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Iris Joana Salada Rodrigues da Silva

Assessing the socio-economic impacts of regional plans in the Ria de Aveiro region

Avaliação dos impactes socio-económicos dos planos regionais para a região da Ria de Aveiro

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia do Ambiente, realizada sob a orientação científica do Doutor Peter Roebeling, Equiparado a Investigador Auxiliar no Departamento de Ambiente e Ordenamento da Universidade de Aveiro e coorientação da Doutora Teresa Fidélis, Professora Auxiliar do Departamento de Ambiente e Ordenamento da Universidade de Aveiro.

Esta dissertação é dedicada à minha irmã, Teresa, e aos meus pais, Jorge e Teresa, por me apoiarem sempre.

“There is a tide in the affair of men.
Which, taken at the flood, leads on to fortune;
Omitted, all the voyage of their life
Is bound in shallows and in miseries.
On such a full sea are we now afloat,
And we must take the current when it serves,
Or lose our ventures.”

Shakespeare

o júri

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Professor Doutor Fernando Manuel Martins Nogueira
Professor Auxiliar do Departamento de Ciências Sociais, Políticas e do Território da Universidade de Aveiro
(Arguente)

Doutor Peter Cornelis Roebeling
Equiparado a Investigador Auxiliar do Departamento de Ambiente e Ordenamento da Universidade de Aveiro (Orientador)

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À minha irmã, big sis, por toda a confiança, paciência, motivação e apoio e por estar sempre presente.

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Palavras-chave

Desenvolvimento Urbano Sustentável, Dispersão urbana, Modelo de simulação de preços hedónicos, Planos de ordenamento do território, PROT - C

Resumo

A urbanização das zonas costeiras sofreu um grande aumento nas últimas décadas, causando uma grande pressão sobre o ambiente e os recursos. O aumento da população levou ao aumento da procura de habitações o que, por sua vez, resultou numa urbanização pouco planeada e desorganizada – levando à destruição e degradação do meio ambiente. Este tipo de urbanização extensa e dispersa é conhecida como dispersão urbana. No sentido de contradizer os impactes negativos da dispersão urbana nas zonas costeiras, surge a necessidade de pôr em prática um desenvolvimento urbano sustentável. Tal pode ser conseguido através da implementação de legislação e politicas focadas na realização de objetivos sustentáveis. Em Portugal, uma dessas políticas é o Plano Regional de Ordenamento do Território (PROT). Vários modelos de uso do solo têm sido desenvolvidos no sentido de avaliar as mudanças de uso de solo históricas e futuras. No entanto, poucos são os modelos usados para avaliar de que forma os planos de ordenamento de território contribuem para uma urbanização sustentável e os seus impactes sociais, económicos e ambientais. Este estudo tem como principal objetivo a avaliação do Plano Regional de Ordenamento do Território para a região de Aveiro (o PROT-Centro), através do modelo SULD (Sustainable Urbanizing Landscape Development), com o intuito de perceber até que ponto este plano contribui para a urbanização sustentável da região. Tendo em conta uma perspetiva de desenvolvimento sustentável, os resultados demonstram que, apesar do cenário integrado não ser a pior opção, também não é a melhor. Nesta perspetiva, os resultados do cenário ambiental demonstram ser a melhor opção para um desenvolvimento urbano sustentável, observando-se benefícios ambientais (através da proteção e apreciação das amenidades ambientais), bem como benefícios ao nível social e económico (através da maior concentração urbana, preço de habitação e valor total do imobiliário na região), contradizendo a problemática de dispersão urbana e os seus impactes negativos. No sentido do cenário integrado ser uma opção mais viável, deveria ser limitada a zona de construção e mantidos os aspetos ambientais da paisagem.

keywords

Sustainable urban development, Urban sprawl, Hedonic pricing simulation model, Regional plannig models, PROT - C

abstract

Urbanization of coastal areas has increased, over the past decades, caused major pressure over resources and the environment. Population growth led to an increasing need for housing, which resulted in a rapid, unplanned and disperse urbanization – leading to the destruction and degradation of the environment. This type of extensive and scattered urbanization is known as urban sprawl. In order to contradict the negative impacts of urban sprawl and protect coastal environments, there is the need to procure sustainable urban development. This can be achieved through the implementation of frameworks and policies focused on achieving sustainability goals. In Portugal, one of those plans is the Regional Spatial Development Plan (PROT). Several land use models have been developed in order to assess historical and future land uses changes. This study aims to assess the regional spatial plan and its components for the Ria de Aveiro region (PROT-Centro), using the SULD decision support tool, in order to understand to what extent this plan contributes to sustainable urbanization of the region. Taking a sustainable development perspective, results show that even though the Integrated scenario is not the worst option it is, also, not the best option. From this perspective, the Environmental scenario results to be the best option for sustainable urban development, showing benefits from an environmental perspective (through the protection and appreciation of environmental amenities) as well as from a social and economic level (through increased urban concentration, housing prices and total real estate value in the region), while contradicting the problematic of urban sprawl and its negative effects. For the integrated scenario to be a more viable option, it should limit unconstrained urbanization and maintain more environmental aspects in the landscape.

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Introduction

1.1. Problem description

Increasingly the search for urban areas and scenically beautiful places leads to population growth in coastal cities and, consequently to a major pressure over the environment and ecosystems in coastal areas. The need to provide housing for the growing population, has led to unplanned urbanization and the occupation of land through urban sprawl (Environmental European Agency, 2006), resulting in the destruction of flora, fauna, habitats and water resources. This diffuse urban development increases the pressure over these areas leading to negative social, environmental and economic impacts, as well as associated welfare losses.

In Europe, between 1990 and 2000, urbanization in the coastal areas grew 30% faster as compared to urbanization in the hinterland, with Portugal being one of the countries with the highest rates (European Environment Agency, 2006).

Coastal areas are very dynamic, important and fragile places, being the connection between the ocean and the hinterland, making them susceptible to stress and pressure, suffering the action from wind, tides and currents that, consequently leads to high levels of coastal erosion. These areas are, also, highly affected by climate change, mainly due to the increase of the sea level (Pawlukiewicz *et al*., 2007). The social factor is, as well, very important in these areas, as the pressure felt in the coastline can be derived from human behavior, such as population growth and territorial development. The demand for habitation and touristic activities increases the value of the area and the cost of life (Pawlukiewicz *et al*., 2007). The Urban Land Institute of the United States of America (Pawlukiewicz *et al*., 2007) developed ten fundamental principles for Coastal development, being them: 1) Enhance value by protecting and conserving natural systems, 2) Identify natural hazards and reduce vulnerability, 3) Apply comprehensive assessments to the region and site, 4) Lower risk by exceeding standards for siting and construction, 5) Adopt successful practices from dynamic coastal conditions. 6) Use market-based incentives to encourage appropriate development, 7) Address social and economic equity concerns, 8) Balance the public's right of access and use with private property rights, 9) Protect fragile water resources on the coast and 10) Commit to stewardship that will sustain coastal areas.

In order to respond to this pressure there is a need for sustainable urbanization in coastal areas and, therefore, a more responsible planning of the territory with regard to people, the environment and the economy. To this end, every country has its own spatial plans that dictate the land-use planning policies and regulations for that region. These national, regional and local plans can have a significant impact on sustainable urbanization. However, there is a lack of connection between global policies and scientific discoveries when it comes to sustainable urban development (Hassan & Lee, 2015). In Portugal, national, regional and municipal plans have contributed to prepare, approve, implement and evaluate spatial planning instruments, as well as consolidated the goals, contents and procedures of the Portuguese planning system (Fidelis & Roebeling, 2014).

The Portuguese Framework Law for the Policy on Territorial Management and Urbanism (LBPOTU) establishes the Regional Spatial Development Plans (PROT). These are strategic instruments in land-use planning that integrate the decisions of the National Plan of Policies and Spatial Planning (PNPOT) and serves as a basis for the development of local plans.

The territorial model of the PROT-Centro is based on a reflection of the territorial textures and territorial structures of the studied region with the goal of finding pertinent geographies that represent the priorities of this plan (CCDR-Centro, 2011). The territorial textures focus on the landscapes, agriculture and forest areas, environmentally valuable areas, natural and technological hazards, and demographic variables. The territorial structures focus on economic variables, such as employment, urban polarities, mobility infrastructures and social vulnerability. As the territorial textures and territorial structures are analysed independently the result of the territorial model are two synthesis letters that integrate the main strategies of planning and development (CCDR-Centro, 2011). Based on this the PROT-C has three main dimension maps: Risks, Agriculture and environmental and Urban, which can be associated with Social, Environmental and Economic dimensions.To achieve a more sustainable land-use planning that is more socially, environmentally and economically beneficial, land use policy practitioners need to have a clear idea about the concept of sustainable urban development. One of the obstacles is not understanding how complex this concept is and, therefore a balance between the different aspects of urban development, such as social, environmental and economic issues, is required (Hassan & Lee, 2015).

Even though regions give special attention to the creation of plans that consider environmental aspects and threats to the region there is no assessment of these plans to understand their expected impacts and effectiveness. Consequently, there is a need to articulate and integrate spatial planning and sustainable urbanization models as to better understand the impacts of urban development.

1.2. Objectives

The overall objective of this study is to assess to what extent regional plans, in general, and their underpinning dimensions (social, environmental and economic), in particular, contribute to sustainable coastal urbanization in the face of global change. Accordingly, the specific objectives of this study are:

- Literature review on approaches that have been developed and applied to assess sustainable urbanization and that supported the development of regional plans.
- Description of the case study area (social, environmental, economic and legal aspects).
- Review the regional plans for the case study area, specifically the PROT-C, and identify significant spatial planning factors and associated territorial models (related to social, environmental and economic dimensions).
- Collate data about population, population density, household characteristics and land use for use in the Sustainable Urbanizing Landscape Development (SULD) decision support tool.
- Adapt, prepare, calibrate and validate the SULD decision support tool for the baseline situation.
- Simulate and analyse the social, environmental and economic impacts of the PROT-C, for the three territorial models and the integrated model, using the SULD decision support tool.

A case study is presented for the Ria de Aveiro Region in Central Portugal.

1.3. Methodology

The research approach followed in this thesis entails the following eight components (see Figure 1).

First, a literature review will be performed on i) the problem of urban sprawl and sustainable urbanization in coastal area, ii) approaches and models for sustainable urbanization around the world, and iii) national and regional plans and their contribution to sustainable urban development.

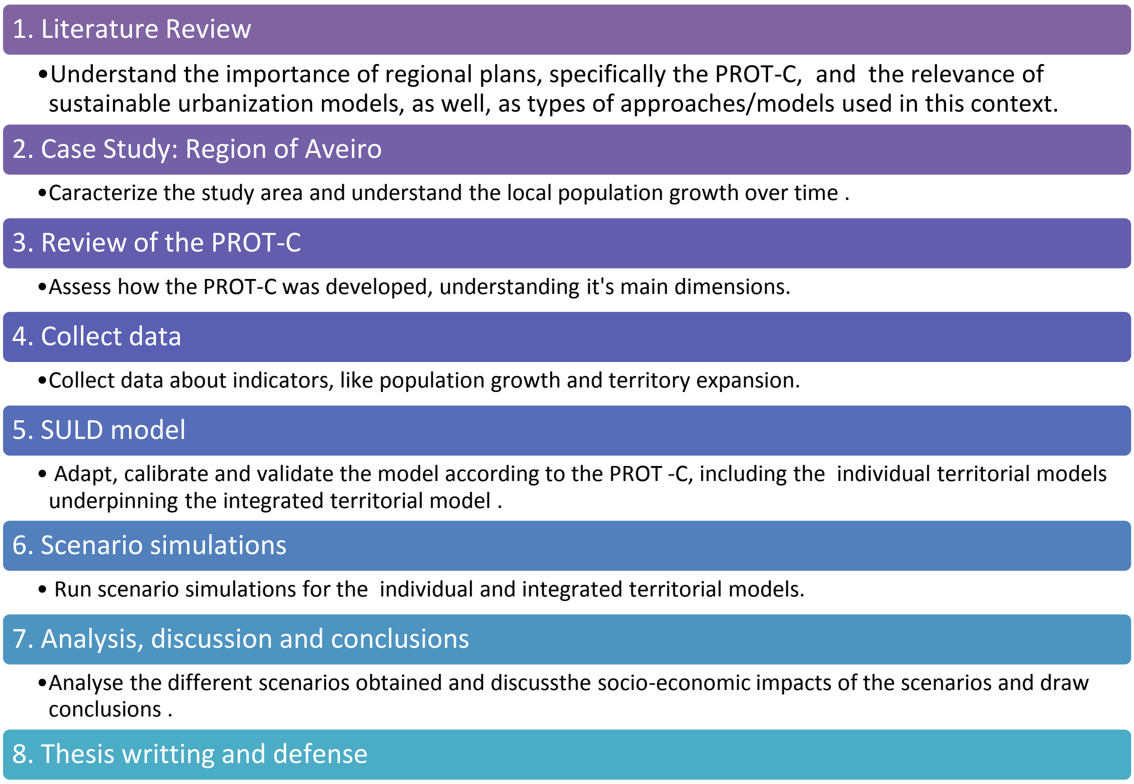

Figure 1 - Research approach.

Second, a description of the case study area will be provided. This study will focus on the Ria de Aveiro Region, particularly the region surrounding the Ria de Aveiro that is part of the Natura 2000 Network. A social, environmental and economic description of the case study area will be provided.

Third, a review of the regional plans will be performed, particularly of the PROT-C, in order to understand the main focus of this plan, as well as its main dimensions. It will be assessed how the PROT-C was developed, how the three territorial models (Risks, Environmental and Urban) and the integrated model were developed and how much weight is given to each dimension (social, environmental and economic). After this assessment, and taking in account the main planning dimensions existent in the PROT-C, the corresponding social, environmental and economic territorial models will be derived for use in the SULD decision support tool (see component 5).

Fourth, data will be collected for indicators such as land use, population size and density as well as social structure, for different moments in time. For this purpose, data will be obtained from the Corine Land Cover (CLC; http://www.dgterritorio.pt/) and the National Institute of Statistics (INE; https://www.ine.pt), amongst others.

Fifth, the SULD decision support tool (see Roebeling *et al.,* 2007, 2016) will be used to simulate scenarios of sustainable urbanization. The model will be adapted, calibrated and validated for the baseline situation (in this case for the year 2000).

Sixth, the different scenario simulations will be analysed. First, the impacts of each individual territorial model (Risks, Environmental and Urban) that compose the integrated territorial model will be studied. Then, the impacts of the integrated territorial model will be assessed. Subsequently, the individual and integrated territorial model impacts will be analysed and compared as to identify which contributes most to the sustainable urbanization of the area.

Seventh, conclusions will be drawn and, in light of the results policy recommendations will be provided.

The final phase of this study will be thesis writing and defence.

1.4. Structure of the dissertation

This dissertation is organized in eight Chapters: Firstly, Chapter 1 **(Introduction)** consists in the presentation and development of the problematic being studied, the exposition of the research objective and its methodology, as well as the structure of the dissertation.

Chapter 2 **(Sustainable urban development)** consists in a literature review, on the thematic of the research. Firstly, the problematic of urban sprawl and the importance to counteract its occurrence is analysed, as well as the understanding of its causes, consequences and possible solutions studied. Secondly, the sustainable urban development in coastal areas, the fragilities of these areas and policies for a sustainable urban development in these areas are analysed. Lastly, the importance of spatial plans for achieving a sustainable urbanization is assessed.

Chapter 3 **(Approaches to land use modelling)** focus on the literature review of different types of land use modelling approaches, being these divided into three types: Projective approaches, Predictive approaches and Explorative approaches. For each, different models of land use, their applications to real case studies and drawbacks are pointed out.

Chapter 4 **(SULD model)** is focused on the description of the model used in the research. A brief mathematical description of the model is provided, highlighting the main equations that support the model, followed by the explanation of the parameterization, calibration and validation procedure – highlighting the main values of these steps.

Chapter 5 **(Case study: Ria de Aveiro Region)** focuses on the description of the social, environmental and economic aspects of the Aveiro region, followed by the analysis of the urban development evolution (based on population growth, population density and land use indicators). Lastly, the regional spatial plan for the Aveiro region (PROT-C) is explored, analysing the various territorial models and how they were achieved and, in turn, focusing on the aspects from those models concerning the study region (Ria de Aveiro region).

Chapter 6 **(Definition of the scenario simulations)** explores the assumptions taken into consideration in order to achieve the Base scenario, the Risks scenario, the Environmental scenario, the Urban scenario and the Integrated scenario, with the last four being based in the territorial models of the PROT-C.

Chapter 7 **(Discussion of results)** consists in the analysis and assessment of the result obtained, firstly for the base scenario, followed by the three individual scenarios and the Integrated scenario.

Finally, Chapter 8 **(Conclusions and recommendations)** consists in the conclusions drawn from the results obtained in the scenario simulations, the evaluation of the PROT-C and recommendations for future researches.

2. Sustainable Urban Development

Currently more than a half of the world's total population lives in urban areas, being projected that, by the year of 2050, 80% of the world's population will be living in cities (Hennig *et al.*, 2015). As such it is necessary to understand the development of urban areas and how we can improve them through sustainable urbanization.

To achieve a sustainable urbanization means to reach an equilibrium between the social, economic and environmental components, taking into account the welfare and comfort of the population, economic development and the protection of natural ecosystems (Brackhahn & KSrkkSinen, 2002).

2.1. Urban Sprawl

Following the industrial revolution, world development and population growth resulted in more extensive and scattered urban expansion, giving origin to a concept called urban sprawl (Morollón *et al.*, 2015). Different authors give different definitions to this concept. According to the European Environmental Agency (European Environment Agency, 2006), this can be defined as a low-density, unplanned expansion of an urban area, to its periphery, showing an undefined pattern with tendency for discontinuity.

Several studies have been performed in order to understand the phenomenon of urban sprawl. As for its origin some authors mention the preference of the population for living in rural/suburban areas. Others mention the price of the land, as it is less expensive to buy a property in the periphery of urban centres (Paül & Tonts, 2005). The development of transportation (mobility) also contributed to urban sprawl, making it possible to live further from urban centres while maintaining the same access to services (Paül & Tonts, 2005).

Numerous are the impacts from increased urban sprawl in a city or region (European Environment Agency, 2006). First, this can increase the consumption of natural resources, such as land and soil, which are non-renewable. The transformation of the soil for the construction of infrastructures changes its natural properties, leading to the reduction in soil biodiversity and decreasing its carbon sink capacity (European Environment Agency, 2006). With the sprawl there is, also, the demand for unique raw materials from remote locations, requiring long distance transportation. Second, urban sprawl leads to increased consumption of energy, as an expanded and dispersed urbanization is less efficient. Also, increased transportation leads to an increase in energy use, greenhouse gas emissions, noise pollution and air pollution (European Environment Agency, 2006).

Third, the change in water properties is an impact of this phenomenon, affecting the hydrographic basin leading to losses (European Environment Agency, 2006).

Finally, the destruction of biodiversity and natural ecosystems, through the destruction of agricultural land, forest areas and wetlands for construction and the exposition of species to noise and air pollution. Also, the disturbance of migration paths threatens habitats and causes instability of natural processes and normal life of several species (European Environment Agency, 2006).

In Europe, urban sprawl has become more significant over the last sixty years, being southern, eastern and central Europe the most fragile areas. This is due to the high population density, economic activities and rapid economic growth in these countries (European Environment Agency, 2006). Regions which benefited from the support of European Union (EU) policies have a higher tendency to suffer from urban sprawl, as it is possible to perform trade-offs between member states which leads to the appearance of super regions that transcend national boundaries. As well, the EU support for long distance transportation promoted urban sprawl in Europe.

Other factors that influence urban sprawl in Europe are climate conditions, history of industrialization of the country, socio-cultural building conditions, topographic conditions and settlement in previously communist regions (Hennig *et al.*, 2015).

Along the European coastlines it is frequent to observe hot spots of urban sprawl, which, allied to the vulnerability of the coastal systems, make these areas extremely sensible.

In Portugal, urban development has suffered a fast growth mainly around the countries major cities, along the coastline. In 2000, 50% of the Portuguese urban areas were concentrated near the coastline, which only represents 13% of the total land area (European Environment Agency, 2006).

When it comes to strategies to counteract urban sprawl, Morollón et al, (2015) conclude that, first, the protection of land should not be done in a small particular way, but to protect a wider space. Second, the gap between urban and green areas should not exist, being the best solution to make a connection between these areas. Finally, there should be an integrated approach, sustained by cohesive local plans. The possibility of mixed land use (residential, commercial and services), was adopted in

Munich and is seen has an important instrument for the cohesion of cities (European Environment Agency, 2006). As well, some authors defend that a solution to counteract urban sprawl is the to follow a smart growth, which consists in the definition of policies that promotes an urban development that features high population density, preservation of green areas, mixed development (residential and commercial) and limitation of road construction, allowing for an increase of quality of life, as well as the proximity to environmental amenities (Resnik, 2010).

Nowadays urban planners aim to reverse urban sprawl, restraining the expansion to countryside areas in order to protect and prevent the destruction of ecosystems, agricultural lands and natural areas, as well as associated cultural and economic values. The study of the region's social, economic and environmental conditions and land-use restrictions to prevent urban development and higher density suburban development are some solutions for this problem (Paül & Tonts, 2005).

