real world (NCGIA, 2000).

The choice and adequacy of the data used, depends on the scope of analysis, and should be considered carefully, as there are many different types of data sets (e.g. the urban areas of the Algarve) which can be used to represent our study area. In establishing evaluation criteria, the following criteria should be considered as relevant for urban propensity modelling within the Algarve: (1) Thematic scope: Urban areas in the Algarve region should be represented with as few errors as possible, and all the different types of land use of the region should be analysed. (2) Spatial scope: The area represented should focus on the coastal nature of the study region. (3) Temporal scope: The answers should not apply only to one static temporal moment, but rather, to a time period that provides at least two points in time (preferably three for validation) to facilitate the analysis of urban area dynamics.

Combining these criteria is not easy, as land-use maps are used for many different purposes and no *prêt-a-porter* situation exists. Thus, three land-use databases available for the Algarve region were analysed, so as to assess which has the most suitable characteristics to study urban growth. Key aspects that are needed are: up-to-date and accurate data at regular intervals of time on the changing urban sprawl, urban land use, urban resources, and, the urban environment (Maktav et al., 2005).

The creation of land-use maps has been largely documented, and, in areas such as remote sensing, is very important and widely studied. Nevertheless, if we were to create our own land-use maps, besides taking a very long time and much financial expenditure, would not alter the results significantly. This is mainly due to the size of our area of study, in which spatial accuracy is not required as much as the overall notion of changing patterns. Thus, instead of technical accuracy, the regional adequacy of the chosen variables, as well as accurate notions of current development, are important aspects.

The CORINE Land Cover (CLC) project started on 27 June 1985, in order to address the following issues: state of individual environments; the geographical distribution and state of natural areas; the geographical distribution and abundance of wild fauna and flora; the quality and abundance of water resources; the land-cover structure and the state of the soil; the quantities of toxic substances discharged into various environments; and a List Natural Hazards (EEA, 1996). In this sense, CLC can be seen as ”an experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community” (85/338/EEC, Council Decision 27/6/1985).

The primary source of information for the CLC is satellite imagery which is represented at a 1:100,000 scale with a 25 ha minimum mapping unit (MMU). Using the MMU means that features smaller than 25 ha or 100 m (hedgerows, etc.) are generalized in the CLC inventory (Paínho and Caetano, 2006). However, these elements are important structural elements of certain landscapes, essential in ecological terms and an inherent integrated part of their character and visual appearance. In this “(…) sense the results presented give only a broad picture of the countryside.” (European Community, 2000).

The MMU is a key aspect to be chosen when undertaking the creation of a land use map. The question is whether CLC with an MMU of 25 ha may be accurate enough for urban growth analysis in the Algarve region. After all, existing urban areas of a smaller dimension than 25 ha may be unrepresented, and this could lead to a misleading and inaccurate representation of the urban growth phenomena. One of the solutions would be the use of a different land-use inventory which would have different temporal moments as well as a smaller MMU, or simply making a land-use map with a smaller MMU that assessed urban areas more accurately. A significant venture is the MURBANDY (Monitoring Urban Dynamics) project, and, as this project covers a long enough period of time, it becomes possible to know how cities have grown in the past (Maktav et al., 2005). The MURBANDY analyses urban dynamics in the coastal region between Albufeira to Vila Real de Santo Antonio. For an integrated tourism analysis however, as suitable as this project is for local spatial assessment, the study area was considered too small. Nevertheless, the project MURBANDY Algarve (Caetano et al., 1999) shared important information concerning urban environmental change and covers the period of greatest tourist development in the area. This led us to consider that carrying a regional study of urban and touristic dynamics would be of great interest. The problem concerning the MMU reported in CLC, was equated by building a comparative qualitative assessment of the main differences between the two projects. While MURBANDY supported higher resolution for urban strata, many urban changes do not fall into the coastal region studied within the MURBANDY framework, thus making CLC a better choice for regional analysis.

5.6. Urban Growth in Coastal Areas Facing a Mass-tourism Industry

As discussed above, the Algarve is the most southern region of Portugal, and it has a very heterogeneous morphology. Because of this heterogeneity the Algarve is a region of unrivalled ecological beauty with interesting eco- and cultural tourism opportunities which generate economic prosperity.

However, as mentioned earlier, the Algarve confronted with an unprecedented interest from the tourist industry in the 1960s, which led to the expansion of the built-up area of the coastal cities. These became major foci for mass-tourism, testing the resilience of the spatial environment, as well as creating the problem of how to cope with economic prosperity, without depleting and exploiting the available resources. The demand generated increasing economic prosperity, and nowadays the region is still one of the wealthiest areas of continental Portugal.

However, the winter population of the Algarve is a tenth of what it is in summer, leading to several social problems, regarding stability within the region in terms of economic welfare, combined with the problem of maintaining existing infrastructures for quite a short period during the year. Tourism, as such, seems to bring forth both a symbiotic and an antagonistic relationship, in which economy and ecology (Archibugi et al., 1988) are key aspects, and the criteria of sustainability then become a decision factor (Buhalis and Fletcher, 1995) in tourism.

Figure 17 shows the urban dynamics calculated by the CORINE Land Cover Project for 1990, 2000 and 2006. Between 1990 and 2000, the areas under urban land use clearly doubled, and were mainly concentrated in the western region, between the district capital of Faro, the location of the international Airport, and the city of Portimão, currently the most touristic parts of the Algarve. While up until 1990 urban land use seems to have been relatively balanced between the seashore and the interior of the study area, from 1990 onwards, there was a strong development of the built environment along the coast, especially in main cities. This tendency reflects the increasing tourist demand in the region, where several infrastructures were created at the beginning of the 1980s to cope with the demand of mass tourism. The figure includes the study region of the CLC Project, as well as the existent urban land covers for 1990, 2000 and 2006 in the region of study.

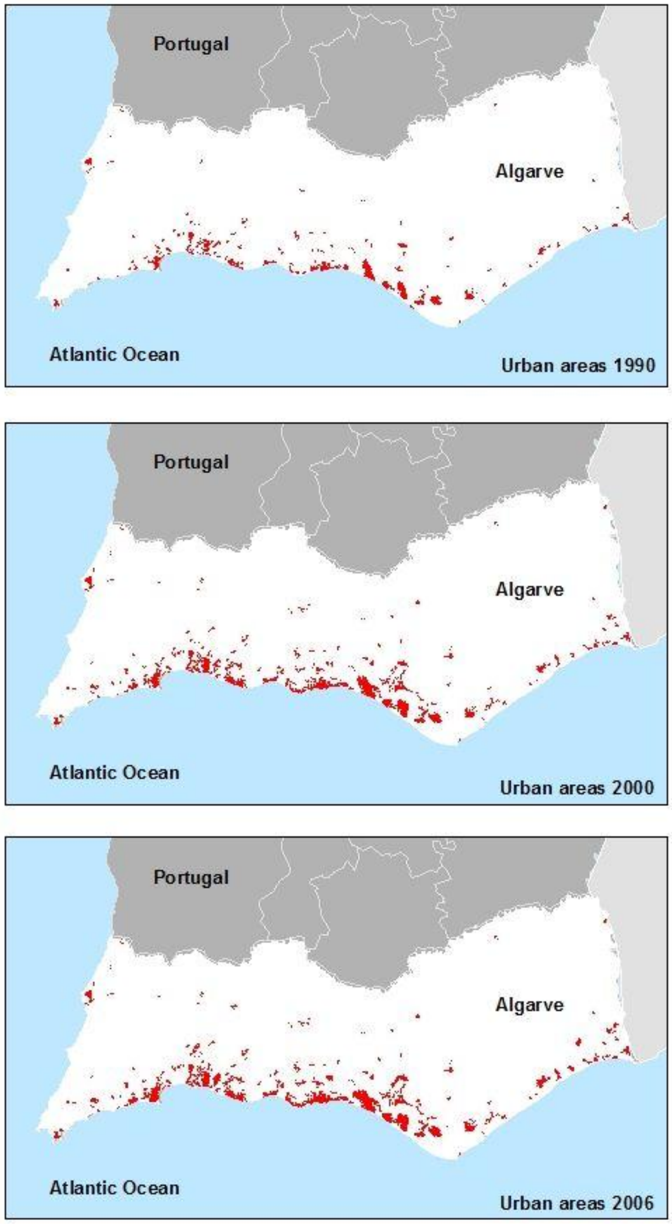


Figure 17– Urban land use in the Algarve in 1990, 2000 and 2006

The calculation of the Euclidean distance allowed us to assess the spatial proximity of urban areas which have the propensity to become tourist attractions. As demonstrated by Figure 18, the number of tourist points of interest (POI's) seems to be greatly influenced by urban proximity. The tendency is strongly related to the greater proximity to tourist

POI's within urban perimeters, but these POI's decrease over distance. However, after a distance of 5 km, the tendency seems to reverse, and again, more tourist attractions are found. This allows us to conclude that: (i) urban proximity seems to be directly related to tourist attractions in the study area: but (ii) after a certain distance, this tendency reverses indicating a different situation based on rural/hinterland tourist attraction; and (iii) tourist POI's, other than those of cultural and natural heritage, are built in proximity to cities to allow easy access.

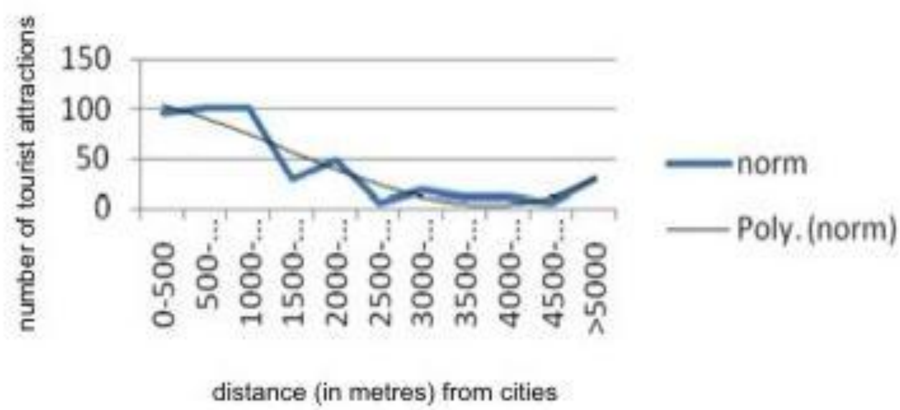


Figure 18– Tourist attractions and distance from urban areas

A high density of tourist POI's also seems to exist close to coastal areas. This proximity is related to the location of urban nuclei within coastal regions. The information on the distances from urban areas to tourist POI's, as well as distances to the coast, has enabled us to generate a propensity map based on normalized weight factors. The Portuguese Tourism database comprises a total of 92 points for the study area focusing on: poles of touristic attraction as infrastructures (golf courses, hotels, etc.); natural landscapes (river basins, natural reservoirs) and cultural heritage (churches, archaeological sites, museums etc.). In addition, urban change within the study area was assessed for 1990, 2000 and 2006. As mentioned earlier, from the 1990s to 2000, this specific spatial segment in the Algarve has experienced the most urban change, as well as tourist growth.

The accuracy of the propensity reached 83 per cent, confirming the calculated suitability and quantifying the propensity of urban proximity to tourist attractors. Tourist attractions showed a tendency to be located in the vicinity of urban areas and along the main transport networks within the area of study. The existing networks play a central role in the spatial location of POI's. While most cultural heritage POI's are positioned within the cities, tourist infrastructures constructed in more recent years are found in the coastal areas (Figure 19).

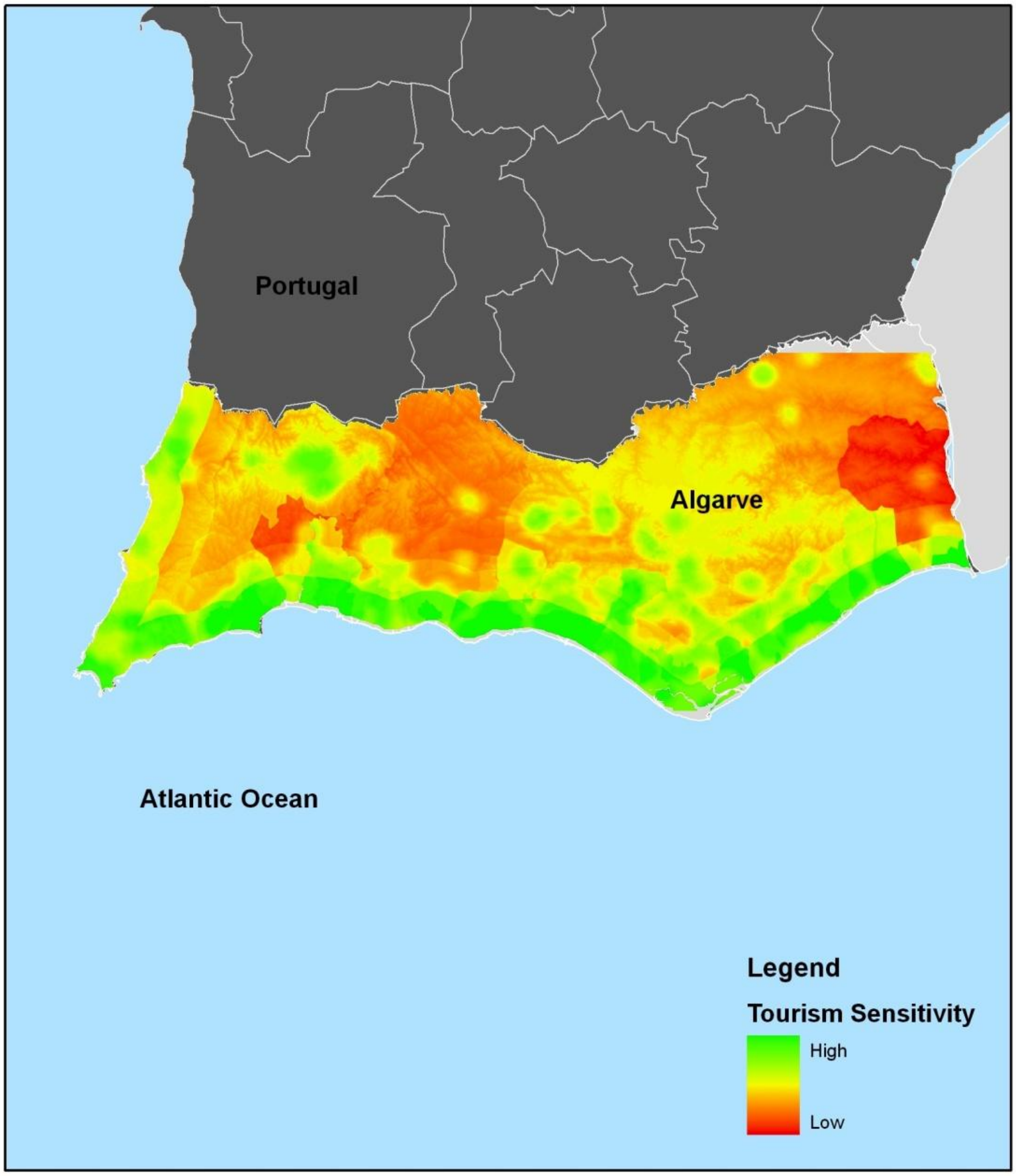


Figure 19– Tourism propensity map with location of tourist attractions

5.6. Urban Growth, Tourism, and Sustainability

Tourism undoubtedly brings with it a wide range of social and economic benefits - to name but a few: it opens up access; facilitates development through the provision of infrastructures; creates employment; encourages links between global societies; brings in revenue to the local authority (see, e.g., Minciu, 2008). However, in the absence of vigilant long-term planning, numerous undesired impacts can arise and disrupt the biophysical and social systems in which the tourism is embedded, and can further cause negative impacts that can be too costly for both the environment and society to bear. The pervasive consequences of throughput caused by economic growth are manifold, ranging from its direct impact on natural environment (Copeland and Taylor, 2004) to its implications for both society (Hirsch, 1976) and governance (Paavola, 2007). As mentioned by the European Environmental Agency (EEA, 2006a), in the Costa Vicentina and the Algarve: "(…) *artificial areas have been increasing and agricultural lands have been decreasing for both the designated site and its surrounding area between 1990 and 2000. Interestingly, in relative terms, the protected site has experienced slightly faster growth of artificial areas and slower abandonment of agricultural land than the areas around it."* Yet, in the context of tourism as a driver of economic development, it is a very challenging task to examine whether the environmental and social costs far outweigh both the financial and the non-monetary benefits that tourism actually generates (Minciu, 2008).

Coastal areas such as the Algarve with various tourist attractions within and close by certainly exert a strong pull for the expansion of built-up infrastructures and thus of urban areas. Such development, if it continues in an uncontrolled manner without carefully taking into account the capacity of the biophysical environment, will make the environment vulnerable to degradation in the long run. In fact, urban pressure in coastal areas is necessarily more significant, because of land shortage, resulting in dense urban areas which lead to higher amounts of environmental pollution, loss of ecosystems, and gradual loss of biodiversity. Tourism, in general, and coastal tourism, in particular, has been proven to be one of the main generators of economic growth for the southern European and Mediterranean regions. However, because of the scarcity of available land, the carrying capacity of urban environments within coastal regions, is very limited. In this sense, if the intensity of tourists is not taken in account (Davenport and Davenport, 2006), the constantly increasing population will inevitably cause the loss of ecologically viable coastal areas (EEA, 2006b). Population increase is therefore a direct result of economic growth, but produces a number of negative consequences for sustainable ecological development and healthy urban environments. Anthropogenic pressures from both visitors and local residents inevitably degrade the environment (e.g. accelerating sand dune erosion) and lead to overexploitation of scarce resources such as water (see, e.g., Garcia and Servera, 2003).

To mitigate the problems that cast a shadow over tourism economic activities associated with tourism, it is imperative, therefore, for the stakeholders involved in tourism to be aware that the pursuit of economic interest alone will in the short run compromise the long-term global sustainability of the area in the future. Government, the tourism industry, property developers, and businesses in general, non-governmental organizations and civil society, and the local residents, all need to work together in developing and implementing future plans that strike the balance between economic benefits and environmental conservation. They need to think of strategies that ensure that the current and future generations of the local population will continue to reap the benefits from tourism, while at the same time the local environment and the socio-cultural heritage are preserved (Turker and Dincyurek, 2007). Some studies (e.g. Li et al., 2006; Walpole and Goodwin, 2000) suggest that, with a sense of ownership from, and with active participation of, the local stakeholders (especially local residents) such sustainable tourism would provide a better development path for the future of the tourist industry and the society at large. What is more, in the context of the Algarve, there is considerable scope for the tourism industry to not only to set its sights on the coastal zones but also to explore and tap into opportunities to enjoy the beauty and tranquillity of rural landscapes. Efforts devoted to this should, however, ensure that tourism goes hand in hand with the impetus to care for the local environmental and the socio-cultural resources base from now into the future. Potentially, such an alternative tourism perspective would have positive knock-on effects in forging and refreshing the linkage between rural and urban areas in mutually beneficial ways. Only then can tourism, by sustaining the urban areas and reinvigorating the rural ones, deliver its greatest contribution to sustainability at least within the socio-geographical limits of the Algarve.

Furthermore, rural and urban dynamics must face the inevitable issue of choices and sustainability. The carrying capacity of land use within coastal areas is becoming diminished as a result of both the expansion of urban areas, and the erosion of coastal zones. The management of certain services, such as tourism, must be rethought for future generations. If not, natural and fragile landscapes located in southern Europe and with a strong tourist industry might be lost forever. By acknowledging tourism as an attractor for urban growth, the 'enlarging Europe' must make the choice between growth and development. However, whatever may be the economic growth of the tourist industry within coastal regions, the scarcity resulting from its impact on the carrying capacity of such areas calls for a new kind of perception of economic opportunities. Mass tourism has been shown to be a handicap for sustainable spatial development and, within such a context of urban growth, it is of the utmost importance to generate new tourist alternatives, related either to cultural heritage or to urban tourism, which do not compromise the available natural resources of those landscapes.

Chapter 6 - Impacts of Environmental Law and Regulations on Agricultural Land-use Change and Urban Pressure:

6.1. Abstract

Land-use change has been an increasing concern in most of Europe. While stakeholder's strategies of coping with land-use change have been constrained mainly due to socio-economic pressures, the natural landscape and fragile ecosystems are often harmed due to infrastructure and urbanization development. However, over the last 30 years, public regulations have become more explicit regarding environmental impacts at the regional level. The spatial assessment of on-going rural and urban policies has led in the case of Portugal to concerns about the consequences of sustainable development in the context of existing legislation. A good example of this is the agricultural land loss that has occurred in Portugal over the last 30 years, in large part resulting from socio-economic pressures with which policy makers have not been able to handle.

The Reserva Agrícola Nacional (RAN) - translated as the National Agricultural Reserve - is an instrument for planning purposes that aims to identify and protect areas suitable for agricultural activities due do their favorable morphological, climatic and social characteristics. The RAN has changed its legal status more than four times in the last 20 years. These changes have mainly been influenced by the policies of regional development for the region. However, the ability to defend the interests of agricultural and rural communities in fragile ecosystems has been largely compromised as a result of socio-economic interactions brought about by the pressures of economic growth.

The spatio-temporal analysis of current land loss and geo-statistical investigation are suitable tools to understand the dynamics of change. The spatial properties of data inventories from the RAN and the CORINE Land Cover project enables the assessment of the changes within the policy context of the Algarve. An integrated assessment of agricultural land loss compared with urban growth parameters and population density is developed to generate a rich laboratory of spatio-temporal analysis of the carrying capacity of the regional/rural environment.

By undertaking a spatial analysis of the appropriation of agricultural land for urban use with overlay of population and urban data, a focus on the consequences of certain regulations on the dynamics of land-use change becomes possible. This paper aims: to further expand on the currently existing decrees which provide support to sustainable development in the region; to provide a qualitative assessment of future roles based on ethical values and economic efficiency; and to offer a feasible framework for policy makers regarding the trends of urban/agricultural dichotomy.

6.2. Introduction

Environmental regulation is one of the most fundamental aspects for competitiveness, making it possible: reduce cost for industry and business; generate new markets for environmental goods and services; create jobs; and protect and sustain natural resources to avoid scarcity (Network of Heads of European Environment Protection Agencies, 2005). That said, environmental law which encompasses the Environmental law system may be defined as "an organized way of using all of the laws in our legal system to minimize, prevent, punish, or remedy the consequences of actions which damage or threaten the environment, public health, and safety. (p. 4)" (Steinway, 2007). However, from a strictly anthropocentric perspective, the very core of legislation of environmental issues is overshadowed by the interests of economic growth. The importance of seeing sustainable development as an interconnected reality, where there should be a fair distribution of resources and in which irreversible options must be handled with care (Gladwin et al., 1995) is often forgotten. Thus, environmental regulation is often infringed as a result of economic factors, making efficient regulation am area of dispute between the paradigm of growth and sustainability. This has especially been witnessed in recent decades, where environmental deterioration and increasing economic growth have brought scarcity to certain ecological sectors, such as agriculture and have led to increasing asymmetries.

Attempting to “minimize the consequences on environment” (Steinway, 2007) becomes a very difficult task, calling for regional decrees which legislate and articulate the policies of sustainable development and environmental change, notwithstanding the paradigm of socio-economic growth. These decrees are, however, often restructured and reorganized to fit the current aspects of environmental degradation, and, as a consequence, they lack a stable and continuous monitoring of sustainability.

Environmental degradation caused by human pressure has been observed in different regions of the world. In Europe, where, in general, strong legislation and a good legal system prevails, urban sprawl has been an inevitable. As a result of population increase and socio-economic growth, there has been significant land abandonment, especially in regions with a higher demand for tertiary sector activities. Environmental regulation, however, has not been able to solve this problem, and, taking as an example the Algarve in Portugal, such pressures have directly been responsible for the destruction of fragile ecosystems, loss of agricultural land, and coastal vulnerability.

Coastal regions share a twofold problem for policy making: as a socio-economic system, they are located in highly productive regions which are far too complex to allow a linear analysis for policy making (EEA, 2006). On the other hand, the productive cycle of such areas relies heavily on ecosystems functionality which may jeopardize by excessive exploitation of goods and services. From a historical perspective, coastal areas have been the cradle for panoply of resources such as agriculture, leading to settlement patterns which have encouraged regional prosperity. Their unique landscape combines often moderate temperatures with a historico-cultural character which has also led to the development of tourist industries in such areas (Vaz and Nijkamp, 2009). However, excessive growth leads to the deterioration of coastal areas, compromising the resilience of such regions. In the long run, the ecosystem services of littoral regions must be carefully planned so as not to harm the fragile ecological habitats in such areas (Costanza et al., 1997).

The issue becomes one of the resilience of the environmental carrying capacity to support the demand for economic growth. While, for example, tourism may be a beneficial activity to some extent (Lacitignola et al., 2007), bringing jobs to certain coastal areas, the counterpart is rapid land deterioration as a result of seasonal population pressure (Kruger, 2005).

The synergetic relation between economic growth and sustainable development is a very complex one, as the effects of socio-economic growth influence the system (or region) in a non-linear way. The dynamics of non-linear complex systems are very difficult to handle, making it necessary for legislation to be multidimensional. However, such environmental legislation has less influence on decisionmaking, while narrowly focused environmental laws have a greater impact (Ruhl, 1999), as their area of application is more precise.

6.3. Spatial Information and Complexity

Spatial analysis has been largely motivated by different scientific disciplines, such as geography, statistics, economics and mathematics. The analysis of complex systems (although a consensus is still lacking regarding their definition), has enabled to create structural analysis to be made of the combined factors of economic, social, and natural drivers (see Newman, 2005). One of the main advantages of complex systems analysis resides in the possibility of to have an integrated approach to understanding the global consequences of interactions (Taylor, 2005). The availability of spatial information and higher spatial resolution georeferenced economic, social, and environmental strata allows a much more coherent approach to integrated analysis: social, economic, and environmental phenomena happen in a specific space and time. By combining different factors from heterogeneous variables that exist within a territorial unit over time, it becomes possible to find a coherent explanation of the key drivers for environmental change, leading to a better approximation of sustainable development.

