CIRCLE-2 ERA-NET

Deliverable 2.1b – *Baixo Vouga Lagunar* Knowledge Database

CIRCLE-MED2-2013

Adaptation to Climate Change from a natural and social science perspective: Water in coastal Mediterranean areas

Please refer to the D2.1b - Baixo Vouga Lagunar (Portugal) database of the ADAPT-MED project

ERA-NET CIRCLE-2 (MED Group)

TRANSNATIONAL CALL FOR PROPOSALS 2013

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

GOVERNO DE PORTUGAL

NOTE TO THE READER

The topic "**Water and Adaptation to Climate Change from a natural and social science perspective in coastal Mediterranean areas**" highlights the role and the importance of water for human life, nature and for the economy, and the societal challenges emerging from climate change to protect our water resources and ecosystem services. In the last decade, many assessments of the climate change impacts in the coastal zones and globally have been undertaken. However, such assessments have rarely been connected to decision-making on adaption strategies, often because of the uncertainties associated to climate change impacts. Nevertheless, generic methods to inform decision making (e.g. the robust decision making) exist, but they have rarely been set up at regional and local scale. In addition, adaptation being trans-sectorial, there is a need to better demonstrate how such measures can be taken within the existing regulation on development, risk prevention and land use planning. In this context, the ADAPT-MED questions: **Is current decision making "adapted to internalize adaptation" into policy making?**

ADAPT-MED: Where and How?

ADAPT-MED will focus in three research sites: The territory around the *Ria de Aveiro* coastal lagoon in Portugal – *Baixo Vouga Lagunar* (BVL), the territory of the *SCoT Provence Méditerranée* in France and the eastern coast of Crete (Greece). All these coastal regions have been affected by increased urbanisation in the last century, and will be diversely affected by the adverse effects of climate change on water resources, aquatic ecosystems and urban infrastructures. The Project will investigate how adaptation is currently being practice in these regions and how this relates to other regulatory mechanisms on spatial planning and risk prevention. ADAPT-MED will also examine what adaptation measures would be desirable and how they can be mainstreamed/integrated within current policy, decision making and regulatory mechanisms. Finally, we will examine how changes in understanding, perception and values can result in changes in climate change adaptation decisions.

The ADAPT-MED strives to contribute to the European and national efforts in favour to **adaptation of coastal zones** to the **effects of climate and global change**, by creating a breakthrough on adaptation decision making practices, in particular by better taking account of vulnerability assessments and their uncertainties. **Stakeholders** will be associated to the project right at the beginning, taking advantage of the current responsibilities of the partners in providing them support for water based ecosystem management and risk prevention related to climate change. They will be involved through national and regional workshops. Wider dissemination will be done through policy briefs, scientific publications and newsletters (ACTeon, BRGM, UAVR (CESAM), ISCTE-IUL,NKUA, 2013).

The present document consists in a knowledge compilation through the available literature regarding ***Baixo Vouga Lagunar*** *(BVL).* It is issued as an **ADAPT-MED** project deliverable but it should also be considered as an extensive knowledge source about BVL.

LIST OF ABBREVIATIONS

APA – Portuguese Environment Agency

ARH – Administration of Hydrographic Region

BVL – *Baixo Vouga Lagunar*

CCDRC - Centro Regional Coordination and Development Commission

CIRA – Inter-municipal Community of the *Aveiro* Region

DRAPC – Regional Directorate for Agriculture and Fisheries of Centre

EIA - Environmental Impact Assessment

ES – Ecosystem Service

GVA – Gross Value Added

I.P. – Public Institution

ICNF – The National Institute for the Conservation of Nature and Forest

IGT – Territorial Management Instruments

IPMA – Portuguese Atmosphere and Sea Institute

IUCN - International Union for Conservation of Nature

POM - Particulate Organic Matter

PROTC - Regional Land-use plan for Centre

PWD – Public Water Domain

SLR – Sea Level Rise

SPA – Special Protection Area

SWOT - Strengths, Weaknesses, Opportunities, and Threats

TEEB - The Economics of Ecosystems and Biodiversity

TMI – Territorial Managing Instruments

UA – Aveiro University

WFD – Water Frame Directive

WP – Work package

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SUMMARY

This report sets a knowledge database for ***Baixo Vouga Lagunar* (BVL)**, as it was defined in **ADAPT-MED** project **WP2**. The adopted methodology includes the collection of the existing published reports and relevant studies, complemented by dedicated stakeholder interviews that help gathering relevant grey literature and stakeholder knowledge.

The report is structured as follows: Chapter 1 introduces the readers to a **general description** of *Baixo Vouga Lagunar* in terms of climate, geologic units and physiographic characterization. Chapters 2 to 4 report on the **water resources and management,** including the main supply sources, demands and management/regulation; the **natural capital**, including the land use and the ecosystems units, the **urban infrastructures**, the **economic development** and the **population**; and the **ecosystem services** provided by *Baixo Vouga Lagunar* water resources. Chapter 5 gives an overview of *Baixo Vouga Lagunar* in the context of **climate change**, including sea level rise and the current adaptation practices. Chapter 6 summarizes the **expected impacts and risks attributed to future changes**, with specific attention to freshwater resources (availability and use, including water supply), urban infrastructure / agglomerations; and the **social, economic and environmental impacts** – combining qualitative, quantitative information. In this chapter, special attention will be given to the **ecosystem services** provided and how these might link natural and socio-economic dimensions of impacts; and to the **main sources of uncertainty** in the available knowledge.

1 INTRODUCTION

1.1 Study site description

The *Baixo Vouga Lagunar* (BVL) - Figure 1 - is located in ***Aveiro*** District, between *Porto* and *Entre-Douro e Vouga* (north), *Dão-Lafões* (east) and *Baixo-Mondego (south).* It extends through 3 000 ha in *Aveiro*, *Estarreja* and *Albergaria-a-Velha* municipalities (Figure 2).