2.2. Sustainable urban development of coastal areas

Coastal zones are unique areas that make the bridge between the ocean and the continental land and that are extremely important, due to their unique environmental features, economic value and potential (such as for the generation of renewable energies). These are, however, very fragile areas, being under significant pressure caused by natural occurrences (like coastal erosion and flooding) and human activities (like severe urbanization and exploration of resources).

The conventional urban development of coastal areas, where habitations are built near the water, has been damaging to the natural areas and ecosystems interfering with coastal dynamics (Pawlukiewicz *et al.*, 2007).

Consequently, coastal governments started to realize that the over construction of coastal areas was not sustainable for the future of the coastal regions, downgrading environmental areas, compromising economic development and decreasing quality of life for the population (MSSD, 2006). Following this, the EU developed policies with the intent to define an approach to reach the sustainable use and management of the coastal resources.

In 2006, it was estimated that for the next 20 years, the Mediterranean regions would have 137 million more tourists and around 27 million more people living in the coastal urban areas (MSSD, 2006) – increasing significantly, the pressure on the region. As such, and with the aim to achieve a better and more sustainable management of coastal areas, the Mediterranean countries developed a *Mediterranean Strategy for Sustainable Development* (MSSD, 2006) – a strategy tool, whose main goal is to help adapt international frameworks to regional and local scales, as well as to act as a strategic guideline for sustainable development.

One of the most significant challenges for the Mediterranean countries is the destruction and degradation of the environment, with the loss of agricultural fields due to urbanization and salinization, overexploitation of water resources, air and noise pollution, coastal erosion and depletion of fish resources. In addition, these areas are extremely vulnerable to natural occurrences such as flooding, earthquakes, landslides, tsunamis, droughts and fires (MSSD, 2006). As for social and economic challenges, there is quite a difference between northern and southern countries, with the later having a higher population growth, being expected to have 90 million more people by the year of 2025.

The implementation of sustainable urban development measures in Portugal faces some challenges, such as problems in the implementation of policies, the lack of public financial resources to promote urban development and the lack of technical skills and knowledge (Barroso, 2011). As such, are identified eight key factors for the successful implementation of those measures (Barroso, 2011): i) prioritization of urban development actions, ii) integration of territorial planning with different themes related to urban development, iii) strategic planning of urban development, iv) knowledge of all involved parts, v) financial flexibility, vi) strong partnerships, vii) flexible bottom-up approaches and viii) active participation of the private sector through all the stages.

The sustainable urbanization gained a bigger dimension in 1994 after the development of the first urban development plan. The success of this first programme lead to the creation of other programmes and projects, including the POLIS programme (Programme of Urban Requalification and Environmental Valorisation of cities).

2.3. Importance of spatial plans in sustainable urban development

If there is not a strong urban spatial plan for a region, urban sprawl is likely to occur in a natural way. The implementation of urban policies and territorial spatial plans make it possible to have a more compact urbanization and, as such, the protection of natural ecosystems and the environment.

According to the United Nations, spatial planning can be defined as “the problem of coordination or integration of the spatial dimension of sectorial policies through a territorial-based strategy” (United Nations, 2008).

Spatial planning, all over the world, has been influenced by the goals to achieve sustainable urban development – considering that sustainable development is the base for policies in major international organizations, such as the United Nations (UN) and the EU (Delladetsima, 2011). This is due to the fact that spatial planning can help to achieve sustainable urban development and decrease urban sprawl, through urban compaction and the reuse of old industrial areas or districts in new urban areas (see e.g. - Roebeling *et al.*, 2014). Also, through spatial planning it is possible to protect areas where no construction has been developed, re-directing construction to already developed areas (Auken *et al.,* 2002).

There is a growing interest, across Europe to deliver sustainable urban policies. The European sustainable development spatial planning is based on a top-down approach, being, first, integrated in international and national policies and frameworks and, subsequently, transposed into regional and local policies (Delladetsima, 2011). Depending on a region’s social, economic and legislative background, the concept and understanding of sustainable urban development is likely to vary.

The EU has developed some spatial planning frameworks, such as the *European Spatial Development Perspective* (ESDP; Breiman, 2002), that provides a common spatial framework that encouraged transnational collaboration, adopted by all EU’s member states and which is supported by the assumption that sustainable development is the main goal of the EU territory (Delladetsima, 2011). Afterwards, in 2007, the *Territorial Agenda of the European Union: Towards a more competitive Europe of diverse regions*, was created and signed by the member states, extending the ESDP policy and prioritizing six spatial developments (Delladetsima, 2011). This Agenda’s goal is to help European regions to achieve sustainable economic growth and increase employment. Another document released by the European Commission on the subject of sustainable development is the *Green Paper on Territorial Cohesion*. It makes a reflection on territorial cohesion, on the disparity of socio-economic development in cities from the same region. Cohesion policy instruments are, also, an important tool in sustainable development as they support sustainable urban development policies and improve urban governance. The aim of this instrument is to increase growth and to pursue social and environmental goals (Breiman, 2002). Other initiatives include the URBACT and Eurocities, which were created with the intention to promote the exchange of urban development practices (Barroso, 2011).

It is important to understand that every European country adapts these frameworks to their own reality – hence, spatial plans will differ, even though departing from the same basis. For example:

- In Greece, sustainable development was a concept without a strong definition, specifically to where policies and planning was related. Nowadays the planning system has a hierarchical and fragmented structure involving the government and interested organizations (Delladetsima, 2011).
- In Norway, municipal plans aim to discourage the development of suburban areas, encouraging the construction in developed areas close to the city centre. Some regions, even, developed policies were the construction in undeveloped land is forbidden (Auken *et al*., 2002).
- In Denmark, the management of coastal zones and the implementation of spatial planning legislation, has been implemented over several years, being the legislation on erosion management updated over time (Vieira, 2000) In 1992, the Planning Act which regulates the interests in the coastal zone, resulted in the establishment of a Coastal Proximity Zone and a Beach Line Protection Zone, as planning tools (Vieira, 2000). This plan identified the regulation for the land use within limited areas, which need to be transposed into local plans. Within this plan it is mandatory to mention the anticipated effects on the landscape and the environment.
- In Finland, the government adopted national guidelines for land use, which aimed to improve the territorial organization, helping to improve the living environment and to promote social, economic, environmental and cultural sustainable development (Auken *et al.,* 2002).
- In Portugal, similar to what happened in other Member-States, urban policies were developed due to the socioeconomic problems related to the deindustrialization – including high unemployment rates, lack of skills of the population and environmental degradation. The Portuguese government has developed and implemented several plans for sustainable urbanization. Nowadays the Cities Policy POLIS XXI is the reference document for urban policies (Barroso, 2011).

Some authors find that the lack of connection between global policies related to sustainable urban development have failed to put to practice some solutions for this problem (Hassan & Lee, 2015). Therefore, policies and frameworks need to be well structured in order to be an asset for sustainable development. As such, the improvement on urban renovation in the Mediterranean region shows how spatial planning policies and frameworks are imperative to support the achievement of sustainable urban development – international, national, regional and local wise.

3. Approaches to land use modelling

In order to assess land use change and evolution, several land use models and modelling approaches have been developed.

Following Fidelis & Roebeling (2014), the land use modelling approaches can be divided into three categories: Projective approaches, Predictive approaches and Explorative approaches.

3.1. Projective approaches

Projective approaches are based on statistical models, which make projections of future land use by relating historical land use changes to bio-physical and socio-economic parameters (Fidelis & Roebeling, 2014). Therefore, use is made of territorial maps and census/survey data from several moments in time.

The LUCC (Land Use & Cover Change) approach is one example of this kind of approach and comprises a wide range of models from different scales and research fields (including landscape ecology, geography, urban planning, economics and regional science).

Several are the LUCC models developed:

- The CLUE (Conversion of Land Use and its Effects) model combines bio-physical and human land use parameters to determine patterns of land use change in a region (Veldkamp & Fresco, 1996; (Verburg *et al.*, 2002). While CLUE was initially intended to be applied to national and continental levels (Verburg *et al.*, 2002), some studies have been developed in order to apply this model to the local and regional level. CLUE has been applied to assess land cover and agricultural changes in Europe (Britz *et al*., 2011), the spatial dynamics of regional land use (Verburg *et al.*, 2002) and to project land use changes in the Neotropics (Wassenaar *et al.*, 2007). From these studies it can be concluded that CLUE can be used to various land use change situations, but it is not able to make land use simulations in areas without previous land use change data (Verburg *et al.*, 2002). Also, the difficulty to obtain realistic values due to large amounts of uncertain qualitative relationships of the CLUE model, has been identified (Veldkamp & Fresco, 1996).
- The SLEUTH model (slope, land use, exclusion, urban extent, transportation and hillshade) is, a cellular automata model that resulted from the merging of two

models: the Land Cover Deltatron Model and the Urban Growth Model (Chaudhuri & Clarke, 2013). The model is capable of projecting urban growth based on past events (Hua *et al.*, 2014) and has been applied to simulate the urban growth in a coastal peri-urban district (Hua *et al.*, 2014) as well as to simulate the impacts of future policy scenarios on land use in Baltimore (Jantz *et al.*, 2004). Based on these studies, it is concluded that SLEUTH does not have the capability to simulate possible impacts of policies, it lacks the ability to redirect growth pressure, and it does not present the actual impacts of land-conservation measures (Hua *et al.*, 2014). As well, there is the inability of SLEUTH to capture a large a wide range of growth processes and patterns (Jantz *et al.*, 2004).

- SPA-LUCC is a Spatial Allocation procedure of LUCC, combining its quantities, or number of pixels to change existing land use/cover, with spatial allocation methods. This model was used to generate and develop land use/cover scenario maps of mountain regions (Schirpke *et al.*, 2012).

Another projective approach is the Carnegie-Ames-Stanford (CASA) approach, a spatially explicit global terrestrial carbon model, which calculates the terrestrial Net Primary Production (NPP) with a monthly periodicity, based on light-use efficiency concept (DeFries & Bounoua, 2004). This model has been applied to study carbon and nitrogen storage in soils (Potter & Klooster, 1997), and the consequences of land use change for ecosystem services (DeFries & Bounoua, 2004). Based on these studies the authors note the fact that the prediction of natural vegetation changes due to interaction of climate change can be very uncertain (Potter & Klooster, 1997), as well as the difficulty to predict factors that influence future land use and the need to use other models in order to study land use change for ecosystem services at local and regional scales (DeFries & Bounoua, 2004). However, this model is not ideal for studies of land use, atmosphere and climate change (Potter *et al.*, 1993).

Also inserted in the Projective approaches is the combination of cross matrix analysis, spatial metrics analysis and gradient analysis (Abrantes *et al.*, 2016). This was used to assess accordance between land cover change and municipal land use planning (Abrantes *et al.*, 2016).

As cons of the projective approaches some authors note that past events do not help to predict the consequences of future land use changes or the impacts of futures policies (see DeFries & Bounoua, 2004).

3.2. Predictive approaches

Predictive approaches predict landscape changes that result from policy and technology changes, based on the behavior of multiple agents (Fidelis & Roebeling, 2014). Hence, agent behavior is a significant parameter to predict future events.

Some LUCC models take into account this behavior, where agents are defined as being autonomous, making decisions that are connected to the environment (Verburg *et al.*, 2006). For example, The Land-Use Dynamic Simulator (LUDAS) is a conceptual MAS-LUCC model, that represents the human-landscape system in rural forest margins, with the aim to explore alternatives that will help mitigate negative impacts of land use change, facilitating the negotiation between the involved agents in land use planning (Le *et al.*, 2008). This model was used to assess the impacts of secondary feedback in land use decision making(Le et al., 2010) and to assess the socio-ecological system dynamics of Agro forests (Villamor *et al.*, 2013). However, LUDAS is unable to incorporate several features of the process of human decision making (Le *et al.*, 2008).

Multi Agent Systems (MAS) are computer systems, based on information collected from the environment, with several agents that interact with each other, though not knowing every aspect about the remaining agents (Panait & Luke, 2005). These systems can be used to explore environmental changes, human actions, as well as policy interventions (Schreinemachers & Berger, 2008). However the MAS concept is not well defined in the community (Panait & Luke, 2005). For example the Mathematical Programming-based Multi Agent Systems (MP-MAS) model aims to understand the impact that agricultural technology, market dynamics, environmental change and policy interventions have in a population of farm household and their agro-ecological resources (Schreinemachers & Berger, 2011). This model was used to study the spread of greenhouse agriculture in northern Thailand (Schreinemachers *et al.*, 2009). However, MP-MAS is not precise in its economic predictions/foresights, since it includes incomplete information (Schreinemachers *et al.*, 2009).

Bio-Economic Farm Models (BEFMs) allow for the assessment of technologies and policies applied to farming and agriculture systems. BEFMs relate management decisions with production possibilities, and are, generally, used for one specific purpose or location (Janssen *et al.*, 2010). A particular example is the Farm System Simulator (FISSM) that aims to provide supply/response functions for Nomenclature of Territorial Units for Statistics (NUTS) and to allow the assessment of agricultural and environmental policies and technological innovations on farming practices, regionally wise (Janssen *et al.*, 2010). The FISSM can be used to simulate the response of EU farming systems to agricultural and environmental policies (Louhichi *et al.*, 2010). Another example is the MODAM (Multi-Objective Decision support tool for Agroecosystem Management) whose main objective is to analyze the relations between economic and ecological goals of agricultural land use (Uthes *et al.*, 2007). MODAM has been applied to assess the ecological effects of policy change of payment decoupling in Germany (Uthes *et al.*, 2007) and to simulate agricultural decision making and consequences to the environment (Zander & Kächele, 1999). However, to some authors, BEFM's lack to be re-used as they are applied for a specific purpose and location, they are not used to assess policies, and stay within the research domain (Janssen *et al.*, 2010).

As cons of the predictive approaches, authors mention the difficulty to connect behaviour to the actual land areas, thus not being reliable to represent spatial behaviour (Verburg *et al.*, 2006). In addition these can be very complex and unpredictable models, as they are based on human behaviour – sometimes leading to non-realistic and not strict results (Kapfer *et al.,* 2015).

3.3. Explorative approaches

Explorative approaches explore the social, environmental and economic outcomes of scenario simulations, using integrated modelling approaches (Fidelis & Roebeling, 2014). In this kind of approach the behavior of the stakeholders is not taken in regard. These approaches include integrated assessment studies, alternative future studies and bio-economic approaches (Fidelis & Roebeling, 2014).

The EESIP (Environmental Economic Spatial Investment Prioritization) modelling approach is an interdisciplinary environmental-economic modelling approach that integrates an agricultural production system simulation model and a catchment water quality model into a spatial environmental–economic land-use model, as to explore patterns of land use and management practice that most cost-effectively achieve specified water quality targets (Roebeling *et al.*, 2009; Van Grieken *et al.*, 2013) as well as to assess the cost-effectiveness of economic instruments aimed at promoting the adoption of practices for water quality improvement (Roebeling et al., 2009a).

The RegIS (Regional Climate Change Impact and Response Studies in East Anglia and North West England) studies the impacts of climate and socio-economic changes through an Integrated Assessment Methodology (IAM). RegIS has been applied to assess the impacts of climate and socio-economic changes in the United Kingdom. Neverthless RegIS shows some drawbacks when it comes to multi-sectoral modelling at local scale (Holman *et al.*, 2005).

Alternative future studies are used to assess future alternatives and impacts of agricultural practices, as it was done for the specific case of Iowa in the USA (Santelmann *et al.,* 2003). Future scenarios are designed through an iterative process, and resulting in land use and land cover maps that are digitized into a Geographic Information System (GIS) as to, in turn, assess on their environmental, social and economic impacts using disciplinary models. Drawbacks of such alternative future studies are the presence of trade-offs between generality, transferability, realism, accuracy and precision, as well as the lack of long term ecological research (Santelmann *et al.,* 2003).

The SULD (Sustainable Urbanizing Landscape Development) decision support tool allows to assess the impact of demographic, green/blue space and infrastructure scenarios on the location of residential development, housing quantity, residential development density, population density, population composition, household living space and real estate values (see Roebeling *et al.,*2007,2014, 2016). SULD is a GIS (Geographic Information System) based optimization model, based on a classic urban-economic model with environmental amenities (Roebeling *et al.,* 2017, 2016). SULD has been used to evaluate the socio-economic values of green and blue spaces in urbanized cities (Roebeling *et al,* 2014, 2016), to study limits to the benefits of increasing population in linked terrestrial and marine ecosystems (Roebeling *et al*., 2007), and to model the residential aspect of urban expansion through the simulation of housing supply and housing demand (Alves, 2014).

Besides the use of modelling approaches, some projects try to give answers to the problem of climate change threats allied/associated to the growing urbanization and consequent pressure on resources and cities themselves. The Blue Green Dream project appears in this context because of the demand to rethink the planning of urban water systems, known as blue assets, and urban vegetated areas, as green assets (see http://bgd.org.uk/).

4. SULD model

In order to assess the social, economic and environmental impacts of the regional spatial plan, the Sustainable Urbanizing Landscape Development (SULD) decision support tool will be used. SULD is a classic urban economic model with environmental amenities, that allows to assess the socio-economic impact of demographic, green/blue spaces and infrastructure scenarios (see Roebeling *et al.*, 2007, 2014, 2016).

4.1. Description

The application of hedonic pricing models has been a popular choice when it comes to studies about the thematic of economy, land-use and urban impacts. These models consist in a regression method that estimates the economic value of properties as a function of the proximity to, for example, environmental and urban amenities (Roebeling *et al.*, 2016). The hedonic analysis of housing prices, thus, isolates the implicit prices of individual housing attributes from a regression of prices on these amenities attributes (Schläpfer et al., 2015). Hedonic pricing models require, however, a considerable amount of primary data about property sales near the considered environmental amenities (see Roebeling *et al.*, 2016).

Building on hedonic pricing theory, hedonic pricing simulation models allow for the estimation of the added value of certain amenities where such primary data are unavailable (Roebeling *et al.*, 2016).

To date, only a few studies have been performed using hedonic pricing simulation models to investigate the added value of green and blue spaces. Some of those studies are supported by SULD (Roebeling *et al.*, 2007), which allows to determine residential development and density, population density, housing quantity and housing prices as a function of the proximity to urban and environmental amenities (Roebeling *et al.*, 2016).

The demand side of the model represents households and their preferences for goods and services, such as their preference for residential space (*S*), environmental amenities (*e*) and other goods and services (*Z*). These preferences are considered similar for each household living in a certain location *i*. The maximization of the utility (*U*) of a certain household in a certain location is constrained by their income (*y*), which can be spent on housing ($p_i^h S$), other goods and services and on travel to urban centers ($p_x x$) and is represented by (Roebeling *et al.*, 2016):

$$Max_{S_i,Z_i}\, U_i(S_i, Z_i) = S_i^{\mu} Z_i^{(1-\mu)} e_i^{\varepsilon} \qquad \text{Equation 1}$$

subject to $y = p_i^h S_i + Z_i + p_x x_i$

being p_i^h the price to rent a house, p_x the commuting costs, x_i the road distance to the closest urban center, μ the demand the residential space and $\mathcal{E}$ the utility respecting the environmental amenities (Roebeling *et al.*, 2007). The environmental amenity level (e_i) at location *i* decreases with the distance from the environmental amenities.

$$e_i = 1 + \sum_q \alpha_q * \ exp^{-\beta z_{iq}} \qquad \text{Equation 2}$$

where α_q represent the level of amenity provided by the environmental amenity of quality q, β is the decrease of amenity level the further away one is from the environmental amenities, z_{iq} is the distance (straight line) from location *i* to the closest environmental amenity *of quality q.* The household's bid rent price for housing can now be derived (see Roebeling *et al.*, 2007) and represents the maximum amount that a household is willing to pay for housing in a certain location *i*.

The supply side of the model is represented by real estate developers, who maximize their profit by trading of returns from development density (*D*) and aims to maximize their profit (π) in a certain location i.

$$Max_{D_i} \pi_i(D_i) = p_i^h D_i - (l_i + D_i^\eta) \qquad \text{Equation 3}$$

with $D_i = n_i S_i$

where, p_i^h is the rental price of housing, l_i is the opportunity cost land, D_i^η is the construction cost function, η is the ratio of housing value to non-land construction costs, n_i is the household density and S_i is the residential space. Thus, it is possible to derive the developers bid-rent price for land (ri^{**}) in a certain location (see Roebeling *et al.*, 2007).

When the demand for housing equals the supply for housing equilibrium is obtained and it is possible to derive the equilibrium land rent price (r_i) at a certain location *i* (see Roebeling *et al.*, 2007):

$$r_i = \left(\frac{k e_i^{\mathcal{E}} (y - p_x x_i)}{u}\right)^{\frac{\eta}{\mu(\eta - 1)}} \qquad \text{Equation 4}$$

where $k = (\mu m)^\mu (1-\mu)^{(1-\mu)}$ and the optimal household density (n_i) is given by $n_i = \frac{D_i}{S_i}$, with the necessary condition for optimality U_i given by $S_i = \frac{\mu(y - p_x x_i)}{p_i^{h*}}$ and the necessary condition for optimality π_i given by $D_i = (\eta - 1)^{-\frac{1}{\eta}} (r_i)^{\frac{1}{\eta}}$.