The cross-linkage of policy decisions implies a direct impact on land use and on territorial management. Spatial information and complex systems may, if combined correctly, create acceptable approaches to land-use change, and provide support in identifying the key drivers for certain land-use changes. This information permits a much more accurate approach to decision making and for understanding the relevant constraints that affect sustainable development (Nijkamp and Scholten, 1993).

6.4. The Study Area

Located in the south of Portugal, the region of the Algarve is one of the most well-known regions of Portugal on account of its prosperous and active tourism sector. The region itself shares a unique historico-cultural legacy inherited from the Phoenician, Roman, and Moorish influence.

The coastal area of the Algarve has a unique ecological landscape, which forms a part of the continental network of conservation habitats, defined under the European Union Directives: 79/409/CEE and 92/43/CEE.

In terms of its geomorphology of the Algarve may be divided into three different areas: the *Interior*, the *Barrocal*, and the *Litoral*, but there is a significant asymmetry between the *Interior* (located at the north of the region) and the *Litoral* (the coastal areas of the Algarve). It is within the coastal area that land tends to be more fertile, and converging ecosystems in the southeast area combine to create the unique *Reserva Natural da Ria Formosa*, known for many different types of species which depend on edaphic soil properties.

Figure 1 shows the geographical region of the Algarve and within it the land which is part of NATURA 2000 network. However, the growing unevenness between populations in the south of the Algarve compared with decline in the north, are jeopardizing the important ecosystems and putting at risk the development agenda of rural areas.

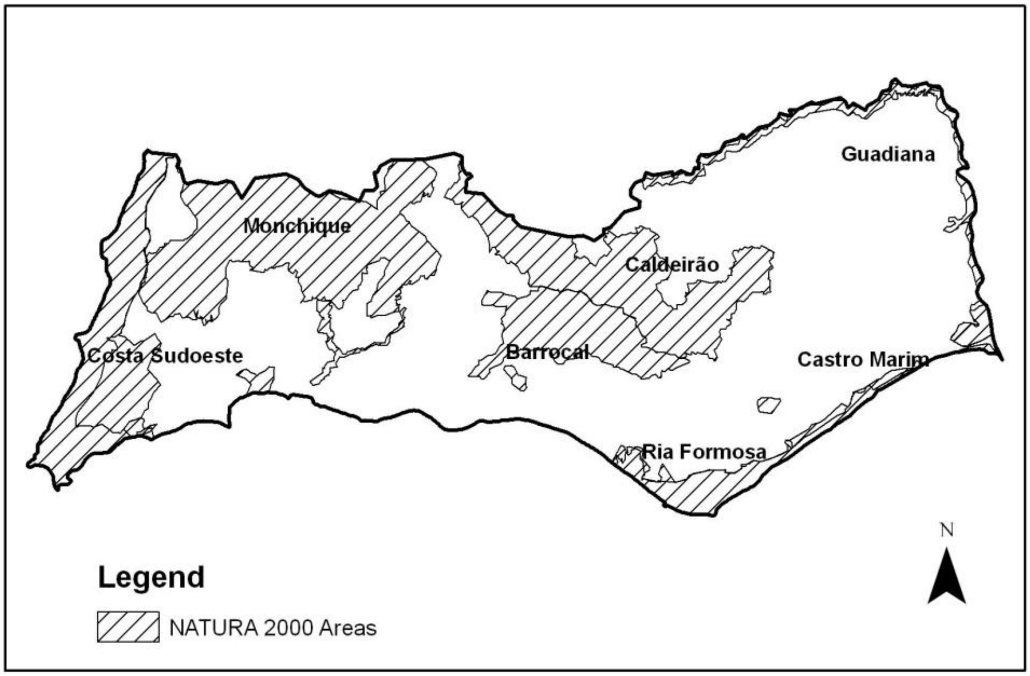


Figure 20 - Location of protected areas within the municipalities of the Algarve

While agricultural activity has been high in the *Barrocal*, which mostly in carob production, and in the *Interior*, where there is sheep herding and other agro-pastoral activities (Assunção, 1989), the *Litoral* has largely lost its agricultural sector to the exploration of tourism activities. Since the 1960s, the increase of tourism brought about by low-cost flights throughout Europe has been seen as an opportunity for economic growth and prosperity for the region. The creation of amenities and infrastructures to support a massive tourism industry has changed the activities of the primary sector to those of the tertiary sector, focusing predominantly on the service sector related to tourism.

The development of the tourist industry has provided better job opportunities, attracting a massive concentration of population in the Algarve, contributing directly to coastal population increase. Figure 2 shows the trend of population growth tendency since mid XVII century.

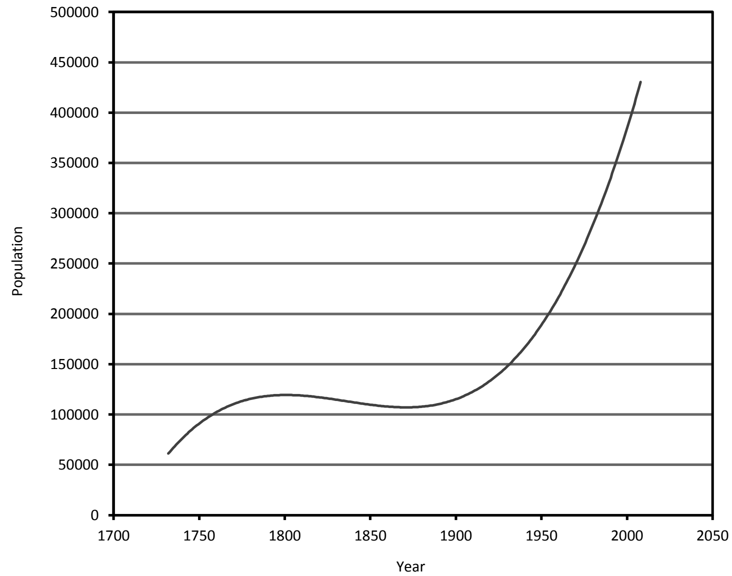


Figure 21 - Population growth in the Algarve since the XVII century

The exponential growth that the Algarve has experienced has particularly increased during the 1980s, and is a reflection of the mass tourism industry.

While population in the Algarve in 1973 was of 63,682 inhabitants, by 1992, the growth rate was 167.62 per cent bringing the total population to 411,468 in 2004. The increase in population during the 18th century was a direct result of the efficiency of the local fishing industry, which provided jobs and economic prosperity during the 18th and 19th centuries. Another marked rise in the growth rate is registered during the 1990s, directly related to a new type of economic growth resulting from the development of the low-cost carriers for tourism purposes. As mentioned earlier, from its beginnings in the 1960s the service sector in the Algarve went on to experience significant growth in the 1990s. However, the population decrease that has occurred over the last 4 years (Table 1), has largely resulted from the economic recession, as well as from a loss of revenues in the tourism industry in the Algarve.

Table 4 - Population growth in the Algarve from 1732 to 2008[2]

Year	Population	Increase	Growth rate
1732	63682	-	-
1802	105412	39.59	65.53
1828	114499	7.94	8.62
1837	127446	10.16	11.31
1991	341075	62.63	167.62
1992	343328	0.66	0.66
1993	345970	0.76	0.77
1994	349658	1.05	1.07
1995	353309	1.03	1.04
1996	357472	1.16	1.18
1997	363387	1.63	1.65
1998	369298	1.60	1.63
1999	375841	1.74	1.77
2000	383399	1.97	2.01
2001	390933	1.93	1.97
2002	398370	1.87	1.90
2003	405380	1.73	1.76
2004	411468	1.48	1.50
2005	416847	1.29	1.31
2006	421528	1.11	1.12
2007	426386	1.14	1.15
2008	430084	0.86	0.87

The construction of the International Airport in the district capital of Faro, as well as the on-going opportunities for coastal tourism, have allowed the tertiary sector to prosper at the expense of the primary sector, thus contributing to city expansion into fertile regions. As suggested by Wrigley (1985), the income elasticity of demand for food is less than 1

[2] Source: Figures for 1732-1837 from Lopes; 1841 *in* Tavares, 1989 and for 1991-2008 from INE.

and therefore the secondary and tertiary sectors are likely to prosper. The consequence, however, may be devastating for ecological coastal regions, given the depletion of important resources. Furthermore, in 2008, the Algarve region had a density of approximately 80 inhabitants per km^2. The asymmetry between the coastal area and the northern area of the Algarve create a great variation in densities which is exacerbated during the summer months when its population triples clustering in the areas of tertiary sectors. Figure 3 shows the population density per parish, clearly reflecting the pattern of clusters along the coastal areas and lower densities in the interior.

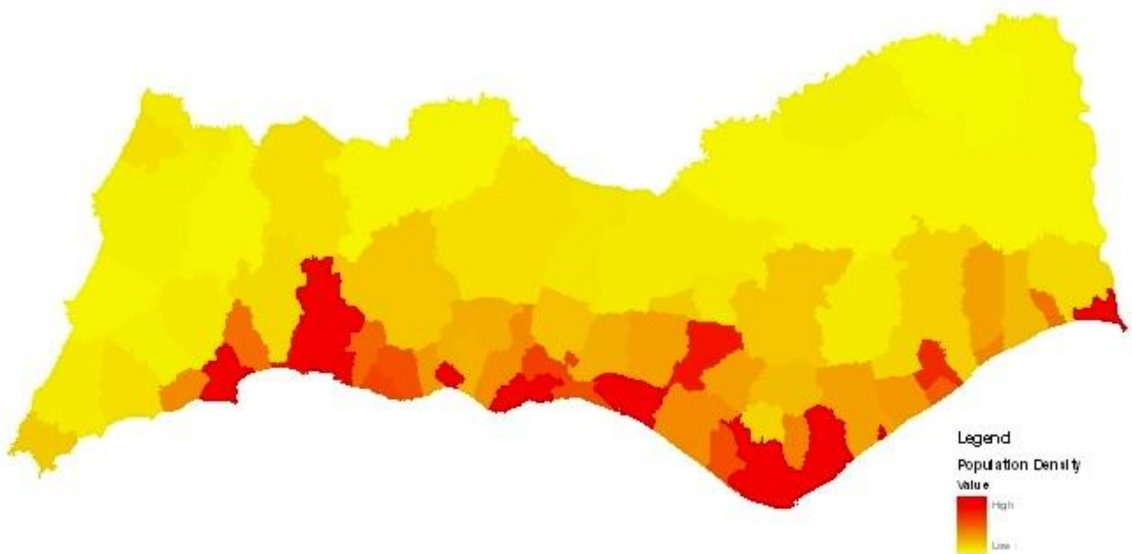


Figure 22 – Population density per parish

The areas with the highest population density can be seen in the surroundings of Faro, the district capital of the Algarve, and in the areas of Albufeira, Portimão and Vila Real de Santo António.

6.5. Data and Methodology

This study is centred on the changes in the extent of Portuguese agricultural land since the end of the 1990s until the present. The depletion of the Algarve's rural areas in recent decades is accelerating and may lead to scarcity in the region. Loss of natural habitats and biodiversity are an increasing concern for regional policy makers, and are widely recognized in the Municipal Plans of the Algarve.

Methodologically, the main objective of this study is to create comparable spatial data sets derived from land-use maps regarding urban land use and cross-link these with the loss of agricultural land by appropriation for urban use in the municipalities of the Algarve.

Thus, this study proposes a land-use accounting methodology which involves studying population density dynamics and urban growth variations for similar time frames. This accounting methodology allows the main driver for agricultural land loss to be identified i.e. it considers whether urban growth may be considered as a significant driver for loss of rural areas, or, on the other hand, systemic population increase might be a key driver of agricultural land appropriation. A multi-temporal analysis for the decades of the 1990s and 2000, allows changes in the extent of both urban and agricultural areas to be tracked. These dynamics are registered as urban variations and agricultural land appropriation variations and assessed together with the population density profile. The impact of this analysis (see Figure 4) leads to a firm characterization of the responsible driver, as well as, a hypothetical evaluation of future trends regarding agricultural land use and population density for the region of the Algarve. This qualitative analysis, combined with the quantitative support from spatial data, enables a better understanding of the dynamics of sustainable development, considering that urban growth is an inevitable reality, but that the need for sustainable cities must also be taken into account.

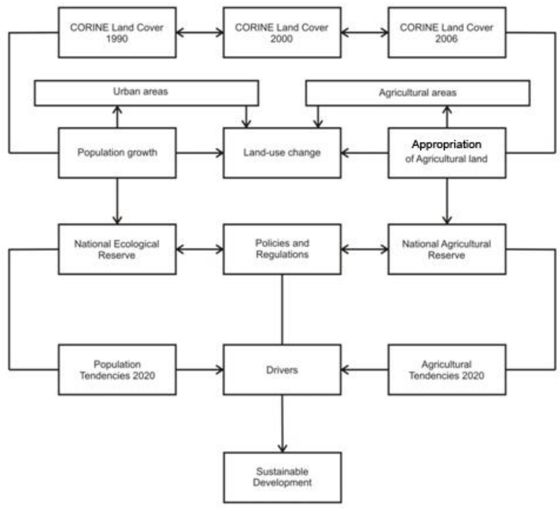


Figure 23 - Flow diagram of methodology

The comparison of the realities of both loss of agricultural land derived from land loss inventories and urban growth will allow us to have a regression analysis using spatial information. Figure 4 shows the workflow involved in the comparison of the CORINE Land Cover period for 1990, 2000 and 2006 with the population growth surveys conducted from 1991 to 2008. Given the change analysis of the CLC periods, urban areas and agricultural areas are mutually assessed to examine land-use change. The diagnosis of population growth and appropriation of agricultural land are reported within the Directives of the framework of regulation between 1989 and 2008. The strategies for the National and Ecological Reserve and for the National Agricultural Reserve are based on existing policies, designed to sustain the available carrying capacity in order to take into account the pressure of population tendencies for the period up to 2020 and agricultural trends for the same period. These drivers are tested with linear regression techniques and forecasted to form the basis of the current critique on the sustainable development of the region.

The multiple time series of population, urban quantification, agricultural quantification, and appropriation of agricultural land, as well as regression correlations allow a comparison of land loss and socio-economic driving forces. The result of this quantification will mitigate the impacts of urban pressure on the coastal areas of the Algarve, as well as recognize the on-going legal importance of quantitative spatial analysis within the notions of land appropriation for urbanization.

The CORINE Land Cover project (CLC) may be considered as a first attempt to derive spatial information about land use in the European context. The CLC started on 27 June 1985, as a programme that would address the following issues: 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 of Natural Hazards (EEA, 1995). In this sense, the CLC can be seen as an experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community (85/338/EEC, Council Decision 27/6/1985).

The Reserva Agrícola Nacional is a Portuguese tool for land management, which covers those areas which due to their favourable morphological, climatic and social conditions are considered to have the most potential for the development of agricultural activities. Essentially, the areas included within the RAN are more fertile, and, thus, would be a serious loss if appropriated for. Nevertheless, local patterns of agricultural activity, typical of the rural areas of the Algarve, have lost some of their traditional positive externalities, leading to an increase in negative externalities generated by non-systemic production sectors. This led in 1976 to the "Land-use Law" (Decreto Lei n. 794/76, 5th November), which brought policies for urban control, and the planning of agricultural activity. However, urban and population pressure, as well as the existing concentration on the secondary and the tertiary sector have led to further agricultural abandonment, and inevitable urban growth in Portugal. A special framework of legislation was conceived in 1982, which expressed the concerns about agricultural land loss, and thus the RAN (Decreto Lei n. 451/82, 16th November) was created, with the main objective of recovering lost agricultural and abandoned land and protecting vulnerable agricultural areas. The RAN is divided in two distinct classes (A and B), based on physical and geographical characteristics (Decreto Lei n. 196/89, 14th June). RAN land is systematically decreasing, while urban areas are registering a steady increase (Figure 5).

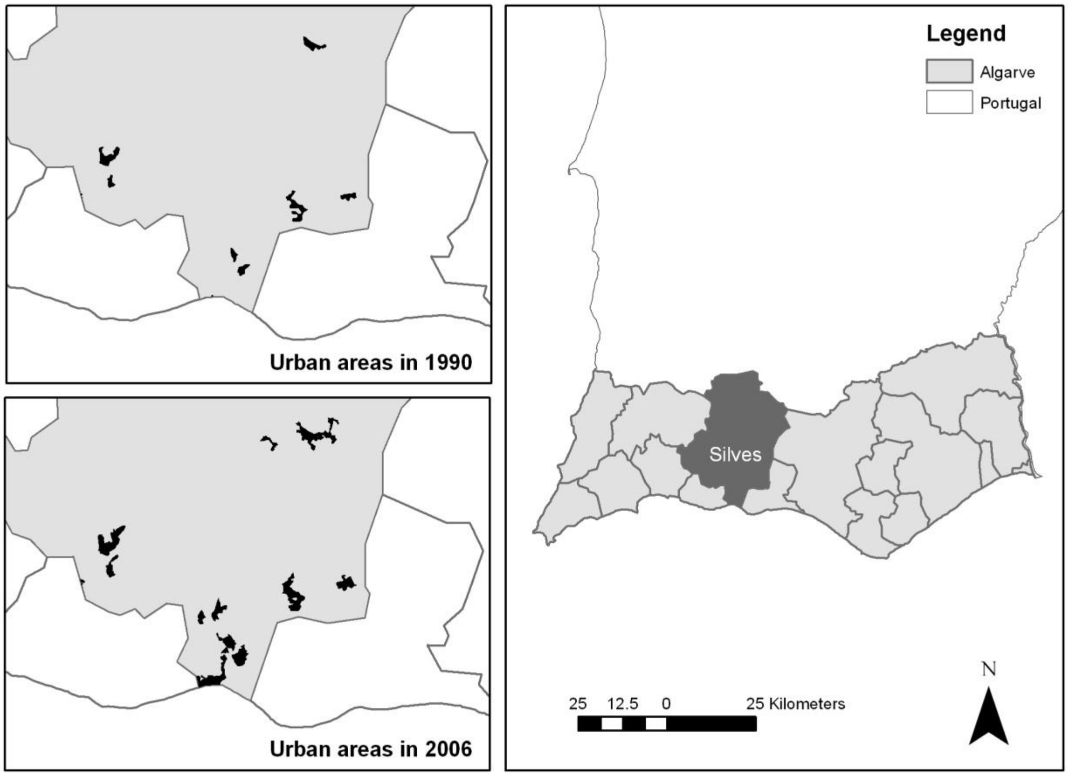


Figure 24 - Urban growth change in Silves

A closer analysis of land appropriation over the last decades shows a fluctuating pattern especially felt since 1996 (Figure 6). Strongly linked to existing land-use policies, the appropriation patterns show an increase since 1994, and in 2005 register the most significant appropriation of RAN land, with a total of 3,722,864 m^2 lost.

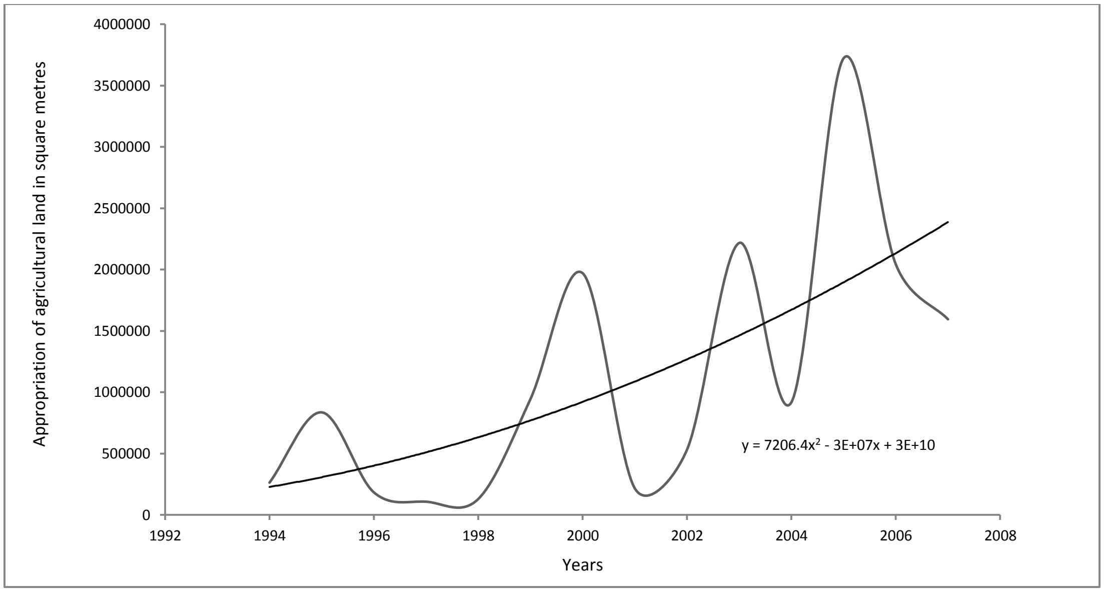


Figure 25 - Evolution of agricultural land appropriation

This pattern is of increasing concern, given the fluctuating nature of agricultural land appropriation and the increasing trend-line of loss of agricultural land. While the peak is, for now, registered in 2005, it seems to be expected that, with the current trend registered over the last decade and a half, that one might expect a further increase in 2010 to a peak comparable in 2003 for land appropriation in 2010. A closer analysis of urban growth tendencies for the Algarve region, as analysed by Vaz et al. (2009), shows the overwhelming tendency of agricultural land loss due to urban pressure.

Analysis of urban growth patterns between the 1990s and 2006 demonstrates a continuous growth along all of the Municipalities (Table 2).

Table 5 - Ratio of urban land variation from CLC 90 to CLC 06 (in pixels)

Municipality	Urban land 90	Urban land 2006	Variation	Ratio
Castro Marim	3463	14145	10682	0.76
Alcoutim	506	2032	1526	0.75
Monchique	1304	5068	3764	0.74
Silves	10445	25517	15072	0.59
Vila do Bispo	6128	14510	8382	0.58
Tavira	7775	17942	10167	0.57
São Brás de Alportel	1836	4149	2313	0.56
Vila Real de Santo António	7816	17374	9558	0.55
Loulé	53601	116356	62755	0.54
Lagos	20980	44301	23321	0.53
Albufeira	30404	64128	33724	0.53
Lagoa	22264	45685	23421	0.51
Olhão	11407	21617	10210	0.47
Portimão	31276	53941	22665	0.42
Faro	21748	30750	9002	0.29
Aljezur	10990	14446	3456	0.24

Although all municipalities registered significant increase over the 15 years of study, a clear increase in urban sprawl has been verified in Castro Marim, Alcoutim and Silves. Curiously, these areas have had a long tradition in the agricultural sector in the Algarve, and have been subjected quite rapidly to urban growth. A further analysis of population density patterns in the Algarve, which also reflects this increase, may be a direct result of competitive prices for construction, as well as of existing road-networks that allow communication to important cities such as Faro, Portimão and Albufeira.

6.6. Conclusions

6.6.1. Urban growth and Agricultural Land Loss

A comparative analysis of existing land-use patterns regarding the appropriation, that is, the re-designation of agricultural land for urban use, allowed us to compare the results of urban variation per municipality with variation of loss of the RAN. The results were quite intriguing: while population density does not seem to have a direct influence on the process of urbanization, the loss of the RAN has a structure of behaviour similar to that of urban land variation. This information is of great interest, as it shows an overall tendency for agricultural land to change to urban use. This is especially the case in Silves, where agricultural production has been traditionally high, and current urban growth is following the tendencies of construction in peri-urban areas.

Data sets of the RAN were summed to the same time frames as CLC data, and information were cross-linked. The result showed that Alcoutim, Monchique and Silves, with the most urban growth, also showed explicit loss of agricultural land by infringing the Agricultural regulation of the RAN in the case of Silves. While at the local level this information is not evident, a regional quantification of variations of the RAN and urban areas provide crucial information of land-change patterns for the Algarve.

A larger framework of study for Portugal, using the CORINE Land Cover data sets also enabled us to confirm that, in the case of Portuguese land-use change, agricultural land has a tendency to change to urban areas.