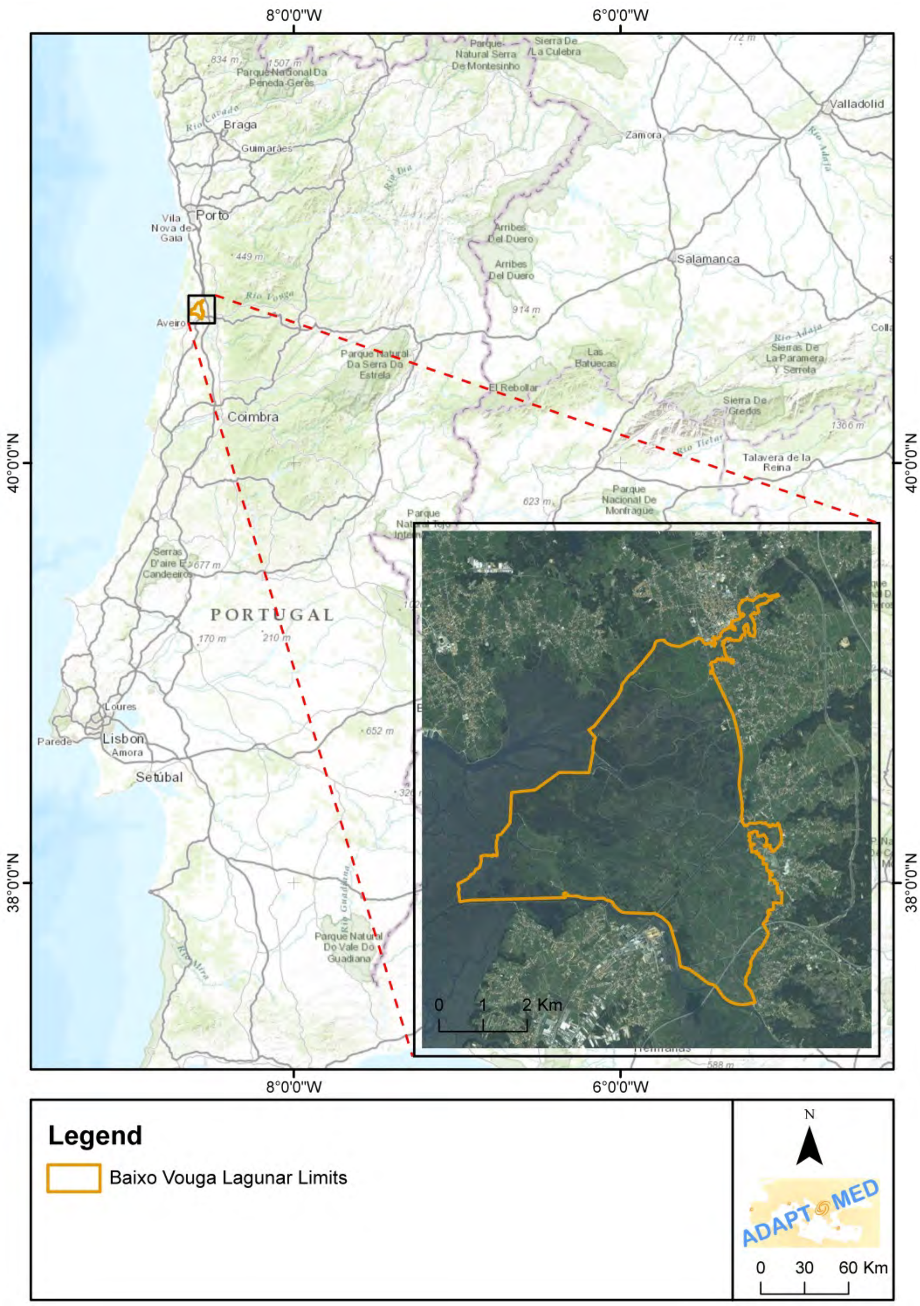


Figure 1 - BVL location in Portugal

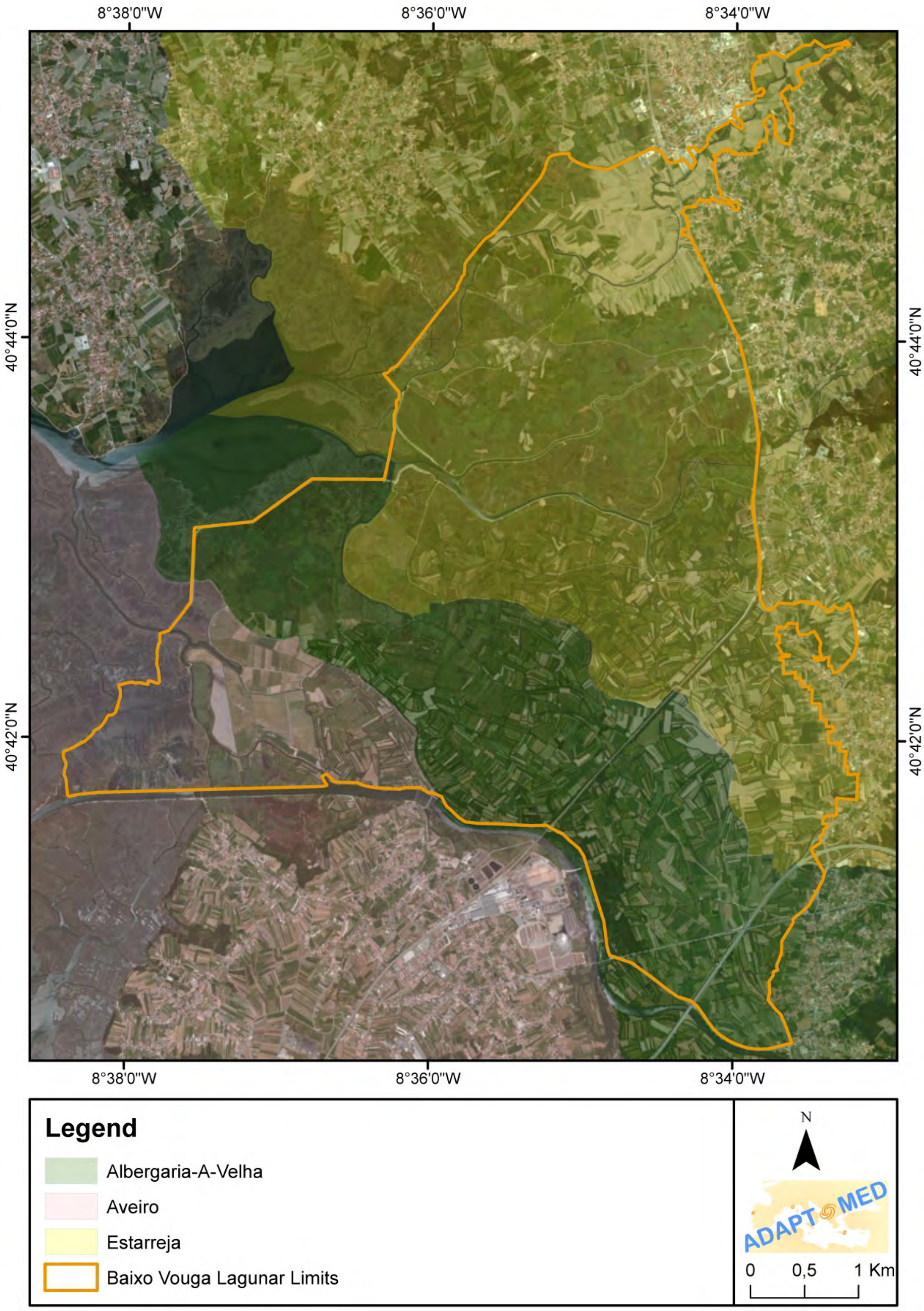


Figure 2 - Baixo Vouga Lagunar municipalities (Source: CAOP2013)

Baixo Vouga Lagunar comprised six parishes – *Angeja*; *Cacia*; *Canelas*; *Fermelã*; *Salreu* and *Beduído*, which according to the 2011 census have a population of 23 556 inhabitants. Since 2013 *Canelas* and *Fermelã* have been merged into a single parish, named *União das Freguesias de Canelas e Fermelã.* Also the *Beduíno* parish has been merged with the *Veiros* parish (outside the BVL area) forming the *União das Freguesias de Beduído e Veiros.* For the purpose of this report we will consider the BVL territory, i.e, the territory covered by the previous *Angeja*; *Cacia*; *Canelas*; *Fermelã*; *Salreu* and *Beduído parishes.*

BVL is a part of *Ria de Aveiro* coastal lagoon, which is classified as a Special Protected Area, under the Natura 2000 Birds Directive (Directive 79/409/CEE, repealed by Directive 2009/147/CE). These are important community areas where, the human activities should be compatible with the bird conservation premises. So, the nature conservation policies and the other sectorial policies (e.g. Territorial Management Instruments) consider those premises and are described in chapter 3.7 (ICNF, 2014b).

Baixo Vouga Lagunar remarkable characteristics permit a strong and balanced relationship between **man, land and water**. The presence of man, through farming, shaped the landscape as a function of production objectives and economic sustainability. Nevertheless, floods and surface saline intrusion are always threatening this balance. In BVL there are three different landscape units: **open fields; wetlands; and '*Bocage'*** (Andresen & Curado, 2001a).

'B*ocage'* is a unique ecosystem in this area, which links both annual and permanent crops. 'Bocage' consists in **small holds divided by living-hedges** (e.g. grey willow, black alder and pedunculate oak) **and draining ditches**. This man-shaped landscape makes a very particular irrigation system managed by farmers, for pastures and for maize/forage production (Figure 3).

Figure 3 – The Vouga River and the 'Bocage' smallholdings

'Bocage' plays not only an important role in farming but also in regional natural communities, mainly for birds. There is a great density of nests of **birds of prey** (Black Kite and Commom Buzard), as well as **mammals** (Leated weasel, Common genet, Otter and Polecat), **amphibians** (Iberian painted frog and European tree frog) and **reptiles** (Iberian emerald lizard). Amphibians are also quite abundant in these freshwater ditches and watercourses, as well as fishes (e.g. lampreys, shad and eels).

Wetlands are characterized by semi-permanent flooded areas or by areas in which soil is saturated with water. In wetlands, the vegetation species composition follows the salinity gradient: in BVL it includes tidal marshes of **rushes** (*Juncus maritimus*) or **reeds** (*Phragmites australis*), and **rice fields**. Marsh vegetation is often chopped by livestock producers for cattle beds.

Open fields correspond to wide agricultural plots with no arboreal vegetation. In Open fields there is production of annual forages (silage maize and hay) or permanent pastures.

The BVL system is threatened, as the ecological and the agricultural infrastructures have been subdued by heavy winter upstream floods (Figure 4), downstream surface saltwater intrusion and due to the lack of maintenance of the hydraulic infrastructures (ditches, dikes, water-gates) and due to changes in the bathymetry. In order to deal with these issues, some interventions have been made such as new banks, containing dikes and improving the ditch maintenance. From 1995 to 1999, a 4 km concrete dike was built, between *Velho* River and *Antuã* River mouth, decreasing the risk of salt water intrusion and coastal related floods (Andresen & Curado, 2001b; LAGOONS, 2012).

In the initial project – *Baixo Vouga Lagunar* Agricultural Project for Water Exploitation - the containing dike was 6 km longer, therefore is not accomplishing its full goal (for a more detailed description of the project see section 5.3). In addition, the tidal prim in the *Ria de Aveiro* lagoon is increasing (LAGOONS, 2012; LAGOONS, 2013), so, the balance between the salt and freshwaters favours upstream saltwater intrusion in BVL (FACTS!, 2012).

Figure 4 - *Baixo Vouga Lagunar* under severe flooding

To frame the opportunities and threats for *Baixo Vouga Lagunar,* we show the SWOT analysis of Fidélis & Carvalho, 2013, which is partially shown in Table 1. From the analysis it is clear that water has an important role in the ecosystem, however it is a difficult to manage due to natural reasons (extreme weather events, landscape, etc.) but also due to the legal framework (complexity, poor communication, etc.) (Fidélis & Carvalho, 2013; Fidélis & Roebeling, 2014).

Table 1 – Opportunities and Threats identified for BVL (source: adapted from Fidélis & Carvalho, 2013)

Opportunities	Threats
Wide range of data and knowledge from research projects New emerging techniques, uses and practices Increasing recognition of the need for integrated and participatory approaches Requirements of Water Frame Directive (WFD) and Flood directive and the role stakeholder and users vulnerable to flood should take Horizon 2020 and related water resources governance challenges	Vulnerability to flooding risks and climate change Complexity of natural functioning systems Salinization of agricultural land in margins Abandonment of traditional water based activities inadequate use of resources Complexity of institutional framework, plans and policies Complexity of types and height of uses and users Centralization of water resources agency

Box 1. The BVL case study

BVL is recognized as model of biodiversity and balance between man activities and wildlife. Several studies and plans aim for possible solutions, however they are not internalized in the operational policies (Hydrographic Basin Management Plans, Municipal Spatial Planning, among others). Coordinated actions are needed as there are several actors and stakeholders involved in BVL, in terms of management and productivity (farmers, private and public sector, among others) - this is where ADAPT-MED will focus.