For the numerical application of the SULD model, the General Algebraic Modelling System (GAMS) is used. This system maximizes the benefits (*B*), for a certain household population (Q_t), from residential land uses (L_i^{res}) and non-residential land uses (L_i^{nres}) net of development costs (l_i + D_i^{η}), for a given household location (Roebeling *et al.,* 2014).

$$Max_{l_i} B(L_i) = \sum_i (l_i L_i^{nres} + (r_i - l_i + D_i^{\eta}) L_i^{res}) \quad \text{Equation 5}$$

subject to $Q_t = \sum_i ni$ and $L_i^{res} + L_i^{nres} = a_i$, and l_i the opportunity cost of land, r_i is the land rent price and $a_i$the grid-cell area at location *i*.

4.2. Parameterization

The Parameterization of this model was previously performed by (Alves, 2014).

Table 1 shows the different parameter values used in the model (obtained from INE and from the model), taking into account that these values are already calibrated. The values were obtained using population statistics. The number of households (*Q*), per household type, was calculated from the population and household values. The average income for households, in the region, is 24439 euros per year, with the households spending on average 28.4% of their income on housing.

Table 1 – Calibrated parameters for the RdA region.

Parameter	unit	hh-type1	hh-type2	Total	Average
Population	#	266042	66511	332553	-
Household size	#/hh	2.98	2.98	-	2.98
Households (*Q*)	#	89276	22319	111595	-
Household utility (*u*)	#	2420	7817	-	5119
Household income (*y*)	€/yr	11555	37323	-	24439
Housing expenditures (μ)	%	29.3	27.5		28.4
Preference environmental amenity ($\mathcal{E}$)	#	0.08	0.08	-	0.08
Environmental amenity lev el (α)	#	10.0	10.0	-	10.0
Amenity distribution factor (β)	#	1	1	-	1
Annual commuting costs (p_x)	€/km/yr	250	250	-	250
Ratio of housing value to non-land construction costs (η)	#	-	-	-	1.379

In order to have the income value of the households, different approaches were considered. Based on the data from the Portuguese National Statistics Institute (Table 2), two types of households were chosen: Households with higher income, corresponding to the values of the 5th quintile and households with lower income, corresponding to the mean of the 1st to 4th quintile. The only data available was from the years 2005 and 2009, having the author extrapolated the values for the remaining years.

Table 2 – Income, in euros, according to income quintiles, for the centro region (Alves, 2014).

Year	Mean of 1st-4th quintile	5th quintile
2001	11555	37323
2002	11730	37911
2003	11910	38509
2004	12095	39117
2005	12285	39734
2006	12526	40435
2007	12786	40826
2008	13055	41220
2009	13334	41619

Also, the SULD model requires the distance (z_i) from each grid-cell i to the environmental amenities water (ZZ1) and forest (ZZ2).These distances are calculated based on Euclidean distances, considering the shortest distance between each cell and the nearest point to the polygon of the environmental amenity considered.

The distance of the environmental amenities for the base map were calculated by Alves (2014; see Annex 4 and Annex 5). To calculate the distance to the forest amenity it was used ArcGIS in order to have the highest level of precision.

4.3. Calibration procedure

The calibration procedure was, also, performed by (Alves, 2014). A comparison between the simulated map (created by SULD) and the reference map (Corine Land Cover (CLC) 2000) was made, where key parametere values were adjusted to obtain the highest agreement between both maps.

Four calibration parameters were chosen for the calibration procedure: i) the base utility level of a household (u_1 and u_2), ii) the share of income on housing expenditures per household type (μ_1 and μ_2), iii) the ratio of housing value and to non-land constructino costs (η) and iv) the ratio of travel time across main and secondary roads (incluencing x_i). The first three parameters were chosen due to their sensitivity in the model, based on previous studies, and the fourth parameter was chosen due to the uncertanty of the ratio between the average speed on main roads and secondary roads.

The base parameter values are presented in Table 3. The x_i values wer obtained from oficial statitical data, the u_1 and u_2 and η values were obtained from a similiar study in the city of Aveiro from (Roebeling, 2014), and the μ_1 and μ_2 values were obtained from statistics and from pre-calibration procedures, that indicate the maximum and minimum variation values for a resonable proximity to urban areas.

Table 3 - Base parameters for calibration (Alves, 2014).

x_i (1)	u_1 and u_2 (2)	η (3)	μ_1 and μ_2 (4)
1/3	2425	1.380	0.294 and 0.276
1/6	2450	1.385	0.296 and 0.278
-	2475	1.390	0.298 and 0.280

Notes: (1) with x_i being the ratio of speed on main and secondary roads.

(2) u_1 and u_2 being the base utility level of a family.

(3) η being the ratio between the value of habitation construction and the value of non-habitation construction.

(4(μ_1 and μ_2 being the share of income on housing expenditures per family.

The calibration procedure was performed following Pontius and Sudmeyer (2004) which accounts for differences between two maps in two vectors. It is considered five comparison components between the two maps: i) agreement due to chance, ii) agreement due to quantity, iii) argeement due to location, iv) disagreement due location and v) disagreement due to quantity. The value of total agreement is obtained through the sum of the agreement components and the value of total disagreement is obtained through the sum of the disagreemnt components. Both agreement and disagreemtn values vary from 0 (disagreement or inexistent agreement) and 1 (total disagreement or agreement).

While doing the comparison and with the aim to compare the urban areas and the agricultural areas with construction prospects of the CLC 2000 map, it was used a mask.

Two sets of runs were made, with fifty four parameter combinations, in order to improve the comparison components. To choose the best values to use in the model, it was made a selection of a few runs, considering the lowest value disagreement due to quantity value and a high total agreement value. The best three runs, from the second set of runs, were chosen (Table 4), with the 9_B run presenting the best total agreement values and a medium disagreement due to location value and the 11_B and 13_B runs presenting the best total agreement and disagreement due to location values. The 9_B run was considered as having the best values to use in the model.

Table 4 - Best values of the second run (Alves, 2014).

Run	**Parameter values***				**Agreement and disagreement components****					**Total disagreement**	**Total agreement**	**Urban cells difference**
	x_i	u_1 **and** u_2	η	μ_1 **and** μ_2	**1**	**2**	**3**	**4**	**5**			
9_B	1/6	2420	1.379	0.293 and 0.275	0.50	0.128	0.107	0.244	0.022	0.265	0.735	-145
11_B	1/6	2420	1.381	0.293 and 0.275	0.50	0.119	0.110	0.268	0.003	0.271	0.729	-23
13_B	1/6	2430	1.379	0.293 and 0.275	0.50	0.119	0.110	0.268	0.003	0.271	0.729	-20

Notes: * See Notes from Table 3

** 1 – agreement due to chance, 2 – agreement due to quantity, 3 – agreement due to location, 4 – disagreement due to location, 5 – disagreement due to quantity

4.4. Validation procedure

The validation of the model was, similar to the parameterization and calibration procedure, previously made by (Alves, 2014). Being necessary to use a diferrent data set for the calibration and validation procedure, the author used a temporal separation, with the years of 2000 and 2006.

For the validation procedure it was chosen the year of 2006 in order to use a reference map that would correspond to the reference map used for the calibration procedure.

During the validation process updated parameters were included, such as, population, family size, family income, and family utility. The first three indicators were obtained through statistics and/or extrapolation of data, whereas the last indicator increased proportionaly to the increase of family income.

In addition, there was the need to update the base map, blocking protected areas, (where, construction is not allowed) and adjusting the distance to florest amenities (due to changes in forest and agricutural areas, impacting directly the area allowed for construction).

The reference map was compared with two different models: a nul model or persistent model that does not change between two periods in time (in this case 2000 and 2006), and a random model that randomly distributes the urban and agricultural cells in the map (folowing Pontius *et al.*, 2014).

Table 5 shows that the best results are from the persistent model and the worst results from the random model. The calibrated model presents good results as compared to with the calibrated model for the year 2000 (Alves, 2014). Hence Alves (2014) concludes that this model had the capacity to be used as a prevision model, showing better results than the random model.

Table 5 – Validation results for calibrated, persistent and random model (Alves, 2014).

Run	**Agreement and disagreement components***					**Total disagreement**	**Total agreement**	**Urban cells difference**
	1	**2**	**3**	**4**	**5**			
Calibrated model	0.50	0.119	0.105	0.259	0.017	0.276	0.724	-118
Persistent model	0.50	0.115	10.380	0.000	0.005	0.005	0.995	-70
Random model	0.50	0.000	0.004	0.259	0.238	0.497	0.503	1565

Notes: Notes: * See Notes from Table 3

** 1 – agreement due to chance, 2 – agreement due to quantity, 3 – agreement due to location, 4 – disagreement due to location, 5 – disagreement due to quantity

5. Case study: Ria de Aveiro region

The Ria de Aveiro region is a valuable area, being environmentally important and contributing to the economic growth of the region and the country. This region, as well as several other cities experienced a rapid urban growth leading to a dispersed and uncontrolled urbanization. As such, it becomes important to analyse the spatial plans existent in the region and its main aspects.

5.1. Description of the region

The Region of Aveiro is situated on the northwest coast of Portugal, between Porto and Lisbon and covers an area of 2808 km^2. It includes nineteen districts, including Águeda, Albergaria-a-Velha, Anadia, Arouca, Aveiro, Castelo de Paiva, Espinho, Estarreja, Ílhavo, Mealhada, Murtosa, Oliveira de Azeméis, Oliveira do Bairro, Ovar, Santa Maria da Feira, São João da Madeira, Sever do Vouga, Vagos and Vale de Cambra (see Figure 2). This study considers the area limited by Vagos, in the south, Ovar in the north and Albergaria-a-Velha in the east.

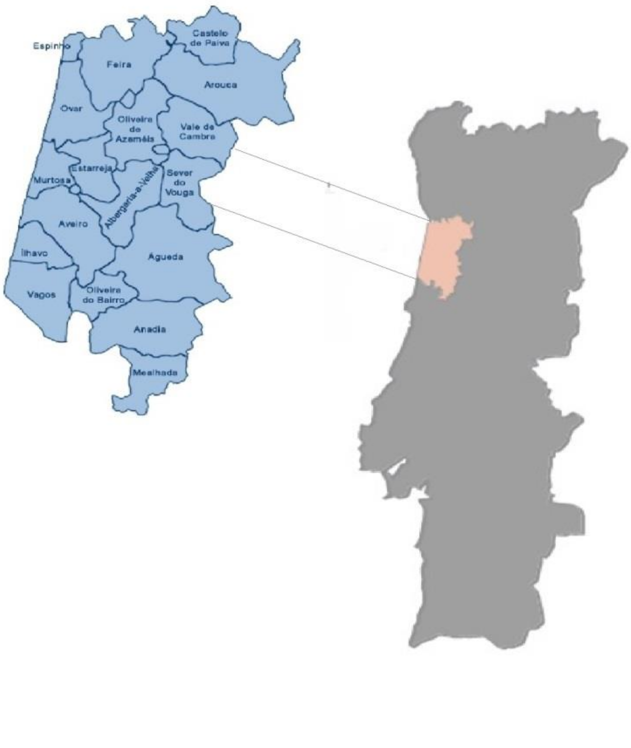

Figure 2 – Map of the region of Aveiro.

The Aveiro region is specially known for the important hydrological occurrences in the area, particularly the Ria de Aveiro (RdA). The RdA region has a population of, approximately 333 114 habitants (data from 2010) and includes the districts of Estarreja, Gafanha da Nazaré, Ílhavo, Mira, Murtosa, Ovar and Vagos (Lillebø *et al.*, 2011).

The RdA is a coastal lagoon of shallow water, composed by several channels and linked to the sea by an artificial channel, being 45 km long and 10 km wide (Lillebø *et al.*, 2011). It is considered one of the most important blue areas in the north of Portugal, harbouring a wide range of plant and animal species.

Due to its significant environmental and ecological importance, as it is the habitat for several endangered bird and fish species, the RdA is considered a protected area under the Natura 2000 Network Directive (Pinto & Leite, 1999). Integrated in the Natura 2000 Network, since 2014, the RdA is considered a Special Protected Area (SPA), listed under the Birds Directive (Directive 2009/147/EC), as it is the habitat of, approximately, 20 000 aquatic bird species – such as the black scotter, the dunlin and the wild duck (Antunes e Santos, 2011). Also part of the Natura 2000 is the Vouga River, which is the main water course to feed into the RdA. It is considered a Site of Community Importance (SCI), being this described in the Habitat Directive (Directive 92/43/EEC) as a site that contributes to maintain the conservation of a natural habitat or that contributes to maintain the biological diversity in the region. The lagoon is, also, important for the conservation of certain fish species (Antunes & Santos, 2011). The region is considered very fragile as it has a potential to suffer floods, given it is a low altitude area with a flat topography (Lopes *et al.*, 2014).

The RdA allows for the existence of several economic activities. Fisheries are a big contributor, being the main income source of some local families and having generated around 12 million euros in 2010. This business is, also, part of the socio-cultural identity of the region (Alves *et al.,* 2011).

Salt production is another significant activity in the RdA, not only from an economic perspective but also from a cultural perspective. This activity had a significant role in the economic development of the region becoming, however, less significant over the past decades. Salt production decreased from 51 000 tonnes of salt, in 1972, to 500 tonnes of salt, in 2002 – increasing the number of abandoned salt pans (Alves *et al.,* 2011).

Even though fisheries, cattle raising and agricultural activities contributed significantly to economic growth in the RdA region, nowadays it is the industrial sector that prevails as the main economic activity, with a number of industrial complexes, factories and ports throughout the region (Alves *et al.,* 2011). In 2009 the RdA region comprised 6.7% of the companies existent in the country (http://www.aida.pt/).

The fact that Aveiro is a coastline city with several activities developed in the area and allied to beautiful landscapes and peculiar characteristics of the lagoon makes the region a big attraction for tourists (CCDR-Centro, 2011).

In terms of accessibility the region of Aveiro has an urban system with a polycentric structure, the centre being the urban area of Aveiro and being surrounded by Leiria-Marinha Grande and Coimbra – Figueira da Foz urban axes (Margarida e Bilelo, 2010). Transport wise, the city of Aveiro is very well positioned, having highways (A1, A17 and A25) that facilitate the connection with the major cities in Portugal (including Lisbon, Coimbra, Porto and Viseu. Besides the highways, Aveiro has an intercity railway station that connects the city with Lisbon, Coimbra and Porto (Quintão *et al.*, 2012)).

Also, the port of Aveiro is known as being one of the most important in the country due to its location near highways and railways, (Quintão *et al.*, 2012), encouraging the economic development of the area, It is the main Portuguese port in terms of transportation of metallurgic products in Portugal, and one of the main ports in the transportation of fractionated cargo, (Ribeiro *et al.,* 2011). It is, as well, an important fishing port with 6% of the continental fish landings. The increase rate of maritime traffic over the past decades, allowed the commercial growth of this port (Alves *et al*, 2011).

Finally, the presence of the University of Aveiro, as well as innovative companies in the region, contributed to the development of the area – allowing for a more competitive and attractive area from both a social and economic perspectives (Teles *et al.*, 2014).

5.2. Urban development evolution

The proximity of the city of Aveiro to the ocean and the RdA was an important factor for the settlement of population in the area. The RdA's several changes, due to ocean currents and the origin of sand strips, resulted in the repositioning of the population around the RdA according to these changes (Ferreira, 2003).

Before the XV century, the two main economic activities of the area were maritime trade and salt extraction, since the soil was not appropriate for agricultural activities.

The development of these activities led to an increase in the population (Ferreira, 2003). The high dependence of the community on maritime activities, the opening of Barra (in the second half of the XVIII century), as well as the investments made in the industry sector helped to further increase the economic development and population growth in the area (Pinto *et al.*, 2009). In the XIX century the development of the transportation sector, especially through the construction of railways that connected the city of Aveiro to Albergaria-a-Velha, Viseu, Mira and Barra, allowed the movement of people in and out of the city. This increased accessibility was a big propellant for the development of industries (Ferreira, 2003). In the beginning of the XX century the city experienced growth and expansion of the urban area due to the implementation of hygiene norms. Also, the region's southern area experienced industrial development with the establishment of some industries. Around this period, one of the RdA's channels (the Cojo channel) was narrowed, in order to construct a pathway that would connect the city to the railway (Pinto *et al.*, 2009).

From the mid of the XIX century to the mid of XX century, the population grotwth increased more than three times in the space of 100 years – from around 6000 inhabitatnt in 1870 to around 23000 inhabitants in 1960. The biggest growth started in the 1920's (see Annex 1).

In the mid of the XX century there was a second wave of urban growth, leading to the construction of schools and the development of an extended urban project – allowing the creation of a new urban area limited by the railways (Pinto *et al.*, 2009). In 1957 the port of Aveiro was inaugurated, being the location of the port carefully chosen in order to have proximity between these infrastructures with local industries and major transportation facilities (Ferreira, 2003).

The construction of the water deposit in the decade of 1960 allowed the delimitation of a new urban area, with the occupation of the surrounding area. The construction of the University of Aveiro, in 1976, was another step taken towards the city's urban expansion (Pinto *et al.*, 2009). This acted as a regenerator of urban evolution, stimulating social and economic growth, creating pressure on the industry sector and resulting in the development of new habitation areas and expanding the urban centre (Fonseca, 2010). As such, the urban area experienced rapid (+500%) expansion between 1975 and 2006, with the main growth being near Oliveira de Azeméis, Estarreja and Ovar (Figure 3). However, urban expansion presents a disperse behaviour corresponding to urban sprawl (see Figure 3; Alves, 2014).

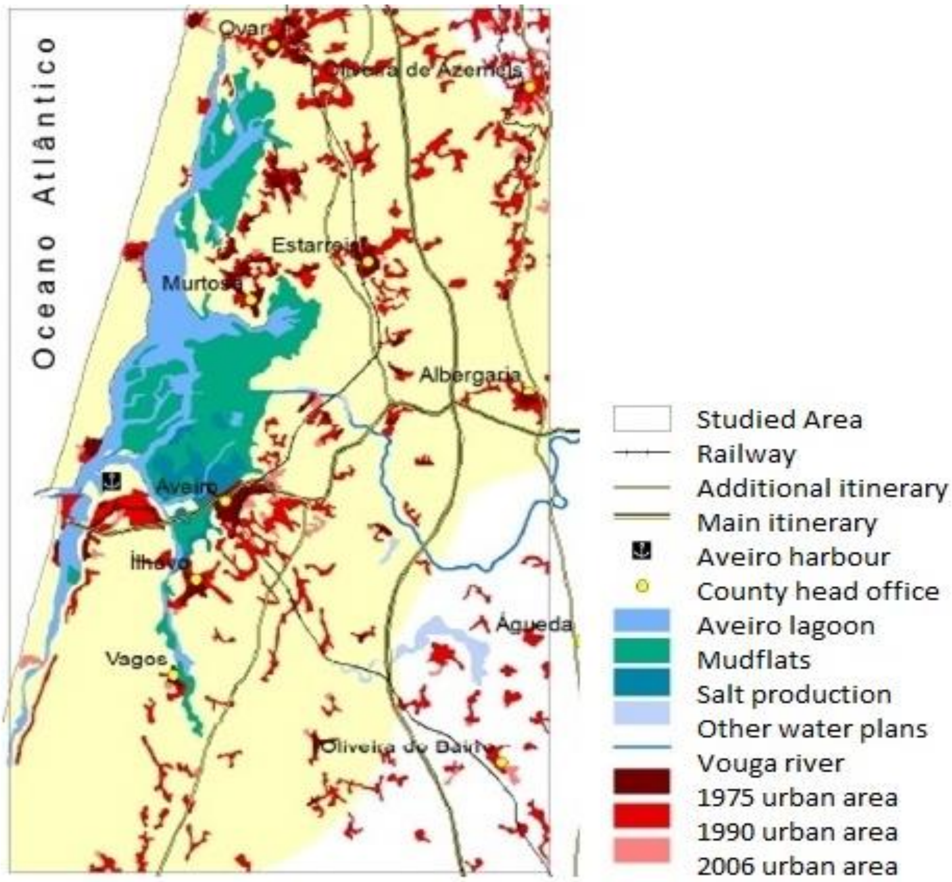

Figure 3 – Evolution of the urban tissue in the RdA region from 1975 to 2006 (Adapted from (Alves, 2014) and based on CLC).

More recent data for the land use, number of inhabitants, population density and average income for the RdA region, shows that the area classified as urban and industrial has increased over the decades (see Table 6). Also, the region's population has decreased, with the population density decreasing. This supports the fact that urbanization in the area began to be dispersed and sprawled. Average income increased, with people having more financial capacity. From 2001 to 2011 the Aveiro region maintained a positive demographic variation of 1.49% (Teles *et al.,* 2014).

Table 6 – Data for land use, population, population density and average income for the RdA region for the years of 2006 and 2011 ((INE, 2006), (INE, 2008), (INE, 2012), (INE, 2013), http://www.pordata.pt).

		2001	2006	2011
Land use (ha)	Urban		17113.9	18225.5
	Industrial		2319.6	3028.1
Population (nº hab)		271546	287576	284119
Population density (hab/km2)		215.9	284.7	281
Average income (€)			820.7	933.8

5.3. Regional spatial plan for the Aveiro region

When it comes to legislation and frameworks, the Aveiro region has different plans: i) Sector Plans, such as the Maritime Spatial Plan, Vouga Watershed Management Plan and the Special Protection Area Ria de Aveiro, ii) Special Spatial Plans, such as S. Jacinto Nature Reserve Protected Area Land Use and Management Plan, Coastal Zone Management Plan of Ovar – Marinha Grande and the Vouga Estuary Spatial Planning and Management Plan, iii) Region Spatial Plan for the central region (PROT-C), iv) Intermunicipal Spatial Planning Plan, and v) Municipal Spatial Planning and Land Use Plans of Aveiro, Estarreja, Ílhavo, Mira, Murtosa, Ovar and Vagos. In addition there is the Polis Litoral Ria de Aveiro, that sets goals for the improvement of the RdA region (Alves *et al.*, 2011).