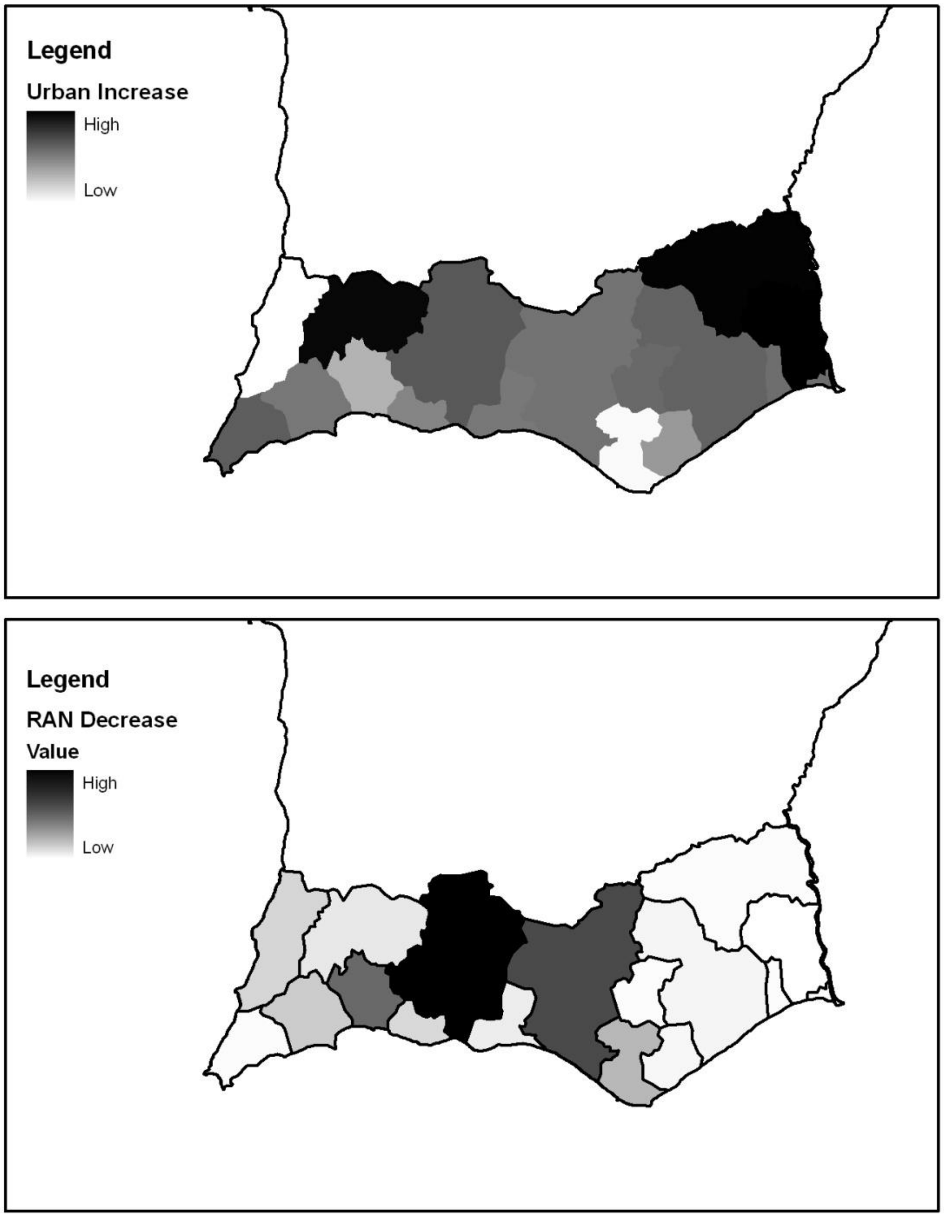


Figure 26 - Comparison of RAN decrease and urban increase in the Algarve

While this acknowledgement is quite obvious, the Algarve shows an increasing tendency of land appropriation, with a rising propensity for urban growth along the appropriated lands. This pattern seems to be combined with a fluctuating tendency of policies in the areas which have allowed the appropriation of agricultural land during certain years

(2000, 2003 and 2005), where these appropriations are mainly linked to important regional activities such as the Euro 2004 football championship.

The economic prosperity brought by the tourist industry, has stimulated the strategy of the creation of infrastructures within the Algarve. Within the concept that currently promotes the Algarve as a sun and beach district – the “Allgarve” – appropriation of agricultural land has led to unavoidable agricultural land loss, especially in peri-urban fringes. The environmental consequences of this growth are evident: traditional agricultural land has greatly decreased, while new infrastructures have increased around certain central areas along the coastal regions.

6.6.2. The Reserva Agrícola Nacional in the Future

On the 29 January 2009 a new legislation came to force Reserva Agrícola Nacional (RAN) under the law 196/1989 of the 4th of June, the objective of this law is, is to reinforce the legal nature and the importance of the public administration of the RAN. According to the United Nations definition and nomenclature of territories, methodologically, this classification envisages the better protection of natural resources throughout the country.

For the first time in the regulation history of the RAN, the use of digital information derived from geo-referenced data sets will have an important role in the analysis and synthesis of crucial information for better management. While in recent there have been an unbalanced management of agricultural land as an inevitable result of the economic growth of urban areas, in the future the better integration of information could lead to improved decision making. The Comissão Regional da Reserva Agrícola might have an important role in reshaping the balance of sustainable development for the Algarve.

It is likely that spatial information will have an important role in creating synergy within this Commission, allowing more interactive and more soundly-based decision making.

Chapter 7 - Past Landscapes for the Reconstruction of Roman Land Use: Eco-history Tourism in the Algarve

7.1. Abstract

Present land use has dramatically changed in the last 50 years. Remote Sensed imagery and its capacity to observe detailed land use patterns have prompted in the last 20 years the acknowledgement of the importance of understanding land development patterns.

Recognizing the impact of spatial observation of land use, leads us to another important question: To which degree can past landscapes be reconstructed by means of archaeological databases as pools of information on past land use explorations? This paper tries to shed some light on the possibilities of recovering ancient landscapes. Using statistical methodologies of spatial analysis and archaeological sites from Roman vestiges in the Algarve as well as the notion of spatial correlation and density patterns to proximity of certain geographic and topological characteristics, we aim to show land use changes in the Roman era in this region.

Understanding past land use may help a more appropriate future interpretation of predictive modelling scenarios, but also, as will be discussed in the paper, share a legacy value for the region of great importance for the tourist industry and the exploration of more sustainable tourism options rather than the ones offered traditionally in the Algarve by prompting for a solution of an eco-history tourism product, recycling existent built environments and creating an opportunity to generate revenues related to historico-cultural assets.

7.2. Introduction

Since over two centuries, “Archaeology has possessed strong conceptual divides between data collection and data analysis, manifested most obviously between excavation and post excavation activities." (Conolly and Lake, 2006).

Material evidence has led to collecting of spatial data related to anthropogenic and archaeological knowledge (Renfrew and Bahn, 2004). Archaeological material evidence such as archaeological sites, with specific spatial characteristics shares a very unique spatial dimension. The combination of anthropogenic sites at a spatial level support modern man to understand his origins, as prompted by Walker and Shiffer (2006):

“(…)*human behaviour consists of people-artefact interactions at various scales, then research questions in the social and behavioural sciences should be reformulated to include amore symmetrical understanding of people and artefacts. One can no longer be satisfied to analytically separate people (and the “social”) from their material matrix. All human activities simultaneously involve interactions in the life histories of artefacts and participation in cadenas. Separating human behaviour from artefacts always results in neglect of the latter.”*

The classical Roman Empire was well established in the southern region of Portugal, the Algarve. One of the consequences of their presence has led to numerous Roman sites. Scholars of the region have since the XIX century has been interested in better understanding Roman socio-economic activity in the area.

Combination of large although sparse, site information, Roman land use becomes a combination of archaeological propensity with ancillary environmental characteristics. The region itself has been a cradle for many past civilizations, where a favourable geographic location has led to commercial and agricultural benefits since the Neolithic. Environmental characteristics as well as georeferenced site information may easily be analysed by means of Geographic Information Systems (GIS). The combination of GIS related to spatial analysis using logistic regression permits us to approach patterns for Roman period land use. Usage of such technologies to 'revive' past land use, may be very suitable not only for historians allowing to better understand cultural complexity (Kvamme, 1990), as well as development of new Tourism products such as cultural heritage tourism.

Furthermore, by recovering the past, one may value the present, as roots of local and regional history are often shadowed and overthrown. However, by sensitizing society to the existent patrimony as well as offering interesting solutions for economic aggregates, sustainable directions of regional development may be achieved. The Algarve which had a high Roman occupancy may become an interesting touristic attraction based on its cultural heritage, offering more sustainable touristic solutions in a context of interdisciplinary approaches to the already very heterogeneous and complex sub-products existing in cities (Swensen, 2006).

The dissemination of cultural legacy at regional level starts with the correct application of spatial technologies in a context of comprehending spatial patterns and land use, emphasizing on the regional dimension of land use planning. Though usually left unconsidered for planning purposes, Archaeology has long relied on survey data to cope with the historic understanding of past civilizations. Thus, articulating survey data brought from Archaeology in a context of economic and spatial analysis seems an unprecedented but yet important task.

Predicting past land use scenarios brings inevitably a certain degree of spatial uncertainty. However, surveyed archaeological site information not only allows the recognition of historical understanding of man's past activities, but also helps to recover the historical tradition and culture of a given region for a 'place in time'. By recovering historical tradition it may be possible revive the past and create interesting trends for preservation supporting sustainable development (Holtorf, 2008) and more efficiently avoid over exploration of economic throughput.

7.3. The Historical Algarve

The region of the Algarve comprises a total of 4899 km^2 which is 5.5% of continental Portugal and is the farthest region to the south of Portugal. Bathed by the Atlantic Ocean to the south and west to the north, a massive mountain range, the *Serra do Caldeirão*, separates the Algarve from the *Alentejo*. This encapsulated morphology of the region, has had influence on a more temperate microclimate than the rest of Portugal, as well as some vegetation and wildlife particularities which have made this area a unique habitat for many different species. From a geomorphologic perspective, the Algarve shows three distinct layers of singular cultural, vegetative and ecological aspects and climatic characteristics from Atlantic coast to the Mediterranean Sea. The location of the Serra do *Caldeirão* and circumscribed by the mountain range, is known as the *Barrocal*, while the region to the south of the *Barrocal* is the Interior and the overly populated region is coastal, and known as the *Litoral*. As inexistence of networks has allowed the maintenance of the Interior and *Barrocal*, the coastal region has been subjected to a mass tourism industry since the sixties, which has led to an often uncontrolled urban perimeter at the coastal Algarve. Furthermore, "(…) the area of the Barrocal due to climatic and pedologic particularities show a very peculiar vegetative coverage whose floral composition and grouping types, if not exclusive are certainly rare outside of this region." (Malato-Beliz, 1986).

Thus, a remarkable contrast encompasses the whole region, as southern Algarve is highly populated and embodies massive urban areas. However, the massive urban areas witnessed in the littoral regions, are far from ancient. Influenced by the de economic development in the Algarve, the original scenic landscapes that once promoted the peculiarity of whitewashed houses are becoming forever lost due to unprecedented city growth (Vaz and Nijkamp, 2008). Nevertheless, among the facades of modern buildings, a more remote and ancestral Algarve lures as an interesting opportunity to rebalance the predominant sun and beach touristic package.

The Algarve, due to its privileged geographical and topographic characteristics, has been of extreme importance since pre-roman civilizations (Gamito, 1997). Its unique location as port to the Mediterranean areas as well as Northern Africa as well its moderate climate and its rich hydrographical bays which allowed a large access to well-tempered pastured of the formerly known area of Lusitania have long been acknowledged centuries ago by Strabo (Strabo, 2007).

With a high Neolithic presence (Nocete et al, 2005; Ramirez et al, 2007) and the existence of several Bronze Age settlements, Archaeological interest started in the beginning of the 19th century onwards, stimulated by scholars such as Estácio da Veiga who catalogued and described a wide range of archaeological findings originating into an important historical volume entitled "Antiguidades Monumentaes do Algarve" (translation: Monumental Antiquities of the Algarve), (Veiga, 2005).

The Algarve in the Roman period is well documented (Santos, 1971, Alarcão, 1974; Teichner, 1994; Bernardes and Oliveira, 2002) and Roman build heritage may easily be seen in the vicinities of urban areas. A typical Roman based of fish spice, garum (Curtis, 1991), was widely produced in the Algarve and exported throughout the entire Roman Empire. Many of the cetarias in which the garum was produced are still visible along the shores of the coast. Production of garum in the southern Hispania has been identified as a key element to economic success during the Roman period in the Algarve (Edmondson, 1990; Osland, 2006).

The former area of Lusitania, prospered greatly in times of Augustus until the end of the period of the Antiquity. Major Roman civitas (cities) such as Ossonoba, Baetica, Portus Hannibalis were fortified and reoccupied during the Moorish period. As a consequence of this mixture of styles, the Algarve shows a variety of Moorish, Roman and Christian heritage in the city areas. Former Roman cities such as Ossonoba, Baetica and Balsa, as well as the ruins of Milreu in Estoi or the present ruins in one of the largest private cities of Europe – Vilamoura – define important Roman socio-cultural residue, related to the economic prosperity during this period.

The abundance of the classical Roman period is marked by the legacy of rich monuments, Roman hot baths, and elaborate mosaic motifs related to a panacea of sea-like creatures and Gods. This historical literacy may very well be an important tool do develop interesting tourism alternatives focusing on a more cultural tourism and support in the Algarve a more sustainable service industry which does not need additional investments, but rather, is self-renewable.

7.4. Archaeological Information Systems

Past land use has not been much explored in the Algarve. However availability of archaeological catalogue and geo-information data, regarding the environment supports by means of geo-statistical inference, allow understanding past land use patterns. As causal relations between georeferenced sites are established, environmental and geographical characteristics help to recover spatial dimension based on archaeological evidence.

The large amount of cetarias in the Algarve region indicates a clear propensity for the production of garum which has been documented as a main production in the south-western Hispania (Silva, 2007). Overall, the Algarve in Roman times seems to have been an area of economic wealth, resulting from its production of garum for the entire Roman Empire, as well as a place of leisure and worship of deities.

Understanding Roman land use was based on surveyed data resulting from almost two hundred years of Roman Archaeological investigation in the Algarve. Distribution of material evidence results from spatial allocation where archaeological survey occurred based on carried out archaeological research. The collection of this spatial information, referenced in bibliographic evidence, summarized a database with 452 occurrences compiling archaeological sites from 1910 up until 2006.

The archaeological sites were interpreted into a GIS using as projection Universal Transverse Mercator (UTM). Later, georeferences archaeological sites were classified into categorical types: Ceramics, Mosaics, Coins, Iron, and Epigraphs.

This information allied to the spatial location and its characteristics represented core information for creating a spatial assessment of past Roman land use.

Geographic Information Systems have had an important role in regional development and planning. Not only do GIS represent a system to access, analyse and represent data (Longley et. al. 2006), but also, their ability to cope with different datasets allows to question and use quantifiable methodologies for different areas that not necessarily belong to the exact sciences. (Wheatley and Gillings, 2002).

A topic in which GIS is having a great impact and has been classified to have as much utility as radiocarbon dating (Westcott and Brandon, 2000) is Archaeology. Since the beginning of the processual Archaeology, material evidence in archaeological prospecting sustained a key role for cultural interpretation (White, 1959). Of inherent spatial character (Schiffer, 1972), past activities based on spatial archaeological data become easier to understand (Hodder, 1972). With technological advance, statistical approaches as well as surveying methodologies and available information have become more assertive and, the possibility to support methodologies and ‘quantify archaeology’, have become an increasingly important venture in archaeological science.

Although the consequences of environmental determinism are sometimes portrait with scepticism (Burns, 2007); environmental determinism in Archaeology may be overcome due to: (1) the possibility to observe past land use sheds information on paths which lead to monuments of historic interest, (2) the context of historic urban and regional planning differs largely from traditional Archaeological dynamics and (3) the articulation among tourism and archaeology or cultural heritage leads to a fusion of areas in which spatial environmental determinism is a pre-determined position.

Over the years, Archaeology greatly benefit from spatial analysis and surveillance by Remote Sensing techniques (Hernandez, 2002), as well as Database management and GIS in general (Connolly and Lake, 2006). The ubiquity of areas in which Archaeology benefits are so different, that correct manipulation of data and research of collected material is often a complex task.

The role of Archaeological complexity involves many different actors with different needs and demands. However, the availability of swiftly available information as well as a practical approach to information usage seems to be a constant whatever the demands. Furthermore, Information should allow the creation of innovative scientific processes, crossing to different actors of the Archaeological frame. In a combined information flux, Anthropologists, Conservationists, Field Archaeologists, GIS Experts and Cultural Heritage Managers could work together combining information. Such an objective can only be achieved with a robust system that supports many in different types of tasks and workflow levels.

Quantification of information in the human sciences is not always a common process as most human sciences relay rather on qualitative analysis and aesthetic / ethic interpretation of phenomena than on exact and precise quantifiable methodologies. However, certain human sciences such as sociology, geography, anthropology and archaeology, have had the need to disassociate themselves from the strictly qualitative sciences, as in real world phenomena, whether past, present of future, nature retains aspects of quantitative relevance. These aspects of quantifiable nature that few human sciences explore have brought forth a convergence between mathematical and statistical methodologies. Such attempts for quantitative and qualitative integrated future knowledge have led to important debates such as the Dahlem Workshops where quantitative and qualitative information combined, set stakes to the paradigms of a sustainable future. For Archaeology specifically an interest in quantitative and technological methodologies, sustained by the possibility of quantifying material evidence has been present (Doran and Hodson, 1975). With the evolution of Archaeological science and GIS, the latter have developed into more user-friendly platforms to allow spatial interpretation. Nowadays they represent an important tool for analysis, comparison and prompting of archaeological phenomena and information (Connolly and Lake, 2006). Relying on Archaeological catalogues that, first started as simple archaeological registries for stratigraphy or site location interest, have in part due to GIS evolved to large data containers with information which may be created, retrieved, eliminated and changed. Hence, the basic circumstances for a database management system were established in the field of Archaeology that allowed integration of information related to archaeological site phenomena. Thus, nowadays, an Archaeological database is not just an advantage for Archaeological registering, but also an extremely important tool for sharing information. This allows creating a knowledge flux between the different actors engaged in Archaeological Science. Technologically, archaeological information demands as a consequence physical storage properties such as databases. Databases permit simple and flexible management of information which is stored centrally and allows integrity and constancy of data as well as multiuser support for data registry. Constructing an accurate and complete database is not always an easy task, as linkage of different information which often is not easily accessible should be assembled effectively.

7.5. Endovélico – Portuguese Database Management System for Archaeology

In 1989 the first attempt of digitizing archaeological information from the Carta Arqueológica de Portugal was created. Nevertheless, only in 1995 a final inventory with geographical information regarding Archaeological sites was build. This initiative became in 1997 part of the Portuguese Archaeological Institute and became an important mark on the actual needs regarding preservation of historic information in Portugal (Divisão de Inventário do Instituto Português de Arqueologia, 2002). The Portuguese Archaeological Institute's main objective is to "detect, protect and manage archaeological vestiges" (Decreto-Lei nº117/97, May 14th, paragraph a) of 1 Article 2). This attempt was an important venture in the national archaeological framework, relevant in the validity and confirmation process of on-going archaeological research. This effort has brought a commutative process of archaeological investigation to Portugal: both parties are enriched by the commutative informative process in which the Endovélico database adds new research and surveyed work, as well as clarifies information of past surveys, useful for researchers. This synergy among institutions and stakeholders may shed new light upon the possibilities of cooperation in the Archaeological field, in which the one decade old Endovélico may prove to have a central role in archaeological preservation and on archaeological prospection in Portugal (Figure 27).

Still, it is important to create a common ground for the ubiquity of archaeological information. This seems to me only possible by creating a further more integrated, flexible and reliable DBMS in which Endovélico has a central part cooperating with the different existent archaeological actors.

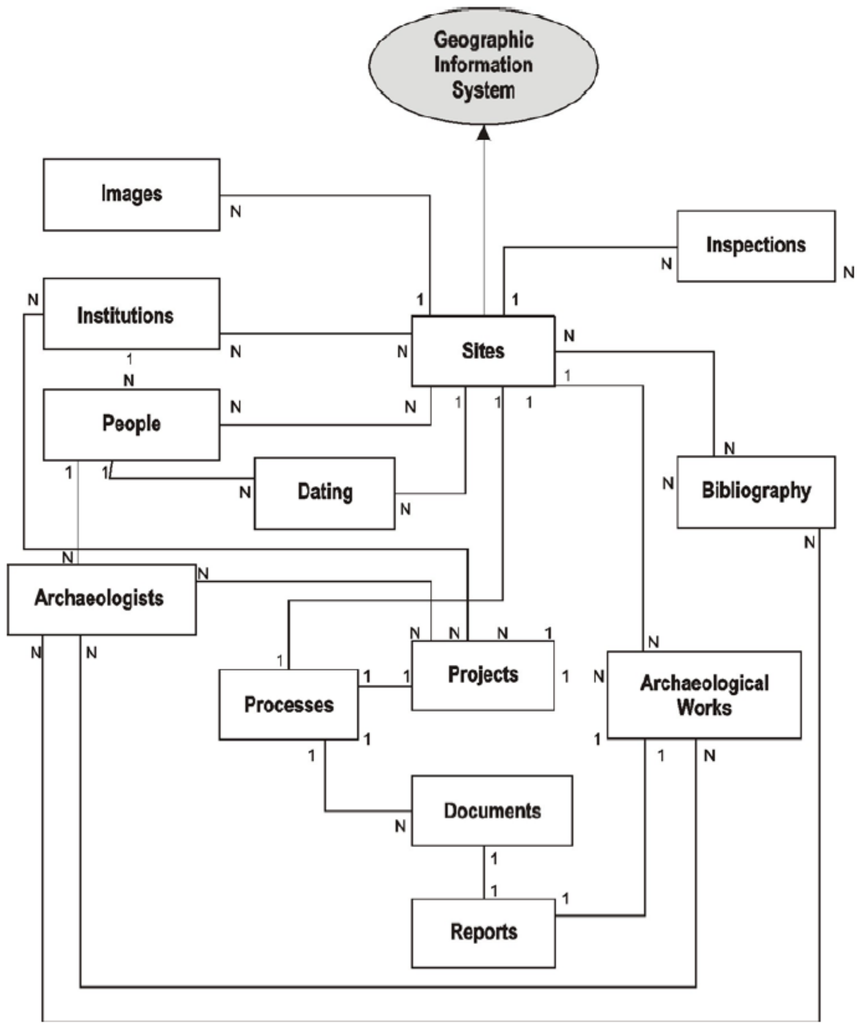


Figure 27- Simplified ER Diagram of Endovélico (adapted from Divisão do Inventário do Instituto Português de Arqueologia, 2002)

7.6. Roman Land Use in the Algarve a Predictive Modelling Approach

The Roman land-use prediction model of the Algarve was created by environmental variables which relate to possible land use patterns circumscribed by archaeological material evidence. Site location was of crucial importance to display allocated information and to allow statistical interference to achieve generalized land use (Kvamme, 1988).

A digital elevation model (DEM) for an area of 5km x 5km which included three river basins and had a proximity to the littoral area of the Algarve was generated (Figure 28). Contour lines and points with altimetry information were combined allowing generating a triangulated irregular network (TIN). The TIN was converted into a spatial matrix/grid, and afterwards modified into integer values. These conversions allowed the quantification of local site strata and elaboration of classifiers with propensity weight.

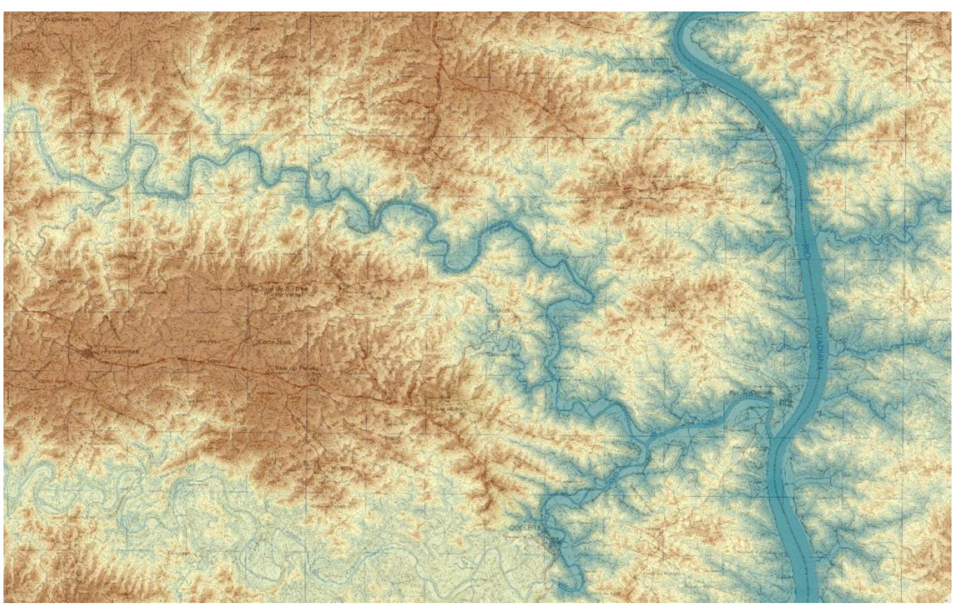


Figure 28 – Overview of study area with interpolated DEM

7.7. Site Potential in the Study Area

Site potential was measured by combining weight factors for generated slope, elevation and aspect data. This coverage was interpolated from the DEM, and is known to have much importance on human behaviour (Miller and Barton, 2008; Hayakawa and Tsumura, 2009).

The variation of weights related to the presence or non-presence depending on spatial location, allowed to recognize specific weight that each of the classes in the variable may have. The combination of those three classes aggregated by the presence of Roman sites gave a propensity map for recognizing the potential of finding future archaeological sites and has a clearer idea of roman land use. Figure 29, represents the calculated propensity based on the aforementioned variables in a context of Roman site prediction.

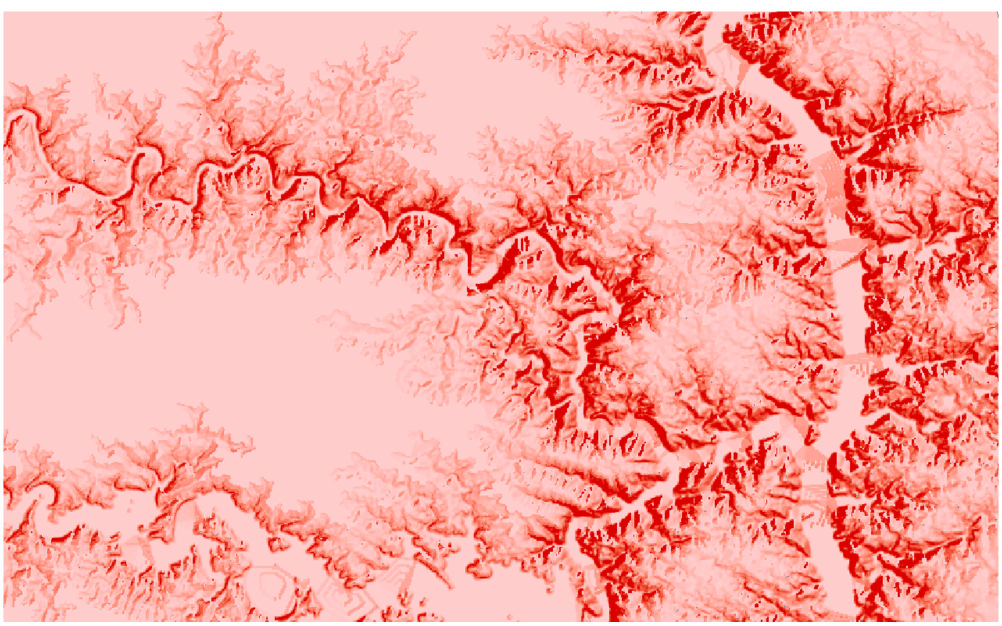


Figure 29– Archaeological site potential

A greater potential exists in the area with low slope as well as low elevation and where hillshade appears higher and that are located in the proximity of river basins. Such conclusions are of utmost importance, as still human residence patterns seem to prefer areas with less slope cost and modern urban areas are usually in the vicinities of river basins or coastal shores, establishing an interesting correlation between past and present human behaviour as well as the central role of past land use traditions.