1.2 Climate patterns

BVL is located in a transition zone between the Atlantic climate (i.e. strong precipitation and cool temperatures all year) and Pre-Atlantic climate (i.e. less precipitation, higher temperature oscillations and hot summers) and is highly influenced by the proximity to the sea. The annual temperature variation, between the colder months and the warmer months, is less than 10ºC, with a dry season during the summer, and a very wet season during the winter (ARH Centro, 2012g). The Atlantic influence protects BVL from the cold and dry winds from the interior of the peninsula during the winter and from the high temperatures during the summer. The air relative humidity is high, during all year and the sun-hours are normal for a typical coastal area (i.e. 2 532 $h \cdot yr^{-1}$), with frequent fog events during the summer (Andresen & Curado, 2001c).

Regarding Köppen Climate Classification, BVL is a classified as **Csb,** which is a Warm-Summer Mediterranean Climate. Detailed explanation is presented in Table 2.

Table 2 - Meaning of the BVL Köppen climate classification (source: ARH Centro, 2012g)

Köppen letters	Meaning
C (group)	Temperate climate, the average air temperature in the three coldest months is between -3ºC and 18ºC and in the hottest is over 10ºC.
s (type)	The dry season occurs in the summer
b (sub-type)	Temperate summer, on which the temperature for the four hottest months is over 10ºC and in the hottest month below 22ºC

Precipitation and temperature

To our best knowledge, there are no weather stations within the *Baixo Vouga Lagunar*, however it was possible to gather climate information from four nearby weather stations, located as shown in Figure 5.

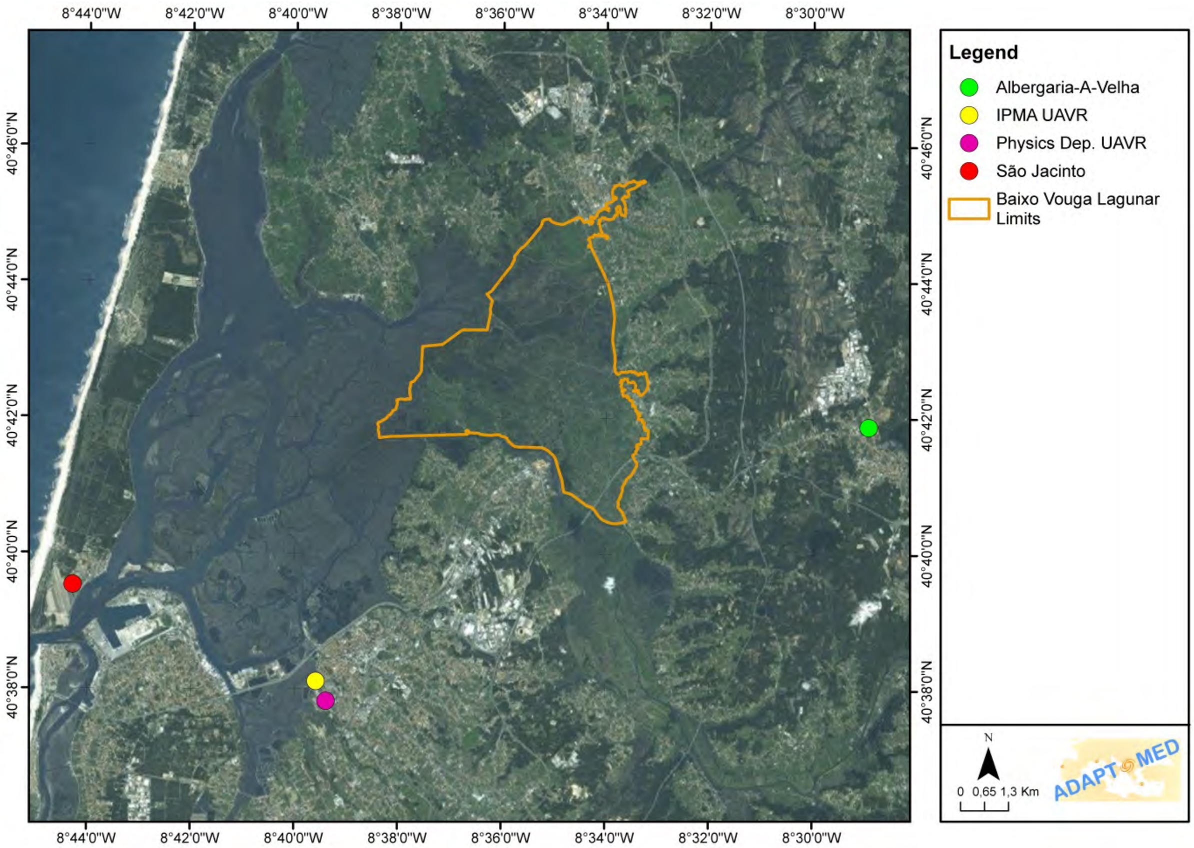


Figure 5 - Weather stations with available data, nearby of Baixo Vouga Lagunar. Legend: IPMA-Portuguese Atmosphere and Sea Institute, the Portuguese Institute responsible for the weather forecast; UAVR – University of Aveiro.

The **annual average precipitation in *S. Jacinto* weather station is 960.6 mm**, which is lower than in the more distant areas to the coast, for example *Albergaria-A-Velha* has a precipitation of 1 274 mm. The rainiest period corresponds to October-March, which has 77 % of the annual precipitation (Andresen & Curado, 2001c; ARH Centro, 2012g)

Figure 6 shows the monthly averages for precipitation, in the nearby weather stations.

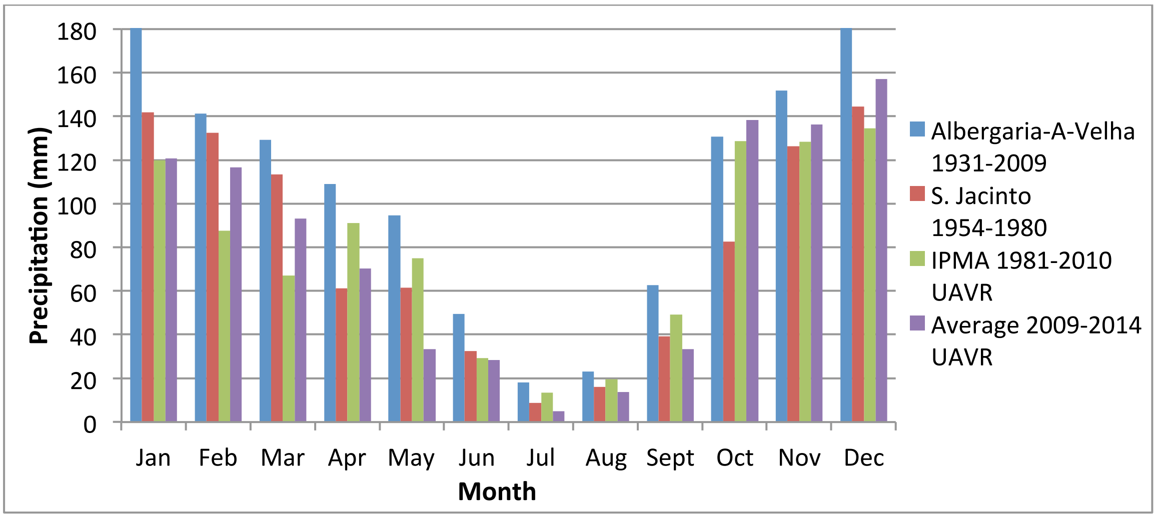


Figure 6 - Monthly average precipitation for *Albergaria-a-Velha* weather station, *S. Jacinto* weather station, IPMA (Portuguese Atmosphere and Sea Institute) weather station located in University of Aveiro and University of Aveiro Physics Department weather station (source: Andresen & Curado, 2001c; IPMA, 2014; UAVR, 2014; SNIRH, 2014)

The average annual temperature is 14.4 ºC, with July usually being the hottest month and December the coldest. The temperature difference between the two months is of 8.6ºC (ARH Centro, 2012g). Figure 7 shows the average monthly temperatures considering the data available from the nearby weather stations.

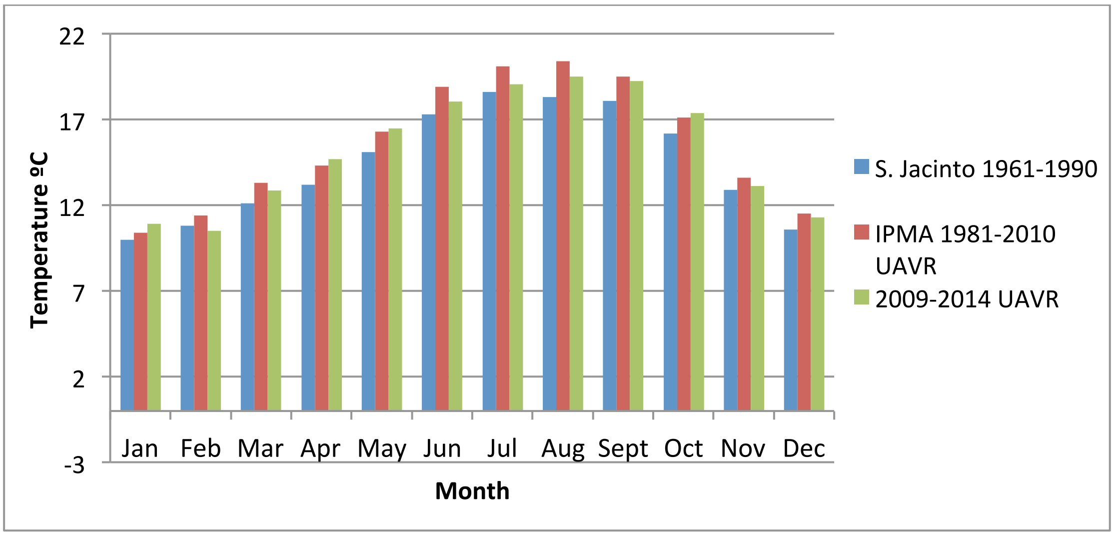


Figure 7 - Monthly average temperature for *S. Jacinto* weather station, IPMA (Portuguese Atmosphere and Sea Institute) weather station located in University of Aveiro and University of Aveiro Physics Department weather station (source: ARH Centro, 2012g; IPMA, 2014; UAVR, 2014)

1.3 Geological characterization

BVL is located in *Aveiro* Sedimentary Basin, in northern sector of the **Meso-Cenozoic West Rim**. It includes **Quaternary structures over a shale substrate**, from a **pre-Ordovician period**. There are also some **Cretaceous structures** and some from **Triassic**, but with less expression than the Quaternary. Figure 8 shows the different geologic structures present in *Baixo Vouga Lagunar* (Andresen & Curado, 2001c; LNEG, 2014).