5.3.1. PROT-C

In Portugal the Commission of Coordination and Regional Development of the Centre (CCDR) is responsible for the development of the Regional Spatial Plans for the centre (Plano Regional de Ordenamento de Território do Centro; PROT-C), which can be defined as an instrument of territorial development that is of a strategic nature and of regional scope (CCDR-Centro, 2011). These plans incorporate the strategies defined in the National Plan of Policies and Spatial Planning (Plano Nacional de Políticas e Ordenamento do Território; PNPOT).

According to the Directive DL 380/99 the PROT aims to: i) develop the national policies at the regional scale, ii) translate the goals related to social and economic sustainable development, iii) serve as a basis to formulate the national spatial planning strategy, and iv) be the reference for local/municipal plans.

The Regional Spatial Development Plan that corresponds to the region of Aveiro is the PROT-C (corresponding to the territorial region denominated by NUTS II), which covers 78 municipalities and approximately 23 000 km^2. This plan aims to develop the centre region and to affirm it as an autonomous region with an active contribution towards sustainable development (Antunes & Santos, 2011).

The strategic goals of PROT-C are:

- To define strategic options for the development of the Centre region;
- To define the organizational model of the regional territory, taking into account the identification of environmentally valuable areas (including Natura 2000 areas and green corridors) to valorise the development of an urban system that integrates sub-regional urban systems and to develop the competitiveness of the industrialization model;
- To identify the relevant areas to implement de PROT-C;
- To define orientations and propose measures for use, occupation and transformation of the land;
- To define measures for an appropriate use of the agriculture and forestry land; and
- To contribute for the national and regional spatial planning policies.

In order to reach the territorial model of the PROT-C (Figure 4), a reflection is made on the territorial textures and structures as well as the structuring systems.

The territorial textures and territorial structures aim to find pertinent geographies that represent the priorities of this plan. The territorial textures focus on indicators related to physical Geography, such as landscapes, agriculture and forest areas, environmental valuable areas, natural and technological hazards, and demographic variables. In the analysis of the territorial textures two were studied in more detail (CCDR-Centro, 2011): i) bio-physical, which consists in the study of climate aspects and dominant agriculture uses for the region and ii) demographic, which highlights the distribution of population throught the centre region. The territorial structures focus on various economic variables, two of those considered more relevant (CCDR-Centro, 2011): i) employment, which identifies the intensity of economic activities in the region and ii) urban polarities, which analyses the urban structure in the region. The analyses of these variables are mapped and incorporate mobility infrastructure and social vulnerability aspects.

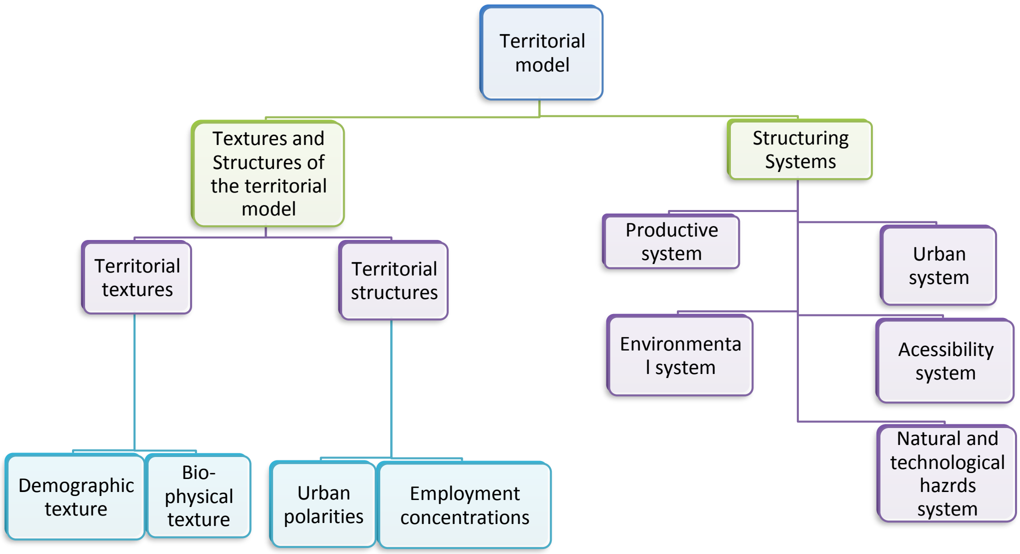

Figure 4 – Construction of the territorial model

There are two problematics that should be considered (CCDR-Centro, 2011): urban sprawl and the decrease of territories of low density. In the coastal area, the focus of this study, the first problematic has a higher incidence due to the proximity to the major urban agglomerations/cities and, hence, bringing conflicts over land use.

The <u>structuring systems</u> are the platforms which contain the necessary information to make synthesis representations and are divided in five systems (Ordenamento, 2011): i) productive systems, which represent the main sources of yield and employment, ii) urban systems, which represent the dynamic of occupation of the soil, iii) accessibility and transportation systems, which focus on infrastructures related to transportation, such as railroad networks, highways and port structures, iv) environmental systems, which integrates landscape and components of environmental protection and valorization, and v) natural and technological hazard system.

Based on this, it is possible to identify three main territorial models of the PROT-C: Risks territorial model (Figure 5), Agriculture and environmental territorial model (Figure 6) and the Urban territorial model (Figure 7). These three models can be associated with Social, Environmental and Economic dimensions. The combination of these three territorial models, form the basis for the Integrated territorial model (Figure 8).

- Risks territorial model

The Risks territorial model (Figure 5) takes into account social vulnerability indices and exposed population indices and resulted in the definition of five risk areas: the coastal area, the coastal/Inland interface area, the high Vouga and medium and high Mondego area, the Maciço central and Beira Serra Sul area, and the frontier area (CCDR-Centro, 2011).

The model considers both natural and technological risks, such as, susceptibility to seismic activity, susceptibility to natural radiation, susceptibility to mass movements, susceptibility to coastal erosion, susceptibility to flooding, susceptibility to drought, susceptibility to heat waves, susceptibility to cold waves, susceptibility to forest fires, susceptibility to maritime contamination, susceptibility to industrial and commercial activities with hazardous materials and susceptibility to the transportation of hazardous products (CCDR-Centro, 2011). The risk of transportation of hazardous materials happens, mainly, in the coastline, where the major highways and railways of the region are set.

In the coastal area the main risks indicated in the plan are the risks related to geodynamic processes, such as coastal erosion, flooding and seismic activity, and risks related to the transportation of hazardous materials and industrial activities that handle hazardous materials. In the coastal/inland interface area the main risks considered are mass movements, flooding as well as cold and heat waves. This area is, as well, susceptible to the transportation of hazardous materials and industrial activities that handle hazardous materials. As for the high Vouga and medium/high Mondego region the main risks pointed out are natural radioactivity, mass movements, forest fires and heat waves, as well as an increasing susceptibility to industrial activities that handle hazardous materials. In the Maciço central and Beira Serra Sul area the main risks to take into consideration are high susceptibility to cold and heat waves, drought and forest fires, mass movements and flooding. As for the frontier area the main risks considered are vulnerability to heat waves and periods of drought. The vulnerability to seismic activity and flooding also needs to be taken into consideration. As well, there is an increase of the susceptibility to transportation of hazardous materials (CCDR-Centro, 2011).

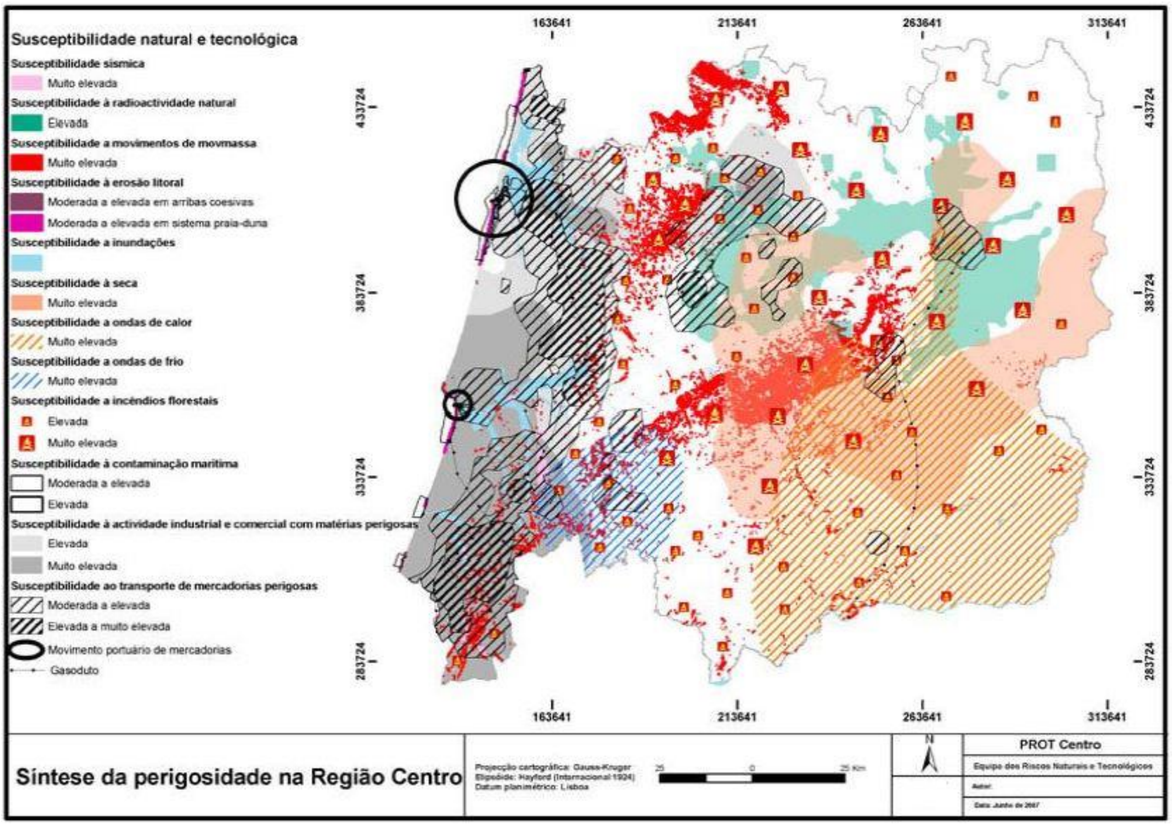

Figure 5 – Risks territorial model (CCDR-Centro, 2011).

- Agricultural and environmental territorial model

The agricultural and environmental territorial model (Figure 6) is a very important model when it comes to the Centre Region, as this area has a high environmental value, being some zones part of Natura 2000 and of the Protected Areas Nacional grid/ network. The PROT-C identifies as environmental valuable areas the Ria de Aveiro, the Mondego estuary, the Natural reserve of dunes of São Jacinto, as well as several lagoons and forest areas. Also, are identified salt production sections and areas that suffer intense coastal erosion.

This model was developed taking into account two main aspects: i) the development of actions that will valorise and promote the sustainability of the environmental aspects of the territory, and ii) the development of qualification measures and areas that have significant environmental issues or that have a high ecological value (CCDR-Centro, 2011).

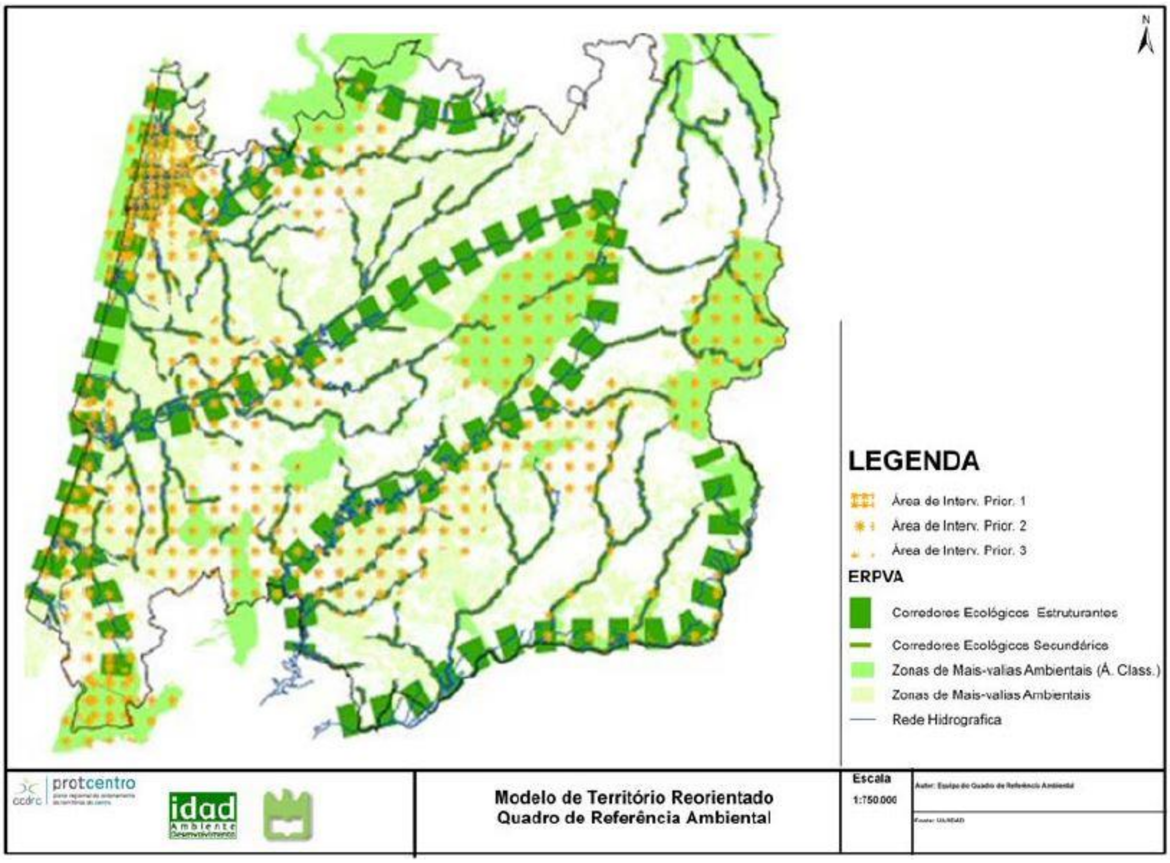

Figure 6 – Environmental territorial model (CCDR-Centro, 2011).

In order to reach an environmental model, it was necessary to consider the levels of pollution of the region, as this affects the natural resources, and human settlements. Taking these into account the model above defines priority intervention areas related to water, soil, air, biodiversity issues and coastal areas (CCDR-Centro, 2011).

The territorial model integrates the ERPVA (Regional Structure of Environmental Protection and Valorisation) which consists in several environmentally valuable areas and systems, such as ecological corridors. The nuclear areas have high environmental value, such as Natura 2000 Network areas, the Protected Areas Nacional grid/ network and sensitive areas. The ecological corridors can be divided in two types: structuring ecological corridors and corridors defined in the Regional Plans of Forest Planning. The first type cross the main water lines of the region and the second type are also known as secondary ecological corridors (CCDR-Centro, 2011). Also, three types of intervention areas are identified (yellow dots in Figure 6) with priorities ranging from high (1) to low (3).

- Urban territorial model

The urban territorial model tries to combine de urban grid with the polarization resultant from ports, universities and airfields, and with the main work/habitation flows.

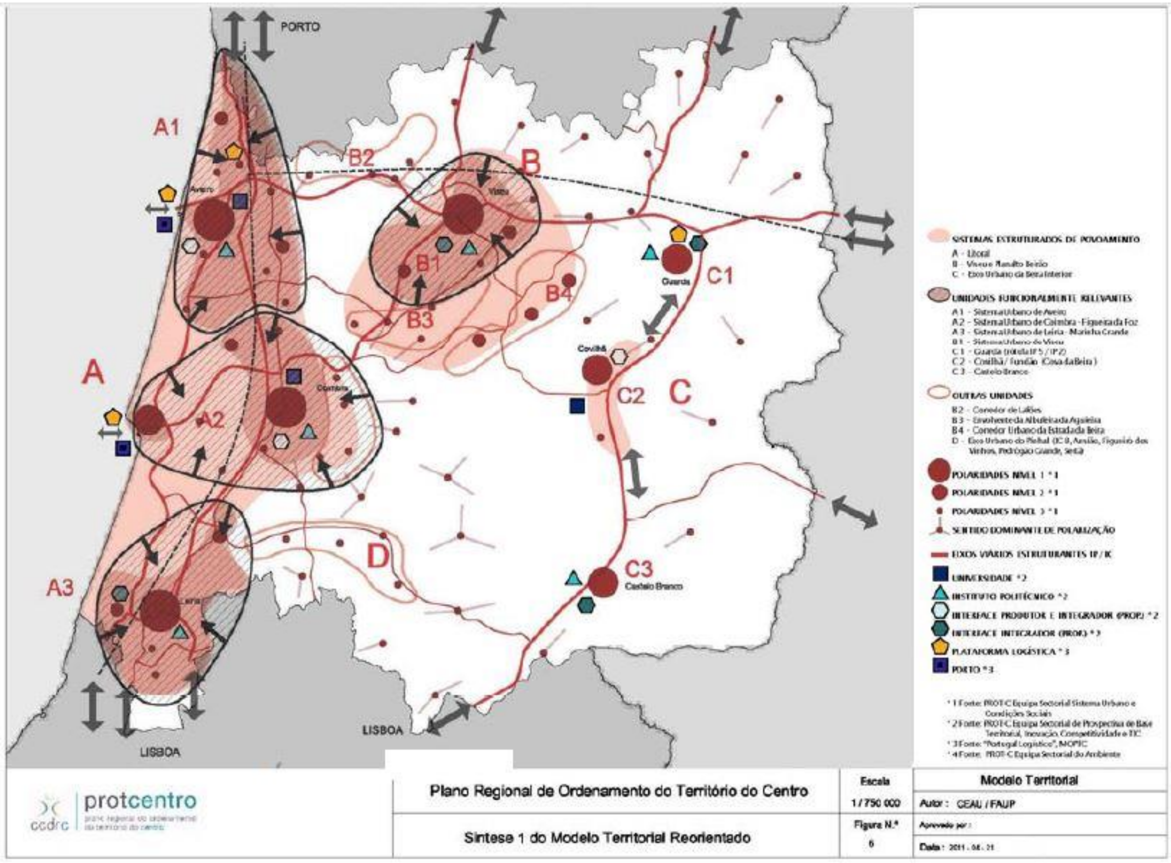

Figure 7 – Urban territorial model (CCDR-Centro, 2011).

In this model, the main urban centres of the centre region are identified (CCDR-Centro, 2011) – being identified in light pink the main population structured systems (A - Coast, B - Viseu and Planalto Beirão, C - Beira Interior) as well as in dark pink the functionally relevant units (A1 - urban system of Aveiro, A2- urban system of Coimbra – Figueira da Foz, A3 – urban system of Leiria – Marinha Grande, B1 – urban system of Viseu, C1 – Guarda, C2 – Covilhã, C3 – Castelo Branco).

According to the model is possible to identify three patterns of agglomeration/dispersion (CCDR-Centro, 2011): i) diffuse tissue where agglomeration and dispersal are mixed (observed in the high Vouga and High Mondego), ii) disperse system where it is observed the spread of agglomerations (observed in Beira Interior) and iii) dispersed thin system where there is excessive fragmentation of the population in areas far away from the main agglomerations (observed in low density areas).

In the Interior region the dispersion of the population is connected to the shredding of the agricultural land use. In the Planalto Beirão the highest density of population happens in the fractionating of the agricultural land. In the central area there is less population due to lack of arable land. In the coastal area highest population levels are observed resulting in conflicts due to the overlap with agricultural land (CCDR-Centro, 2011).

- Integrated territorial model

Figure 8 presents the Integrated territorial model, which was made after the reflection on the three main territorial models. This territorial model aims to represent the priorities defined by the PROT.

In the coast line, Coimbra has a strategic position regarding the cities of Lisbon and Porto and having a good accessibility network – thus assuming the status of a strong regional reference. Also, the city of Aveiro cannot be disregarded, showing high potential and, generating new kinds of services, due to the connection between the university and the companies (CCDR-Centro, 2011).

According to the fundamental report of the territorial model of the PROT-C this model should not be interpreted as having rigid and precise limits. Since planning is a complex task it needs to have a variable geometry, leaving open spaces for future developments (CCDR-CENTRO, 2008).