7.8. Validating Site Potential for the Region of the Algarve

Data limitations do not allow a representation of a generalized DEM for the complete region of the Algarve while maintaining the high spatial resolution. This unfortunately, limits the possibilities of regional interpretation of site propensity which would be of enormous importance for regional and urban planning purposes. Nevertheless, the accuracy of the prediction may be allocated to other areas within the region of study, as to verify if the following assumptions: (1) Roman preference to areas with higher hillshade; (2) preferred south or north location for human activity; (3) proximity to river basins and coastal bodies.

Should those variables prevail for other study areas within the region, a generalized land use model based on Roman sites may be applied and relevant information compared. Validation therefore, is an important step to test the reliability and the relevance of calculated potential which identifies interesting information on regional patterns for urban planning.

To understand the accuracy at regional level of the generated propensity model of 5km x 5km area, a DEM with lover spatial resolution was used. The Shuttle Radar Topography Mission (SRTM) DEM with 90m spatial resolution is the ideal candidate to tackle accuracy of observed sites. Table 6 below, shows projected accuracy for generic model and relative weights, depending on correctly classified sites.

Table 6 – Weight Matrix of variable criteria for site propensity

	High Spatial Resolution			
	Classified	Non Classified	Accuracy	Weight
Elevation (48-120m)	11	8	0,578947	79
Slope (0 - 33%)	14	5	0,736842	100
Aspect (North and South)	9	10	0,473684	64

Propensity map for regional comparison was created by structuring a propensity equation with relative weights of elevation, slope and aspect.

The resulting formula may be expressed as follows:

$$P = (w_1X_1+w_2X_2+w_3X_3)/N,$$

Where w1, w2 and w3 represent the relative accuracy for each of the variable and x1, x2 and x3 show the used landscape variables. Most archaeological sites may be found in the interval of 80-100% of archaeological site potential (Figure 30) which supports the accuracy of generalizing local scale sites into a more regional scope of analysis.

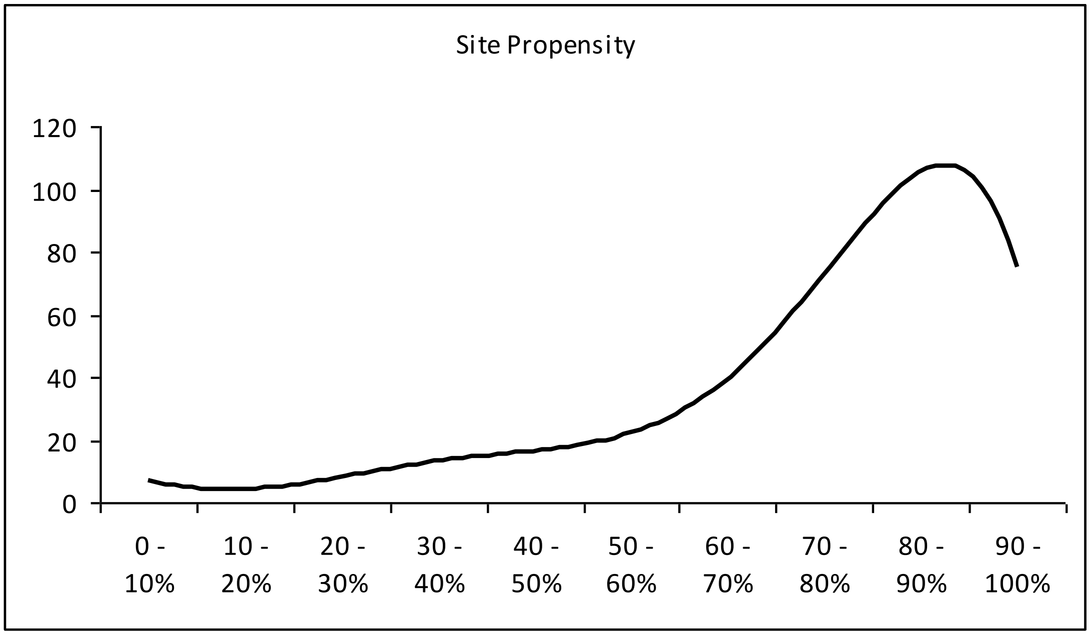


Figure 30– Overall site propensity for Roman sites in the Algarve

7.9. Conclusions on Archaeological Predictive Models

The comparison of these two different propensities at micro and macro-scale, shed an interesting conclusion regarding the possibilities of joining different types of spatial information located at different scales. By creating a simple predictive model in an archaeological context for Roman ceramic site prediction, we have witnessed the possibilities of combining local spatial strata to a more aggregated macro-analysis level, and by means of stochastic methodologies, arrived to conclusions regarding site propensity. Relevant information should be considered: (1) possibilities of combining smaller and higher scales of study as spatial patterns seem to be constant over regional territory for anthropologic behaviour. (2) Calculated cost surfaces of Roman land use have confirmed that Roman land use and settlement occur in proximity of river basins.

(3) The spatial direction human settlements might have faced does play an importance on anthropogenic circumstances.

7.10. Conclusions on Policy Choices and Healthier Tourism: Eco-history Tourism

The Algarve, has witnessed a rapid increase in its tourist industry since the beginning of the 60s. The exploration of a tourist product related to sun and beach, has brought forth an emphasis on a mass-tourism industry which often shows no particular interest in the Algarve as a spot of historico-cultural legacy. This phenomenon is a direct consequence of the existent coastal hotels and resorts, as well as only a recent effort to promote the cultural legacy of this region.

Tourism in the Algarve faces currently several competitors regarding touristic products it addresses, as low airfares give opportunity for tourists to visit more tropic destinations, with unrivalled ‘sun and beach’ offers. Choosing other touristic products such as historical tourism / cultural tourism relating to the rich fauna and flora of the region, allows tackling a new concept of eco-history tourism for the Algarve. The evidence of rich Roman land use in the Algarve and the existence of abundant roman historic patrimony, suggest a route of Roman past portrait by a typical Mediterranean landscape and an opportunity for a new kind of touristic product. Recent studies (Carrasco et al, 2008) indicate a prosperous reminiscence of mosaics found in the southern part of the former region of Hispania (Algarve and south Andaluzia) which emphasize the relevance of this area as a pole of a cultural heritage of the Roman Empire. Should Archaeology and Tourist industry collaborate in joint initiatives to promote based on scientific data the concept of eco-history tourism, a sound alternative could be found to forfeit the consequences of a massive tourist industry which bring at the medium run, little benefit for a sustainable environment and healthier landscape.

As such, this paper has suggested a new approach for defining an innovative area for the touristic sector: Eco-history tourism. On one side, this touristic product relies on scientific information (such as archaeological predictive models) as well as factual information on archaeological sites (by usage of databases) to confirm relevant patterns of past land use in regions. This information supported on proved evidence, may help to mediatise regions for their archaeological legacy, offering a cultural tourism alternative which is an interesting solution for developing conservation and cultural sustainability alternatives. In the Algarve, such a product would adapt quite well, given the already existent tourism infrastructures, while exploring less competitive tourist alternatives than current offered products. Regions such as the Algarve with a diverse and attractive fauna and flora would permit ecotourism to do well, while offering a past identity to the region focused on the existing monuments and empiric/scientific findings.

Chapter 8 - Urban Heritage Endangerment at the Interface of Future Cities and Past Heritage

8.1. Abstract

Uncontrolled urban growth has been an increasing concern in regions in Europe and elsewhere. Brought forth by a natural tendency of population growth in relation to unsustainable land use, city sprawl has led to complex spatial development that are creating both benefits and challenges for decision makers. A major problem inherent in inadequate growth of cities is the direct threat to fragile cultural and ecological heritage, which may escalate to permanent and irreversible damage due to factors such environmental depletion and landscape decay. Using modern geoscience and spatial information technology as tools to analyse and forecast urban growth, a regional spatial decision system may be designed that offers useful and timely information on the risk of overburdening the carrying capacity at regional level regarding archaeological heritage.

The present paper will develop a predictive model for urban sprawl in relation to the location of potential urban archaeological sites. This integrated spatial model approach, offers a novel methodology for a common problem of urban archaeological preservation within rapidly growing cities as is the case of the Algarve in Portugal where new empirical results are found.

The use of the Algarve as a laboratory for testing this methodology results from the combined analysis of urban growth potentials and threats combined with the abundant presence of archaeological heritage. Our approach supports the paradigm of city growth in context of the European agenda emerging from the Valetta Treaty, in which

archaeological heritage is recognized as a key element for sustainable regional development. This paper proposes thus an integrative spatial analysis methodology on the issue of historico-cultural endangerment, proposing a novel approach of comparative spatial analysis for decision making at regional scale on urban heritage endangerment.
Keywords: Geographic Information Systems; Urban Growth; Heritage Endangerment; Spatial Decision making; Spatial Vulnerability

8.2. Introduction

The last decades have witnessed unprecedented urban growth in Europe. This growth has been felt predominantly around the urban fringes and has led to loss of agricultural land (EEA Report, 2006). Accompanied by a population increase in urban areas, a quarter of Europe's territory has been affected by urban sprawl and 80% of population is currently settled in cities.

The European framework has recently considered the importance of constant monitoring of urban growth and preservation of historical cities, as to protect more fragile historic areas and their surrounding ecosystems.

The relationship between urban change and environmental carrying capacity have found a common analytical framework in the application Geographic Information Sciences (GISc) (Goodchild 1997), where Geographic Information Systems (GIS) play an intricate role in assessing and monitoring spatial change (Longley 2002) by helping to better understand the land use impacts in relation to scarcity of fragile resources.

The acknowledgement of the importance of monitoring urban sprawl has been especially considered by the European Spatial Development Perspective (ESDP) where management of cultural and natural resources were one of the key topics of discussion: "Natural and cultural heritage in the EU is endangered by economic and social modernization processes. European cultural landscapes, cities and towns, as well as a variety of natural and historic monuments are part of the European heritage. Its fostering should be an important task for modern architecture, urban and landscape planning in all regions of the EU." (European Commission 1999).

Coping with urban change is a mandatory necessity to maintain our life quality at present. While at the short term local sustainability plays a major relevance, in the long run common structural changes must be considered (Capello 2001). This definition clearly exemplifies the relevance of conservation of our heritage, in which archaeological heritage preservation has a vital role in sustainable development of cities.

Urban growth has imperilled many archaeological sites and historical buildings. From a short-term perspective, a stronger focus on stakeholders should lead to the promotion of cultural awareness supporting, for example, touristic services related to heritage tourism which might boost the local and regional economy while reducing negative externalities (Vaz and Nijkamp 2009).

Monitoring urban growth within heritage tourism offers an alternative to the process of centralization of touristic activities. Centralization of tourism attractions is a result of lack of efforts regarding heritage preservation and exploration of neglected historico-cultural landscapes. As a consequence, concentrated tourism in certain heritage sites, will reflect on the challenging carrying capacity of local areas in a vicious cycle (Russo 2002), but also, respond on permanent loss of fragile archaeological sites at the long run.

The contextualization decision makers, relies on the integration of practical measures: (1) Short-run (local measures): Protection from existing urban patrimony often endangered due to air pollution - a consequence of human activity within city due to gas emissions - with creation of diversified cultural heritage offer. (2) Long-run (regional measures) Promotion of the analysis of future urban growth leading to a sounder choice of future urban development which may as a consequence benefit directly urban planning reducing negative impacts.

The solution to avoid negative externalities at the long-run should preferably employ predictive modelling approaches, regarding both - urban growth and archaeological heritage. Both of these approaches are spatially explicit, and are of crucial importance for sustainable development. For example, the possible integration of Stonehenge in UNESCO's endangered sites list (Webster 2007), is a clear illustration of the importance of understanding the future impacts of urban and periphery planning.

Furthermore, the notion of urban sustainability and "living cities" are characterized by their uniqueness in centuries of diverse historic patrimony. The impact of growing cities must not jeopardize the continuum of the secular memories of urban areas. Rather, as will be discussed later, should articulate the secular presence in the modern conception of urban preservation agenda. This may only be achieved by a transversal effort of different areas in which planners must contribute in understanding the synergistic dimension of economical positive externalities and carrying capacity of vulnerable areas. The city, thus, is a present identity of our forefathers which must be passed to future generations.

The concept of living cities underpins a framework of common heritage: expansion of urban cities while preserving past heritage. This is not an easy task, as both realities are often convergent and create local friction. The research challenge of this paper is to predict at local level, which municipalities in the Algarve are suffering more from the pressures of urban growth and present highest archaeological propensity. This spatial assessment of the convergent surfaces of friction of endangerment, is defined as archaeological endangerment, and reports to areas in which special care should be taken.
From a logical framework, this model starts with the construction of a calibrated urban growth model (UGM), identifying the pressures of urban sprawl in the Algarve. As urban areas more prone to urban sprawl become evident, an application of a widely used methodology of archaeological predictive modelling is used to understand the municipalities with higher potential for Roman archaeological sites. This model is understood as an Archaeological Predictive Model (APM) which drives from a logistic regression based on site evidence of 380 Archaeological sites in the Algarve. The resulting surfaces of the UGM and APM are overlaid and the regions with highest probability for endangerment are examined. The municipalities that show largest endangerment should be prepared to cope with the threat of urban growth, but also analyse archaeological heritage as a unique opportunity for the active tourist sector which is the main activity of the Algarve.

8.3. Methodology

The approach in this study draws forth from a comparative assessment of the convergence of areas with higher propensity of urban growth, crossed with regions of high archaeological site prediction. The application of this method to the Algarve, leads to a comparative spatial assessment of the areas that show most vulnerability on archaeological sites through urban pressure, which may influence permanently the historic landscape of the Algarve.

The urban growth model (UGM) follows a classical SLEUTH modelling approach, encapsulating socio-economical and geophysical variables (Annex 1) that respond to the most plausible outcome of urban sprawl in the Algarve in the forthcoming years. SLEUTH is a widely used UGM approach, which conceptualizes the division of land use for a cell of a specific size. Each cell follows a criterion of transition from the automaton, based in this case in the transition brought from a Markov transition chain for known time frames (1990 and 2000). The UGM is validated based on ground truth of land use from the most recent time frame (2006) and then later projected to 2020. These results are then compared with the APM surface, in an attempt to find hotspots and municipalities which present a higher risk factor for urban archaeological heritage endangerment.

The integration of both spatial information systems, permitted to elaborate on a spatial model which reported the location of probable Archaeological sites and valued historico-cultural places in the vicinities of existent urban fringes. Thus, the modelling approach may be seen as a comparative analytical process, in which the 'collision' of both predicted realities (the future of urban growth and the predicted location of archaeological sites) shape a common layer of spatial significance which supports decision makers and integrates the importance of the Valetta Treaty.

8.4. An Urban Growth Model for the Algarve

The Algarve represents a very interesting region of study, as the region is, as mentioned earlier, suffering from an increasing friction between natural ecosystems and urban growth. The archaeological richness of the Algarve as well as the ecological diversity and available land-use inventories of European interest (Paínho and Caetano 2006), frame this region as a relevant case of consequences of unmonitored urban growth (Figure 31). The coastal fringe in the Algarve has most considerably change in the last 20 years. Accompanied by a population increase and the demand for new infra-structures to cope with the tourism sector, the Algarve has predominantly expanded along the coastal shores, putting at risk fragile ecosystems part of the NATURA network, such as the *Reserva Natural da Ria Formosa*. Cities in the Algarve represent a very diverse cultural legacy, brought forth from the Moorish influence combined with the Roman and traditional Portuguese styles. It is therefore a cradle of different civilizations, which shared the region since the Neolithic (Calado and Rocha, 2006).

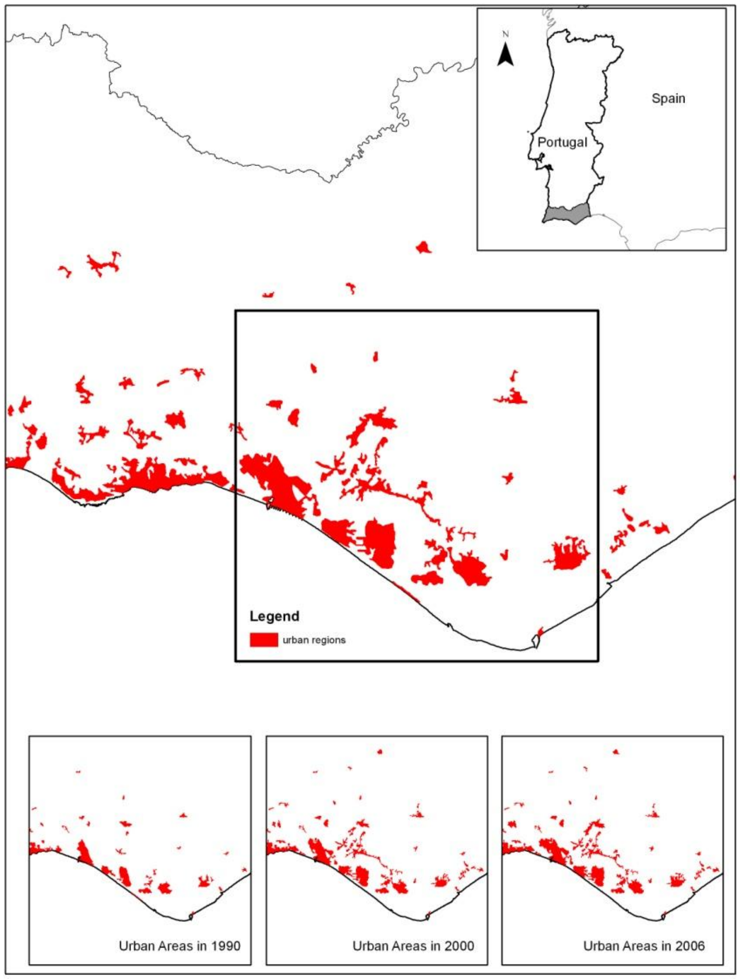


Figure 31– Location of study area and urban change

The application of UGM at regional level have been widely successful, and allow an accurate interpretation of urban growth dynamics and changes facing land-use as well as resulting impact (Oguz et al. 2007; Jantz et al. 2010). The importance of such models is intrinsically related to the need to monitor sustainable urbanization is closely linked to global sustainable development (Li et al., 2000; Camhis 2006). Urban Growth Models (UGM) follow a long tradition in the spatial sciences (Wilson 1974) and have been for decades considered of great interest in simulating future growth patterns (Tobler 1970).

The cell based model approach, due to their similarity to urban growth behaviours are an optimal choice for tracking urban change (Batty 2005). As such, these models may have an important role for the decision making process regarding future urban growth and regional planning strategies (Piyathamrongchai and Batty 2007). The change is conditioned by the distinct states adopted by urban or non-urban, represented as **S**. These states, **S**, are influenced by the subsequent propensity derived from the Markov transition matrix (***f***). Thus, the state of the cell may be defined by:

$$Sc^{t+1} = f(Sc^t, Sn(c)^t) \quad (1)$$

The transition rule takes into account the previous time (***t***) within the propensity of the surrounding neighbourhood, returning thus, the status as (***t+1***).

The Markov transition matrix (***f***) is calculated by the relationship of the existing change from one land-cover to another and may be represented as:

$$P_t = \begin{matrix} p_{11} & \cdots & p_{1Nw} \\ \vdots & \ddots & \vdots \\ p_{Nw1} & \cdots & p_{NwNw} \end{matrix} \quad (2)$$

P_t is the probability of transition for x_i to x_j in *t* steps given the weights as:

$$P_{ij}\ \ x_i, x_j\ \ = \frac{x_{ij}\ \ x_i, x_j}{d_i} \quad (3)$$

and

$$d_i = \sum_{j=1}^{N_w} w_{ij} \quad (4)$$

Due to the capacity to create a transition matrix based on conditional probabilities of P_{ij}, land use change probabilities may be assessed underpinned by multi- temporal land use covers. Thus, a resulting matrix will necessarily evoke the changes occurring within a defined time-span. The mechanisms of change between t and ***t+1*** are thus detected and repeated as to allow an accurate perception of the moment ***t+2***, in which every pixel changes based on a transition rule as function of the neighbouring pixels as to form the ***t+2*** moment expressed as a land use map.

The importance of this known time reference was that of validation to allow a future projection of urban growth for 2020. As we could see, coastal areas of the Algarve have shown the largest increase of urban growth in last decades and tend to grow even further becoming most probably continuous artificial areas. The propensity map (Figure 32) for urban growth used the CORINE Land Cover data information for urban areas, proximity to road networks, population density per parish and proximity to coastal areas.

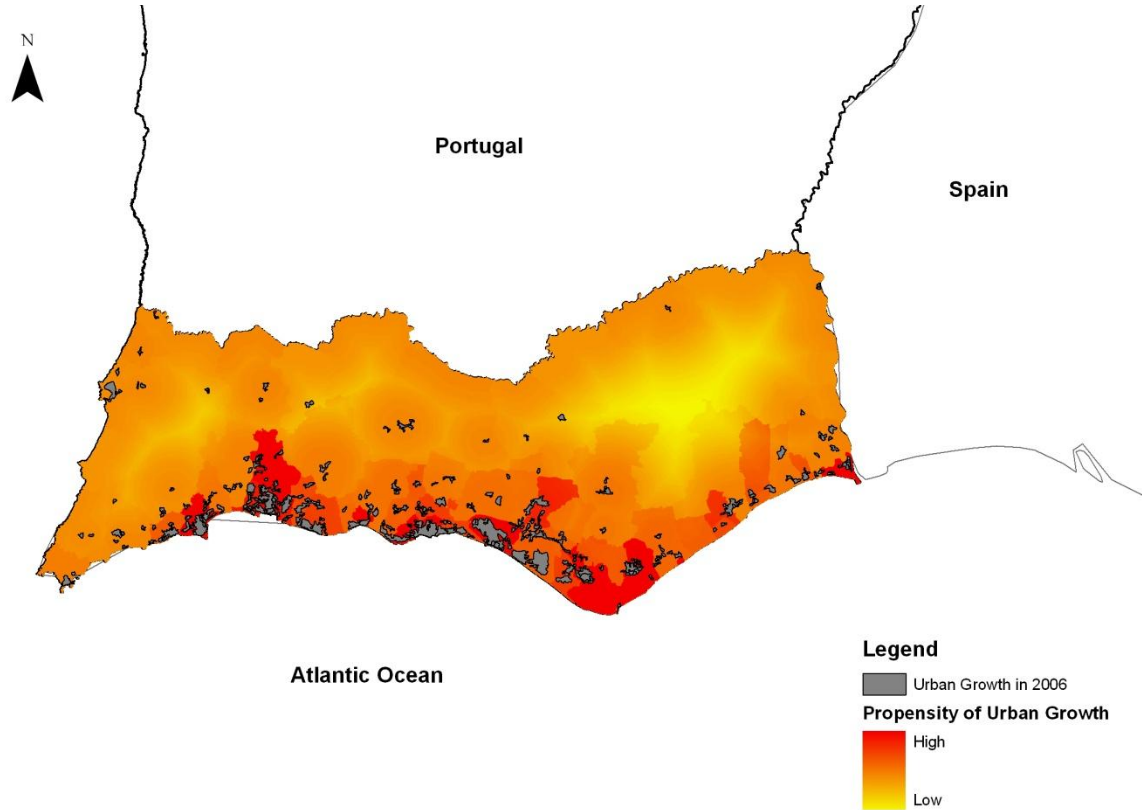


Figure 32– Propensity of Urban Growth Map and Urban Growth by 2006

Understanding of spatial dynamic models and urban growth scenarios is important and have been studied widely (Meaille and Wald 1990; Al-kheder and Shan 2005).

Urban growth in the Algarve started suddenly in the 1960s with the exploration of Tourist industry in this region. The Algarve expanded and its littoral cities became major foci of mass-tourism, especially during the summer season, due to its temperate climate and beach areas. The demand generated an increasing economic prosperity in the Algarve and are four decades later naturally taking its course. The Algarve has prospered due to this active industry and the coast line of the Algarve is in fact, one of the most expensive areas of Portugal for habitation and many large and expensive investments are found.

Population of the Algarve in winter is a tenth of the population in the summer season. One of the problems of the Hostel Industry in the Algarve has been to cope with the seasonality of the Tourist Industry which has much less activity during the winter time. Tourism, as such, has shown for the Algarve both, a symbiotic and antagonistic where antagonistic relationships are strongly linked to the rigidity of the supply in short-term compared to the elasticity of demand (Matias 2004).

The Algarve has specific fauna, flora and cultural characteristics, that make this region worthwhile of alternative for tourism opportunities that generate more symbiotic effects rather than the already existing antagonistic ones. The main problem lies in the re-qualification of existing urban tissue and the capacity to cope with a further landscape adequate urbanization of those areas. Also, new urban areas support the aggregation of previously existent urban tissues, leading to a continuous artificial land cover highly endangering the natural landscapes as well as the existent ecosystem. As consequence of this, small towns such as Olhão have become cities, where proximity to the districts capital Faro, transformed Olhão into a dormitory city. The consequence of this agglomeration generated a continuous urban area of circa 5 km reaching from Faro to Olhão. This continuous urban area, due to the proximity to the Natural Reserve and the existence of important cultural heritage resources, has in fact endangered valued patrimony. Monitoring and creation of prospective future scenarios is an important task to avoid similar situations in future.

Currently, ongoing regional policies, such as Programa Regional de Ocupação do Território do Algarve (PROTAL) protects some aspects of growth in the region. Still, it is important to understand urban growth in this region, as it has been modestly studied and if assessed correctly may help future environmental collapse by direct impact on strategic planning or sensitizing and creating social awareness.