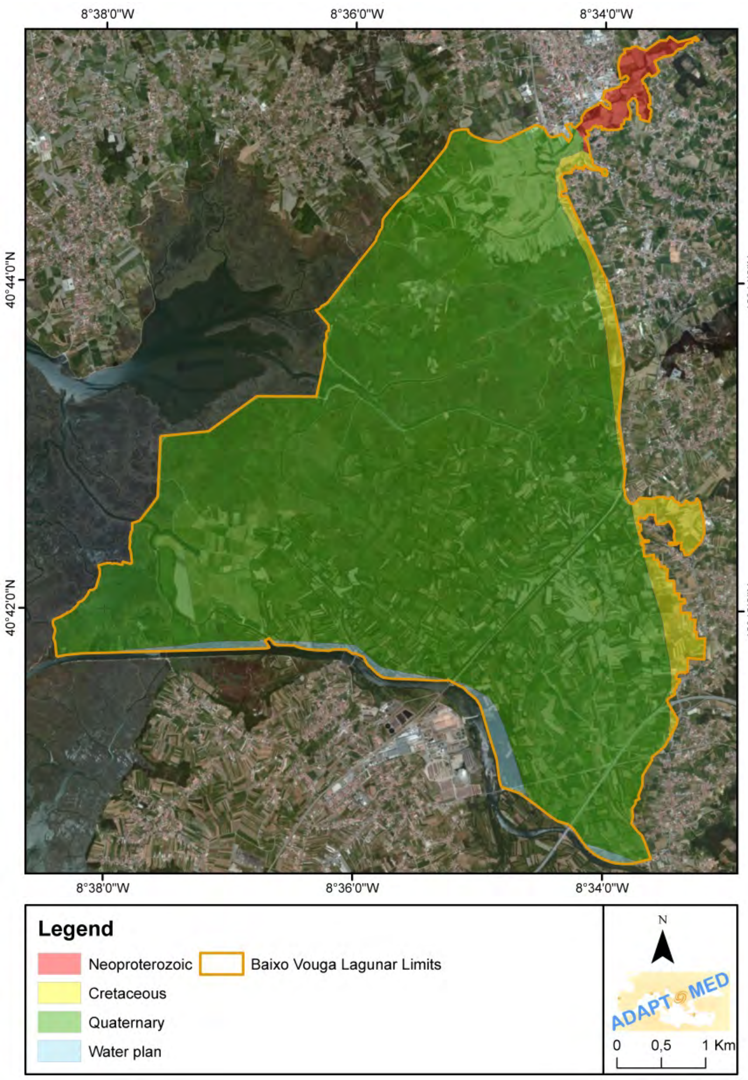


Figure 8 - Geologic structures in *Baixo Vouga Lagunar* (source: LNEG, 2014)

1.4 Physiographic characterization

The *Baixo Vouga Lagunar* represents a Lowland Plain landscape, mostly below 5 meters of elevation, located in the ***Vouga* river draining basin** as shown in Figure 9.

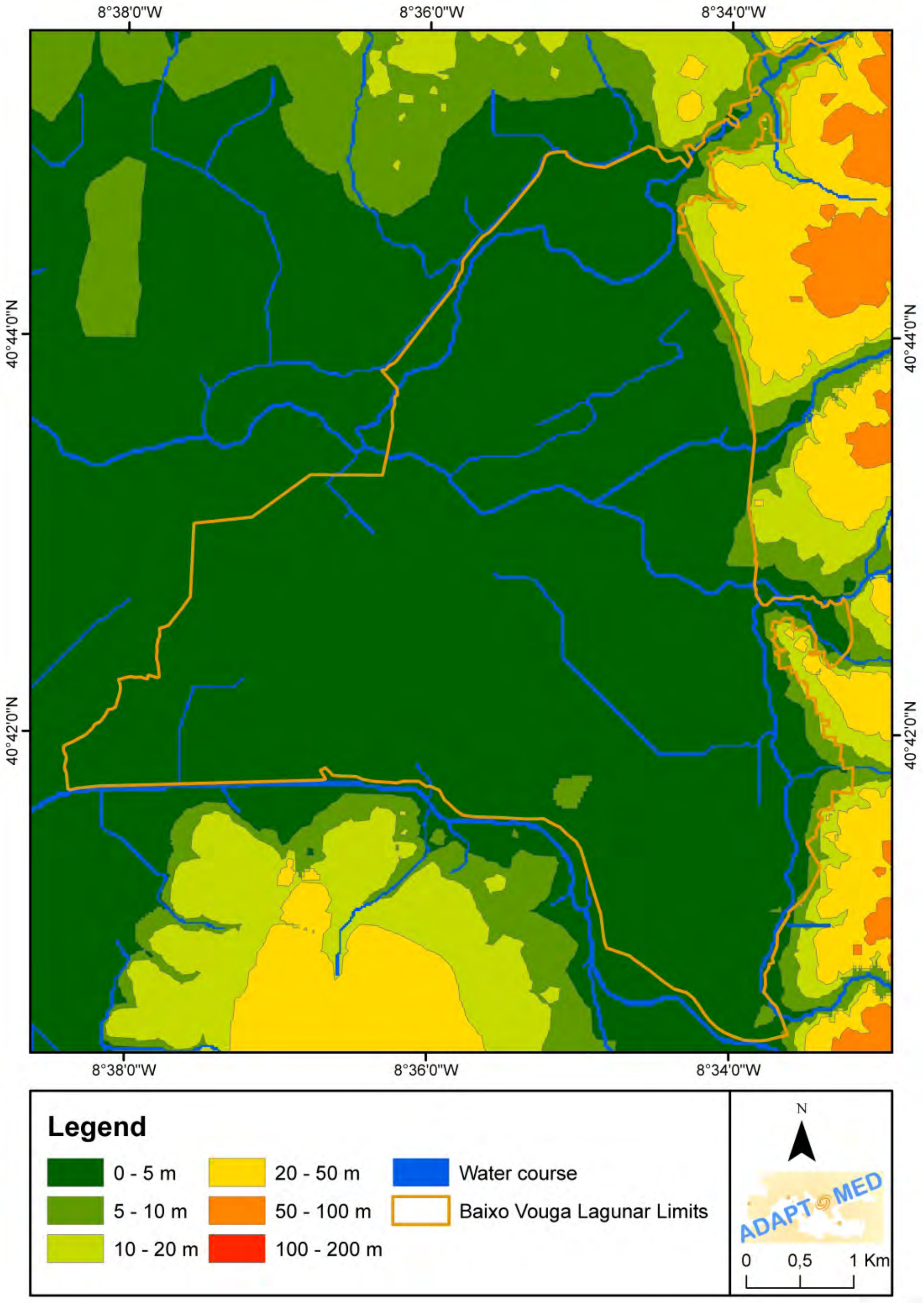


Figure 9 - Hypsometry in BVL (Source: CEAP, 2013)

2 WATER RESOURCES AND MANAGEMENT

The *Baixo Vouga Lagunar* is located in the confluence of ***Vouga*** river with ***Ria de Aveiro*** coastal lagoon. The lagoon system in BVL comprises low-depth waterways under the tidal influence (**transitional waters**) and several **freshwater** courses, where *Vouga* is the main river (Simão, et al., 2009).

2.1 Water resources

One of the main characteristics of *Baixo Vouga Lagunar* is the relation between freshwater and transitional waters. The freshwater courses in BVL are *Vouga, Antuã, Fontão* and *Jardim* rivers and the *Agra, Regato Corgo* and *Vala dos Amiais* streams. The transitional watercourses (with brackish water) in BVL are *Esteiro de Canelas*, *Esteiro de Salreu*, *Esteiro do Barbosa, Esteiro da Linha* and *Esteiro de Estarreja* (Figure 10).