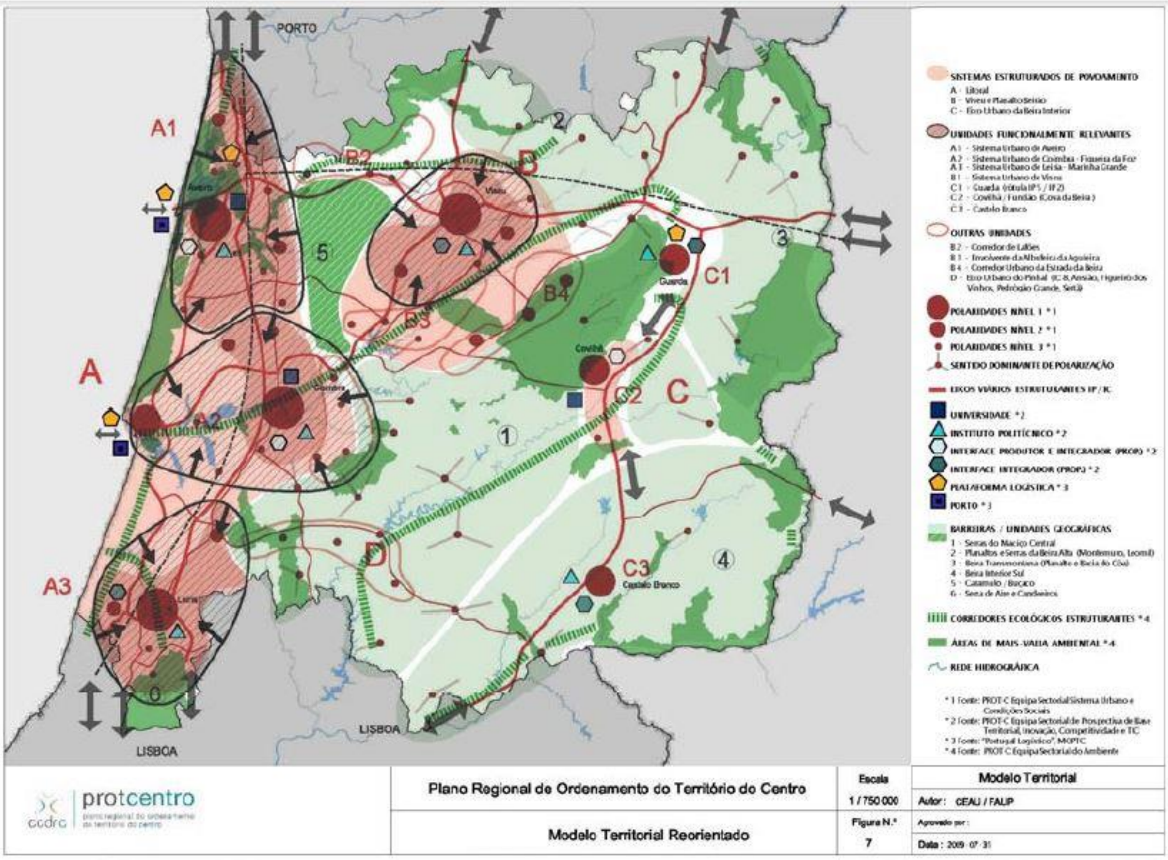

Figure 8 – Integrated model (CCDR-Centro, 2011).

In order to ensure that the environmental aspects were taken in consideration during the planning of the PROT-C, this was submitted to a Strategic Environmental Assessment.

Taking into account the Strategic Environmental Assessment, the Environmental Report of the PROT-C displays some flaws of this plan, such as:

- The strategic interventions proposed for the territorial dynamic can contribute to increase the artificialization of the territory, and therefore increase the risks associated.
- The PROT-C does not foresee the occupation of the soil in long term.
- There is not a direct preoccupation with the communities, lacking ways to enhance the skill of the people as individuals.
- There is a lack of compatibility between the economic development and the social dimension.
- There is a lack of preoccupation making sure that the economic activities encounter the environmental objectives.

Thus, there is still room for improving the PROT-C, increasing its sustainable development vision/focus.

5.3.2. Downscaling the PROT-C to the RdA region

A deeper assessment of the territorial models is needed, looking in more detail to the RdA region, understanding the main aspects pointed out in the PROT-C analysis. Thus, are presented the four territorial models highlighting the RdA region (Figure 9).

a)	b)	c)	d)

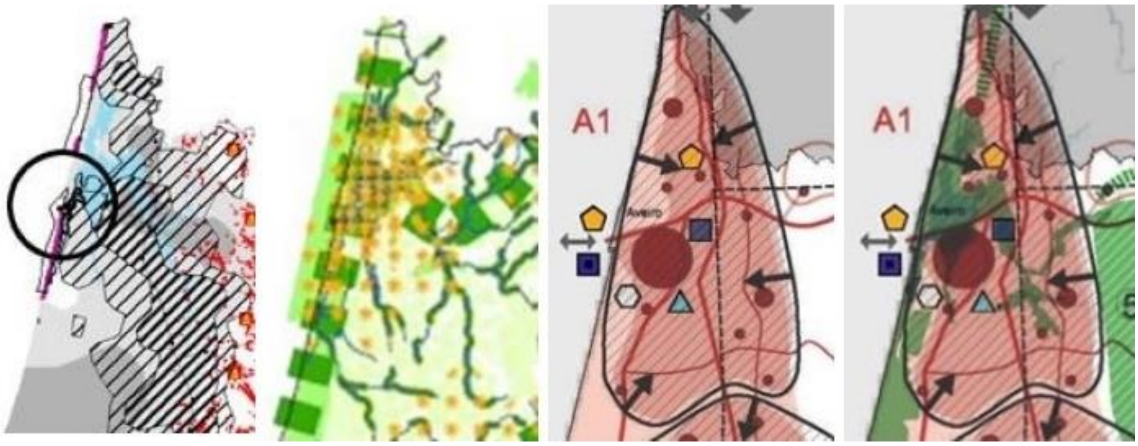

Figure 9 – Zoom in of the territorial models for the region of Aveiro, corresponding to the a) Risks model, b) Environmental model, c) Urban model and d) Integrated model.

The Risks territorial model identifies de RdA region as being susceptible to costal erosion, floods and sismic activity, as well as having a high levels of susceptibility related with industrial activities, such as the ones that handle hazardous materials and activities related to transportation and handling of hazardous products (CCDR-Centro, 2011).

The Agricultural and Environmental territorial model identifies the environmentally fragile areas of the RdA region, being the Costa Nova area classified as a zone with high susceptability to coastal erosion. Also, as mentioned above, the RdA and the dunes of S.Jacinto are identified as environmentally valuable areas. This territorial model, also points out the importance of promoting interventions in order to decrease emissions due to transports and industrial sources in the Aveiro region, as well as to control the urban expansion near wetlands and water sources. The model identifies the

Aveiro region as a priority 1 intervention area. Lastly, the plan highlights that the territorial model should be accompanied with specific measures, intervening in Aveiro and Ílhavo urban centre and the industrial area of Estarreja to reduce transport emissions, and in the Ria de Aveiro and Pateira de Fermentelos planning the touristic activities and controlling urban expansion near wetlands (CCDR-Centro, 2011). The PROT also identifies the importance of valorize the Ria's multi-uses and the increasing pressure due to urban growth and consequente infrastrutures.

The Urban territorial model identifies the several urban polarities of the Aveiro region, being the major one the city of Aveiro followed by the Ilhavo urban centre. Aveiro stands out due to the varied range of services, including the University of Aveiro and Polytechnical Institutes, as well as having a well defined interaction network (CCDR-Centro, 2011). The urban polarities of the region can be classified as diffused tissue, having both concentration of population and dispersion, and having a defined interaction network with nearby cities. The RdA region is, also, defined by a strong industrial aspect, having a strong logistics component due to theport of Aveiro (CCDR-Centro, 2011).

The Integrated territorial model highlights the importance of Aveiro for potential growth of companies due to the increase relation of these with the University of Aveiro. However, the integrated model does not identify how much weight each dimension (social, environmental and economic) has for the creation of the same (CCDR-Centro, 2011).

The PROT-C identifies, as the main conflict of this territorial model, the high number of infrastructures and extensive urbanization of the territory mixed with land for agriculture purposes. This is due to the type of transportation network that supports urbanization and industry, which crosses agricultural areas, leading to a point of saturation and conflict (CCDR-Centro, 2011).

The PROT-C highlights, as well, that there should be an articulation of urban policies for the Aveiro, Ílhavo and Vagos agglomerations, focusing on disperse urbanization, high urban pressure and the sensibility of the Pateira area (CCDR-Centro, 2011).

6. Definition of the scenario simulations

For the development of the scenarios for the three territorial models and the integrated model, assumptions were made, based on the different territorial models of the PROT-C. Thus, the definition of the scenario simulations is a translation of the assumptions of the PROT-C into specific land use maps and parameter values in SULD. These are described below for the Base scenario (section 6.1), the Risks scenario (section 6.2), the Environmental scenario (section 6.3), the Urban scenario (section 6.4) and the Integrated scenario (section 6.5).

6.1. Base scenario

The base scenario has been created, calibrated and validated by Alves (2014; see Chapter 4 and Figure 10). The base map is supported by the land use data from CLC for the year of 2000 (Alves, 2014), being used as indicators the land use, population, development density, area of habitation and the real estate value (Alves, 2014). The following six land use classes were identified: 1) forest, 2) water, 3) agricultural land, 4) industry, 5) protected area and 6) urban area.

In the base model, were identified the main urban centres of the area, being: 1) Albergaria-a-Velha, 2) Aveiro, 3) Estarreja, 4) Ílhavo, 5) Murtosa, 6) Ovar, 7) Oliveira de Azemeis, 8) Oliveira do Bairro and 9) Vagos (see Figure 10).

Two types of environmental amenities were identified, water and forest. Water is considered an environmental amenity as it allows the proximity to beaches, fauna and flora, as well as the desire of the population to live near the ocean. Forest is considered an environmental amenity due to the desire to live in areas with low occupation density and near green spaces. The Natura 2000 Network area is classified as “Protected areas”, not being allowed to develop any kind of constructions in this area.

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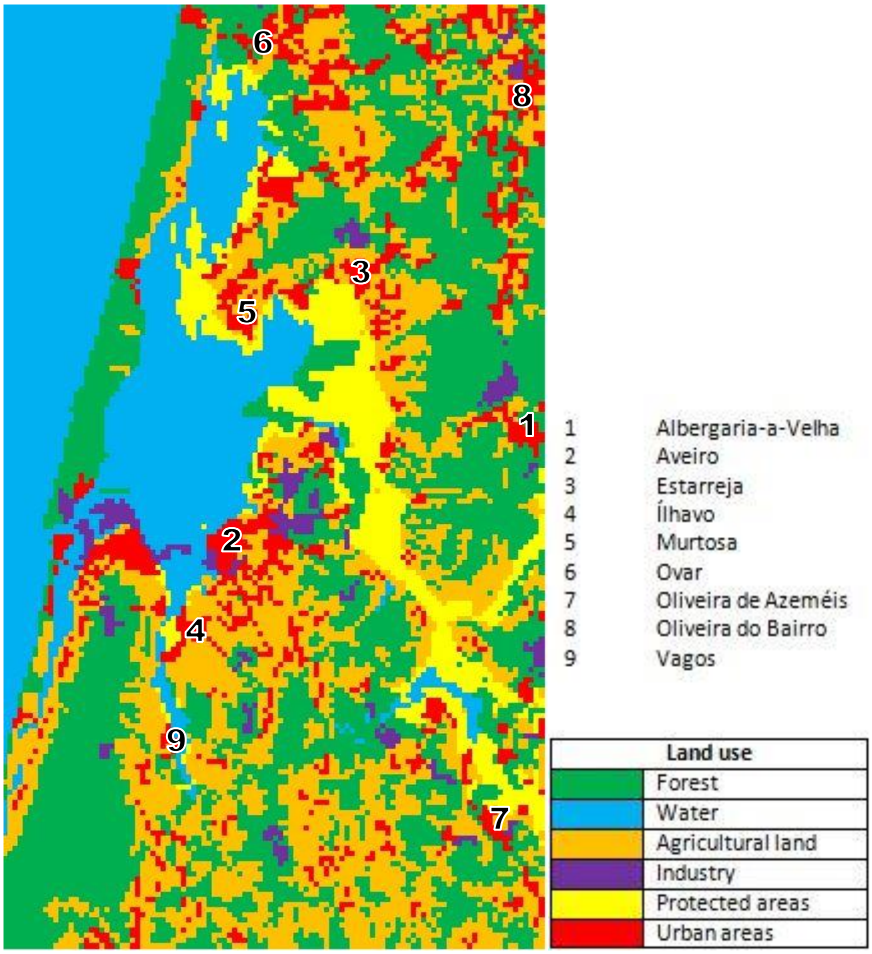

Figure 10 – Base scenario.

6.2. Risks scenario

The Risks territorial model of the PROT-C identifies the Aveiro region as a sensible area, being classified with high to very high susceptibility to transportation of hazardous materials. Thus, for this scenario simulation it was important to identify the area's main transportation/mobility means that could affect the RdA region. As such, were identified the four main highways (A1, A17, A19, A25 and the IC2) and the three main railways (the North Line, which connects Aveiro to Lisbon and Porto; the Vouga Line, which goes through Albergaria-a-Velha and the Ramal of Aveiro) in the area.

In order to ensure the security of population against this transportation risk, a protection area (buffer) was identified where construction should not be allowed.

The distances taken into account for the buffer were based on the information from the PrismA project (http://www.prismaproject.eu/index.php/pt/aveiro-pt; Prisma Project, 2015), which considered the impacts of toxic cloud, BLEVE (Boiling Liquid Expanding

Vapor Explosion) and pool fire, for the A25 highway and for the railway that connects the Aveiro harbour to the city (see Table 7).Only the buffer to avoid lethal effects was taken into consideration and the higher distance value from these risks, was chosen – with the highway buffer being 230 meters and the railway buffer 380 meters (see Table 7.) Where the buffers overlapped with already existing urban areas, construction would still be allowed in that region. Also, some highways and railways overlap with each other (see Figure 11).

Table 7 – Distance for lethal effects for the railway and highway in Aveiro (PrismA Project, 2015).

	Lethal effects		
	Toxic cloud	BLEVE	pool-fire
Railway	86 m	381 m	91 m
A25	51 m	230 m	68 m

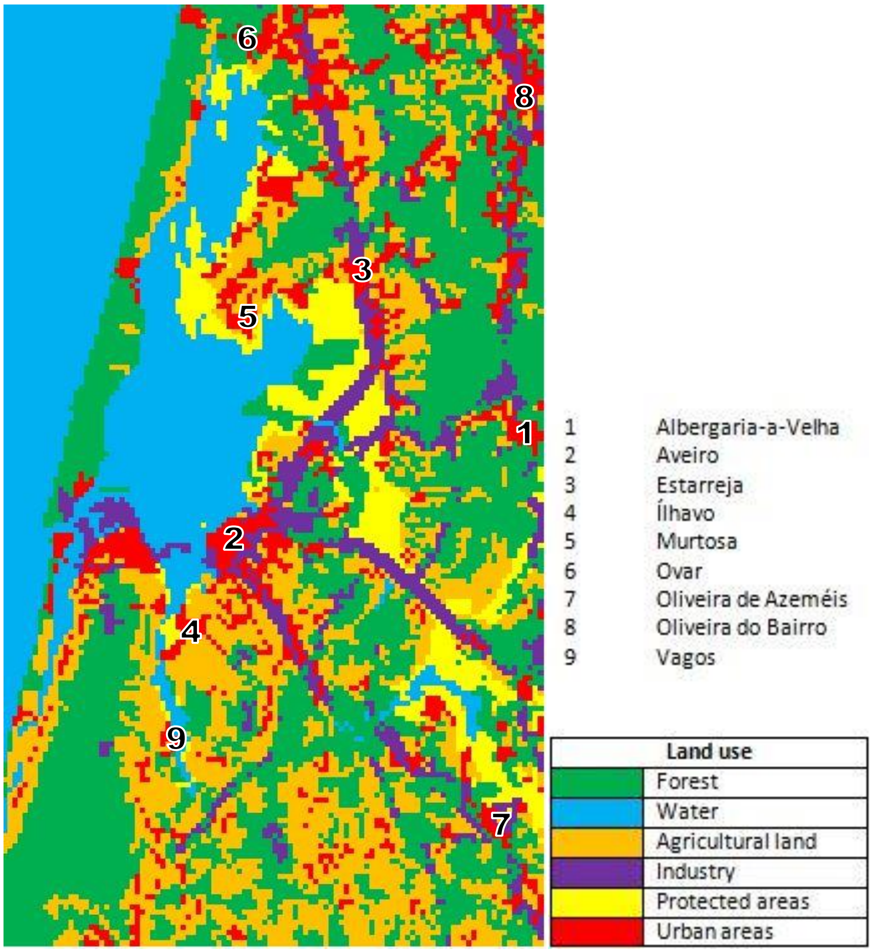

Figure 11 – Map of the Risks scenario with buffer around the main roads and railways.

6.3. Environmental scenario

For the development of the Environmental scenario, the intervention areas and the environmental importance of the region mentioned in the Agricultural and environmental territorial model of the PROT-C were taken into account (see Figure 12).

In this model all water courses existent in the study area were taken into account and were identified as an environmental amenity. Note that the water courses considered are not always continuous lines, due to the spatial scale of analysis (cells size of 250m by 250m) relative to the size of the water courses.

Similar, to the risk model, and due to the importance of maintaining the valuable environmental resources/areas, the area around the water lines will be protected with a buffer, not allowing construction in the zone. For the buffer it was considered the area of protected land from Natura 2000 Network around the water lines. As such, it was assumed a distance of 500 meters for this buffer.

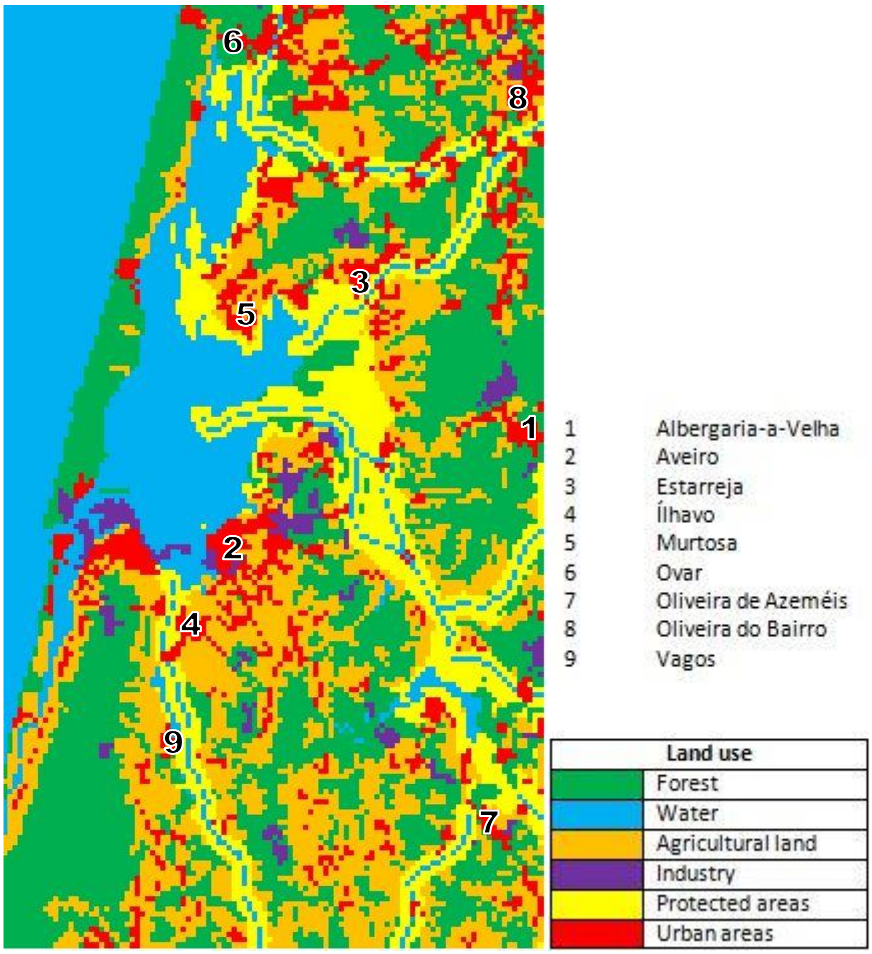

Figure 12 – Map of the Environmental scenario with buffer around the water lines.

As this scenario has influence on the water amenity component, it was necessary to recalculate the distance to this amenity (Annex 6). For this was used the same method (Euclidian distances) used to calculate the base distances (see Chapter 4).

6.4. Urban scenario

The Urban scenario is intended to have the maximum outcome for economic development. As such, the relevant function units identified in the Urban territorial model of the PROT-C are taken into consideration – with the largest part of the RdA region being identified as a relevant unit and, with the coastline area not being considered available for urbanization. Hence, the Urban scenario created allows construction in any forests area, being the only exceptions the coastline and the Natural 2000 Network area, (see Figure 13).