8.5. Archaeological Predictive Model for the Algarve

Since 1970 an ongoing scientific debate regarding archaeological predictive modelling has existed. This debate has been accompanied by technological advances which led to possibilities of better understanding and predicting archaeological past. The initial models proposed strong statistical backgrounds (Savage 1990) mainly as a result of Archaeological *processualism*.

It is in the beginning of the 90s that APM reach ongoing discussions in an attempt to withdraw new conclusions. This pragmatic decade of Modelling, is marked by the fact in which Archaeologists become quite certain that Predictive Modelling may not only rely on correlations towards environmental factors, but also historic non- quantifiable data has an important meaning for prediction. As the main question is, if a specific location contains Archaeological vestiges, the argument becomes one of available theories of spatial distribution of archaeological material as well as empirical and historical observations of site records (Wheatley and Gillings 2002). It is in this scenario that disagreement occurs more often, as scientists do not agree yet on a common methodology and a general theory which entwines correlative and cognitive approaches. Nonetheless, in this spirit of controversy, deductive and inductive approaches for APM have risen over the past decades. The inductive Models are considered to be more spatially related, and as a consequence of empirical and analytical tools related to environmental variables. Deductive modelling focuses mainly on the available historical data leading towards a more cognitive nature. One of the classic inductive models has been Logistic Regression Models (LRM). LRM have been used since the 70's for Archaeological evaluation. Considered as a classical approach towards modelling (Kvamme 1991) those models present a lack of capability to understand anthropological change due to their simple stochastic methodologies (Sebastian and Judge 1988). The existent roman sites from a collection of site inventories were used as to allow a total of 370 Roman archaeological sites in the Algarve. Given the bibliographical support of topography, proximity to water (Brandt et al, 1992) and the importance of trading circuits in the Algarve area during the Roman period, these variables were combined with the location of archaeological findings from the same period. Thus, allowing the following relation:

$$A = D + f_1 B + f_2 C + f_i x \ldots + e \quad (5)$$

where A equals site density; B, C and x represent the independent variables considered; f_1, f_2 and f_i represent the weights for B, C and x respectively; D is a constant; and e is an error term. Thus, B and C represent independent variables in which the relationship to the sites is of utmost importance for our model and becomes the key for the parameterization of a propensity map, in which the different probabilities of finding a site in a given location may be assessed. Furthermore, geographical trades such as slope, hillshade, aspect and current land-cover as well as soil type were stochastically analysed by the dependency of the variables using Kolmogorov-Smirnov to test for statistical significance with results as follows (Table 7).

Table 7 – Results of Random / Not Random variables

Variable	**Dmax**	**D K-S**	**Dmax-D K-S**	**Relation**
Aspect	0.153	0.079	0.07	Not Random
Elevation	0.000	0.079	-0.08	Random
Hillshade	0.075	0.079	0.00	Random
Land use	0.005	0.079	-0.07	Random
Slope	0.849	0.079	0.77	Not Random
Soil	0.194	0.079	0.12	Not Random
River Distance	0.973	0.079	0.89	Not Random

While Random variables were discarded, Not Random variable allowed to draw the final equation with independent variable considered as: Aspect, Slope, Soil and River Distance. This resulted in the following propensity for finding archaeological sites, defined by the tendency of finding more Roman archaeological sites in the coastal regions, than in the interior (Figure 33). The settling patterns of the Romans in the Algarve are quite similar to the contemporary areas of city settlement, suggesting the expected secular construction of cities as in the past. Proximity to river basins and some regions of the interior in the Algarve, showed however to have additional importance.

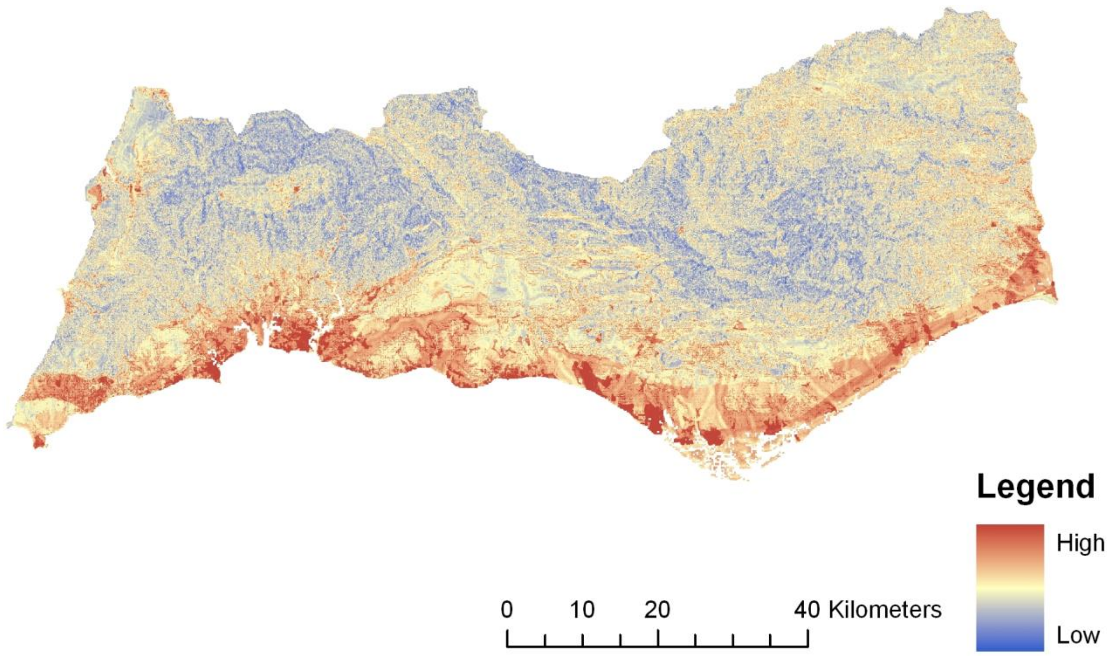


Figure 33– Archaeological Predictive Model for the Algarve

This Predictive Model consisted of a sensitivity analysis of low to high propensity of finding Roman archaeological sites. As proposed by Kvamme (1999) a jack-knife sample of 70 random Archaeological sites was left out of the model, as to test the effectiveness of predicting archaeological sites. Most sites were found within the 70 to 80% range, corresponding to a satisfactory result for archaeological site propensity.

Most archaeological sites are located in the perimeters of the larger city boundaries, suggesting a settling pattern in the Algarve since the Roman period. This relationship is consistent with the available historical resources, pointing out the location of the ancient Roman cities of *Ossonoba* in present days Faro, *Balsa* (Tavira), Esuris (Castro Marim), *Portus Hannibalis* (Portimão) among others. Surrounding those regions, the interior of the Algarve shares also a high propensity for Roman sites. These areas are of particular

Archaeological interest, and should be valued for scientific purposes to better understand Roman civilization in the Algarve.

8.6. Urban Cultural Endangerment - A Spatial Modelling Framework for the Algarve

The importance cultural assets lead to the construction of a model which compares urban growth with archaeological site propensity in the Algarve. Understanding these dynamics, permits a better decision process regarding: (i) preservation of archaeological sites from a cultural heritage perspective, (ii) proactively take measures on construction sites to cope with existing heritage, (iii) sensitize for archaeological heritage preservation while sharing the local information on existing heritage. The comparison of both models was achieved by the analysis of urban growth and archaeological heritage propensity (Table 2).

Resulting from the average mean of those propensities per municipality, the urban heritage endangered per municipality was exposed.

Table 8 – Urban Heritage Endangerment

Municipality	Urban Growth	Heritage	Average risk	UHE (%)	Pressure:
Lagoa	181	185	182.92	71.74	UG(1)
Olhão	182	166	174.23	68.33	UG(1)
Faro	185	157	171.16	67.12	UG(1)
Portimão	181	153	166.81	65.42	UG(1)
Albufeira	171	157	163.91	64.28	UG(1)
Vila Real de Santo António	156	150	153.11	60.04	UG(1)
Vila do Bispo	109	148	128.61	50.43	AH(2)
Loulé	121	125	122.96	48.22	AH(2)
Tavira	76	119	97.38	38.19	UG(1)
Castro Marim	93	141	117.43	46.05	AH(2)
Silves	108	120	114.35	44.84	AH(2)
Aljezur	100	115	107.35	42.10	AH(2)
São Brás de Alportel	104	104	104.22	40.87	UG(1)
Alcoutim	79	118	98.72	38.71	AH(2)
Monchique	92	95	93.38	36.62	AH(2)

The Municipalities with the highest probability of Urban Heritage Endangerment were identified as Lagoa (71,74%), Olhão (88,33%), Portimão (65,42%) and the districts capital of Faro (67.12%). All these municipalities represented also highest propensity for urban growth, identifying urban growth as a key pressure for Archaeological Heritage Endangerment.

The role of Archaeological Predictive Models is twofold: As the analysis of site location allows a better understanding of behavioural civilization patterns as proposed by traditional APM literature, nowadays, it has an important impact (and less explored) in the decision making process for sustainable development. In a region such as Portugal, where historico-cultural heritage is an important asset for the tourism industry, evaluation of site potential can create regions with specific niches for heritage tourism.

It has been shown that Predictive Archaeological Models may be important to understand spatial dynamics of the past. Not only in a historical context could they make sense, but mostly, the capability to predict accurately the location of Archaeological sites may help future technology to discover new findings as well as understanding behavioural patterns of past societies. There is much need for such work in an area such as Portugal where little of such work has been done although there is a vast historic and civilization background.

We may conclude generally, that the Romans in the Algarve had a similar preference to ours relating to spatial occupation, as the highest propensity of sites is in fact, in proximity to current urban areas. This characteristic concatenated to the fact of constant urban expansion and sprawl, justifies the need of the ongoing study. Urban growth has been a constant situation in the last decades. This is an eminent concern, and has been largely discussed in a European context. Regionally, the Algarve is suffering from this problem, and the continuous growth at the constant rate it has had in recent years, will quite quickly in the next 15 years endanger natural and artificial patrimony. One of the reasons which appear to be related to the urban growth areas in the Algarve is tourism. As urban areas with higher tourist activity are more rapidly expanding than others. As cultural heritage is a phenomena which may work as a tourist product by itself, it is up to stakeholders to allow a more sustainable development of further tourist growth having in mind cultural patrimony. It is clear that urban growth can't be hindered, and the tendency is for the creation of mega-cities. The question is then how can cosmopolitan areas be sustainable and conciliate fauna, flora and manmade patrimony simultaneously? This is indeed a challenge for the short future and may be a decisive step for future generations.

Monitoring in next years in the proposed areas may be a proactive approach for future preservation: As cities grow cultural heritage teams may become engaged as housing is planned, recovering archaeological sites and cataloguing this valuable patrimony considered to be "the most universally valued and most even distributed resource in the world". (Box, 1999). Also, the decision making process on where to build may become more accurate, as strategies such as the PROT (Plano Regional de Ordenamento do Território) exist. Until 2020, the urban landscape will change rapidly and cultural heritage may be jeopardized. The need for action is absolute and urgent to avoid future endangerment of the studied municipalities. Special care should be taken in the municipalities of Lagoa, Olhão and Albufeira that, due to a mix of existing archaeological vestiges and historico- cultural background as well as rapid growth seem to be mostly jeopardized. Olhão shows a very high propensity for cultural heritage and further excavations and ongoing research regarding this municipality should take place especially in the areas of imminent urban construction. Much work can still be done regarding both studied dimensions. Regarding Archaeological Predictive Modelling, it has been shown that albeit divergences from the scientific community they are an important tool which may be used in a regional context. Thus, new methodologies that intertwine the doubts of the scientific community are of much importance. As APM become more accurate avoiding the problem of accuracy and consistency (Berman, 2006), urban growth models have to be better understood. Using GIS for UGM is a mandatory direction for future urban planning and predicting the scenarios in such a context is very important. Analysing urban growth with CORINE Land Cover seems to be a sound direction, as it is the actual European spatial data inventory that shows the scenarios for an entire European tendency of growth. Still, the Minimum Mapping Unit of the CORINE Land Cover as we have seen is quite large, and as a result, it would be an interesting opportunity to in future study how accurate CORINE Land Cover may become or actually is in an urban growth study context.

The future is indeed a question of European and regional synergies in an attempt to inform as well as create knowledge. The Transversal areas called for in such venture, share a common ground in the usage of IT and GIS to shed directions of monitoring and sustainable planning. Above all, this work has made us realize, that the most important future step for sustainability is the need to work together and think together in the attempt to grasp new processes and ideas which may create mainly more accuracy on proposed methodologies in the hope of sustainable preservation and growth.

Chapter 9 - Historico-cultural Sustainability and Urban Dynamics: A Geo-Information Science Approach

9.1. Abstract

Interest in cultural heritage is on a rising curve in Europe. In particular, in the EU, an increasing tension can be observed between a common European economic and social ideology and the presence of a local or national cultural identity which is often heterogeneous and originates from different historical periods. Against this background, rapid urban development (for instance, related to mass tourism or leisure time behaviour) is having far-reaching and severe implications for the varied natural and historical landscapes which are part of the identity of each individual nation or locality. Challenges in understanding such different environmental changes (rise in urban land use, loss in biodiversity, environmental degradation and pollution) are currently prompting much policy and research interest in Europe. The recognition of such prominent landscape changes has specific spatial dimensions which may be assessed from the perspective of pro-active preservation in favour of sustainable development. In this context Geographic Information Systems (GIS) can play a key role because they offer the possibility to map out and understand the above-mentioned changing patterns more accurately.

This paper is an attempt to understand and analyse the threats to the Algarve’s cultural heritage due to the quickly changing environment as a result of mass tourism and rapid urban growth. The paper shows how GIS and spatial analysis may provide a better understanding of pro-active policy initiatives and measures aiming at landscape

protection and help to identify which strategies are currently available for the assessment of historico-cultural sustainability. By using different land use maps provided by the CORINE Land Cover study, we aim to interpret statistical and temporal changes in land use in the Algarve area and to understand how they relate to prior conditions. This study is undertaken using linear regression and statistical inference methods, as well as simple Markovian urban growth models aided by Cellular Automata transition rules.

As a case study, the Portuguese area of Faro-Olhão is assessed with a view to: (i) a better understanding of the underlying urban growth trends; and (ii) the design of analytical tools to cope with the current jeopardy of environmental and socio-cultural heritage regions in this area. Our analysis attempts to shed more light on the effectiveness of local and regional policies that are being formulated in line with a common European framework in which a more sustainable cultural environment is advocated, while recognizing that cities will inevitably continue to grow. In summary, the paper outlines the foci of sustainability challenges that must be faced by the Algarve and indicates how stakeholders can actively be engaged in sustainability policies.

9.2. Dynamic Urban Spaces and their Historico-cultural Heritage

Over the past decades, the history of human geography in many countries has shown a tendency towards more urban patterns of living accompanied by an extension of people's action radius. Urbanization has become a worldwide phenomenon. This is exemplified in Europe, with an average urbanization rate of 70 to 80 %. We observe not only a rise in 'urbanity', seen from the perspective of urban or metropolitan population densities, but also new tendencies towards more distant suburbanization or de-urbanization patterns.

Even rural areas are increasingly being turned into accessible areas that are well connected to urban centres and also display urban lifestyles. ‘Accessibility’ and ‘mobility’ are key words in a modern dynamic space-economy, not only at intraregional scales but also at interregional and even international scales.

The dynamics in settlement and mobility patterns is prompting a wide array of research and policy questions on socio-economic equity, spatial disparities, growth differentials and sustainable development. Nowadays, many cities and regions exhibit a tension between competitive growth strategies and sustainable community strategies (e.g. environmentally-benign initiatives, preservation of socio-cultural heritage). Consequently, in various countries, cities and regions have currently become battlefields between growth advocates and conservationists. As well as being global command and control centres (Sassen 1998), urban spaces appear to be concentrations of ecologically- and historically-valuable assets which reflect a memorable past.

The socio-economic, political-geographic and cultural-scientific history of the dynamics of places and localities on our earth is reflected in their historico-cultural heritage. This patrimony comprises cultural assets, such as old churches, palaces, museums, urban parks, historical architecture of cities, or landscapes of historical interest. Historico-cultural heritage also includes archaeological sites, which sometimes not only have a local value but may have a worldwide significance (e.g. Pompeii). All these assets mirror the rich history of a city or region and are a permanent source of scientific and cultural inspiration for researchers, planners, and the public at large. This ongoing interest in socio-cultural heritage originates from two sources: (i) a society in motion is prompted to ask new questions about its past in order to better understand the choices to be made concerning its future pathways; (ii) the progress in scientific research and in research techniques (e.g. infrared technology) allows researchers to investigate cultural assets in a different way that often leads to novel findings.

These developments have also generated new departures for research in the cultural and archaeological sciences, as is witnessed by the following quotation: "*Archaeology has traditionally possessed strong conceptual divides between data collection and data analysis, manifested most obviously between excavation and post-excavation activities*" (Conolly and Lake 2006). Actually, the emphasis in modern archaeology is not so much on excavation and material reconstruction of a historico-cultural asset, but increasingly on data analysis using GIS and spatial modelling techniques (Renfrew and Bahn 2004). Exploratory research is increasingly giving way to contextual and explanatory modes of research based on advanced data analysis. For example, the geographic identification of the position of observation towers on the walls of ancient cities or the search for vestiges of carbonized animal bones ('blue collar research') is nowadays followed by massive data analysis linking these findings to research outcomes elsewhere ('white collar research'). These changes in research style call for creative modes of new analytical investigation. In this context, Schiffer (2004) argues: "*Human behaviour consists of activities, which can be aggregated by the investigator to create analytic unities at many scales. Virtually every activity consists of interactions among people and one or more technologies. Along with technologies for procuring raw materials and preparing food,* *there are, for example, religious, social, recreational and political technologies, which enable people to interact with plants and animals, other people, and, as Walker (2001) has pointed out, even supernatural entities.*" Thus, research on historico-cultural assets in an urbanized society is increasingly characterized by modern digital data analysis.

The present paper will address research and policy issues on sustainable development in the Algarve region, Portugal. This area used to be a peripheral natural area with rich flora and fauna, but in recent decades its pleasant climate has attracted massive flows of foreign tourists, to the extent that the entire coastal zone of the Algarve shows clear signs of being an urbanized environment. This new development may endanger the historical and natural character of the areas whose cultural assets date back to the period of the Phoenicians, Romans and Moors. Its unique physical geography has led to a specific environmental, agricultural, architectural and social constellation whose roots can be found in the Neolithic period. The socio-historical complexity of this area calls for sophisticated research methods in order to unravel the location and functions of different civilizations, their cultural complexity, and their local identity. The research for our Algarve case study has three characteristics:

Strategic: identification of geographic patterns and historic remains to trace the historic patrimony of this area;

Scientific: use of modern GIS and satellite information complemented with cellular automata approaches to better map out and examine historical and modern artefacts;

Human-historical: tracing the behavioural and social interaction patterns of ancient civilizations in connection with modern development in the area.

The tools used in our research are: Database design and conversion into *shapefiles* using DB4; Spatial analysis in combination with GIS technology (ArcMap®); Topographical reference using ortho-photomaps from satellite information including archaeological data (see Westcott and Brandon 2000). Clearly, the use of geo-information science tools is a prerequisite for sophisticated applied research on the history and the present situation of the area concerned. As Gillings and Goodrick (1996) put it: "*GIS is increasingly being seen as much as a place to think as a simple data management and mapping tool.*"

Our paper is organized as follows. Section 1 explains the importance of understanding the dynamics of change in urban spaces and the need to develop sustainable policies while preserving the historico-cultural heritage. Next, Section 2 discusses the recent possibilities of geo-science and their diverse capabilities of coping accurately with regional management. In Section 3, we describe recent technological developments in GIS that can lead to a better understanding of the usefulness of Cellular Automata and spatial data analysis as research tools for dealing with spatial sustainability. Section 4 will then describe the Algarve as a laboratory of interesting possibilities for analysing cultural heritage ventures in a European context in combination with the application of GIS technology. On the basis of GIS data, we next develop a scenario of urban growth in the Faro-Olhão area in the Algarve, recognizing the current state of endangerment with a practical emphasis on the possibilities of GIS analysis and cognition. Finally, we will outline future directions and challenges of GIS as a toolbox for monitoring urban growth from a spatial and cultural resource perspective.

9.3. Geo-science Tools

GIS technology was originally developed as a set of sophisticated digital mapping tools, but has gradually moved into a real scientific discipline, viz. geo-science, which forms an integrated set of ICT-based methods and tools (including satellite information, remote sensing, cellular automata) which lies at the heart of modern detailed spatial and dynamic analysis of objects of all kinds (see, e.g., Clarke and Hoppens 1997, Engelen et al. 1999). Its user-friendliness and polyvalence makes geo-science an appropriate methodology for a wide variety of dynamic spatial analyses, e.g. objects in urban planning, traffic management, archaeological investigations, architecture and cultural heritage (see, e.g., Wheatley and Gillings 2002, Conolly and Lake 2006). Geo-science has derived its current popularity not only from its advanced representational possibilities in space and time, but also – and in particular – from its high predictive potential (see, e.g., Syphard et al. 2004, Al-Kheder and Shan 2005, Cabral 2006). This also holds for cultural heritage and archaeological site management (see, e.g., Sebastian and Judge 1988, Kvamme 1999, Warren and Asch 2000, Ebert 2004, Verhagen 2007, Box 2005, Pontius and Chen 2006).

Since the Malta Convention on the management of cultural heritage resources, geo-science has assumed a prominent position in presenting, mapping and analysing cultural and archaeological assets, a tendency which in recent years has in fact been strengthened as a result of the policy need for sustainable local development. The overall idea is that cultural assets should not lose their scientific relevance in the case of urban or infrastructural development, so a balance has be to found between archaeological or historico-cultural interest, on the one hand, and socio-economic and spatial development on the other, an intention also clearly outlined in the Valetta Treaty. The use of satellite information, in order to uncover spatial land-use and land-cover, has proven to be extremely fruitful for our in-depth analysis of the problems concerned here. The technologies involved are manifold and include such applications as Landsat, Thematic Mapper, SPOT or Corona. The various applications were summarized by Montufo (1997) as follows: "*The results obtained by using satellite imagery for a survey of ancient rural land-use patterns are highly dependent on three factors:*

The existence of the remains for former land-use patterns in the study area.

The existence of other patterns that can be confused with ancient land use patterns.

The ability of the system to record and discriminate between patterns."

The usage of satellite imagery for GIS is evident. Satellite imagery is of extreme importance to help locate and understand the dynamics of land use/land cover, as well as to represent and have a clear and as sharp as possible notion of space and morphological surroundings. Hence, one could consider satellite images as the principal asset used in a GIS for spatial understanding and relevant spatial analysis that can provide support for later decision making. Thus, Remote Sensing in Archaeology anchors itself in the very essence and usage of GIS in archaeology – it can be used either for research, to answer questions regarding past human activity or for management, to support in a proactive way decision making and cultural heritage preservation. "*It is generally recognized that the increasingly intensive use and modification of the landscape resulting from modern* *demands for efficient infrastructure and land use (agricultural production, mining, energy sources, leisure/tourism facilities) exerts growing pressure on cultural heritage in the landscape*" (Grøn and Loska 2002).

Satellite monitoring for cultural heritage management is an important issue that has been a very important tool in a rapidly changing world, helping better and more sustainable governance. "*Satellite images are an excellent tool to monitor change in large natural and/or cultural sites*" (Hernandez 2002), in which the quick perception of the ongoing reality and the state of the site can easily be assessed at low cost and with no specific restrictions or boundaries. Hence, size and limit of observations do not depend as much on politics, but rather on scientific intuition. Not only does satellite imagery represent a tool that on a periodic basis can monitor any change and occurrence but it can also be seen as a data set that allows predictive modelling which may be an asset for regional and local planning. The advantages of Satellite Remote Sensing can be synthesized as follows (Hernandez 2002):

It offers a valuable tool to assist conservation activities;

All information is exactly localized and gathered in one tool;

Information can be updated continuously;

Better decision making by spatial analysis;

Possibility of direct extraction of topographic and thematic maps for use on the actual terrain.

The 'Cultural Cycle', as explained by the Department for Culture, Media and Sports of the United Kingdom (http:www.culture.gov.uk/NR/rdonlyres/50E5EC89=7A5E-4B33-8CFA), can very well be adapted to the circumstances of monitoring cultural heritage via remote sensing satellite imagery. The Cultural Cycle has 6 key dimensions of action: Creation; Making; Dissemination; Exhibition/Reception; Archiving/Preservation; and Education/Understanding. Satellite Remote Sensing, used to monitor cultural heritage, can have an impact on the last three dimensions, in which the objectives could be understood as follows:

Reception: reception of the satellite data with cultural heritage information for analysis;
Archiving/Preservation: importing results of imagery in a GIS, Land cover/Land use analysis to monitor change and actively preserve;
Education/Understanding: dissemination of results to create social awareness of the importance of cultural identity.

The importance of monitoring cultural heritage sites with satellite imagery is crucial, as it is a form of understanding ongoing change and has a direct impact on preservation issues, which is so important in a very quickly changing world. Thus, strategies can be taken more reliably and more systematically. Remote sensing via satellites and its growing technology is a tool for change.

It is clear that quite substantial investments are required for cultural heritage and archaeological research in urban areas. As such, the available database is no more than a mere reference of what originally might have existed in a given area. The gap between the originally existing sites and the currently identified ones may change (Joukowsky 1980). One of the most interesting possibilities in Cultural Resource Management in a GIS context is after all the capacity to predict change or dynamic behaviour given a set of rules or parameters. In this sense, predictive modelling is of extreme importance and should be largely used to facilitate the stakeholders' decision making process, and has great potential as a tool for archaeologists working in cultural resource management (Hill et al. 2007).