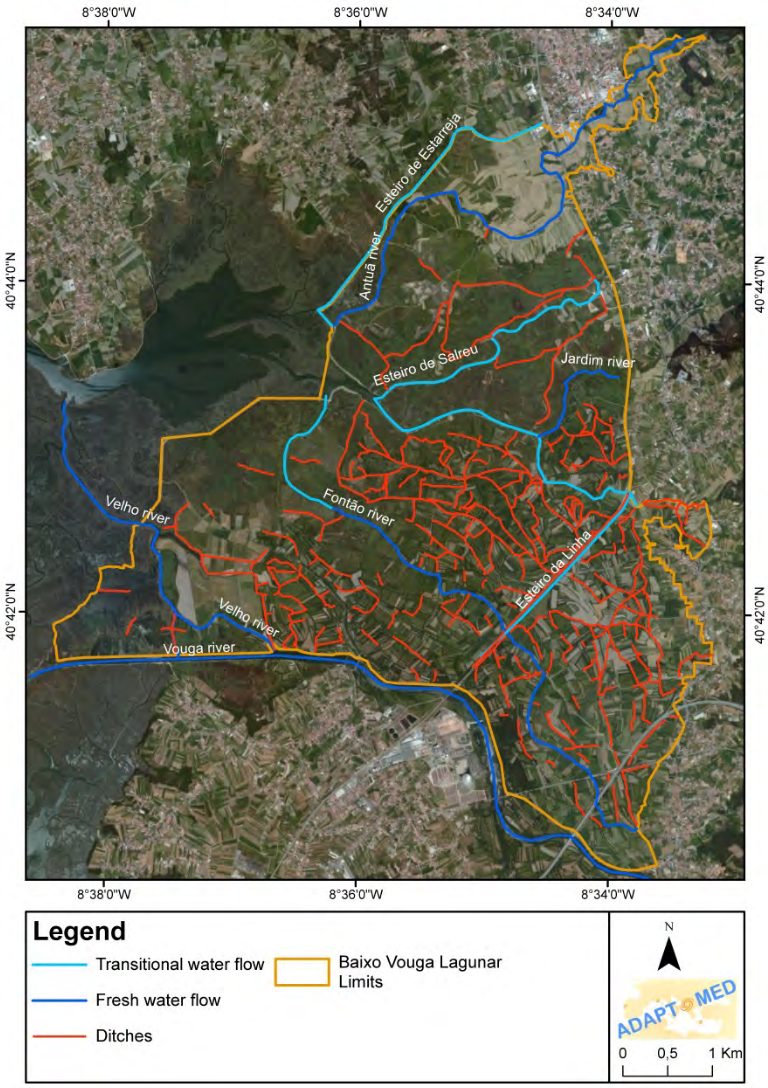


Figure 10 - Main watercourses and ditches in *Baixo Vouga Lagunar* (source: adapted from Andresen & Curado, 2001c)

The freshwater courses form the primary natural drainage network, which together with a network of small drainage channels ensure the drainage of freshwater to *Ria de Aveiro*. In addition, these watercourses are also connected to a network of irrigating channels supplying water for agriculture. The characteristics of the BVL freshwater courses are shown in Table 3.

Table 3 - Main watercourses characteristics in BVL (Source: Andresen & Curado, 2001c; Dias, 2001)

	Hydrographic basin		Water course		Peak flow during flood, for different return periods (T), in m^3s^{-1}	
Watercourse	**Area, km^2**	**Average slope, %**	**Length, km**	**Average slope, %**	**T=2 years**	**T=5 years**
Vouga	2425	-	160	-	-	875
Antuã	145.8	14.7	35.2	1.70	181,6	248,1
Jardim	18.8	9.3	10.4	0.71	38,5	54,1
Fontão	23.8	10.1	16.9	0.48	39,0	55,1
Regato Corgo	7	-	7	-	12,4	16,0
Agra	16.8	7.8 (a)	9.3	0.49	22,9	32,7
Amiais	7.6	9.0	6.7	0.33	12,1	17,6

(a) Includes *Regato Corgo* streams

Regarding the groundwater sources, the main present aquifer is formed by Quaternary structures (see chapter 1.3) and it is divided in two sub-aquifers:

- Quaternary surface aquifer: essentially composed by fine sand
- Quaternary base aquifer: composed by course sand and gravel

The two structures are divided by a sludge layer, which allows some exchanges between them. The permeability averages between 300 to 500 $m^2 \cdot day^{-1}$ (vertically) and 30 to 50 $m \cdot day^{-1}$ (horizontally) (Andresen & Curado, 2001c).

Regarding the transitional water, the BVL downstream areas are under the influence of *Ria de Aveiro* coastal lagoon. The lagoon is approximately 45 km long and 10 km wide and covers between 66 km^2 to 83 km^2 (i.e. low tide - high tide). It receives from downstream 25 to 90 million m^3 of transitional water during the tidal, levelling from 1 m to 3 m. From upstream it receives less than 2 million m^3 of freshwater (2/3 is due to *Vouga* river). Therefore, the salinity is mainly influenced by the tidal and by the freshwater drainage (Lopes, et al., 2011; Vargas, 2012; LAGOONS, 2013). Figure 11 shows the transitional water and the freshwater flows in BVL.

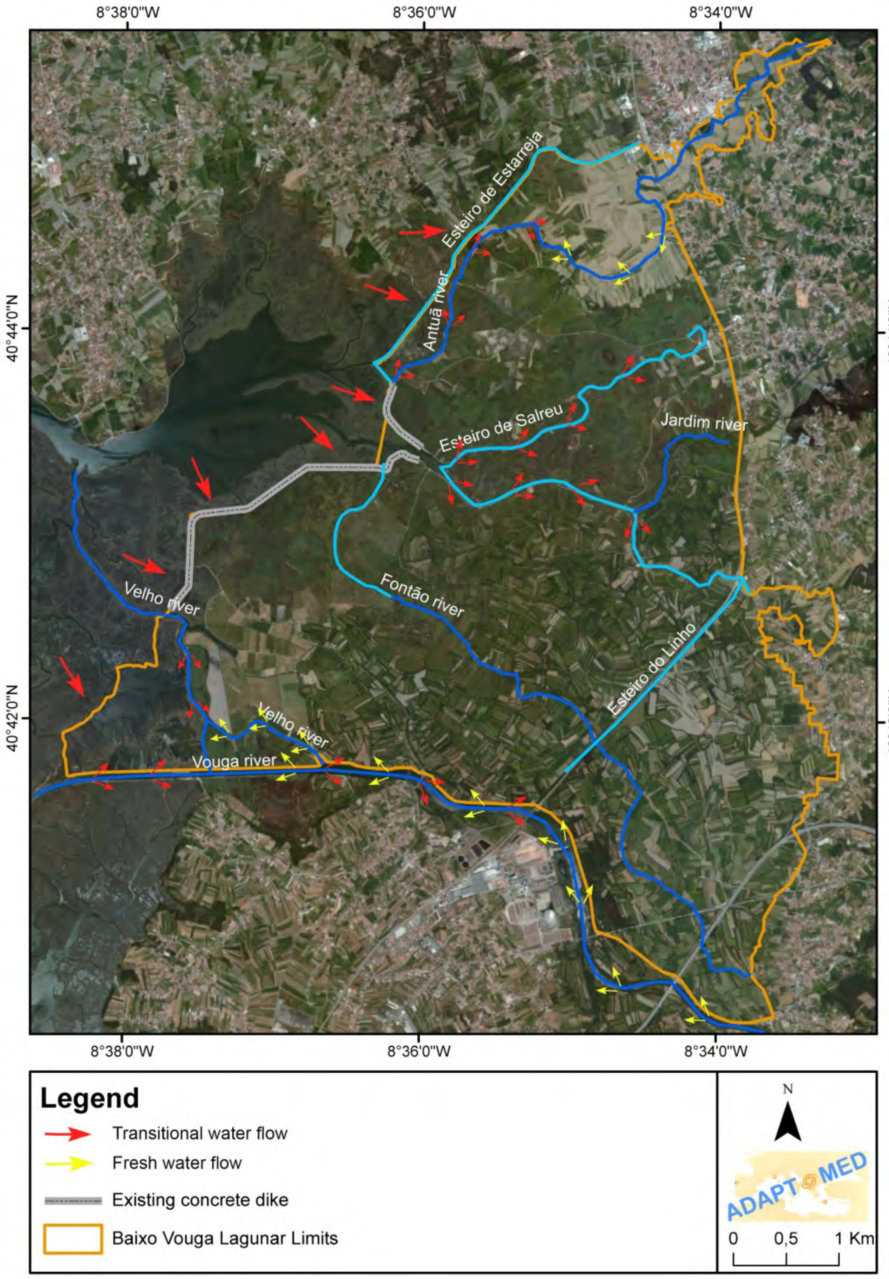


Figure 11 - Transitional water and freshwater flows in BVL (source: adapted from Alves, et al., 2013a)

The salinity patterns, induced by climate change, are being studied through numerical modeling that includes possible future scenarios considering the IPCC scenarios (please see the project websites: ADAPTARIA – http://climetua.fis.ua.pt/legacy/adaptaria/en/index.html and LAGOONS – http://lagoons.web.ua.pt).

2.2 Water main sources and demands

The freshwater resources are used to maintain the soil moisture and irrigation for agriculture purposes. *Baixo Vouga Lagunar* is divided in three sub-basins illustrated in Figure 12.