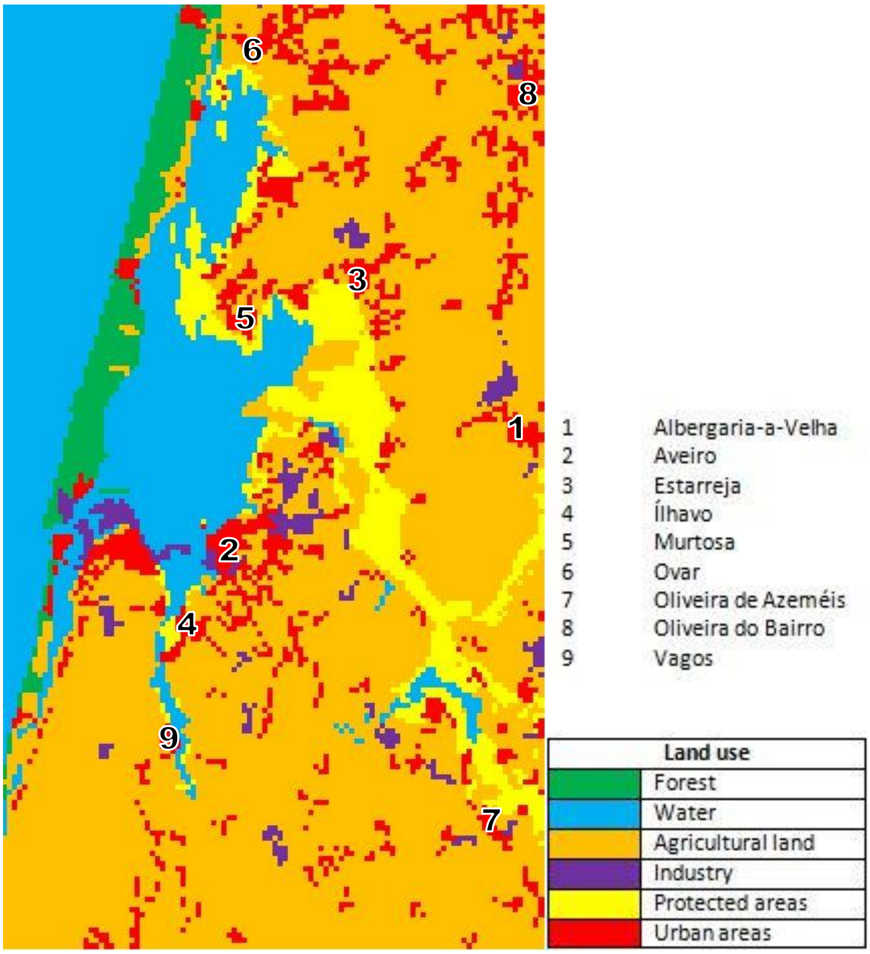

Figure 13 – Map of the Urban scenario.

Once again, in this scenario, the area classified as part of Natura 2000 Network (protected areas) was blocked for construction. For this scenario the distance to the environmental amenities (water and forest), was, also, recalculated (Annex 6 and Annex 7), according to the changes in land use.

6.5. Integrated scenario

For the development of the Integrated scenario (see Figure 14), and based on the considerations from the integrated territorial model of the PROT-C, none of the Risks scenario assumptions were taken into account. As such, the integrated model only collates features from the Environmental and the Urban scenarios.

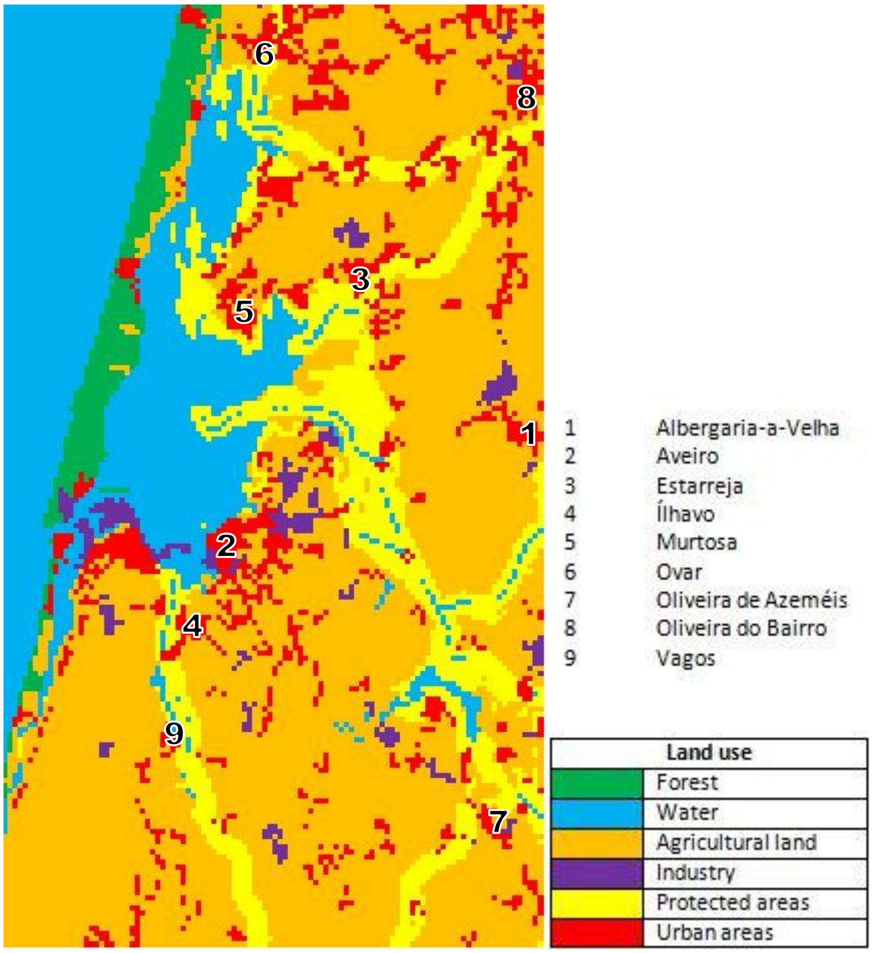

Figure 14 – Map of the Integrated scenario.

From the Environmental scenario, the water courses are considered as environmental amenities. From the urban scenario the relevant units are taken into account, discarding the forest areas that overlapped with these units, but keeping the original features of the coastline.

As in the previous scenarios, this model doesn't allow the construction in Natura 2000 Network areas.

In this model, the component with more weight is the urban / economic factor, followed by the environment and, lastly, the risk factor.

For the Integrated model, there was, as well, the need to recalculate the distance to the environmental amenities (water and forest).

7. Discussion of the results

7.1. Base scenario

Land use in the base scenario (Figure 15), encompasses 41488 ha of forest, 28788 ha of water, 35050 ha of agricultural land, 247 ha of industrial area, 7131 ha of protected area and 9860 ha of urban area. The average living space is of 96 m^2 per household. The average real estate (rental) value equals 38 €/m^2/yr and the total real estate (rental) value for the RdA region equals 497 million/yr (see Table 8).

Results can be divided and assessed in two groups: households with lower income (res1) and households with higher income (res2). The households with lower income correspond to, approximately, 80% of the region's population and occupy 92% of the urban area. The households with higher income correspond to 20% of the total population, occupying only 8% of the urban area.

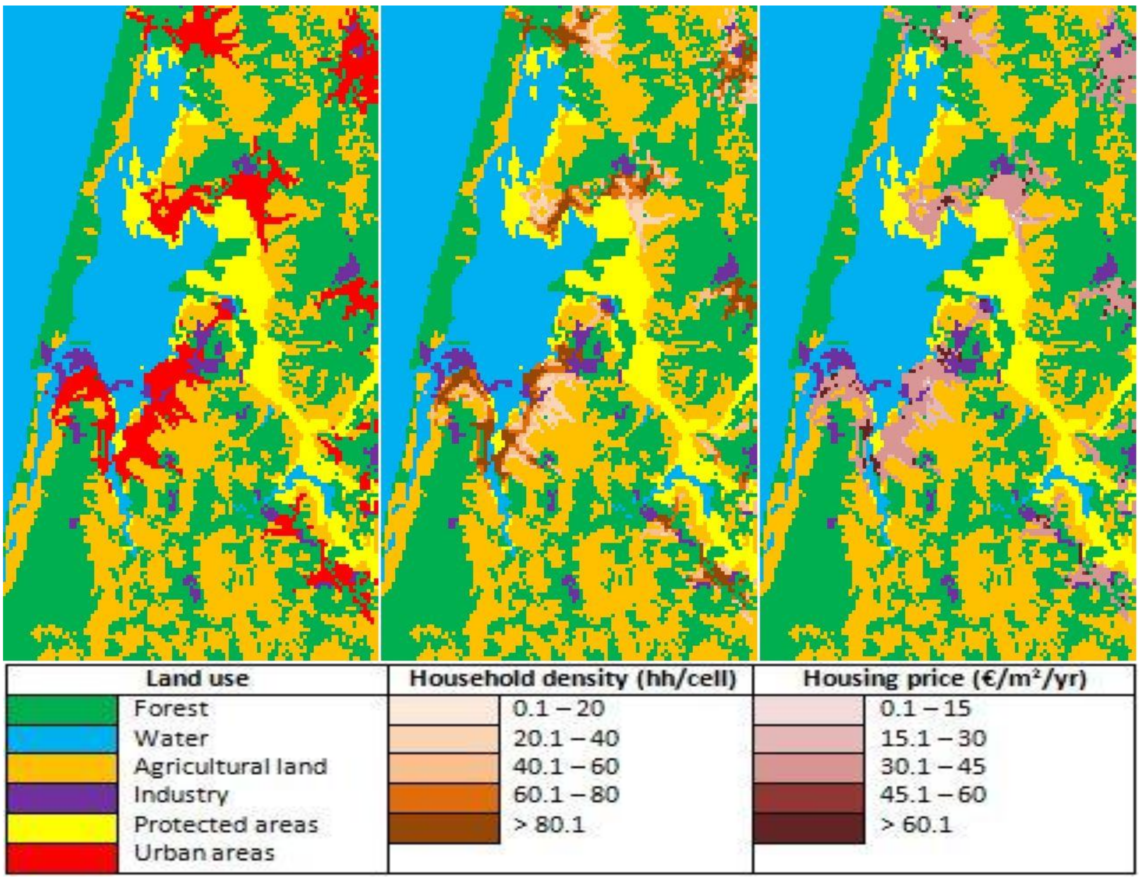

Figure 15 – Map of land use, household density and housing price for the Base scenario.

The largest household density is concentrated near the urban centres and environmental amenities. Average population density in urban areas is 33.7 inhabitants/ha (or 70.7 households/grid-cell), ranging between 29.7 inhabitants/ha for lower income households (or 62.4 households/grid-cell) and 72.8 inhabitants/ha for higher income households (or 152.7 households/grid-cell).

Table 8 – Results for the base scenario and simulation scenarios.

	Unit	*Base*	*Risks scenario*		*Environmental scenario*		*Urban scenario*		*Integrated scenario*	
Land use:										
- Forest	ha	41488	41488	0.0%	38488	-7.2%	4256	-89.7%	4256	-89.7%
- Water	ha	28788	28788	0.0%	29656	3.0%	28781	0.0%	28419	-1.3%
- Agriculture	ha	35050	33777	-3.6%	32401	-7.6%	23553	-32.8%	50789	44.9%
- Industry	ha	247	818	231.4%	243	-1.5%	247	0.0%	243	-1.5%
- Protected area	ha	7131	7131	0.0%	13456	88.7%	8206	15.1%	14688	106.0%
- Urban										
- res1	ha	8946	9679	8.2%	7547	-15.6%	55175	516.7%	22150	147.6%
- res2	ha	913	883	-3.4%	772	-15.5%	2344	156.7%	2019	121.0%
- total	ha	9860	10561	7.1%	8319	-15.6%	57519	483.4%	24168	145.1%
- Total	ha	122563	122563	0.0%	122563	0.0%	122563	0.0%	122563	0.0%
Population:										
- res1	#	266042	266042	0.0%	266042	0.0%	266042	0.0%	266042	0.0%
- res2	#	66511	66511	0.0%	66511	0.0%	66511	0.0%	66511	0.0%
- Total	#	332553	332553	0.0%	332553	0.0%	332553	0.0%	332553	0.0%
Living space:										
- res1	m^2/hh	82.2	83.3	1.3%	78.6	-4.4%	115.1	40.0%	99.9	21.6%
- res2	m^2/hh	150.5	148.7	-1.1%	144	-4.3%	182.2	21.2%	173.3	15.2%
- Average	m^2/hh	95.9	96.4	0.6%	91.7	-4.4%	128.5	34.1%	114.6	19.6%
Real estate value:										
- res1	€/m^2/yr	35.5	34.5	-2.7%	37.2	4.8%	18.6	-47.5%	26.5	-25.3%
- res2	€/m^2/yr	63.1	63.6	0.9%	66.2	4.9%	46.7	-26.0%	47.3	-25.0%
- Average	€/m^2/yr	38.0	37.0	-2.8%	39.9	4.8%	19.8	-48.0%	28.2	-25.8%
- Total	10^6 €/yr	497.3	492.9	-0.9%	498.7	0.3%	401.4	-19.3%	441.4	-11.2%

Notes: res1 = Households with lower income. res2 = Households with higher income.

The living space is lower for households with lower income (82.2 m^2/household) and higher for households with higher income (150.5 m^2/household). As for real estate (rental) values Figure 15 shows that these are higher near waterfronts and forest areas

– meaning that households prefer to live near environmental amenities, and consequently are willing to pay more to live close to these areas. The average real estate (rental) value is 35.5 €/m^2/yr for families with lower income and 63.1 €/m^2/yr for families with higher income. The real estate (rental) value is highest closer to amenities and/or urban centres (up to 72.8 €/m^2/yr) and lowest in rural areas (down to 17.1 €/m^2/yr).

Comparing the two types of households assessed, it can be conclude that households with higher income locate in more attractive and concentrated areas and own larger and more expensive properties.

7.2. Scenario simulations

7.2.1. Risks scenario

Figure 16 shows the maps of land use, household density and housing price for the Risks scenario.In this scenario it is possible to observe a decrease in agricultural area by 3.6%, an increase of industrial area by 231.4% (due to the protection buffer around the region's highways and railways) and an increase in urban area by 7.1%.

Living space presents a +0.6% increase (to 96.4 m^2/household), while the average real estate (rental) value decreases by 2.8% (to 37.0 €/m^2/yr) and, the total real estate (rental) value for the RdA region decreases by 0.9 %, (to 492.9 million €/yr; see Table 8).

Comparing the Base scenario map (Figure 15) with the Risks scenario map (Figure 16) it is possible to observe that urban areas are still near the urban centres and environmental amenities, moving closer to the highways and railways. Urban land use increases by 8.2% for the lower income households (res1) and decreases by 3.4% for the higher income households (res2). Average population density descreaes by 6.6% (to 31.5 inhabitants/ha or 66.0 households/grid-cell), thereby noting a 7.6% decrease in population density for lower income households (to 27.5 inhabitants/ha) and a 3.5% increase in population density for higher income households (to 75.4 inhabitants/ha).

Living space increases by 1.3% for households with lower income (to 83.3 m^2/household) and decreases by 1.1% for households with higher income (to 148.7 m^2/household). This is caused by the existence of the buffers around highways and railways, which leads to the necessity to construct in other areas. Households with higher incomes, that have sufficient purchasing power, will choose live near environmental amenities and consequentely, households with lower income, that have smaller purchasing power will have to live further away from these amenities.

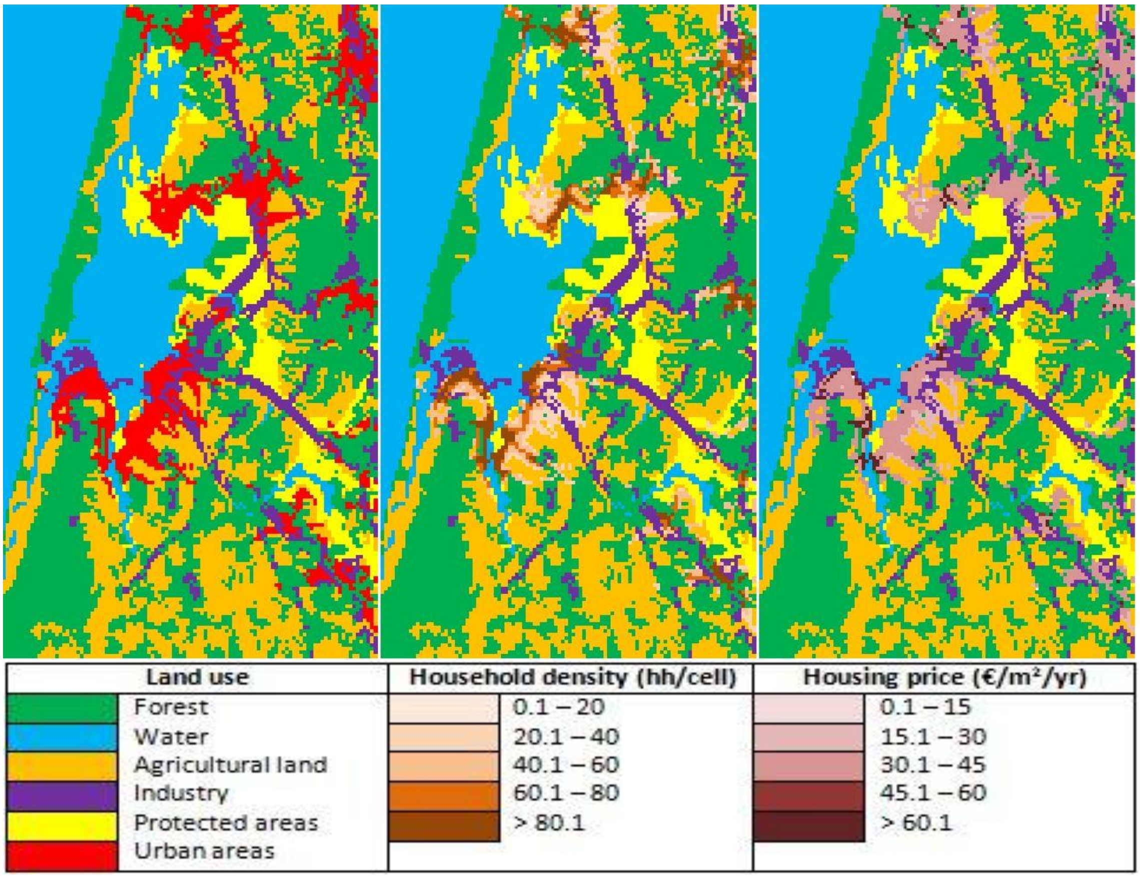

Figure 16 – Map of land use, household density and housing price for the Risks scenario.

The average real estate (rental) value decreases by 2.7% for households with lower income (to 34.5 €/m^2/yr) and increases by 0.9% for households with higher income (to 63.6 €/m^2/yr). Similar to the Base scenario the real estate (rental) value is highest closer to environmental amenities and/or urban centres (up to 72.8 €/m^2/yr) and lowest in rural areas (down to 24.3 €/m^2/yr). These changes in housing prices can be explained by the buffer around the highways and railways that leads to the decrease in real estate value near those areas (lower income households are unable to live close to the major access roads for their daily home-work travel) and the increase in real estate value near environmental amenities (higher income households increasingly compete for the now more scarce areas near environmental amenities).

The real estate price is higher closer to the environmental amenities where, increasingly, higher income households live; the real estate price is lower near major access roads where lower income households live.

7.2.2. Environmental scenario

In the Environmental scenario the forest area decreases by 7.2%, the water area increases by 3.0%, the agricultural area decreases by 7.6%, the industrial area decreases by 1.5%, the protected area increases by 88.7% (due to the protection buffer around the water courses) and the urban area decreases by 15.6%. Living space decreases by 4.4% (to 91.7 m^2/household) and the average real estate (rental) value increases by 4.8% (to 39.9 €/m^2/yr), while the total real estate (rental) value for the area increases by 0.3% (to 498.7 million €/yr; see Table 8).

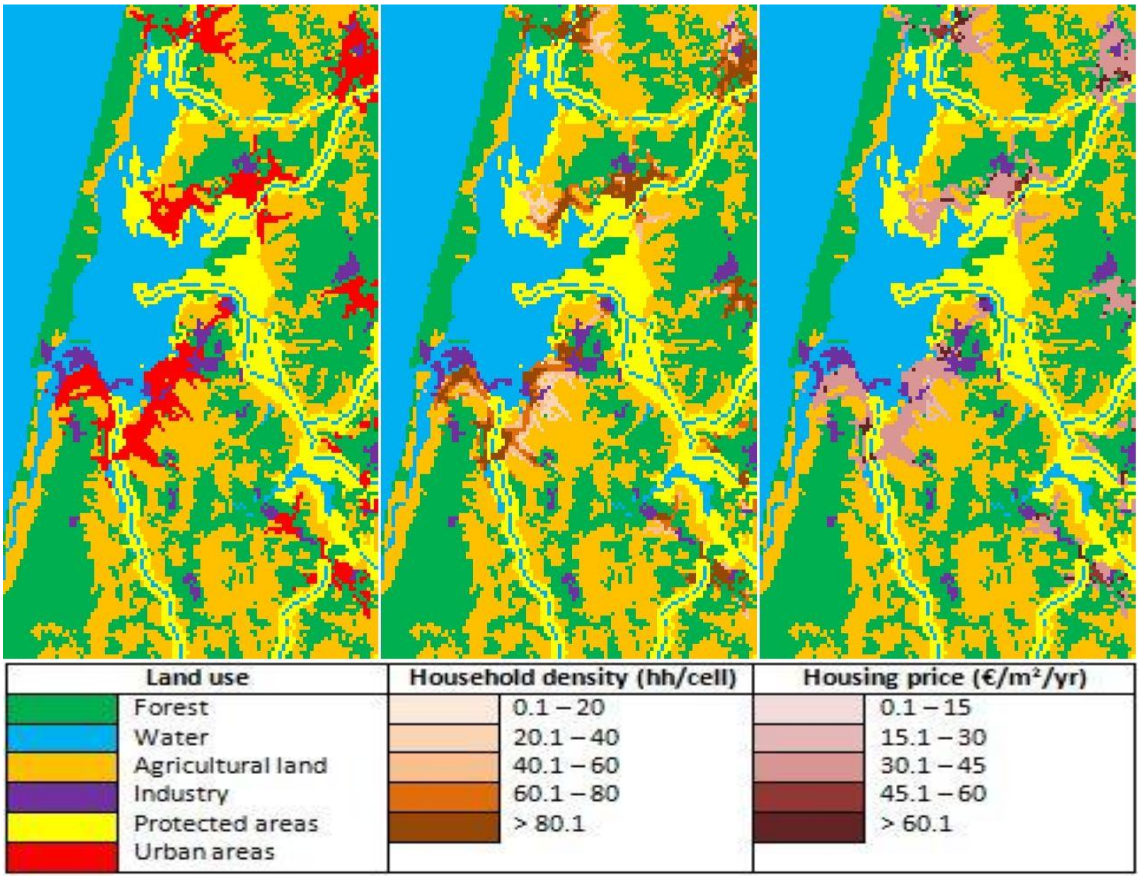

Figure 17 – Map of land use, household density and housing price for the Environmental scenario.