9.4. Cellular Automata, GIS and Cultural Heritage: Methodological Challenges

The human need to understand the environment has always been a constant in the endeavour to gather knowledge. Since the dawn of history, human beings' aspiration to go beyond the common-sense rules to understand patterns and interactions has brought them the capability to survive. Not only has population adapted to nature, but discovering technology has amazingly quickly developed it in such a way, so as to gradually allow the construction of a new kind of nature: that of virtual reality and the era of the machines. The origin of this new system is no more than yet another of the ongoing reflexes of nature, and can be described according to Ludwig Von Bertalanffy's 'General System Theory': "*There exist models, principles, and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements, and the relationships or 'forces' between them. It seems legitimate to ask for a theory, not of systems of a more or less special kind, but of universal principles applying to systems in general."* (Von Bertalanffy 1950). Intrinsically, this statement calls out for a convergence of different areas, sculpting a new kind of science that finds its roots in biology, physics, geography, sociology, and many other areas, that together have contributed to the construction and fundamental notions of Systems Theory.

In fact, a system can be defined as an ongoing interaction of reciprocal influences between different agents (Legrand 1991). It becomes quite obvious that with the existing advances of technology and computer aided processes, these agents can be *virtually* represented, and their 'behaviour' specified by a set of variables in such a way that one can create behaviourist non-linear approaches to estimate and predict patterns in an in vitro environment in the computer. In any recreation of any agent that simulates behaviour, time is a crucial variable that deals precisely with the dynamics of change of the agent in a temporal context. Thus, the models that allow the creation of such agents and the context that allows their patterns to be studied must be a consequence of what are called dynamic models, in which the temporal factor represents a crucial factor to allow the study of the dynamic and its motion. Hence, Agent-Based Models are the logical step to combine dynamic models with intuitive agents that relying on a set of variables allow predictive behaviour. These specific kinds of models have their branches in areas of the computational sciences and find a vast utility in many related areas. As they are capable of reflecting quite clearly the behaviour of groups and biological variables, they have been used quite extensively in the social sciences. After all, in these circumstances *"computers offer a solution to the problem of incorporating heterogeneous actors and environments, and nonlinear relationships (or effects)"* (Lansing 2002).

One of the sub-forms of exploring and modelling these systems that evolved as the consequence of understanding these agents was Von Neumann’s first cellular automata. Cellular Automata (CA) are discrete mathematical models that consist of a grid of cells that allow interaction of variables within the designated system, involving the variable time, thus representing a dynamic system in which patterns of behaviour may be observed. The applications of CA are manifold and are often used in any area which studies a system that is inherently dynamic and wants to predict a set of behaviours given a number of rules with a temporal basis. Because of their intrinsic nature (a grid-based system with a specific number of cells) they are quite adaptable to a Geographical Information System (GIS) environment. Given the necessary software and programming experience or attachable models, one can adapt CA easily to the context of a GIS and do predictive multi-temporal dynamics of change on a spatial basis.

An important task of GIS is to monitor ecological change, in order to make a direct impact on change and sustainability. The combination of GIS with CA allows change of land use to be precisely tracked and assessed and may be an important guide for regional policies and stakeholders. In this sense, one of the important uses of CA in a GIS context is the possibility to measure and predict urban growth in a given area. This context is not new, as it had originally become important in the 1960s (Wilson 1974). But, it is with the development of computer hardware and software that CA has finally provided the possibility of giving reliable results that can also explain dynamics visually, if interpreted in a GIS. Although it is obvious that urban growth and increase of land use cover is inevitable, nevertheless, the analysis and interpretation of results can have a direct impact on how best such change can be oriented. CA must be seen in this context as a positive tool for monitoring dynamics towards firm results which can answer a question such as "What if urban growth continues to evolve under unchangeable conditions?" This simple question and its complex answer may be assessed with Urban Growth CA and is a step towards the preservation of fauna, flora and cultural heritage resources. Artificial areas, like cities, will continue growing, but perhaps with the help of technology in a more humane and sustainable form.

9.5. Algarve: A GIS Laboratory for Cultural Heritage

The Algarve is a region with heterogeneous morphology, which can be divided into three distinct areas: littoral (the coastline of the Algarve, which as a result of the rise of the tourist industry since the 1960s has largely been transformed into a number of medium-sized urban areas); barrocal (the central area of the Algarve, often related to agriculture); and the interior (composed of mountains that separate the Algarve from the rest of Portugal to the North).

Rapid urban growth took place in the Algarve from the mid-1960s with the explosion of the mass tourism industry in the area. At that time, the bewildering choice of tourist activities immediately endangered important natural and cultural assets, which consequently deprived the Algarve of some of its once natural charm, transforming the littoral areas into landscapes of bricks and mortar. This new landscape, characterized by hotels, towering over a once ecological scenario is still visible today, as tall buildings extend along the shores of the Atlantic Ocean.

While the tourist industry continues to flourish in the Algarve area, many important ecological topographic characteristics were lost forever in the chaotic 1960s and 1970s that the Algarve experienced. Now, almost 40 years later, in an integrated European context where sustainability has become an important issue, stakeholders are trying as best they can to manage the still important ecological and cultural assets in order to preserve the important landscape characteristics that have made the Algarve special since the time of the Phoenicians. A good example of this endeavour is PROTAL (Programa Regional de Ocupação do Território do Algarve – Regional Programme of Territorial Occupation in the Algarve), which was reviewed in 2006. This programme is in effect a manifesto of the willingness to provide sustainable land use organization and its needs in this region.

Europe's natural tendency of population growth threatens a dire scenario for small regions such as the Algarve: as much as initiatives such as PROTAL may try, urban growth is an unavoidable consequence, and sustainability has to cope further with larger and more complex urban sprawl which, if not monitored accordingly, obviously jeopardizes the landscape.

This seems to be the case in the vicinity of the Algarve's district capital, the city of Faro, which, with a population of slightly over 58,000 according to CENSUS 2001, experienced a total tourist population for the municipality of Faro of 204344 individuals (INE, 2006), that is, an increase of 3.5 times during its summer months. Even though tourism may be beneficial for the region's growth and has proved to be the main source of employment, if it is not correctly managed such a seasonal swelling of population may be detrimental for sustainable development.

Furthermore, not only seasonality but also employment opportunities are contributing directly to city growth, and this may clearly be seen on the periphery of the district capital Faro. An example of such growth is the city of Olhão, just 5 km from Faro, which is increasingly becoming the capital's dormitory city, as a result of more affordable prices as well as recent building opportunities.

This, as well as easy access to Faro and other important cities such as Portimão, Albufeira and Vila Real de Santo António, have made Olhão a booming city which is extending mainly along the main roads on Faro's periphery. GIS tools and spatial data inventories such as CORINE Land Cover may be important tools to analyse with some accuracy the urban growth phenomena, as data inventories reveal with CORINE Land Cover 90 and CORINE Land Cover 2000 the important dates of growth between Faro and Olhão, which may be dynamically assessed because of the existence of two distinct moments in time.

Homer's *Odyssey* is proof that his Heroes already knew the west of the Mediterranean (Maia, 1987). "*But the other cliff, thou wilt note, Odysseus, is lower – they are close to each other; thou couldst even shoot an arrow across – and on it is a great fig tree with rich foliage, but beneath this divine Charybdis sucks down the black water*" (*Odyssey* XII, 102). This unique region, extending over almost half of the Iberian Peninsula from as far as the southern lands of the river Tagus to Spanish Andalusia, was settled by many civilizations.

The region of the Algarve belonged to the Tartessos region, and was described by the geographer Strabo (63 BC – 24 AD, in his renowned work *Geographica,* which gives an accurate historical and social description of the Ancient World. The existence of different civilizations is manifold and archaeological evidence remains from as early as the times of the Celts (Maia, 1987) as well as abundant Palaeolithic remains, are visible (Veiga, 1887). During the Roman occupation, Augustus redrew the administrative boundaries in the first century, and the region became a part of the province of Lusitania. It was only much later, at the beginning of the 12th century that Lusitania became segmented into a number of different provinces. One of those provinces was the Al-Garb, a name from the Moorish, meaning "The Occident". Later, in 1250 the Al-Garb province was conquered by the Christians and became the region of the Algarbe and was incorporated in the sovereignty of Portugal. The heterogeneous morphology of the present-day Algarve was quite similar in the times of the ancient Algarve. "*Turdetanium is a prosperous country with all kinds of products and in large quantity. This richness is doubled by exports. The existing estuaries serve as routes of transportation which is carried out by tiny boats that enable the connections from the river deltas to the open sea. The abundance of rivers and estuaries makes almost the entire region navigable.*" (Strabo, *Hispania Antiquae,* III).
Strabo also gives us a clear idea of the inhabitants' behaviour in Roman times, mentioning also some of the major cities at that time: "*The inhabitants built their cities with great proximity to their rivers and estuaries. Those cities are Asta, Nabrissa, Onuba,*

Ossonoba, Mainoba and a few others. The existing channels that connect those cities also ease the already abundant commerce. Commerce is carried out with the entire Italy and Rome being quite accessible by boat." (Strabo, *Hispania Antiquae*, III).

The city of Faro, formerly known as Ossonoba, dates back to the 4th century BC. Regarding Ossonoba, in the last 100 years an archaeological debate has taken place concerning its exact location. No one knows for sure whether this ancient city was located on the existing urban area of Faro or rather, on the outskirts of the current city.
This dilemma deserves special attention from the archaeological and scientific community, as Ossonoba with already pre-Roman influence became the capital of the Roman *civitas* (vast Roman administrative region). This rich multicultural background of the Algarve, as a heterogeneous region of the Mediterranean, bestows on it a richness of cultural heritage, intertwined with Phoenician, Roman, Moorish and early Christian archaeological history.

The region as a whole, with its multi-cultural identity, has in itself become a very interesting study: European policies and urban growth characteristics apply easily, and its cultural heritage is a very visible attraction which should be protected actively as otherwise it may be endangered.

9.6. Foci of Algarve Sustainability Challenges

9.6.1. Introduction

Nowadays the Algarve area faces many sustainability challenges, which call for solid GIS-based research. The literature (Clarke and Hoppens 1997, Syphard 2004, Al-Kheder 2005, Cabral 2006) strongly recommends the usage of Euclidian distance factors (urban proximity, road proximity), as well as morphological characteristics (slope, land use) for predicting urban growth which is stochastically assessed. As tourism seems to be a key growth factor in the Algarve region, distance from the International Airport of Faro was taken into account, as well as proximity to the University campus. Social leverage was analysed using CENSUS data per parish (*freguesia*).

Table 9 illustrates the data inventories used for the creation of our urban growth model. It is this combination of different important geographic inputs that will enable an accurate assessment of urban change in the studied area. Road information was digitized from the Portuguese Digital Map at 1:500000 and georeferenced as polyline shapefile layers in ArcGIS.

Figure 34 explains the overall methodological process used, showing that the multiple data chosen for urban growth assessment will constitute our suitability map that, with linear information of growth change between CLC90 and CLC2000, will lead us to a first estimation of urban growth towards a known temporal frame: the year 2008. This prediction is done using Cellular Automata iterations based on a Markovian transition matrix as will be explained later. Should the projection for 2008 prove to be accurate, assemblage of data will allow estimation for 2038. We will next in Subsection 5.2 describe the underlying database for our study.

Table 9 - Data chosen for urban growth model

Data Layer	Source	Original Projection	Used for
ENVIRONMENTAL DATA			
Algarve DEM 90m resolution	SRTM (Shuttle Radar Topography Mission - NASA)	UTM	For creation of slope
Slope	SRTM (secondary data)	Lisbon Hayford-Gauss	Significant Layer for APM
Portuguese Administrative Chart	Portuguese Geographic Institute	Lisbon Hayford-Gauss	Definition of Municipality and *Freguesias* Boundaries
Land Use for Portugal	Requested from Portuguese Environmental Institute, belonging to CORINE Land Cover 90 and 2000 Project.	Lisbon Hayford-Gauss	Significant Layer to understand land use / land change between CLC90 and CLC2000
Roads	Digitized on screen from Carta de Portugal Digital 1:500000 scale – Portuguese Geographic Institute	Lisbon Hayford-Gauss	Road distance is critically analysed as an important factor for network proximity between Faro and Olhão
SOCIAL DATA			
CENSUS 1991 and CENSUS 2001	National Institute of Statistics (INE)	No Projection	Used to balance weight factors among *freguesias* and tendencies of growth

9.6.2. Spatial Data Inventories and Urban Growth

The CORINE (Coordination of Information on the Environment) Land Cover (LC) project started on 27th June, 1985 as a programme that would address the following issues: 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).

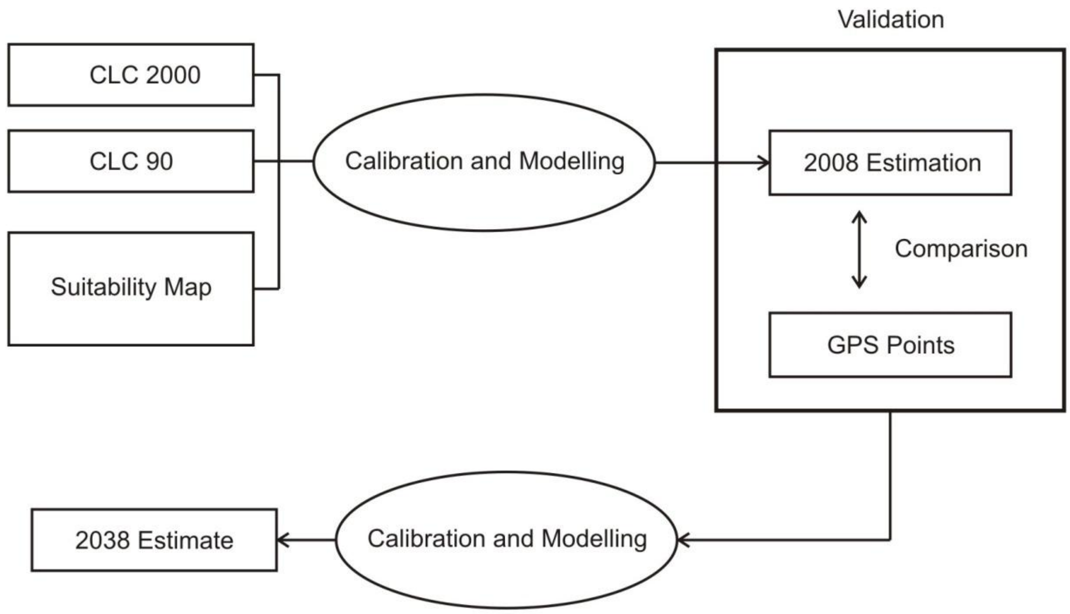


Figure 34 - Methodological approach for projecting urban growth prospecting

In this sense, CLC can be summarized as *"an experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community"* (Official Journal L 176, 6.7.1985) (EEA). With the mapping of CLC2000, besides the already manifold usage of CLC, we have the advantage of assessing two distinct moments in time and, thus, an evaluation of changes in landscape and land use can be obtained by the analysis of multi-temporal images (Prol-Ledesma et al. 2002). Following the very important notion that dynamic modelling needs time-based support and that CLC usage was a standardized opportunity to assess change, we could not think of a more convenient method of assessing the change of urban areas than comparing the urban areas of Faro-Olhão in the CLC90 with the CLC2000 series. CORINE Land Cover has a general nomenclature which can be divided into five distinct types, namely: Urban, Agriculture, Forest, Wetlands, and Water bodies. All of these five types are present in the Algarve area. Creating a cross-tabulation matrix for both CLCs, we could compare CORINE Land Cover 90 and CORINE Land Cover 2000 at a glance, and understand the possible changes within both time frames. From this comparison we drew the following conclusions:

(1) Most of the agricultural areas have changed to urban areas;

(2) A lesser quantity of forest areas have changed to urban areas;

(3) Some forest areas have changed to agriculture areas;

(4) A few agriculture areas have changed to forest.

Therefore, the matrix results indicate some clear and simple conclusions which are considered quite typical in an actual environmental context: urban areas expand on man-made soils, while unploughed land becomes ploughed and normally changes from Forest to Agricultural. Agricultural changes to Forest may be related to abandonment or to governmental incentives for Forest preservation. As no such incentives were planned for the Algarve region, the most probable reason for the change is related to agricultural abandonment. This information is of crucial significance to support a linear notion of urban growth tendency. It is this tendency that will manifest itself as a propensity of change which can be applied as a rule for our urban growth. Table 10 shows a cross-tabulation matrix for assessing changes in the different land-use classes between CLC90 and CLC2000 (the columns represent CLC90, while the rows represent CLC2000).

Table 10 - Cross-tabulation matrix between CLC90 and CLC2000

	Urban	Agricultural	Forest	Wetlands	Water bodies	Land use Change
Urban	100.00	1.07	0.29	0.10	0.00	1.46 %
Agricultural	0.00	98.69	0.85	0.00	0.00	0.85 %
Forest	0.00	0.15	97.87	0.00	2.58	2.73 %
Wetlands	0.00	0.09	0.39	99.90	1.25	1.73 %
Water bodies	0.00	0.00	0.59	0.00	96.17	0.59 %

On the other hand, Table 11 suggests the possibilities of conditional change to different land use types based on Markovian transition rules for an 8-year estimate, which allows us to estimate how much will be changed in 2008.

Table 11 - Markovian Transition Probability Matrix

	Urban	Agricultural	Forest	Wetlands	Water bodies
Urban	85.00%	3.75%	3.75%	3.75%	3.75%
Agricultural	13.21%	83.89%	1.79%	1.11%	0.00%
Forest	2.28%	6.75%	83.19 %	3.10%	4.67%
Wetlands	15.08%	0.00%	0.00%	84.92%	0.00%
Water bodies	0.00%	0.00%	12.31 %	5.94%	81.75%

9.7. Urban Growth Trends for the Faro-Olhão Area

A suitability map may be understood, as a consequence of present spatial interpretation, to recognize possible future land use scenarios. An initial rehearsal regarding urban growth tendencies was done by generating a comparison of CLC90 and CLC2000 with respect to urban growth change which allowed us to assess the existing growth for the area linearly. The insertion of further variables, such as recovered population data, distance weights to roads, urban centres, as well as international airport distance and university location, prove to be key economic drivers for future urban growth in the Algarve region. This may be seen in Figure 35, where a suitability map results from the selection of the variables and consequently, the addition of the different layers, arriving at a conclusion about the propensity for urban growth in the studied area.

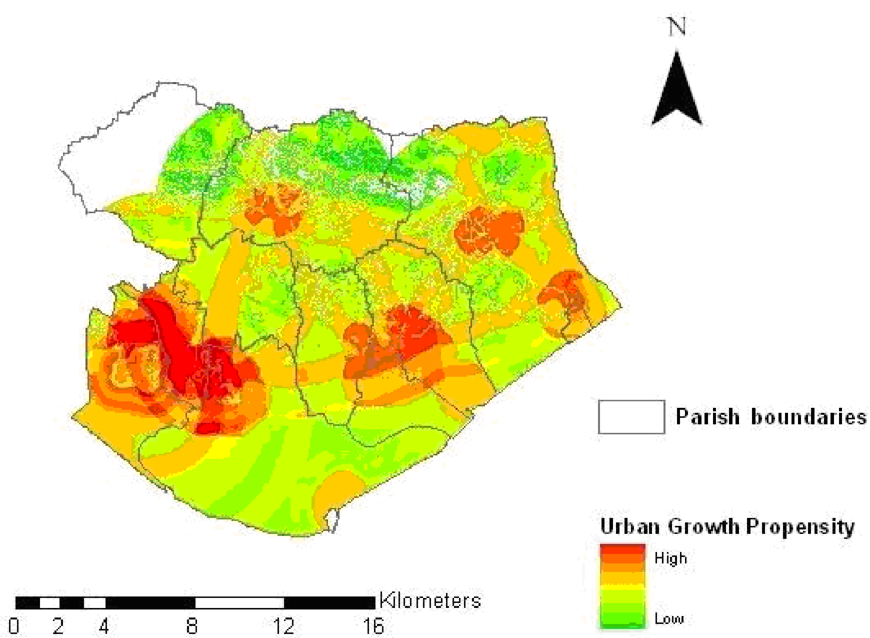


Figure 35- Suitability map for urban growth

This weighted and normalized information, as shown in Annex 1, allowed us to create a suitability map for the most probable urban growth tendencies in the forthcoming years. It is thus an example of prospective planning regarding existing urban growth, anticipating, as well as coping with, the natural tendencies of important factors that govern urban sprawl.

It can be clearly seen that a tendency for further growth around the periphery of Faro is likely to happen. As CENSUS data have pointed out, the most probable districts of further growth are on the outskirts of the district capital. In recent decades, proximity to the National Road 125 and to the University of the Algarve campus has been shown to be important factors for continuing urban growth. The overall trend appears to be a continuing growth of Faro-Olhão, as well as the possible growth of other urban nuclei such as Estoi and Quelfes. Using IDRISI as a software tool with easily usable Cellular Automata (CA), linear CORINE Land Cover cognition, and the calculated suitability map will all allow us to assess the tendency of urban growth more accurately and thus understand the necessity for commitment towards the preservation of the cultural landscape which may occur in the near future.

Clark Labs – IDRISI comprises the perfect tool for accurate assessment for CA. CA transition rules are related to a set of possibilities constituted by iterations of Markovian probability matrixes (if the CA_Markov module is used, as is the case in our study). The advantages of using Markovian probability matrixes related to CA mainly concern the possibility of measuring different land use changes that are supported in the initially generated matrix. This is a considerable advantage, as it shows the capacity of these matrixes to cope with different kinds of land use trends and their transformation.

Four important principles will allow cells to iterate, thus originating a CA. These principles (Batty, 2007) create the concept of a CA for our region of study. Firstly, the land use of the region of the Algarve is represented in raster format with a specific dimension of equally seized cells that relate to others by a given proximity or adjacency. Secondly, our cells can only take one state at a time, that is, one cell can only change into urban, agricultural, wetlands or water bodies and never into two of the classes simultaneously. Thirdly, changes in a cell depend on the existing *neighbourhood* of the particular cell, influenced by our fourth condition, the propensity to change previously calculated on our suitability map. The basic cell thus relates to its local *neighbourhood* and gains a spatial dimension which may be perfectly adequate for land use prediction and urban growth. An example of CA neighbourhoods may be observed in Figure 36.

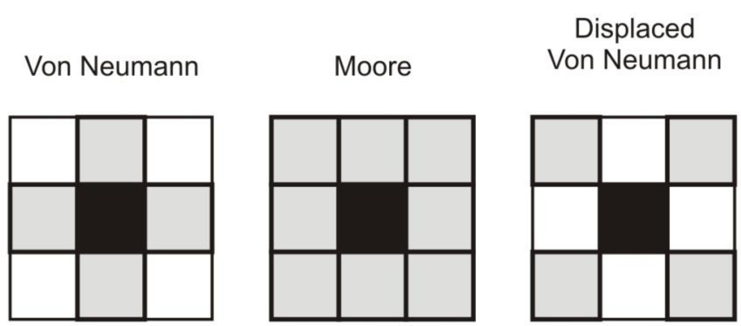


Figure 36 - Example of Cellular Automata Neighbourhoods

Our urban growth model forecasts urban growth based on CLC90 and CLC00 information for two distinct time frames: 2008 and 2038. The reason for projecting the 2008 land use is related to the importance of validating the assumptions and choice of variables in our initial input. In this sense, two hypotheses occur: (i) our model shows enough accuracy and we are thus prompted to model the 2038 land use situation and urban growth tendencies; or, (ii) inaccuracy leads us to reframe our pool of variables and their choice in order to better grasp the tendencies of urban growth in the Algarve.

The validation of the 2008 urban growth was done on the actual terrain, using 100 surveyed points to target urban and non-urban areas. As a result, Producer and User Accuracy were tested, showing us the overall accuracy of our modelled 2008 land use for urban areas. Our 2008 forecast generated a result of global exactitude of 93 per cent and a kappa statistic of 86 per cent. These encouraging results allowed us to continue with our forecast of the 2038 land use/land change panorama. User Accuracy is a result of the division of the number of correctly classified pixels in each category by the total number of pixels that are classified, and indicates the probability that a pixel classified in a given category actually represents that category on the ground (Lillesand et al. 2004). A clear tendency of urban growth around the periphery of existing urban centres seems to exist (Figure 36). Thus, rather than the appearance of new urban centres in the Faro-Olhão area, growth seems to occur depending on attractiveness factors such as proximity to the University and to the International Airport. Those reasons seem to be the explanation for extended growth particularly along the west side of the Faro perimeter. Previously small and almost inexistent agglomerations at the beginning of the 1990s will inevitably form larger areas with some endangerment of the natural and historic landscape.