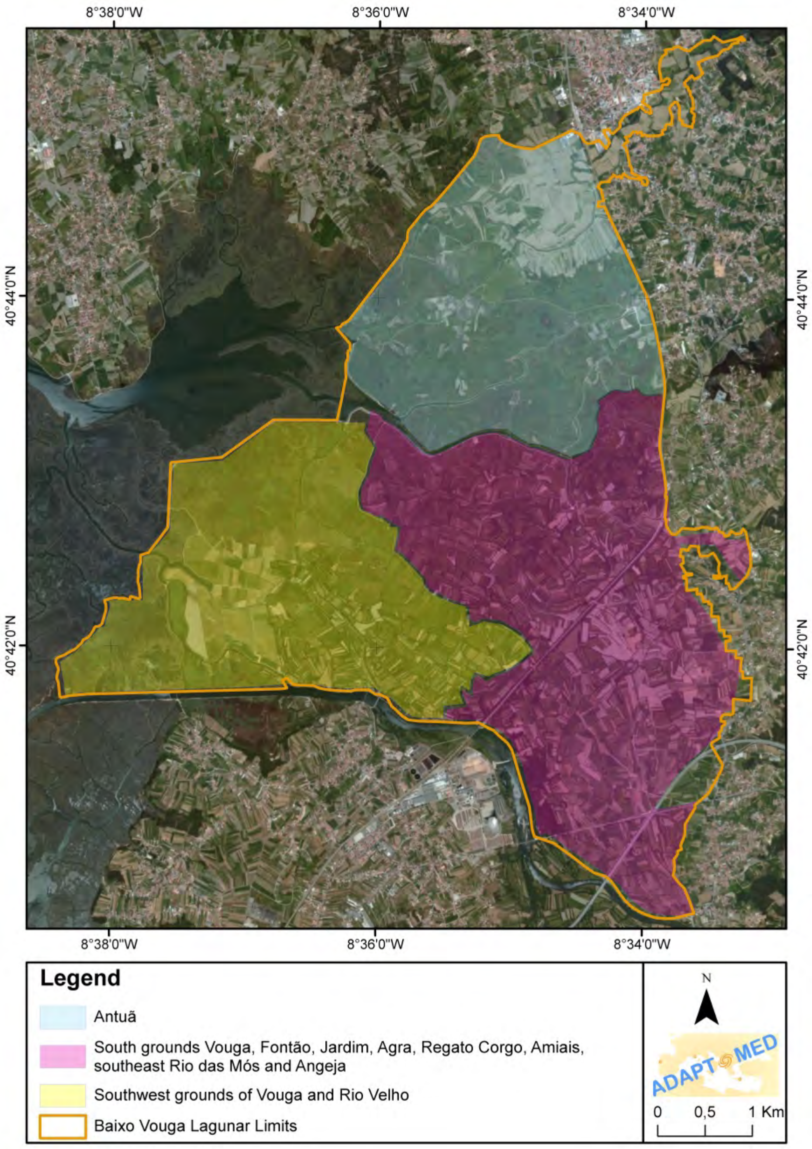


Figure 12 - Sub-Basins in *Baixo Vouga Lagunar* (source: Andresen & Curado, 2001c).

In terms of irrigation for agriculture, generally the phreatic level is high enough to allow the usually irrigated crops (like maize) to be produced without direct irrigation. Some temporary weirs are installed in order to increase the water level in the main watercourse. In this way the water flows naturally to the ditches and, therefore, towards the agriculture plots. Also along *Vouga* and *Antuã* there are surface water withdrawals to support irrigation needs, mainly in drier years. In areas where water is less abundant, there are wells and boreholes (a few hundreds) to pump groundwater. The abstracted water in the *Aveiro*, *Albergaria-A-Velha* and *Estarreja* is indicated in Table 4.

Table 4 - Volume of abstracted water for supply (m^3), for BVL municipalities (source: ARH Centro, 2012i)

Municipality	Surface abstraction in m^3 (public)	Underground abstraction in m^3 (public and private)
Albergaria-a-Velha	1 696 207	90
Aveiro	851 551	1 790 059
Estarreja	2 143 911	913
Total	4 691 669	1 791 062

Based in the available literature, it was not possible to build the cartography for the surface and groundwater abstractions, in *Baixo Vouga Lagunar.*

2.3 Water management

The Portuguese Water Planning System results from EU Water Framework Directive, transposed through Water Law (Law nº 58/2005, 29.12 altered by the Decree-Law nº 245/2009 of 22.9 and by the Decree-Law nº 130/2012 of 22.6). It defines the management basis framework regarding inland surface waters, transitional waters, coastal waters and groundwater. The Water Law led to the establishment of new regional authorities, the Administration of Hydrographic Regions (ARHs) which now are integrated in the Portuguese Environment Agency (APA). The Law established three types of regulations: “water resources management plans”, the “water resources land use plans” and the “measures for the protection and improvement of water resources”. These are described for *Baixo Vouga Lagunar* in chapter 3.7 (Fidélis & Roebeling, 2014).

The Law nº 54/2005 of 15.11 defines the Public Water Domain (PWD), which includes: coastal waters, inland waters under the tidal influence and the respective banks; navigable or buoyant water courses, ditches, lakes and lagoons and its banks (in public property); non-navigable or non-buoyant watercourses and its banks (in public property); and groundwater (in public property).

The use of water by privates, within the PWD, requires a licence issued by the public water authority (APA, Ex-ARH – Administration of Hydrographic Region). There are three water utilization licences that can be granted for exploitation (AR, 2005; APA, 2014b):

- Authorization – for private water resources use (without term);
- Licence – for some private and public water resources use (maximum period of 10 years);
- Grant – for public water resources use (maximum period of 75 years).

To obtain a license or a grant it is necessary, in most of the cases, to pay an **environmental fee,** named Environmental Recovery Surety**.** Once obtained, it is necessary to pay a tax regarding the water consumed, which for 2013 was 0.003 €$\cdot m^{-3}$ for the uses related to agriculture and aquaculture (APA, 2014b).

During the last decades there have been several management interventions in *Ria de Aveiro*, which influenced salt-freshwater equilibrium at *Baixo Vouga Lagunar* downstream area. In the

1950's, the inlet channel was improved through the construction of breakwaters and the depth was increased upstream. The dredging continued through the 1990's in the main channel but also in the secondary navigation channels network. These interventions led to changes in the tidal prism and increased the water velocity. The changes in the tidal include the increase surface saltwater intrusion duration, especially in spring tides, which puts *'Bocage'* under pressure (LAGOONS, 2013).

The main purpose of the primary drainage channels network in BVL is to direct, when needed, the excess of upstream freshwater to *Ria de Aveiro*. However, it also offers a pass way for saltwater, leading to salinization of agriculture soils. So, in order to minimize this effect a tidal protection system was developed. It includes several dikes/pathways in the right bank of *Vouga* river, in *Velho* river and in *Ilha Nova*, in both banks of *Esteiro de Canelas*, *Esteiro do Barbosa* and *Esteiro de Salreu*, as shown in Figure 13. In the watercourses that are directly connected to *Ria de Aveiro* there are also manual water-gates and tidal water-gates (Andresen & Curado, 2001c). These infrastructures are described in chapter 5.3.

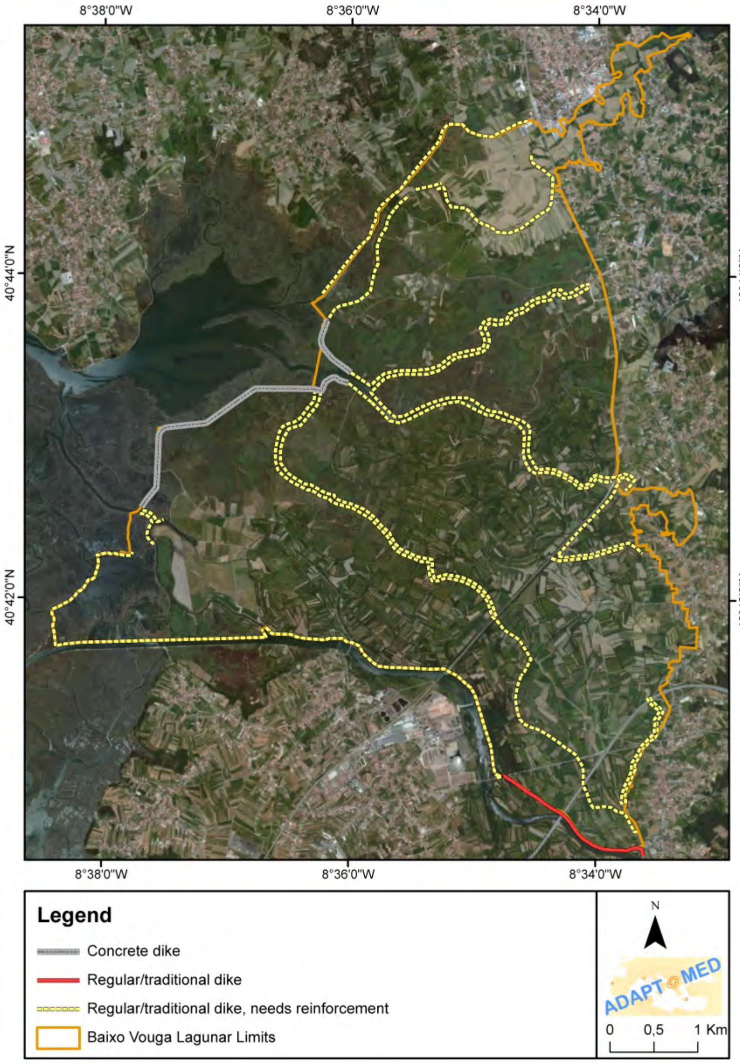


Figure 13 - Primary flood protection system (source: Andrsen & Curado, 2001b)

The water management for agricultural purposes is based on an ancient network of water channels and ditches. Along BVL, there is a secondary watercourse network (ditches), which is connected to the primary network. Then there is a tertiary network in the plot boundaries, which guarantees water supply for the crops. This network is also responsible for draining excess water from the plots. The farmers and the DRAPC (Regional Directorate for Agriculture and Fisheries of Centre) usually manage the weirs and water gates.