In this scenario (Figure 17) the land use occupation does not differ a lot from the Base scenario (Figure 15), once again with the properties being near to the urban centres and environmental amenities. The average population density, increases by 18.5% (to 40.0 inhabitants/ha or 83.8 households/grid-cell), while showing higher concentration near the water courses, with a 18.5% increase in population density for lower income households (to 35.3 inhabitants/ha) and a 18.4% increase in population density for higher income households (to 86.2 inhabitants/ha).

Living space decreases for both types of households, decreasing by 4.4% for households with lower income (to 78.6 m^2/household) and decreasing by 4.3% for housedolds with higher income (to 144.0 m^2/household). This decrease is associated with the increase in real estate (rental) values, discussed below.

Even though, the housing price distribution is similar to the Base scenario, with the highest values being near environmental amenities, the average real estate (rental) value increases by 4.8% for households with lower income (to 37.2 €/m^2/yr) and increases by 4.9% for households with higher income (to 66.2 €/m^2/yr). Compared to the Base scenario, the real estate (rental) value is highest closer to environmental amenities and/or urban centres. Highest real estate (rental) values are somewhat lower (up to 72.4 €/m^2/yr) and lowest values are somewhat higher (up to 26.8 €/ m^2/yr) due to the larger availability of environmental amenities that, respectively, result in reduced competition for most attractive areas and increased general attractiveness of the area

As such, even though the properties near environmental amenities are smaller and more expensive, there is a clear preference from, in particular higher income householders, to live near those areas. This results in a more compact urbanization as well as the conservation of the environment.

7.2.3. Urban scenario

The Urban scenario shows changes in land use, compared to the Base scenario, with the forest area decreasing by 89.7%, the agricultural land decreasing by 32.8%, the protected area increasing by 15.1% and the total urban area increasing by 483.4%. Living space presents a +34.1% increase (to 128.5 m^2/household), while the average real estate (rental) value decreases by 48.0% (to 19.8 €/m^2/yr) and the total real estate (rental) value for the RdA region decreases by 19.3 %, (to 401.4 million €/yr; see Table 8).

Comparing the land use from this scenario (Figure 18) with the Base scenario (Figure 15) it is possible to observe a more scattered and spread urban dynamic, with the majority of the territory designated as urban territory. However, and according to the household density values, the main concentration of population is, still, near the urban centres, with the majority of household density values being very low. Urban land use increases by 516.7% for lower income households (res1) and by 156.7% for higher income households (res2), due to the permission to construct any area except the Natura 2000 network area and the coastline area. Average population density, decreases by 82.9% (to 5.8 inhabitants/ha or 12.1 households/grid-cell), with a 83.8% decrease in population density for lower income households (to 4.8 inhabitants/ha) and a 61.0% decrease in population density for higher income households (to 28.4 inhabitants/ha).

Living space experiences an increase by 40.0% for households with lower income (to 115.1 m^2/household) and an increase by 21.1% for households with higher income (to 182.2 m^2/household), due to the lack of environmental amenities and associated decrease in real estate values.

The average real estate (rental) value decreases by 47.5% for households with lower income (to 18.6 €/m^2/yr) and decreases by 26.0% for households with higher income (to 46.7 €/m^2/yr). This is due to the small amount of environmental amenities existent in the area, reducing the value of housing (reduced willingness-to-pay) and, thus, allowing for the purchase of larger properties. Highest housing prices decrease though continue to be observed near the coastline (up to 60.9 €/m^2/yr) and, similarly, lowest housing prices decrease and continue to be observed further away from the coastline (down to 10.8 €/ m^2/yr).

The loss of environmental amenities, such as forests, decreased greatly the real estate (rental) values, allowing households to construct larger properties in low density urban areas. Households with higher income occupy the area near the (remaining) environmental amenities on the coastline, as they can afford to pay for those properties. As for the households with lower income, they occupy the area furthest away from coastline, as it is cheaper while having bigger houses in compensation. Even though, observing a growth in the construction sector, the total real estate (rental) value of the region largely decreased.

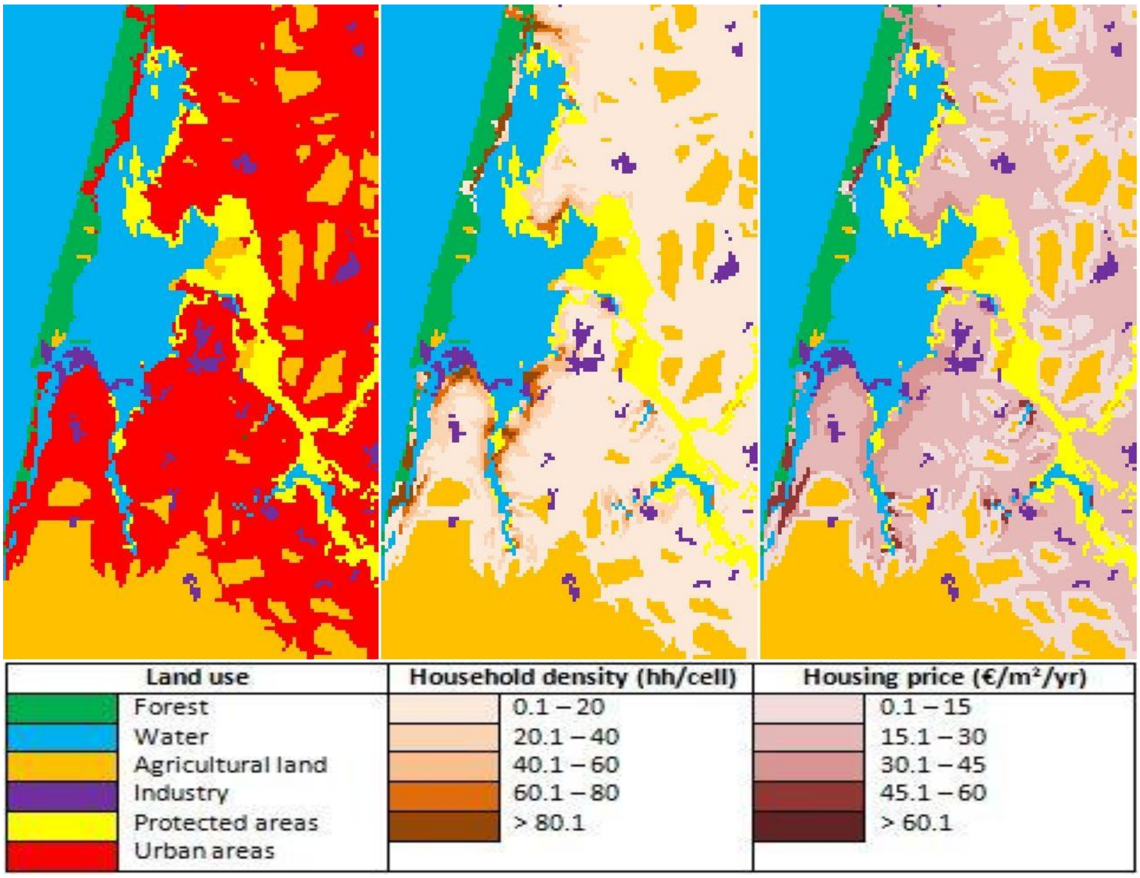

Figure 18 – Map of land use, household density and housing price for the Urban scenario.

7.2.4. Integrated scenario

The Integrated scenario shows a decrease in forest area by 89.7% (similar to the Environmental scenario), a decrease of water area by 1.3%, an increase in agricultural area by 44.9%, a decrease in industrial area by 1.5%, an increase in protected area by 106.0% and an increase in urban area by 145.1%. Living space increases by 19.6% (to 114.6 m^2/household) and the average real estate (rental) value decreases by 25.8% (to 28.2 €/m^2/yr), while the total real estate (rental) value for the area decreases by 11.2% (to 441.4 million €/yr; see Table 8).

The land use observed in Figure 19 is less disperse than in the Urban scenario, but it is possible to verify that that the urbanization is not just around the urban centres. The population density values are higher near the coastline and water courses, showing the preference of households to live near environmental amenities. Average population density decreases by 59.2% (to 13.8 inhabitants/ha or 28.9 households/grid-cell), thereby noting a 59.6% decrease in population density for lower income households (to 12.0 inhabitants/ha) and a 54.8% decrease in population density for higher income households (to 32.9 inhabitants/ha).

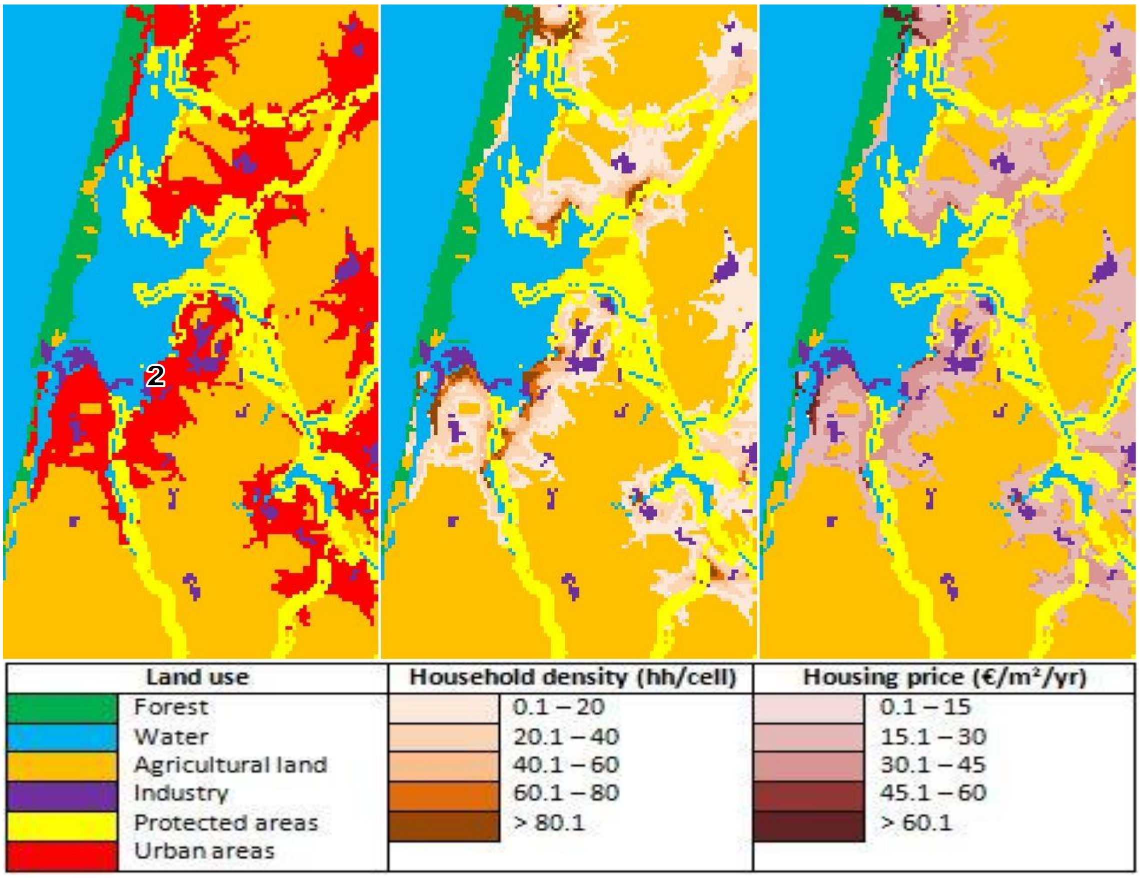

Figure 19 – Map of land use, household density and housing price for the Integrated scenario.

Even though the only difference between the Urban scenario and the Integrated scenario being the addition of the water courses, the increase in urban area is much smaller in the later scenario. This due to the valorisation of water courses, with households wanting to live near them and, thus, leading to a more concentrated urbanization. Compared to the Base scenario, the urban area occupied by the lower and higher income households increases by 147.6% and 121.0%, respectively. The living space increases by 21.6% for lower income households (to 99.9 m^2/household) and by 15.2% (to 173.3 m^2/household) for higher income households.

As for the housing prices, these are higher near the coastline and around the RdA area. The average real estate (rental) value decreases by 25.3% for households with lower income (to 26.5 €/m^2/yr) and decreases by 25.0% for households with higher income (to 47.3 €/m^2/yr). Highest real estate (rental) values, close to the existent environmental amenities, are somewhat lower (up to 70.6 €/m^2/yr). Similarly, lowest real estate (rental) values, further away from environmental amenities, are somewhat lower (up to 17.5 €/ m^2/yr). The real estate price is higher for households with higher income than for households with lower income.

8. Conclusions and recommendations

8.1. Conclusions

Urban sprawl is a problematic issue nowadays. There is the waste of land and resources, the destruction of environmentally valuable areas, waste of energy and resources, and the increase in greenhouse gas emissions. It is imperative to work to achieve a sustainable urban development, reaching an economical balance, the protection of the environment and its ecosystems, as well, as comfort and good quality of life for the population. Therefore, it is important that there are solid spatial plans that can help to achieve these goals.

Analysis of the Regional Spatial Development Plan for the Centre Region in Portugal (PROT-C) shows, that the plan is too general and somewhat confusing with the indications to achieve sustainable urban development. It is difficult to understand how the territorial models are created and how some assumptions were made. As for the integrated model, it is not specific how much weight each aspect (social, environmental and economic) was taken into account to build it, not being explained the choices made in this creation. Even though spatial plans, and particularly the PROT-C, need to be general so there is room for each location to adapt it to their reality, it is clear that the plan is too general and broad – leaving too many details for interpretation.

Assessment of the impacts of the PROT-C for the three territorial models and the integrated model, using the SULD decision support tool, shows that there are big differences between scenarios. The Risks scenario results in a small increase in urban area (+7.1%) and living space (+0.6%), while the average real estate (rental) value per household and the total real estate (rental) value for the region decrease (-2.8% and -0.9%, respectively). Similarly to the base scenario, the population is concentrated near urban centres and environmental amenities (specially near the coastline). In the Environmental scenario there is a large decrease in urban area (-15.6%) and living space (-4.4%), while there is a significant increase in average (+4.8%) and total (+0.3%) real estate (rental) values. The population increasingly concentrates around environmental amenities and, hence, urban sprawl is reduced. The Urban scenario results in a very large increase in urban area (+483.4%) and living space (+34.1%), accompanied by a large decrease in average real estate (rental) value (-48.0%) and total real estate (rental) value for the RdA region (-19.3%). In particular lower income households are scattered around the landscape, leading to disperse urbanization and urban sprawl. Finally, the Integrated scenario results in a very large increase in urban area (+145.1%) and living space (+19.6%) as well as a large decrease in average (-25.8%) and total (-11.2%) real estate (rental) values. There is some urban dispersion throughout the territory, however not as severe as the one observed in the Urban scenario.

As such, which scenario option can be considered the best solution? Analysing all the maps and data obtained and taking into consideration a sustainable perspective, where is possible to obtain the best results social, environmental and economically wise, it is possible to conclude that, even though the Integrated scenario is not the worst option it is, also, not the best option. The Risks scenario leads to some urban expansion and sprawl, though may provide public (health) benefits not accounted for in this analysis. The Urban scenario does not seem to be a good solution, not being beneficial either from an environmental perspective or from an economic perspective. With this perspective the Environmental scenario shows to be the best option for a sustainable urban development, showing benefits from an environmental perspective, with the protection and appreciation of environmental amenities, but also from a social and economic perspective, increasing the housing prices and increasing the total real estate value of the region by 30%, as well as contradicting the problematic of urban sprawl and its negative effects. For the Integrated scenario to be a more viable option, it needed to consider less urban aspects and more environmental aspects.

In this investigation, were not developed future simulations taking into account population growth for the area. However, and considering the results obtained, it is possible to affirm (even though without concrete data to support) that for the ideal scenario (Environmental scenario) the increase in population would not bring many changes, as the scenario shows a large amount of area still available for construction, without harming and destroying the environmental amenities.

The use of the SULD model to assess the contribution of spatial plans to sustainable urban development allows to obtain concrete information on how spatial plans and their assumptions work towards the accomplishment of sustainable urbanization goals. This information, being not merely qualitative but quantitative, provides a more realistic notion of the likely impacts of spatial plan.

8.2. Recommendations

Considering the research and work done, and considering that no projections were made for future scenario situations, it would be interesting to make a simulation scenario considering future population growth. This provides a quantitative way to assess future urbanization and if the population growth would jeopardize a sustainable urbanization perspective.

This type of research with the SULD model could also be applied to other spatial plans existent and to different regions, in order to understand how these plans contribute to a sustainable urban development. In particular the POLIS programme and Spatial Coastal Plans (POOC).

Also, this type of research, where it is possible to quantify sustainable urbanization, should be presented to the entities that are responsible for spatial planning, so that during the process of making these plans they can be based on quantitative data. This will aid in the identification of planning strategies that, present the best options for sustainable urbanization.

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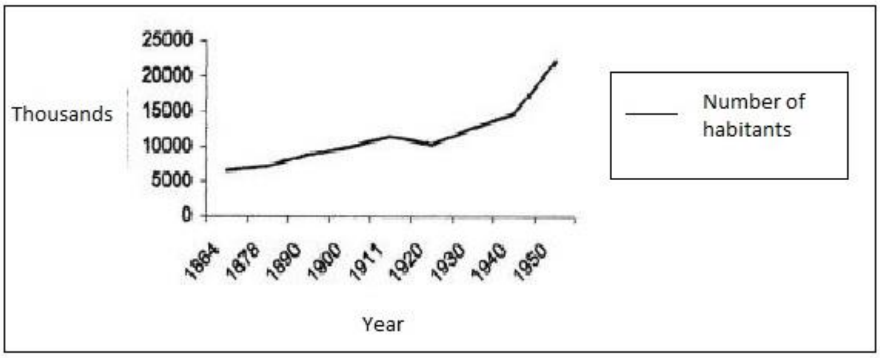
Annex

Annex 1 - Population evolution in the city of Aveiro from 1864 to 1950 (Adapted from (Ferreira, 2003)).



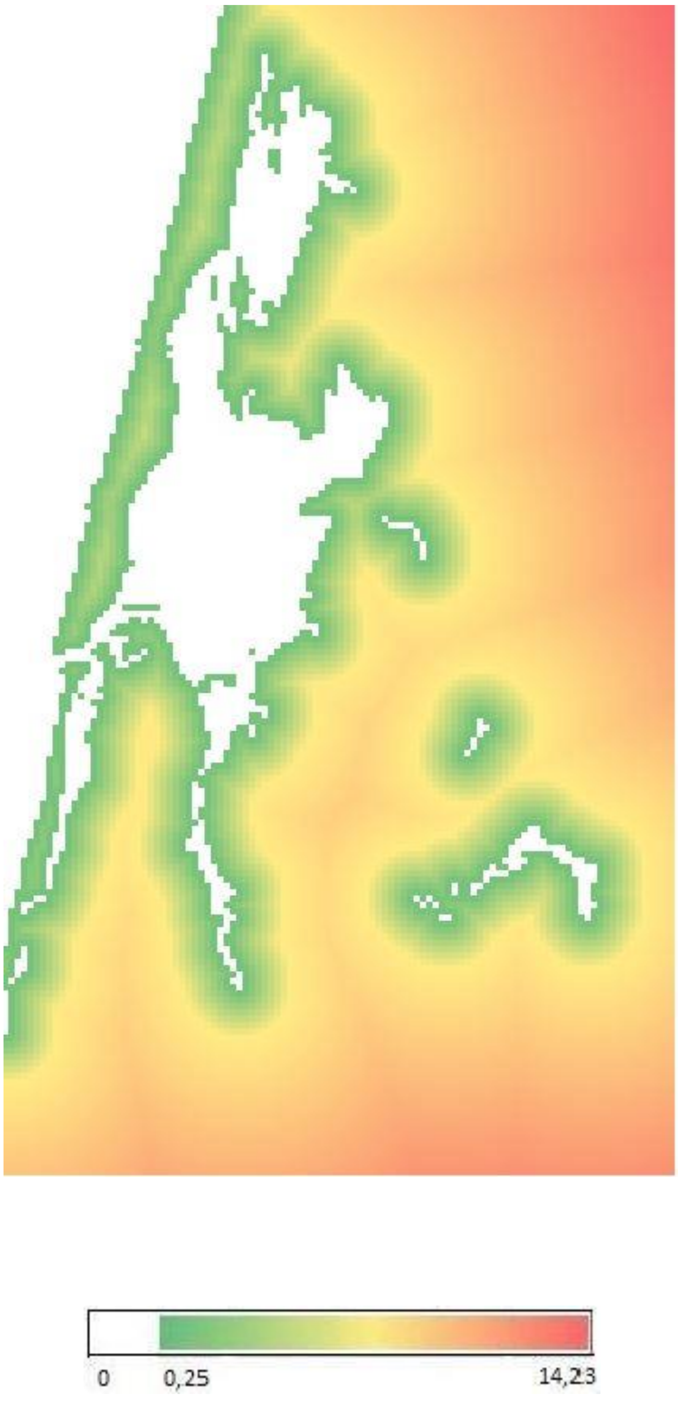
Annex 2 – Values for land use, population density, average income and area for the case study cities, for the year 2006 (INE, 2006).