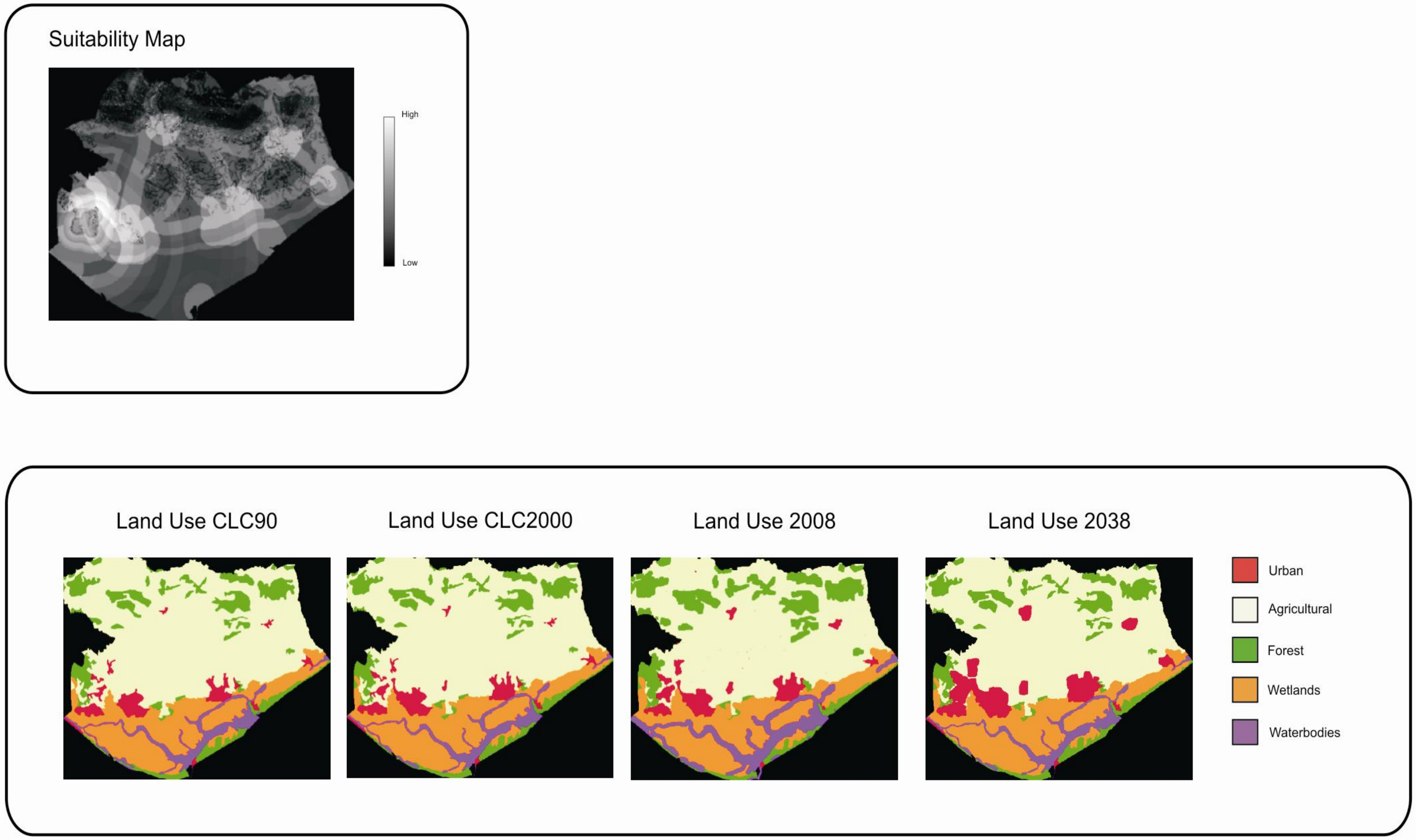


Figure 37 - Expected urban growth - Assessing the historico-cultural heritage in the Faro-Olhão Area

In the mid-19th century, Estácio da Veiga actively studied the heritage which remained from prehistory in the Algarve. Later he founded the first Archaeological Museum, which could be considered as the first academic initiative of archaeology in the Algarve. Prehistory and protohistory had already gained some relevance as archaeological records, but the clearly visible Roman and Moorish influence seemed to gain weight due to the growth of archaeological Romanticism which was important at the time when Estácio da Veiga was gathering information and continuing an, alas unfinished, fifth volume to his *Antiguidades Monumentais do Algarve*. (Veiga, 2006)

It was the initiative of the Instituto Português do Património Arquitectónico (IPPAR) in 1989 that for the first time resulted in an archaeological map of Portugal, which summarized some of the important archaeological remains in the region. Based on the *Carta Arqueológica de Portugal,* as well as on other bibliographical research, we were able to compare a total of 43 archaeological sites regarding their proximity to urban growth. The results were obvious: of our 43-site sample, 72 per cent were located within a radius of less than 1 km from urban areas, while 26 per cent were located within a maximum of 2 km radius, against only 2 per cent which are located within 3 km of the urban perimeter. This indeed is an alarming scenario, as our comparison was based on the generated land use for 2008. As illustrated in Figure 38, regarding the proximity of our archaeological remains to the urban area in our 2038 projection, the average expansion of up to 1 km in the next 30 years is endangering and could destroy 72 per cent of the region's archaeological sites if no monitoring and planning takes place. Among the analysed sites, prehistoric site locations, Roman necropolises, Roman villas and Moorish artefacts were taken into account. One of the sites directly targeted for eminent endangerment are the Ruins of Milreu, which were classified as a National Monument in 1910 and are considered to be one of the largest Roman Villas in Portugal.

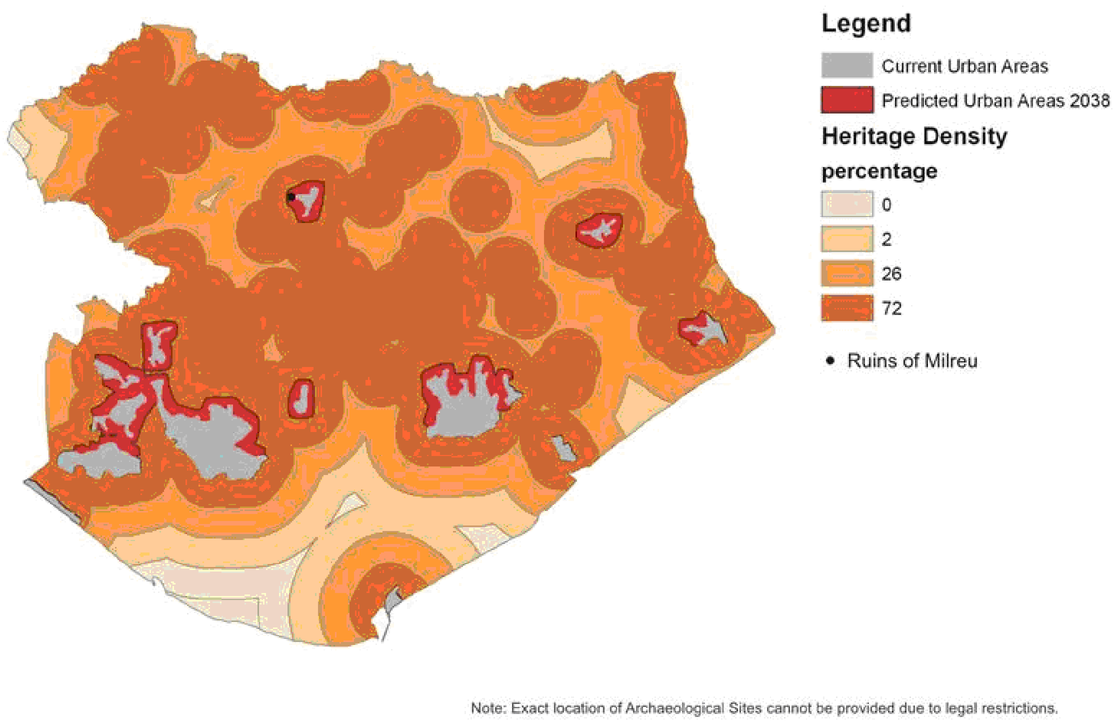


Figure 38 - Site propensity to change to urban use and urban growth prediction

9.8. Policy Lessons and Conclusions

It has become clear that the Algarve is an area of the utmost importance regarding a long tradition of historico-cultural heritage. GIS tools with their capability to assess spatial information and cope with large-enough databases from various sources seem to be an important pillar for strategic decision making support, as well as for regional planning and monitoring heritage endangerment. Urban growth, an unavoidable reality, may jeopardize a fragile cultural background which shares valued patrimony. The spatial cognition of such archaeological sites and better notions of urban growth and sprawl based on urban growth models and spatial analytical processes have proved to be important tools for an ongoing research agenda of historic and socio-cultural heritage protection in the Faro-Olhão area. It is our hope that, with the increasing accuracy of urban growth models, the historico-cultural heritage endangered by the growth of urban peripheries may be better analysed, leading to sounder and more sustainable cities which would never lose the asset of their cultural identity, but pass it on to future generations to cherish.

Chapter 10 - Conclusions

10.1. Main Focus

This dissertation is an application of geographic information systems (GIS) to the possibilities of visualizing and analysing human environmental pressures at the regional level. Deriving from different converging environmental pressures in the Algarve, this thesis originates from a multiple framework of analogous studies. In this sense, this dissertation is an appreciation of GIS to the possibilities of visualizing and analysing human environmental pressures at the regional level.

Geographical Information Systems (GIS) are ubiquitous systems with a large spectrum of possible applications in the regional sciences. Coupling socio-economic data with spatial information, allows detecting integrated necessities at local and regional level. The application of complex system dynamics takes the application of GIS to regional sciences a step further: not only does it become feasible to understand the current context of environmental consequences, but, permitting to predict future outcomes given continuing trends, suggests more focused policy targets. This is a very important contribution to sustainable development, in which pro-active monitoring strategies support better decision making and may help to protect already vulnerable environments. As a consequence, the possibility of monitoring with GIS the dynamics of the regional context, gives also a much richer instrument for social sensitizing. The production of an output in a map becomes a social tool in which sensitizing of protective measures creates a bridge between science and society. In this research the Algarve was used as a laboratory to assess the dynamics of regional change brought by economic growth (Tourism) and urban change (increasing coastal sprawl). The asymmetry registered within the region of the Algarve and the integration of a neglected cultural heritage product (its archaeological landscape) has allowed sketching alternatives in the regional decision making in order to prevent future damage on fragile ecosystems. The carrying capacity of the Algarve was also analysed, allowing to successfully predicting the future of urban sprawl, given a continued policy direction. The application of GIS to the context of regional decision making has been considered as an outstanding tool for better and more reliable decision making for the implementation of regional strategies.

10.2. Main Outcomes

Socio-economic factors can be considered an important driver for land-use change. The human impact on the environment however, is leading to rapid loss of ecosystems with permanent damage on fragile Ecosystems. This is especially the case in coastal regions, where economic activity is largely concentrated, and where friction is due to excessive concentration of human activity. Understanding the consequences of the complex interaction formed between socio-economic factors and its impacts on natural and historical heritage. Most of environmental change has a direct impact on land-use and the carrying capacity of natural resources and historical heritage may be assessed spatially.

The dissertation is divided into three parts, in which the first part shows the application of spatial analysis and geographic information systems as tools to interpret environmental change. The influence of social, economic and natural drivers is also discussed, showing that the integration of these factors is not an easy task, but that complex systems science does show positive solutions to weight and understand non-linear spatial modelling. Furthermore, in this dissertation, the application of GIS is seen from a spatial modelling dimension: cellular automata have been used as tools to assess the underlying dynamics incorporated in complex system analysis.

The second part renders the different studies that deal with the socio-economic and spatial dimension of environmental change in the Algarve. The first study integrates a spatial modelling approach towards urban growth in the observed region. A spatial model is used to build multiple scenarios of possible trends and consequences for urban growth in the Algarve (Chapter 5). It is shown that the current tendencies of urban growth, are leading to an increasing pressure of the urban environment of the fragile marine ecosystem of the *Ria Formosa*. However, it is also demonstrated that, if decision makers change their current trends, there is still a chance in the next 10 years as not to overburden the marine ecosystems of the Algarve. In research, Tourism is identified as the main driver for ecological pressure in the coastal region of the Algarve. Nonetheless, Tourism is very important for the Algarve economic growth and thus, it should not be neglected. The interaction of the tendency of urban growth and the proximity to cities suggest that Tourism should be re-balanced, by equating alternative services which would lead to a better distribution of spatial pressure brought by urban sprawl and unplanned touristic growth (Chapter 6). A strong relation between loss of agricultural land and urban growth is also proven (Chapter 7), showing that the abandonment of the rural sector and agricultural activity in the Algarve is, actually, not the best solution for the regional stability - the trends of loss of agricultural land within the relations of urban growth are analysed. The dichotomy of land abandonment, urban sprawl and Tourism is then evaluated in a predictive framework. Addressing decision-makers, an alternative scenario to the current tourism forms is offered by assessing the archaeological wealth of the region of the Algarve (Chapter 8). Using a database expanding more than 200 years of scientific analysis of the Roman era in the Algarve, an archaeological predictive model (APM) has been developed to understand what are the current location of Archaeological sites, and where the highest concentration of Archaeological activity within the region is. The interesting conclusion of current city proximity to location of ancient sites is captured in the next chapter (Chapter 9) by proving the importance of historico-cultural heritage, and how it may be integrated in a context of city growth and as well as a Tourism service opportunity. Archaeological heritage, which has proven to be abundant, especially in the regions more interior to the current location of Tourist attractions, would be an interesting alternative to ease the pressure on coastal areas. Finally, a conclusive study discusses the consequences of urban heritage endangerment through city growth and the need to reassess Touristic activity, by use of a more accurate interest of policymakers (Chapter 10).

10.3. Main Limitations

Technical:

The outcomes of the different articles produced during this dissertation relied on the existence of available land cover maps and other spatial information. The CORINE Land Cover for instance, was used in most of the produced articles but does have some limitations. The available minimum mapping unit of 1 ha for the CORINE Land Cover, generalizes the projected future urban landscape. While for regional decision making this might not be a problem in the Algarve, where there is a clear division between rural and urban areas and a clearly defined over-exploration of the coastal regions, the study may not be generalized to some extend in some other regions of the world. By creation of self-assessed land covers however, not relying on a 1 ha MMU, this problem might be overcome. It is fundamental to acknowledge that for the southern European landscape, and especially for regions where extensive Tourism has been witnessed, this is a sound methodology for observation of urban change. Another limitation is found in predicting the unpredictable: the future of urban growth and the exact location of archaeological findings, share a common problem. The latter, while considering the location as a result of environmental location as the main driver, does not consider the historical importance, or the anthropological choice that is made by non-environmental factors. This has been a long existing criticism to archaeological predictive models, and thus may bias the results for the correct scientific usage for Archaeological sciences. For regional development purposes however, the exact location is in itself quite irrelevant, as the important outcome is rather linked to a greater probability in finding archaeological or historical vestiges, which has a social effect on the common historical landscapes that might have existed region wise.

Methodological:

The previous problem also affects urban growth. In fact, the regressive methodologies for calculating future urban sprawl are based on existing socio-economic and historical data of multi-temporal urban areas in space. This however, might be not a rigorous outcome, as urban growth might develop considerably differently given a certain unpredictable event. An interesting comparison could be the calculation of urban growth tendency before the Tsunami that devastated part of the touristic path-tendencies and urban expansion in Indonesia. Should a natural disaster occur at regional level, spatial prediction of urban change or socio-economic tendencies are, to say the least, unpredictable. However, the paper on "Multi-scenarios for urban growth" does offer advances in building future outcomes in a context of urban extension given the calibration of specific factors. Thus, the outcomes do change to fit more improbable tendencies. It is important to acknowledge that these are still simulative studies, made on more or less accurate scenario-based proposals and certainty is therefore a dependent variable of prediction of change – traducing the dynamic change into a value of probable occurrence.

10.4. Main Prospects

The usage of GIS as tools to assess the consequences of regional environmental change has been analysed in this dissertation. Furthermore, the accuracy of urban growth models and projections made show that there is a relevant contribution in using Geographic Information Systems for regional decision support. The ontological question of the Geographic Information as a science (Geographic Information Sciences – GISc) is yet another important direction that becomes feasible to understand within the context of regional sciences. From a holistic perspective, GIS is much more than a toolbox for assembly of the understanding of the spatial impact. Rather, the application of

Geographic Information Systems to the scientific universe of regional sciences may deal with the importance of what is a city, and in the context of a city, how development of urban areas can be forecasted in benefit of future of best decision making. The bridge between GISc and regional sciences steps closer in tackling issues that are intrinsically of sociological nature, rather than exact science based. Moving up in the hierarchy of the complex system dynamics, we may find Geographic Information Sciences to be the scientific understanding of the dynamics of space, within a context of complexity applied to human behaviour in space. Thus, this dissertation also pleads for a direct contribution for the development of the context of GISc. Future work could cover different dimension on the possibilities of measuring change in a convergence of carrying capacity of regional systems.

The contributions would tackle issues such as: i) geocomputation; ii) geovisualization and, iii) geostatistics. While the nature of the first calls out for the paradigm of using intelligent systems to compute results in space, geovisualization should allow perceiving the results for social sensitizing. One of the most important aspects derived from Geographic Information Systems is related to the capability of visualizing results in space, as to call forth for a social awareness of the consequences of our impact at regional level. At last, the assembly of spatial data in a context of geostatistics, permits a better perception of the analysis of the quantified strata of spatial change. A recent field, spatial econometrics, seems as a highly relevant and potential field of study to assess the integration of socio-economic data with occurrence in space. Computing the results from a regional spatial perspective should be applied to other regions in the world. The application of the results of comparative analysis of urban growth tendencies in different regions, could contribute to empirical knowledge of how cities and society changes, and what is the role of decision making in the process of land-use change and population dynamics versus economic growth. Also, interesting topics for future studies is the application of such analysis to megacities, detecting how their growth stresses the ecological systems of neighbour urban areas.

References

ALARCÃO, J., 1974, Portugal Romano, (Coimbra: Verbo).

ALLEN, P. M., 2001, The Dynamics of Knowledge and ignorance: Learning the New Systems Science, In *Integrative Approaches to Natural and Social Dynamics*, (eds: M. Matthies, H. Malchow and J. Kriz), (Berlin: Springer Verlag), pp. s

AL-KHEDER, S. and SHAN J. (2005) Cellular Automata Urban Growth Simulation and Evaluation - A Case Study of Indianapolis, Proceedings of the 8th International Conference on GeoComputation, pp. 1-19.

ANDERSON, P. W., 1972, More is different - broken symmetry and nature of hierarchical structure of science, *Science*, 177, pp. 393-396.

ARCHIBUGI, F., NIJKAMP, P. and SOETEMAN, G. J., (1988) The Challenge of Sustainable Development. F. Archibugi and P. Nijkamp (eds), In: Economy & Ecology: Towards Sustainable Development, (Dordrecht: Springer), pp. 1 – 14.

ARROW, K., BOLIN, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C. .. . S. .., et al. (1995). Economic growth, carrying capacity, and the environment. Ecological Economics, 15(2), 89-90.

ASSUNÇÃO, J. P., 1989, A Influência dos Factores Ecologicos e Humanos na Evolução da Agricultura Algarvia, O Algarve - Na perspectiva da Antropologia Ecológica, pp. 271-290.

AXELROD, R. C. and COHEN M. D. (2000) Harnessing Complexity: Organisational Implications of a Scientific Frontier. New York: Free Press.

BATTY, M. (2007) Model Cities. Town Planning Review, 78 (2): 125-151.

BATTY, M., (2005) Cities and Complexity – Understanding Cities with Cellular Automata, Agent Based Models and Fractals, MIT Press, Cambridge, MA.

BATTY, M., Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models, and Fractals, MIT Press, Cambridge, MA, 2007.

BAYNES, T. (2009) Complexity in Urban Development and Management. Journal of Industrial Ecology, 13(2): 214-227.

BARREDO, J. I., KASANKO, M., MCCORMICK, N., LAVALLE, C. (2003), Modelling dynamic spatial processes: simulation of urban future scenarios through cellular automata, Landscape and Urban Planning, 64(3): 145-160.

BECKERMAN, W. (1994). 'Sustainable development': Is it a useful concept?. Environmental Values, 3(3), 191-209.

BENENSON, I., TORRENS, P. M., 2004 Geosimulation: Automata-Based - Modelling of Urban Phenomena. Wiley.

BERKES, F., COLDING, J. and FOLKE, C. (2003) Introduction. In: F. Berkes (ed.)Navigating social-ecological systems: building resilience for complexity and change.Cambridge: Cambridge University Press.

BERNARDES, J. P., OLIVEIRA, L., 2002. A calçadinha de S. Brás de Alportel e aantiga rede viária do Algarve central, (Faro: Universidade do Algarve).

BERTALANFFY, L. von (1950) An Outline of General Systems Theory. British Journalfor the Philosophy of Science, 1(2): 134-165.

BILSBORROW, R. E. & OGENDO, H. W. O. O. (1992). Population-Driven changes in land usein developing countries. Ambio, 37-45.

BOX, P., (1999) GIS and Cultural Resource Management: A Manual for Heritage Managers, UNESCO, Bangkok.

BRANDT, R; GROENEWOUDT, B. J. and KVAMME, K. (1992) An Experiment in Archaeological Site Location: Modelling in the Netherlands using GIS Techniques, World Archaeology, Vol. 24 No.2, pp. 268-282.

BUHALIS, D. and FLETCHER J., 1995, Environmental impacts on tourist destination: an economic analysis In Sustainable Tourism Development, edited by Nijkamp, P. and H. Coccossis, (Avebury: Ashgate), pp. 3-24.

BURNS, G, 2007, Predictive Modelling of Cultural Resources in the Theban Necropolis, Luxor Egypt, Master thesis dissertation, Graduate School - College of Charleston.

CABEZA GUTÉS, M. (1996). The concept of weak sustainability. Ecological Economics, 17(3), 147-156.

CABRAL, P., Étude de la Intersection Urbaine par Télédétection, sig et Modélisation, Mathématiques et Applications aux Sciences Sociales, École des Hautes Études en Sciences Sociales, Paris, 2006.

CAETANO, M., MONTEIRO, F. and RAMOS, I. L. (1999) Monitoring Urban Dynamics: Portugal no Contexto Europeu, 5º Encontro de Utilizadores de Sistemas de Informacao Geografica.

CALADO, M and ROCHA, L (2006), Menires e Neolitização: História da Investigação no Algarve, pp. 75-88. Proceedings of the 4th Meeting of Archaeology in the Algarve (Silves, 24-25th November, 2006).

CAMHIS, M (2006), Sustainable Development and Urbanization in The Future of Sustainability, Editor: Keiner, M., Springer

CAPELLO, R. (2001) Urban Growth in Italy: Economic Determinants and Socio-Environmental Consequence, Report 10:2001, CERUM

CARRASCO, J.M.C; FERNÁNDEZ UGALDE, A.; GARCÍA, S. D., RODRÍGUEZ, A. G.; LANCHA, J.; OLIVEIRA, C; RUEDA ROIGÉ, J. F. and TERUEL, N., 2008, A Rota do Mosaico Romano - O Sul da Hispânia (Andaluzia e Algarve) Cidades e villae notáveis de Bética e Lusitânia romanas, (Universidade do Algarve: Faro)

CBD 2003. Biodiversity and Climate Change. Convention on Biological Diversity Publication. CBD Technical Series 10.

CEC (Commission of the European Communities) (2006). Cohesion Policy and cities : the urban contribution to growth and jobs in the regions.

CILLIERS, P. (2005) Complexity, deconstruction and relativism. Theory Culture &Society, 22(5): 255 - 267.

CLARKE, K. C. and HOPPEN, S. (1997) A self-modifying cellular automaton model ofhistorical urbanization in the San Francisco Bay area, Environment and Planning(Planning and Design), 24: 247-261.

COHEN, B. (2004). Urban growth in developing countries: A review of current trends and a caution regarding existing forecasts. World Development, 32(1), 23-51.

CONOLLY, K. and LAKE, M., 2006, Geographical Information Systems inArchaeology, (New York: Cambridge University Press).

COPELAND, B. R. and TAYLOR, M. S. (2004) Trade, growth and the environment, Journal of Economic Literature, 42(1): 7-71.

CORREIA, A. and CROUCH, G. I. (2004). A Study of Tourist Decision Processes: Algarve,Portugal, Consumer Psychology of Tourism, Hospitality and Leisure, (G. I. Crouch, R. R.Perdue, H. J. P. Timmermans, M. Uysal ed.) (Cabi Publishing: Oxfordshire, UK)

COSTANZA R, D'ARGE R, DE GROOT R, FARBER S, GRASSO M, HANNON B, LIMBURG K, NAEEM S, O'NEILL RV, PARUELO J, RASKIN RG, SUTTON P and VAN DEN BELT M, 1997, The value of the world's ecosystem services and natural capital. Nature, 387:253–260.

COSTANZA, R., GRAUMLICH, L. and STEFFEN, W., 2007, Sustainability or collapse:Lessons from integrating the history of humans and the rest of nature In Sustainability orcollapse? An integrated history and future of people on earth, edited by Costanza, R.,Graumlich, L. and Steffen, W., Dahlem Workshop Reports, (Cambridge, MA: MITPress), pp. 3-19.

CURTIS, R. I., 1991, Garum and Salsamenta. Production and Commerce in Materia Medica, Studies in Ancient Medicine 3, Brill, Leiden (1991).

DALY, H. E. and FARLEY, J. C. (2004). Ecological economics: Principles and applications. (Island Press: London).

DAVENPORT, J. and DAVENPORT, J.L. (2006) The impact of tourism and personalleisure transport on coastal environments: A review. Estuarine Coastal and Shelf Science, 67(1-2): 280-292.

DIVISÃO DO INVENTÁRIO DO INSTITUTO PORTUGUÊS DE ARQUEOLOGIA,2002, Endovélico - Sistema de Gestão e Informação

Arqueológica, Revista Portuguesa deArqueologia, 5(1), pp. 277-283, URL: (http://www.ipa.mincultura.pt/pubs/RPA/v5n1/folder/277-283.pdf, consulted on 02-03-09).

DONELLA, H., MEADOWS, J., MEADOWS, D. L., & Publishing, G. (2004). Limits to growth: The 30-year update. (Chelsea Green Publishing Company: Chelsea).

DONOGHUE, D. N. M, 2002, Remote sensing: environmental change, Progress in Physical Greography, 26(1), pp. 144-151.

DORAN J.E. and HODSON, F.R., 1975, Mathematics and Computers in Archaeology (Edinburgh: Edinburgh University Press).

DRAIN, M. (1989) L'Algarve et la notion Geographique d'Arriere-Pays, O Algarve - Na perspectiva da Antropologia Ecológica (M. Gomes Guerreiro, ed.), INIC, Lisboa, pp. 61-72.

DUNLAP, R. E., and W. R. Catton, Jr. 1979. Environmental sociology. Ann. Rev. Sociol. 5: 243-273.

EBERT, D., Predictive Modeling and the Ecology of Hunter Gatherers of the Boral Forest of Manitoba, BAR S1221, Archaeopress, Oxford, 2004 Edmondson, J. C., 1990, "Le Garum en Lusitanie urbaine et rurale: hierarchies dedemande et de production" In Les Villes de Lusitanie romaine: hierarchies et territories.Table ronde internationale du CNRS (Talence, 8-9 decebre 1988), pp. 149-206.

EEA (1995) CORINE Land Cover, EEA Report (consulted on 05.08.09, http://www.eea.europa.eu/publications/COR0-landcover).

EEA (1996) CORINE Land Cover, European Environment Agency, Report 01/1995,Copenhagen: European Commission, (URL: http://reports.eea.europa.eu/COR0landcover/en, consulted on 20-08-09).