During the summer, Portucel (paper pulp manufacture industry) builds two temporary dikes in the *Vouga* river in order to retain the freshwater and this way guarantees the supply it needs for the manufacturing process (645 125 $m^3 \cdot yr^{-1}$) (ARH Centro, 2012i). These dikes also prevent the saltwater upstream flow, mainly during the high tide. Farmers also benefit from the dikes, as the associated phreatic level increases it provides the necessary water for the crops. It seems that there is a good communication between farmers and Portucel, that is, the dike opening width is adjusted taking into account the farmers' needs.

Currently, there is a dam complex in construction in *Vouga* river, the *Ribeiradio-Ermida* dam. It will establish two reservoirs with the total capacity of 87 million m^3 (EDP, 2010). The Declaration of Public Utility was emitted in 2013 and it estimates that the construction will be finished in the end of 2014. The dam is been taken into account by the BVL stakeholders as a beneficial infrastructure for water management, as it can contain the excess water, preventing floods, while assuring the ecological flow during the summer (EDP, 2014).

3 NATURAL CAPITAL AND ECONOMIC DEVELOPMENT

3.1 Natural capital

The natural capital include the landscape, the watershed and the associated biodiversity, that provides the ecosystem goods and services underpinning human well-being and economic activities.

BVL comprises large areas of **tidal marshes:** downstream, area is characterized by **salt marshes**, whilst upstream area is characterized by **freshwater marshes;** followed by **forest, open fields** and the *'**Bocage'*** landscape.

Tidal marshes

Salt marshes belong to the most productive ecosystems in the world with recognized associated ecosystem services. Specifically, but depending on vegetation type, density and habitat characteristics, salt marshes provide raw materials, coastal protection (attenuating and/or dissipating waves), erosion control (providing sediment stabilization and retention in vegetation rhizosediment), water purification (buffering potential for excess nutrients and pollutants), maintenance of fisheries (providing food resources, shelter and nursery grounds), carbon sequestration, tourism, recreation, education and research activities (DBIOUA, 2001; AMBIECO, 2011; LAGOONS, 2012).

In *Baixo Vouga Lagunar* the local population used to harvest **sea rush** (*Juncus maritimus*) and **reed** (*Phragmites australis*) for hay (Figure 14). Sea rush was used as bed for livestock, as raw material for mats, and for protecting the marine salt in the saltpans from wind and rain. Regarding grazing in BVL salt marshes there is only an indigenous cattle species, the certified ***Marinhoa*** breed (Andresen, et al., 2002), but the grazing pressure is not comparable to other European systems. In the southwest part of BVL (*Ilha Nova*), the soil salinization has favored the establishment of pioneer marsh **samphire** (*Salicornia ramosissima*). This salt tolerant plant is eatable by humans and is used as *gourmet* dish in some European countries; it can also be used for salt replacement in salads (Pinho, 2010; CIRA, 2014b).

Figure 14 – Tidal marshes in *Baixo Vouga Lagunar*

Forests

According to 2007 Portuguese Land Use Cartography (see 3.2), forest represents only 4 % of BVL. The most common species are the **poplar** (*Populus sp.)*, the **willow** (*Salix sp.*), the **alder** (*Alnus glutinosa),* the **common oak** (*Quercus robur)* and the **laurel** (*Laurus nobilis*). With the land abandonment some plots are being used for eucalyptus (*Eucalyptus globulus)* planting for paper pulp production. This phenomenon introduces changes in the original BVL landscape and in the associated biota (Andresen & Curado, 2001c; IGP, 2014b).

Open fields

The open field are quite homogeneous areas and are mainly used for agricultural purposes (temporary crops, permanent pastures, etc.) as it allows great continuous extensions for crop production. In higher salinity content areas **reed fields** (*Phragmites australis)* are observed, often managed by farmers where the reed plants are chopped, along the year, for enabling rice production. There are no arboreal and shrub vegetation in the open fields, so the plots hedges are made with artificial fencing (Andresen & Curado, 2001c).

'Bocage'

'Bocage' is characterized as smallholdings or small agricultural plots closed by living-hedges. The most common arboreal species are the **black alder** (*Alnus glutinosa)*, the **grey willow** (*Salix atrocinerea*) and the **common oak** (*Quercus robur*). The living-hedges are pruned each seven years, which is essential to contain the arboreal and shrub advance. The pruned material is used as bed material for cattle and as wood for burning. The small-holds inside is used for agricultural purposes and for grazing by the livestock. Therefore, it is not a homogeneous landscape as side-by-side plots could have different crops, cattle, or even being managed in a different way (e.g. living-hedges). The soil saline content is also visible in *'Bocage'*, namely in more downstream areas, where salinity tolerant species like the reeds (*Phragmites australis*), rushes (*Juncus maritimus*) appear and the living edges are replaced by the tamarisk (*Tamarix africana*) (Andresen & Curado, 2001c).

Wildlife in *Baixo Vouga Lagunar*

Baixo Vouga Lagunar is an environmentally sensitive habitat, important for 173 species of birds, such as the **fish-hawk** (*Pandion haliaetus*), the **purple heron** (*Ardea purpurea*), **the black kite** (*Milvus migrans*), the mallard duck (*Anas platyrhynchos*) and the white stork (*Ciconia ciconia*). According to EU Directive 79/409/EEC, the species in bold should be subject of special conservation measures, regarding its habitats. It is also an important habitat for mammals like the least weasel (*Mustela nivalis*), the hedgehog (*Erinaceus europaeus*) and the European otter (*Lutra lutra*), for amphibians like the common toad (*Bufo bufo*), the tree frog (*Hyla arborea*), the fire salamander (*Salamandra salamandra*), the marbled newt (*Triturus marmoratus*) and the Iberian Painted Frog (*Discoglossus galganoi*), for reptiles, namely the Iberian emerald lizard (*Lacerta schreiberi*) and the viperine water snake (*Natrix maura*), and for several fish species including the eel (*Petromyzon marinus*) and the lamprey (*Lampetra planeri*). According to the EU Directive 92/43/EEC some of these species are classified as "strictly protected" (e.g. the otter and the tree frog). Also for IUCN (International Union for Conservation of Nature), the otter is in the "red list", classified as "Near Threatened" as well as the Iberian Emerald Lizard. (EEC, 1979; EEC, 1992; Leão, 2003; CPU, 2007; Leão, 2011a; Leão, 2011b; IUCN, 2014).

Box 2. Natura 2000 in Baixo Vouga Lagunar

The Baixo Vouga Lagunar is integrated in Ria de Aveiro Special Protection Area (SPA – with the Natura 2000 code PTZPE0004) - Figure 15. This SPA regularly supports over 1 % of the population of the pied avocet (*Recurvirostra avosetta*) and 60 % of the population of the purple heron (*Ardea purpurea*) (ICNF, 2014b). In June 2014, Ria de Aveiro was included in the National List of Sites, in order to feature as a Site of Community Interest. This classification acknowledges the importance of Ria de Aveiro ichtyofauna communities and coastal and estuary habitats (CM, 2014; ICNF, 2014c).

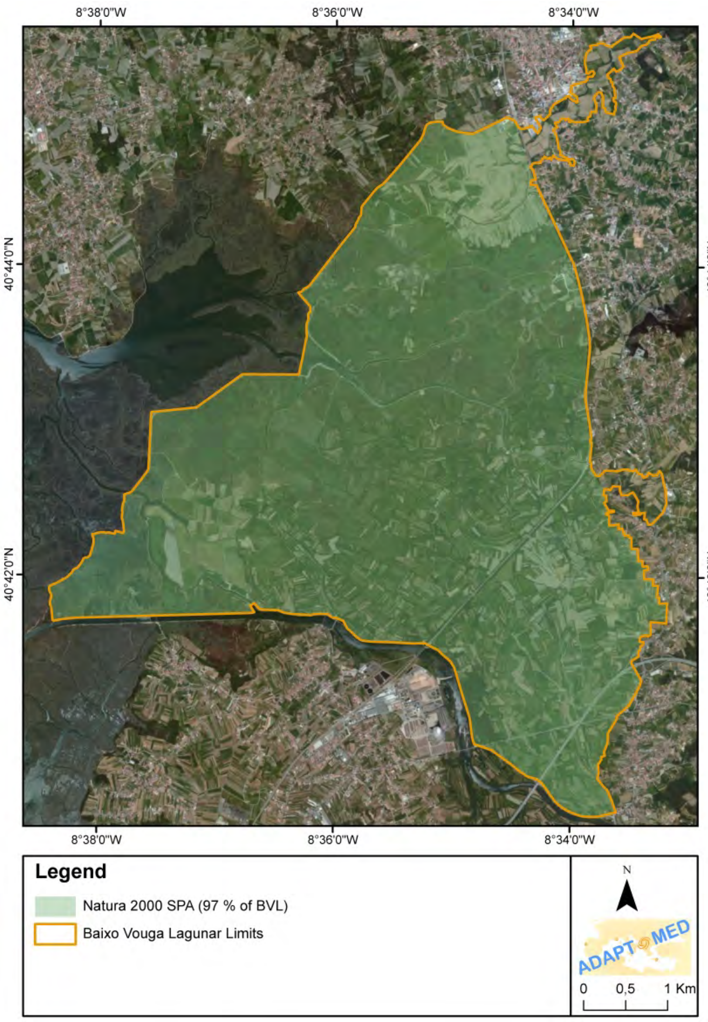


Figure 15 - Natura 2000 - Special Protected Area of *Ria de Aveiro* integrated in BVL

The *Baixo Vouga Lagunar* was also classified as part of the Portuguese Ecological Structure, mainly due to its classification as Natura 2000 (CEAP, 2013). There were identified **high valued Natural/Semi-Natural vegetation** and **high valued soils** in BVL, shown in Figure 16.