	2006						
	Land use identified in the PMOT (ha)				Population density (hab/km2)	Average income (€)	Area (km2)
	Urban	Urban Park	Industrial	Tourism			
Albergaria	1837.1	0	244.2	0	164.5	814.9	157.6
Aveiro	2915.2	841	716.7	0	372.5	995.1	197.5
Estarreja	1899.5	43.7	156.3	0	260.4	919.2	108.8
Ílhavo	1828.5	16.7	227.9	0	549.2	837.7	73.5
Murtosa	948.4	63.1	25	543	134.1	641.1	73.1
Oliveira do bairro	2142.4	4.2	357.3	0	263	822.7	87.3
Ovar	2998.5	0	523	71	390.1	802.2	147.4
Vagos	2544.3	91.1	69.2	13.2	143.8	732.3	164.9
Total	17113.9	1059.8	2319.6	627.2	2277.6	820.65	1010.1

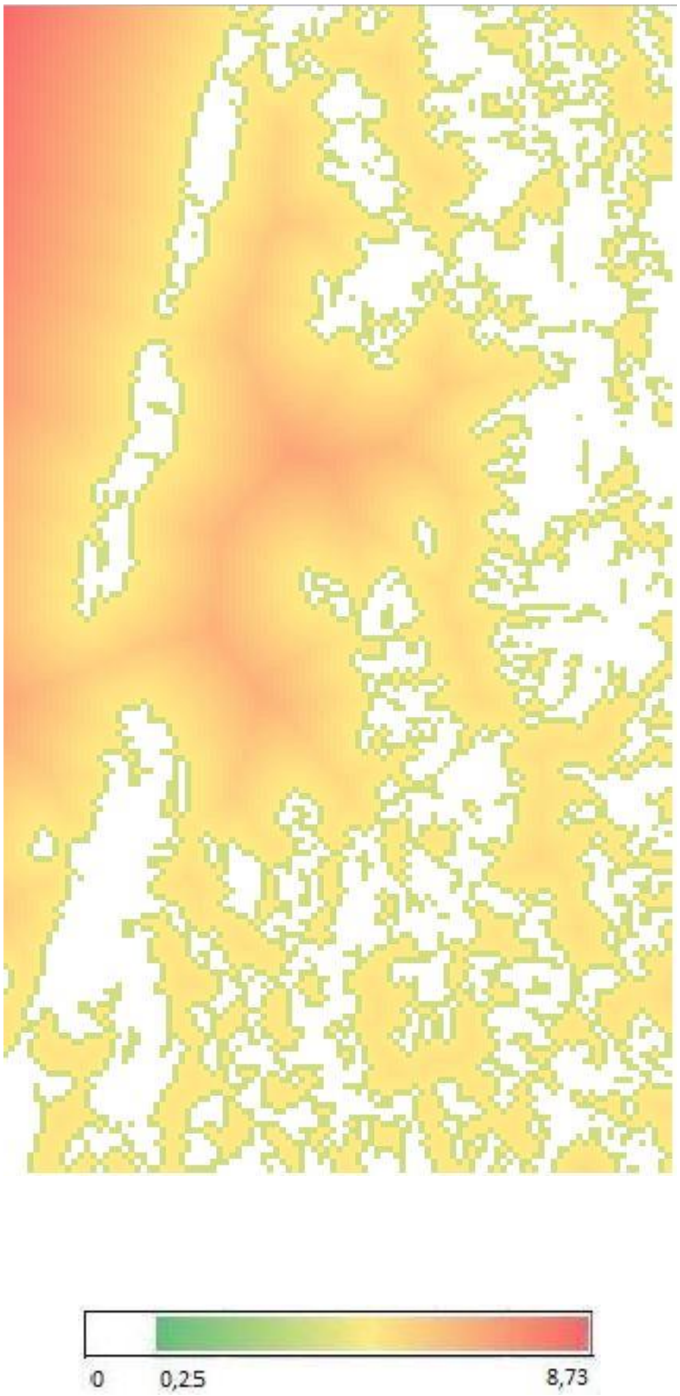
Annex 3 – Values for land use, population density, average income and area for the case study cities, for the year 2011 ((INE, 2012))

<table>
<tr><th rowspan="3"></th><th colspan="7">2011</th></tr>
<tr><th colspan="4">Land use identified in the PMOT (ha)</th><th rowspan="2">Population density (hab/km2)</th><th rowspan="2">Average income (€)</th><th rowspan="2">Area (km2)</th></tr>
<tr><th>Urban</th><th>Urban park</th><th>Industrial</th><th>Tourism</th></tr>
<tr><td>Albergaria</td><td>1837.1</td><td>0</td><td>244.2</td><td>0</td><td>158.6</td><td>909.51</td><td>158.8</td></tr>
<tr><td>Aveiro</td><td>2915.2</td><td>841</td><td>716.7</td><td>0</td><td>397.1</td><td>1093.3</td><td>197.6</td></tr>
<tr><td>Estarreja</td><td>1899.5</td><td>43.7</td><td>156.3</td><td>0</td><td>248.4</td><td>1038.56</td><td>108.2</td></tr>
<tr><td>Ílhavo</td><td>1828.5</td><td>16.7</td><td>227.9</td><td>0</td><td>524.2</td><td>992.14</td><td>73.5</td></tr>
<tr><td>Murtosa</td><td>948.4</td><td>63.1</td><td>25</td><td>543</td><td>143.9</td><td>764.92</td><td>73.1</td></tr>
<tr><td>Oliveira do bairro</td><td>2142.4</td><td>4.2</td><td>357.3</td><td>0</td><td>263</td><td>929.04</td><td>87.3</td></tr>
<tr><td>Ovar</td><td>2998.5</td><td>0</td><td>523</td><td>71</td><td>374.3</td><td>897.21</td><td>147.7</td></tr>
<tr><td>Vagos</td><td>3655.9</td><td>127.4</td><td>777.7</td><td>0</td><td>138.5</td><td>846.02</td><td>164.9</td></tr>
<tr><td>Total</td><td>18225.5</td><td>1096.1</td><td>3028.1</td><td>614</td><td>2248</td><td>933.8375</td><td>1011.1</td></tr>
</table>

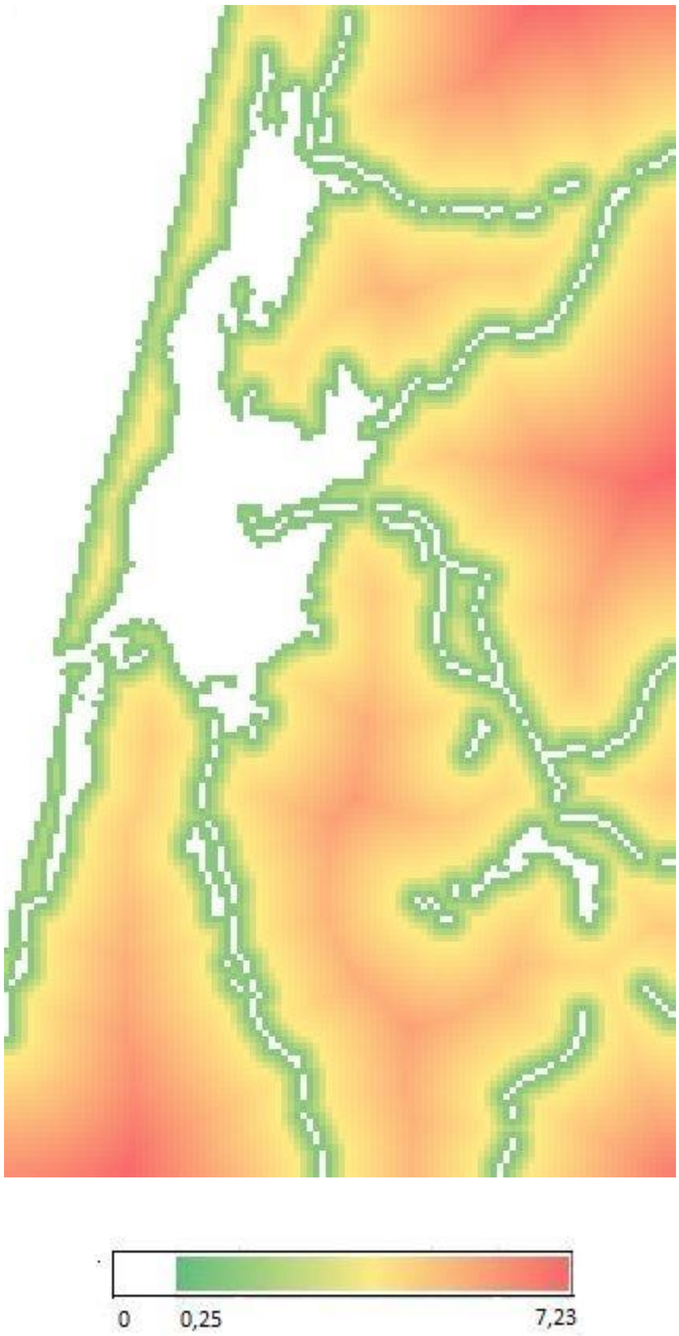
Annex 4 – Distance to the environmental amenity water (base scenario)



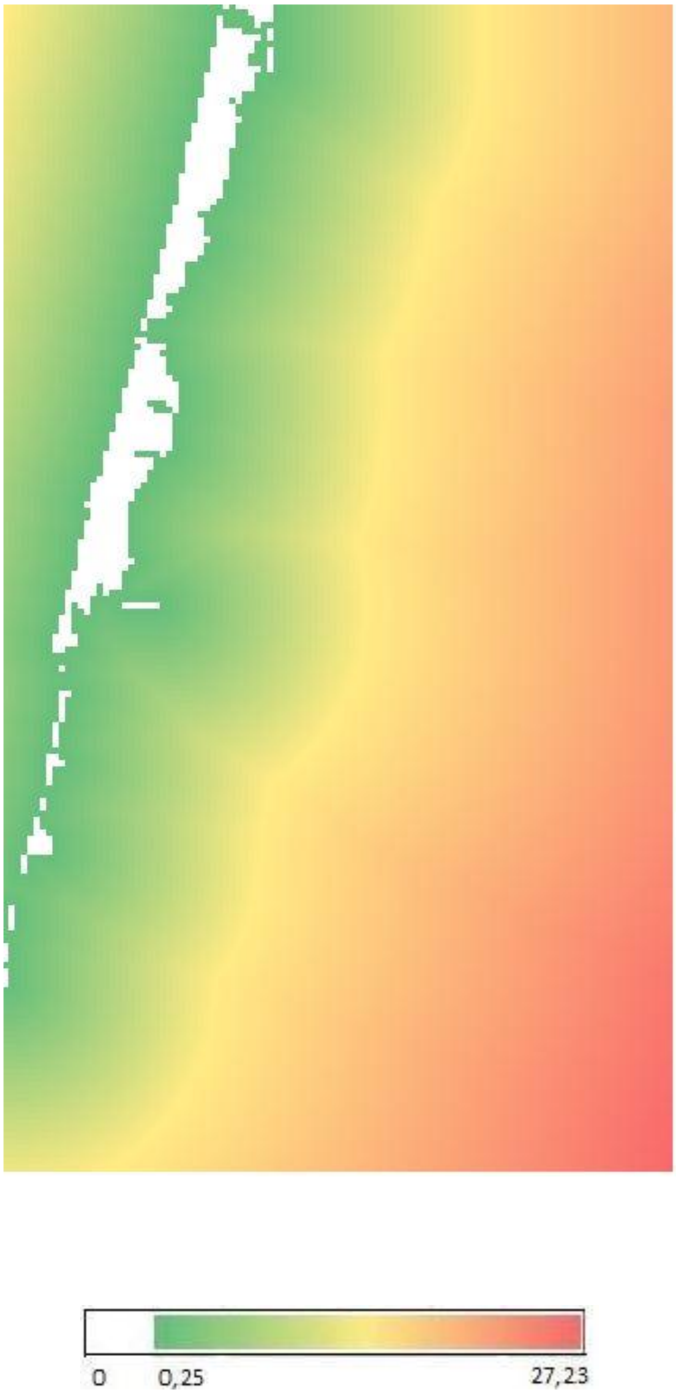
Annex 5 – Distance to the environmental amenity forest (base scenario).



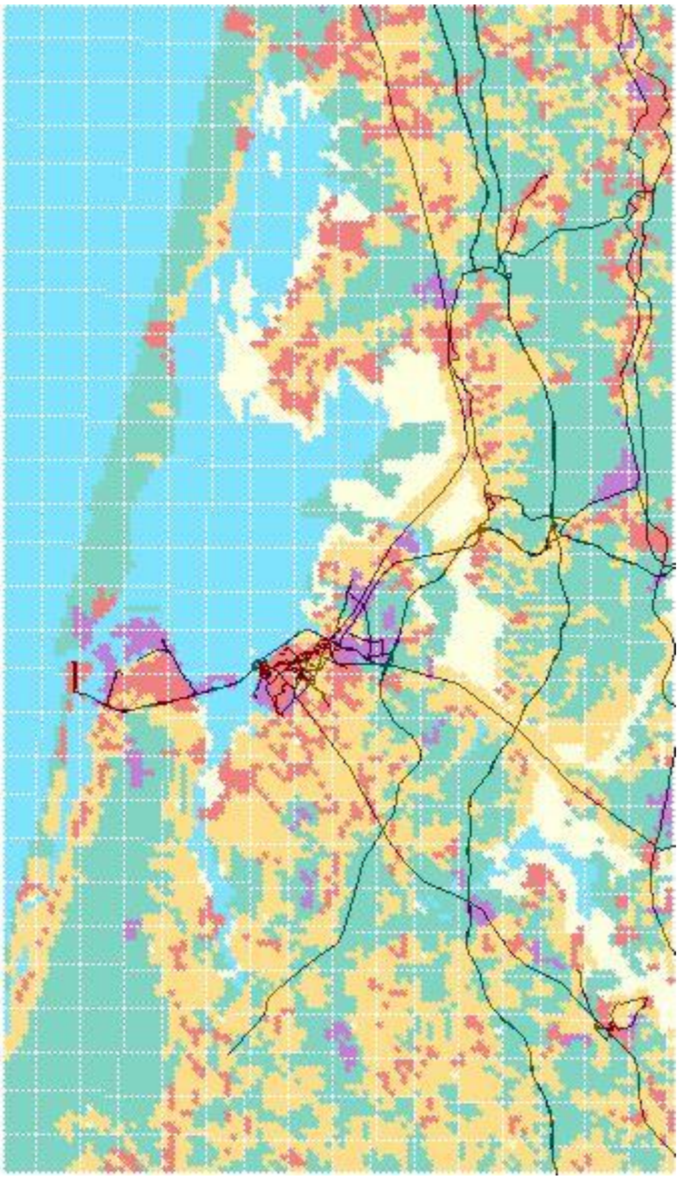
Annex 6 – New distance to the environmental amenity water.



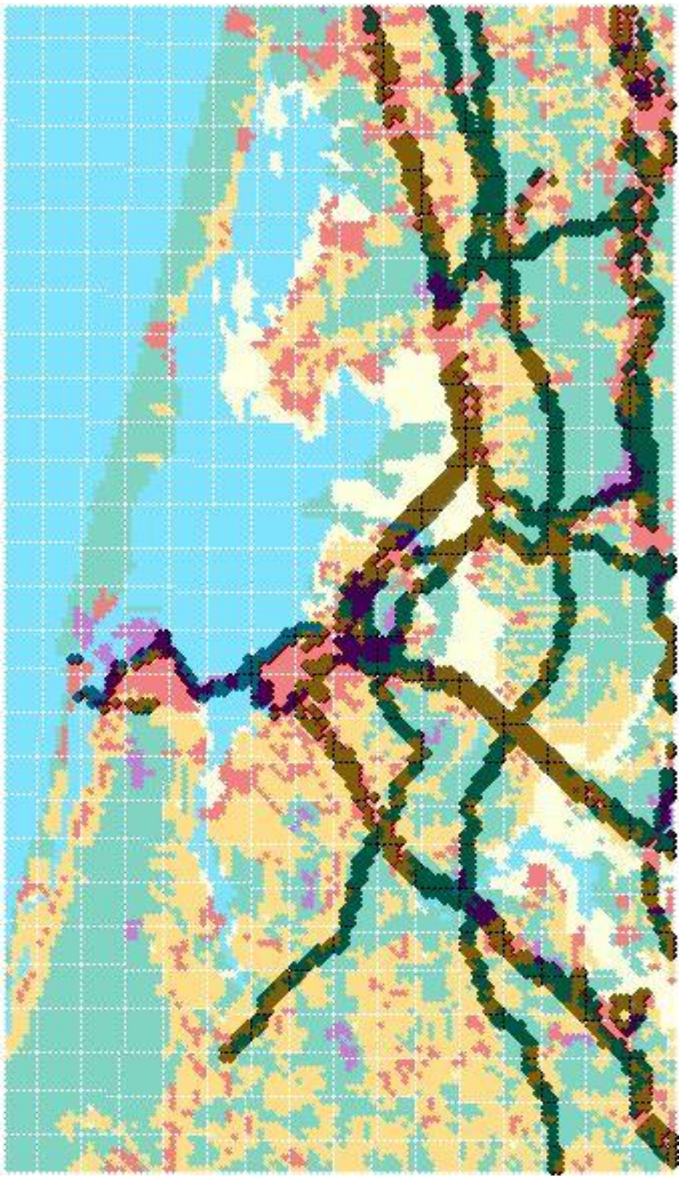
Annex 7 – New distance to the environmental amenity forest.



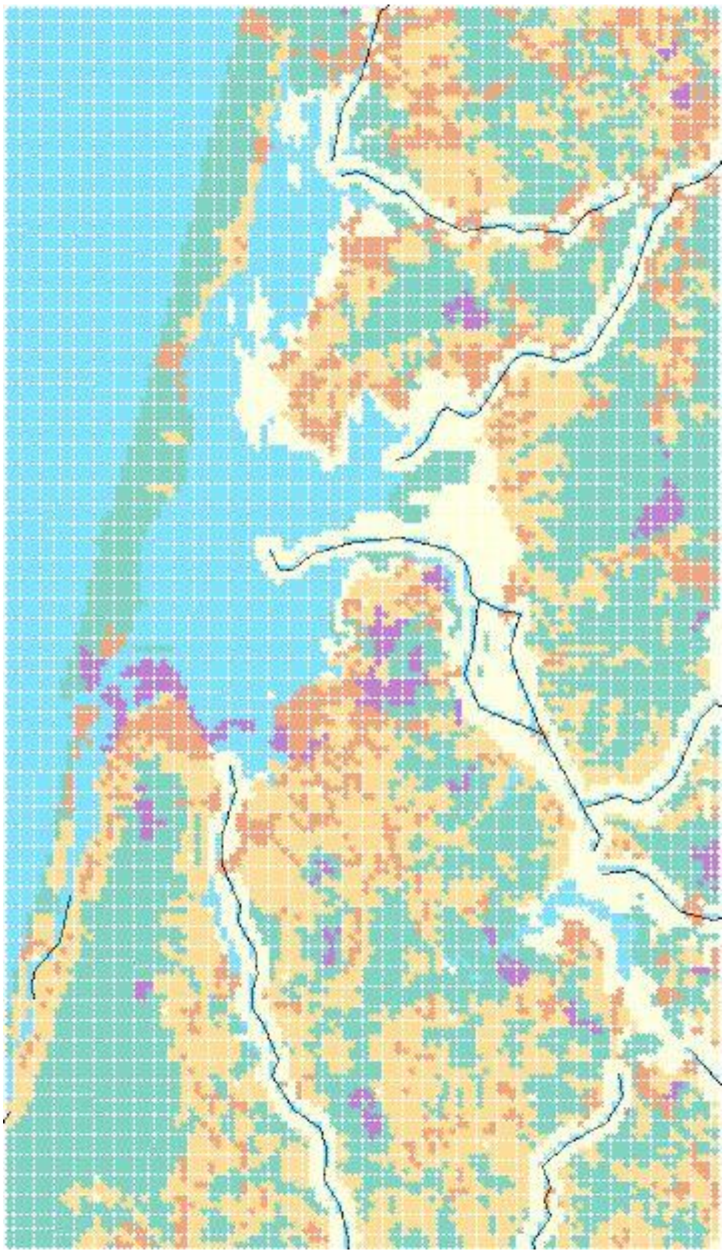
Annex 8 – Risks scenario with buffers around main roads and railways.



Annex 9 – Risks scenario with buffers around main roads and railways.



Annex 10 – Environmental scenario with water lines.



Annex 11 – Environmental scenario with buffer around the water courses.