EEA (2006a) The changing faces of Europe's coastal areas, EEA Report No 6/2006(http://www.eea.europa.eu/publications/eea_report_2006_6 consulted on 05.08.09).

EEA (2006a) Urban sprawl in Europe - The ignored challenge, EEA Report No 10/2006 (consulted on 18.02.10, www.eea.europa.eu/publications/eea_report_2006_10)

EEA (2006b) Priority issues in the Mediterranean environment, EEA Report No 4/2006(http://www.eea.europa.eu/publications/eea_report_2006_4 consulted on 07.08.09,).

EEA (2006b) The changing faces of Europe's coastal areas, EEA Report No 6/2006 (consulted on 05.08.09, http://www.eea.europa.eu/publications/eea_report_2006_6).

ENGELEN, G., S. Geertman, P. Smits and C. Wessels, Dynamic GIS and Strategic Physical Planning Support: A Practical Application, Geografical Information and Planning (J. Stilwell, S. Geertman and S. Openshaw, eds.), Springer-Verlag, Heidelberg, 1999.

ÉTIENNE and MAJET, 2002, Salaism et sauces de poisson hispanique, (Diffusion E. deBoccard: Paris)

EUROPEAN COMISSION, (1999) "ESDP European Spatial Development Perspective: Towards Balanced and Sustainable Development of the Territory of the European Union".

EUROPEAN COMMUNITY (2000) From Land Cover to Land Diversity in theEuropean Union, (URL: http://ec.europa.eu/agriculture/publi/landscape/index.htm,consulted on 20-12-07).

GALE, R.P. and CORDRAY, S.M., 1994. Making sense of sustainability: Nine answers to what should be sustained?. Rural Sociology 59, pp. 311–332

GAMITO, T. J. (1997) A cidade de Ossonoba e o seu território envolvente, Noventaséculos entre a serra e o mar., Lisbon: IPPAR, pp. 343-360.

GARCIA, C. and SERVERA, J. (2003) Impacts of tourism development on waterdemand and beach degradation on the island of Mallorca (Spain). Geografiska AnnalerSeries A-Physical Geography, 85A(3-4):287-300.

GILLINGS, M., and G.T. GOODRICK, Sensuous and Reflexive GIS; Exploring Visualization and VRML, Internet Archaeology I, 1996, internet: http://intarch.ac.uk

GLADWIN, T.N; KENNELLY, J. J. and KRAUSE, T-S., Shifting Paradigms for sustainable development: implications for management theory and research, Academy of Management Review, 20(4), pp. 874-907.

GOODCHILD, M. F. (1990), "Spatial information science", Proceedings, Fourth International Symposium on Spatial Data Handling (Zurich, Switzerland): 3–12

GOUDIE, A. (2006). The human impact on the natural environment: Past, present, and future. Blackwell Pub.

GRØN, O., and A. Loska, Development of Methods for Satellite Monitoring of Cultural Heritage Sites, Technical Report NIKU, Norwegian Space Centre, Oslo, 2002.

GUERREIRO, M. M., MENDES, J., VALE, P. and SILVA, J. A. (2008) Análise da Satisfação dos Residentes com o Turismo: o caso de uma área destino no Algarve, Portugal. Turismo Em Analise, 19(3): 488 - 504.

HAN, J.; HAYASHI, Y.; CAO, X., 2009, Application of an integrated system dynamics and cellular automata model for urban growth assessment: A case study of Shanghai, China, Landscape and Urban Planning, 91(3), pp. 133-141.

HAUGHTON, G. and COUNSELL, D., 2004, Regions, Spatial Strategies and Sustainable Development, (Routledge: London).

HAYAKAWA, Y. S. and TSUMURA, H., 2009, Utilization of laser range finder anddifferential GPS for high-resolution topographic measurement at Hacituğrul Tepe,Turkey, Geoarchaeology, 24(2), pp. 176-190.

HERNANDEZ, M., Use of Satellite Imagery and Geographical Information Systems to Monitor World Heritage Sites, World Heritage Paper 10, UNESCO, 2002.Herold, M., Goldstein, N. and Clarke, K. 2003. The spatio-temporal form of urban growth:

HILL, B., M. Devitt and S. Sergeyeva, Understanding Past and Future Land Use, ArcUser Online, http://www.esri.com/news/arcuser/0507/pastlanduse.html, April-June, ESRI, 2007.

HIRSCH, F. (1976) Social Limits to Growth. Cambridge, Mass: Harvard University Press.

HODDER I., 1972, Locational models and the study of the Romano-British settlement., Models in Archaeology, edited by D. L. Clarke, pp. 887-909. (London: Methuen & Co. Ltd.).

HOLTORF, C., 2008, Is the Past a Non-renewable Resource. In The Heritage Reader, edited by Fairclough, G, Harrison, R., Jameson Jnr, J. H. and Shoffield J., (Oxon: Routledge), pp. 125-133.

HUSSEN, A. M., 2004, Principles of Environmental Economics: Economics, Ecology and Public Policy, 2nd edition, (London:Routledge).

ILLGE, L., Schwarze, R., 2009, A matter of opinion—How ecological and neoclassical environmental economists and think about sustainability and economics, Ecological Economics, 68: 594-604.

INE, Anuário Estatístico da Região do Algarve - Statistical Yearbook of the Algarve Region, Instituto Nacional de Estatística, Lisbon, 2006.

INTERNET SYSTEMS CONSORTIUM, 2006, Available online at

Isard W., 1956. Location and Space-Economy, (Cambridge, MA: MIT Press).

Jantz, C. A.; Goetz, S. J; Donato, D.; Clagget, P., 2010, Designing and implementing a regional urban modeling system using the SLEUTH cellular urban model, Computers, Environment and Urban Systems, 34(1), pp. 1-16.

JOUKOWSKI, M., A Complete Manual of Field Archaeology: Tools and Techniques of Field Work for Archaeologists, Prentice Hall, Englewood Cliffs, 1980.

Journal of Remote Sensing, Vol.12 No.7, pp.699-714

KOOMEN, E., STILLWELL, J., and BAKEMA, A. (2007). Modelling land-use change. (Springer: Dordrecht).

KRUGER, O., 2005, The role of ecotourism in conservation: panacea or Pandora’s box?, Biodiversity and Conservation, 14, pp:579-600.

KVAMME, K. (1991) Geographic Information Systems and Archaeology. In Computer Applications and Quantitative Methods in Archaeology, edited by G. Lock and J. Moffett, (Oxford: BAR International Series), pp. 77-84.

Kvamme, K. (1999), Recent Directions and Developments in Geographical Information Systems, Journal of Archaeological Research, 7(2), pp. 153-201.

KVAMME, K., (1988), Development And Testing Of Quantitative Models In Quantifying The Present And Predicting The Past, edited by Judge, J. and Sebastian, L., (Denver: US Department of the Interior, Bureau of Land Management), pp. 325-418.

KVAMME, K., 1990, The Fundamental Principles and Practice of Predictive Archaeological Modeling. In Mathematics and Information Science in Archaeology: A Flexible Framework edited by Voorrips A., (Bonn: Holos-Verlag), pp. 257-295.

KWAMME, K.L., Recent Direction and Developments in Geographical Information Systems, Journal of Archaeological Research, vol. 7, no. 2, 1999, pp. 153-185.

LACITIGNOLA, D.; PETROSILLO, I.; CATALDI, M. and ZURLINI, G., 2007, Modelling socio-ecological tourism-based systems for sustainability, Ecological Modelling, 206, pp.196-204.

LANSING, J.S., Artificial Societies and the Social Sciences, Artificial Life, vol. 8, 2002, pp. 279-292.

LEEUWEN VAN, E.S., HAGENS, J.E. and NIJKAMP, P. (2007) Multi-Agent Systems: A Tool in Spatial Planning. disP, 170 (3): 19-32.

LEGRAND, G., Dicionário de Filosofia, Edições 70, Lisbon, 1991.

LEONTIEF, W., 1966, Input Output Economics, 2nd Edition, (New York: Oxford University Press)

LI, W.J., ZHANG, Q., LIU, C. and XUE, Q. (2006) Tourism's impacts on natural resources: A positive case from China. Environmental Management, 38(4): 572-579.

LI, X. & Liu, X. (2008). Embedding sustainable development strategies in agent-based models for use as a planning tool. International Journal of Geographical Information Science, 22(1), 21-45.

LI, X.; Gar-On Yeh, A., 2000, Modelling sustainable urban development by the integration of constrained cellular automata and GIS, International Journal of Geographical Information Science, 14(2), pp. 131-152.

LILLESAND, T. M., KIEFER, R. W. and J. W. CHIPMAN, Remote Sensing and Image Interpretation, 5th Edition, John Wiley and Sons, USA, 2004.

LONGLEY, P. (2002) "Geographical Information Systems: will developments in urban remote sensing and GIS lead to 'better' urban geography?" Progress in Human Geography, pp. 26 – 31.

LONGLEY, P. A., GOODCHILD, M. F., MAGUIRE, D. J. and RHIND, D. W. (2006) Geographic Information Systems and Science (2nd edition). West Sussex: John Wiley and Sons.

MAIA, M. A. Romanização do território hoje português a sul do Tejo – Contribuição para a análise do processo de assimilação e interacção socio-cultural 218 a.C – 14 d.C, PhD Thesis in Prehistory and Archaeology, University of Lisbon, Faculty of Letters, Lisbon, 1987.

MAKTAV, D., ERBEK, F. and JURGENS, C. (2005) Remote sensing of urban areas. International Journal of Remote Sensing, 26(4): 655-659.

MALATO-BELIZ, J.V.C., 1986, O Barrocal Algarvio, Col. Parques Naturais 17, (Serviço Nacional de Parques, Reservas e Património Paisagístico: Lisboa).

MALATO-BELIZ, J.V.C., 1986, O Barrocal Algarvio, Col. Parques Naturais 17, (Serviço Nacional de Parques, Reservas e Património Paisagístico: Lisboa).

MARK, D. M. (2003). Geographic Information Science: Defining the Field. In M. Duckham & M. F.Goodchild & M. F.Worboys (Ed.), Foundations of Geographic Information Science (pp. 3 – 18). New York, NY: Taylor & Francis

MATIAS, A. (2004) "Economic Geography, Gravity and Tourism Trade: - The case for Portugal", I Congress on Tourism Economics, Universitat de les Illes Balears, Palma, 28-29 May 2004.

MEADOWS, D.; RANDERS, J.; MEADOWS, D., 2004, Limits to growth – The 30-Year Update, Chelsea Green Publishing.

MEADOWS, D., 2008, Thinking in Systems, (Earthscan: London).

MEAILLE, R. and WALD, L., 1990. Using geographical information system and satellite imagery within a numerical simulation of regional growth. International Journal of Geographical Information Systems, (4)4, pp. 445–456.

MEYER, W. B. and TURNER, B. L. (1992). Human population growth and global land-use/cover change. Annual Review of Ecology and Systematics, 23(1), 39-61.

MILLENNIUM ECOSYSTEM ASSESSMENT, 2005 Millennium Ecosystem Assessment, Ecosystems and Human Well-Being: Synthesis, Island Press, Washington, DC (2005).

MILLER, A. and BARTON, M., 2008, Exploring the land: a comparison of land-use patterns in the Middle and Upper Paleolithic of the western Mediterranean, Journal of Archaeological Science, 35(5), pp. 1427-1437.

Miller, P., 2009, Saving Energy starts at Home, National Geographic, March 2009, pp. 60-35.

MINCIU, R. (2008) Tourism growth and its effects in the economy. Amfiteatru Economic, 271-276.

MONTUFO, A., The Use of Satellite Imagery and Digital Image Processing in Landscape Archaeology. A Case Study from the Island of Mallorca, Spain, Geoarchaeology, vol. 12, no. 1, 1997, pp. 71-85.

MORAVCSIK, A. (1993). Preferences and power in the european community: A liberal intergovernmentalist approach. Journal of Common Market Studies, 31, 473-473.

MOUSSAÏD, M., HELBING, D., GARNIER, S., JOHANSSON, A., COMBE, M., and THERAULAZ, G. (2009). Experimental study of the behavioural mechanisms underlying self-organization in human crowds. Proceedings. Biological Sciences / the Royal Society, 276(1668), 2755-62.

MUNDIA, C. N. and MURAYAMA, Y. (2010). Modeling spatial processes of urban growth in african cities: A case study of nairobi city. Urban Geography, 31(2), 259-272.

NATIONAL BUREAU OF ECONOMIC RESEARCH (NBER), consulted on 15.12.08, website: http://www.nber.org/workinggroups/ee/ee.html

NCGIA (2000) The NCGIA Core Curriculum in GIScience URL: (http://www.ncgia.ucsb.edu/giscc/, consulted on 20-07-09).

NETWORK OF HEADS OF EUROPEAN ENVIRONMENT PROTECTION AGENCIES, 2005, The contribution of Good Environmental Regulation to Competitiveness, European Environmental Agency. (url: http://www.eea.europa.eu/highlights/Ann1132149255, consulted on: 22nd December 2009).

NEVILLE, A. (2007). Mountains of silver and rivers of gold: The phoenicians in iberia. Oxbow Books Ltd.

NEWMAN, L. (2005) Uncertainty, innovation, and dynamic sustainable development. Sustainability: Science, Practice, & Policy, 1(2): 25-31.

NEWTON, A., ICELY, J. D., FALCAO, M., NOBRE, A., NUNES, J. P., FERREIRA, J. G., ET AL. (2003). Evaluation of eutrophication in the ria formosa coastal lagoon, portugal. Continental Shelf Research, 23(17-19), 1945-1961.

NIJKAMP, P. and MILLS, E., 1987, Advances in Regional Economics, Handbook of Regional and Urban Economics, Editor: Nijkamp, P., pp. 1 – 17 (North-Holland – Elsevier: Eastbourne).

NIJKAMP, P. and SCHOLTEN, H., 1993, Spatial Information Systems: Design, Modelling, and Use in Planning, International Journal of Geographical Information Science, 1, pp, 85-96.

NOBRE, A., 2009, An Ecological and Economic Assessment Methodology for Coastal Ecosystem Management, Environmental Management, 44:185–204.

NOCETE, F., SAÉZ, R., NIETO, J.M., CRUZ-AUÑÓN, R., CABRERO, R., ALEX,E. and BAYONA, M. R. (2005) Circulation of silicified oolitic limestone blades in South-Iberia (Spain and Portugal) during the third millennium B.C.: an expression of a core/periphery framework. Journal of Anthropological Archaeology, 24: 62-81.

OGYZ, H., KLEIN, A. G. and SRINIVASAN, R., (2007) "Using the Sleuth Urban Growth Model to Simulate the Impacts of Future Policy Scenarios on Urban Land use in the Houston-Galveston-Brazoria" Research Journal of Social Sciences, 2, pp. 72-82.

O'NEILL and KAHN, 2000. R.V. O'Neill and J.R. Kahn , Homo economicus as a keystone species. BioScience 50 (2000), pp. 333–337.

OSLAND, D., 2006, The early Roman cities of Lusitania, (Archaeopress: Oxford)

PAAVOLA, J. (2007) Institutions and environmental governance: A reconceptualization. Ecological Economics, 63(1):93-103.

PAÍNHO, M. and CAETANO, M. (2006) Cartografia de Ocupação do Solo: Portugal Continental, 1985-2000: CORINE Land Cover 2000. Amadora, Instituto do Ambiente.

PARKER D. C., Manson, S. M, JANSSEN, M.A., HOFFMANN M.J. and DEADMAN P. (2003) Multi-agent systems for the simulation of land-use and land-cover change: A review. Annals of the Association of American Geographers, 93(2):314-337.

PENA, A; and CABRAL, J., 1997, Roteiros da Natureza, (Temas e Debates: Portugal)

PICÓN-FELICIANO, A. J., VÁSQUEZ, R., GONZÁLEZ, J., LUVALL, J., and RICKMAN, D. (2009). Use of remote sensing observations to study the urban climate on tropical coastal cities. Revista Umbral, (1).

PIYATHAMRONGCHAI, K. and M. BATTY, M., 2007, Integrating Cellular Automata and Regional Dynamics Using GIS, In Modelling Land-Use Change Progress and Applications, edited by Koomen, E.; Stillwell, J.; Bakema, A. and Scholten, H. J., (Dordrecht: Springer), pp. 258-277.

PNPOT (Programa Nacional da Política de Ordenamento do Território), Relatório, consulted at: http://www.territorioportugal.pt/pnpot/

PONTIUS, G.R., and H. CHEN, GEOMOD Modeling, Idrisi 15: The Andes Edition (J.R. Eastman, ed.), Clark Labs, Worcester MA, 2006.

PORTUGALI, J. (2006) Complexity theory as a link between space and place. Environment & Planning A, 38(4): 647-664.

PROL-LEDESMA, R. M., E. M. URIBE-ALCÁNTARA,and O. DIAZ-MOLINA Use of cartographic data and Landsat TM images to determine land use change in the vicinity of Mexico City, International Journal of Remote Sensing, vol. 23, no. 9, 2002, pp. 1927 – 1933.

RAMIREZ, P. B.; BEHRMANN, R. B.; BERMEJO, R. B., 2007, Chronologie de l'art Mégalithique ibérique : C14 et contextes archéologiques, L'Anthropologie, 111(4), 590-654.

REGGIANI, A. and NIJKAMP, P. (eds) (2009) Complexity and Spatial Networks – In Search of Simplicity, Berlin: Springer.

RENFREW, C. and P. BAHN, 2004, Archaeology: Theories, Methods and Practice. (London: Thames & Hudson).

RUHL, J. B., 1999, Sustainable Development: A Five Dimensional Algorithm for Environmental Law, Stanford Environmental Law Journal, 18(31), pp. 31-64.

RUSSO, A.P., 2002., Annals of Tourism Research Volume 29, Issue 1, January 2002, pp 165-182.

RUTH, M. and COELHO, D. (2007) Understanding and managing the complexity of urban systems under climate change. Climate Policy, 7(4): 317-336.

SANCHEZ-MARRE, M., GIBERT, K., SOJDA, R. S., STEYER, J. P., STRUSS, P., RODRIGUEZ-RODA, I., ET AL. (2008). Intelligent environmental decision support systems. Developments in Integrated Environmental Assessment, 3, 119-144.

SANTOS, Maria Luisa E. V. dos, 1971, Arqueologia romana do Algarve, vol. I, (Lisboa: Associação dos Arqueólogos Portugueses).

SASSEN, S., Globalization and its Discontent: Essays on the New Mobility of People and Money, The New Press, New York, 1998.

SAVAGE, S.H., 1990, GIS in archaeological research. In Interpreting Space: GIS and archaeology, edited by: Allen, K. M. S., Green, S. W., Zubrow, E. B. W. (London: Taylor & Francis), pp. 22-32.

SAWAYA, K. E., OLMANSON, L. G., HEINERT, N. J., BREZONIK, P. L. and BAUER, M. E. (2003) Extending satellite remote sensing to local scales: land and water resource monitoring using high-resolution imagery. Remote Sensing of Environment, 88, pp. 144-156.

SCHIFFER, M. B, 1972, Archaeological context and systemic context, American Antiquity 37, pp. 156-65.

SCHIFFER, M.B., Studying Technological Change: a Behavioural Perspective, World Archaeology, vol. 36, no. 4, 2004, pp. 579-585.

SEBASTIAN, L. and JUDGE, J. (1988) Predicting The Past: Correlation, Explanation, And The Use Of Archaeological Models, In Quantifying The Present And Predicting The Past, edited by Judge, J., Sebastian, L., (Denver: US Department of the Interior, Bureau of Land Management), pp. 325-418.

SIEBERT, H., 1993, Spatial Aspects of Environmental Economics in A.V. Kneese and J.L. Sweeney (eds.), 1993, Handbook of Natural Resource and Energy Economics, (Amsterdam: North-Holland), pp. 125-164.

SILVA, E. and CLARKE., K.C. (2005) Complexity, emergence and cellular urban models: Lessons learned from applying sleuth to two Portuguese metropolitan areas. European Planning Studies, 13(1): 93-116.

SILVA, L. F., 2007, Balsa, Cidade Perdida, (Tavira: Câmara Municipal de Tavira).

STEINWAY, D. M., 2007, Fundamentals of Environmental Law, in Environmental Law Handbook, 19th edition, ed: Sullivan, T., pp. 1-66. Plymouth, UK: Government Institutes - The Scarecrow Press.

STERN, D. I., COMMON, M. S., and BARBIER, E. B., 1996. Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development. World Development, 24, 1151-1160.

STEWART, I. (2002) Does God play dice? The new mathematics of chaos. Oxford: Blackwell.

STRABO (2007) Geographica – Drittes Buch, Zweites Kapitel: Beschreibung des inneren Landes von Bätika oder Turdetanien. Berlin: Marixverlag.

STRASZHEIM, M. (1987), The theory of urban residential location, Handbook of Regional Economics,(P. Nijkamp, ed.). North-Holland Publ. Co., Amsterdam, pp. 717-757.

SWENSEN, G., 2006, Incorporating urban heritage into local community planning, In Multiple Landscape – Merging Past and Present, edited by van der Knaap, W. and van der Valk, A., (Wageningen: Ponsen & Looijen bv.), pp. 157-170.

SYPHARD, A. D., CLARKE, K. C. and FRANKLIN, J. (2004) Using a Cellular Automaton Model to Forecast the Effect of Urban Growth on Habitat Pattern in Southern California. Ecological Complexity, 2: 185-203.

TAYLOR, P. J. (2005) Unruly complexity: Ecology, interpretation, engagement. Chicago: The University of Chicago Press.

TEICHNER, F., 1994, Acerca da vila romana de Milreu/Estoi: continuidade da ocupação na época árabe, Arqueologia Medieval, 3, pp. 89-100.

TOBLER, A., 1970, A Computer Movie Simulating Urban Growth in the Detroit Region W. R. Tobler Economic Geography, Vol. 46, Supplement: Proceedings. International Geographical Union. Commission on Quantitative Methods. pp. 234-240

TRIBE, J. (2005) The Economics of Recreation, Leisure and Tourism, 3rd Edition. Oxford: Elsevier.

TURKER, Z. and DINCYUREK, O. (2007) Sustainable tourism as an alternative to mass tourism developments of Bafra, north Cyprus. Open House International, 32(4):107-118.

TURNER, B. L., KASPERSON, R. E., MEYER, W. B., DOW, K. M., GOLDING, D., KASPERSON, J.

X., et al. (1990). Two types of global environmental change. Global Environmental Change, 1(4), 14-22.

UNEP, 2007. UNEP 2007 - Annual Report. United Nations Environment Programme.

URRY, J. (2005) The complexity turn. Theory Culture and Society, 22(5):1-14.

BERGH, J.C.J.M., Ecological Economics and Sustainable Development, Edward Elgar, London, 1996

VAZ, E and Nijkamp, P. (2009), Historico-Cultural Sustainability and Urban Dynamics, In Enhancing the City: New Perspectives for Tourism and Leisure, edited by Giovanni Maciocco and Silvia Serreli., (UK: Springer), pp. 155-177.

VAZ, E.; Vaz, M. T.; Nijkamp, P., 2009, Spatial analysis for policy evaluation of the rural world: Portuguese agriculture in the last decade, FEWEB Research Memoranda, Free University of Amsterdam.

VEIGA, S. P. (2005) Antiguidades monumentais do Algarve (Coimbra: Universidade do Algarve).

VEIGA, S. P. M. E. da, Antiguidades monumentaes do Algarve. II, Imprensa Nacional., 1887, Lisbon.

VEIGA, S. P., 2005, Antiguidades monumentais do Algarve, (Coimbra: Universidade do Algarve).

VERHAGEN, P., Case Studies in Archaeological Predictive Modelling, ASLU 14, Leiden University Press, Leiden, the Netherlands, 2007.

WALKER, W. H., and SCHIFFER, M. B., 2006, The Materiality of Social Power: The Artifact-Acquisition Perspective, Journal of Archaeological Method and Theory, 13(2), pp. 67-88.

WALPOLE, M. and GOODWIN, H.J. (2000) Local economic impacts of dragon tourism in Indonesia. Annals of Tourism Research, 27(3):559-576.

WARREN, R.E., and D.L. ASCH, A Predictive Model of Archaeological Site Location in the Eastern Prairie Peninsula, Practical Applications of GIS for Archaeologists: A Predictive Modeling Toolkit (K.L. Wescott and R.J. Brandon, eds.), Taylor and Francis, London, 2000.

WESTCOTT, K. L., BRANDON, R. K., 2000, Practical Applications of GIS for Archaeologists: A Predictive Modeling Kit. (London: Taylor and Francis)

WESTCOTT, K.L., and R.J. BRANDON, Practical Application of GIS for Archaeologists: A Predicative Modelling Kit, Taylor & Francis, London, 2000.

WHEATLEY, D. and GILLINGS, M., 2002, Spatial Technology and Archaeology: The Archaeological Applications of GIS (London: Taylor & Francis).

WHITE, L., 1959, The Evolution of Culture, (New York: McGraw-Hill).

WHITE, R. and Engelen, G. 2000. High-resolution integrated modelling of the spatial dynamics of urban and regional systems. Computers, environment and urban systems, Vol.24, pp.383-

WHITE, R., Engelen, G. and Uljee, I. 1997. The use of constrained cellular automata for high- resolution modelling of urban land use dynamics. Environment and Planning B, Vol.24, pp.323-343

WILSON, A. (2006) Ecological and urban systems models: some explorations of similarities in the context of complexity theory. Environment & Planning A, 38(4):633-646.

WILSON, A.G. (1974), Urban and regional models in geography and planning (New York: Wiley & Sons)

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT (1987). Our Common Future. Oxford, Oxford University Press.

WRIGLEY, E. A., 1985, Urban Growth and Agricultural Change: England and the Continent in the Early Modern Period, Journal of Interdisciplinary History, 15(4), pp. 683-728.

ZAHRA, A. and RYAN, C. (2007) From chaos to cohesion — Complexity in tourism structures: An analysis of New Zealand's regional tourism organizations. Tourism Management, 28(3):854-862.