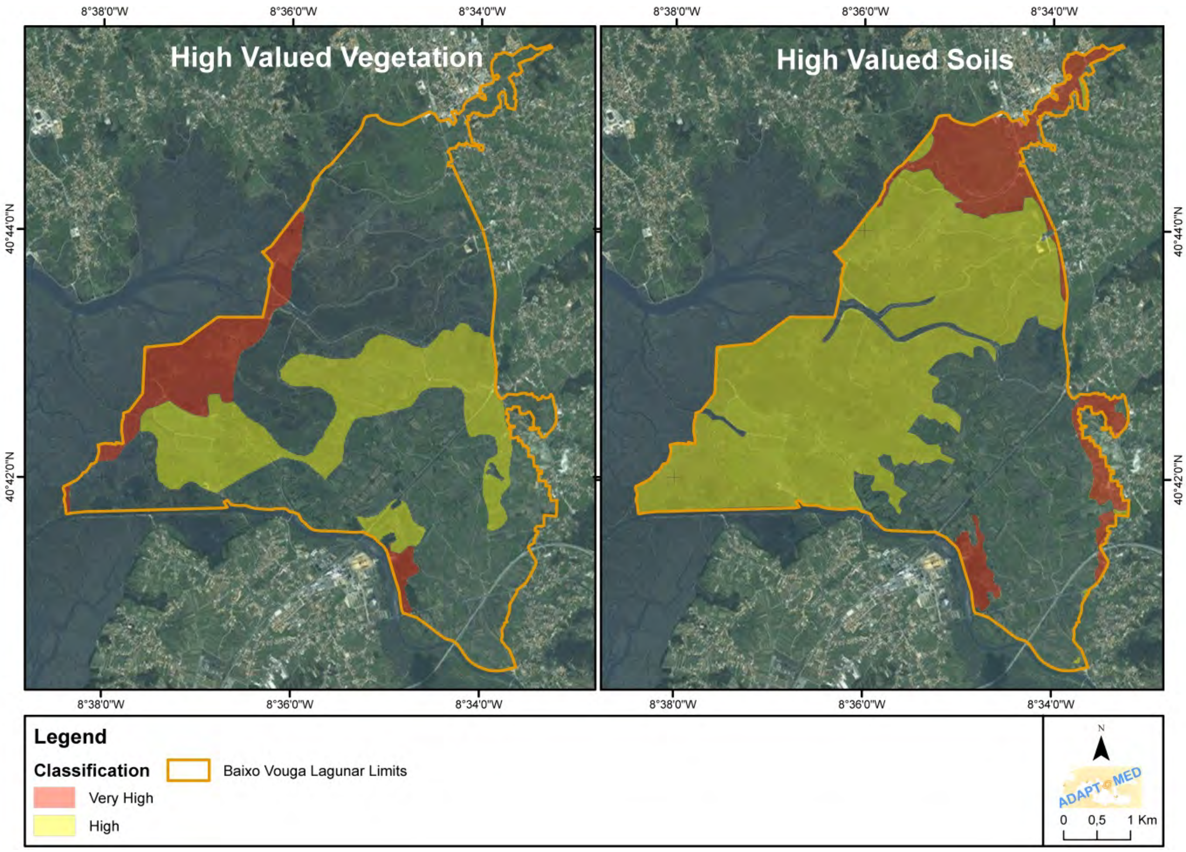


Figure 16 - High Valued Vegetation and High Valued Soils (Source: CEAP, 2013, available in http://epic-webgis-portugal.isa.ulisboa.pt/)

3.2 Land use

Baixo Vouga Lagunar comprises a recent agro-ecosystem characterized by fertile soils managed for livestock purposes and agricultural production. However, this area is not in full potential due to its structural faults, such as in the irrigation system and in the drainage system, and also due to the soil constant flooding and the exposure to surface saltwater intrusion. The traditional smallholdings, '*Bocage*', measure about 0.5-8 ha and are bounded by hedges of willows, alders and water ditches, which fragment the landscape and define the property boundaries. The sown crops in BVL are directed related to the existing bovine livestock feeding necessities, which essentially consists in **pastures and forages**. There is also a small expression of **rice fields,** which in the past had a greater expression (Andresen & Curado, 2001c; FACTS!, 2012). Some examples of land use are illustrated in Figure 17.

The most usual annual crop rotation consists in **maize** (for silage and grain) and then **temporary forage** (oat, alfalfa or mixtures of several species). The permanent pastures are essentially **natural grasslands** and in some cases **improved pastures** (that is, fertilized and/or sown) (Andresen & Curado, 2001c).

There are the different sources for the land use in *Baixo Vouga Lagunar*, which were obtained through different methodologies, as described in Table 5 and Figure 18 illustrates the results obtained in those sources. Effectively, there are differences between the used methodologies like the categories and the detail level. Nevertheless, it was possible to cross-check the three sources and observe that *Baixo Vouga Lagunar* is mainly occupied by permanent pastures (42 %), followed by annual crops (35 %). Saltmarshes and freshwater wetlands represent 13 % of the study site.

Figure 17 - Maize fields, natural grasslands for *Marinhoa* cattle and rice fields (© AI Lillebø)

Table 5 - Sources for land use in BVL

Source	Methodology
Land Use in Andresen & Curado, 2001b.	It was obtain by IHERA (Hydraulics, Rural Engineering and Environment Institute) prior studies and in-field questionnaries during the Environmental Impact Assessement (EIA).
Corine Land Cover 2006	Satellite photo-interpretation (Landsat), level 3
Carta de Ocupação do Solo 2007	Portuguese Land Use Cartography for 2007, Ortophotomap interpretation, level 2

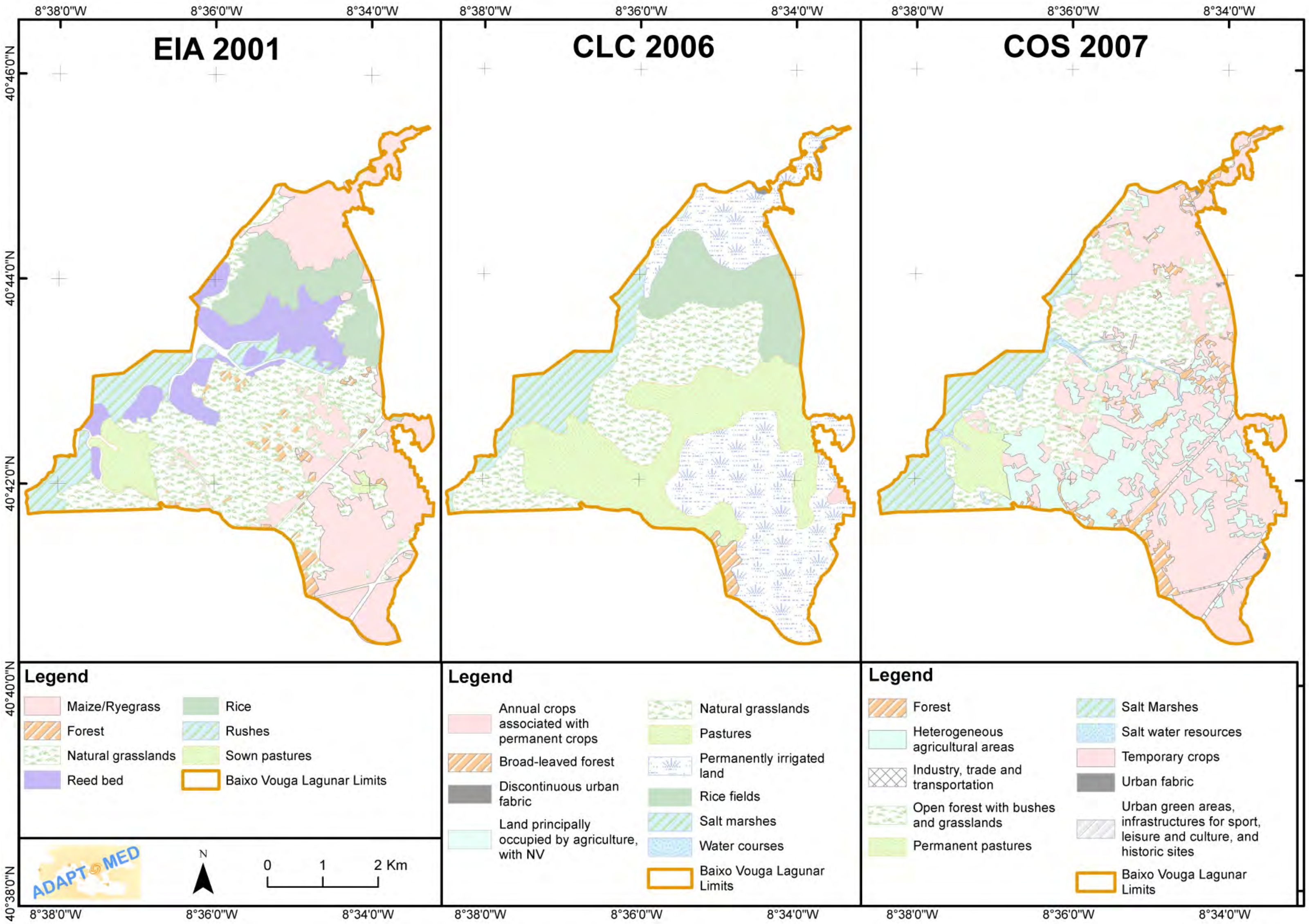
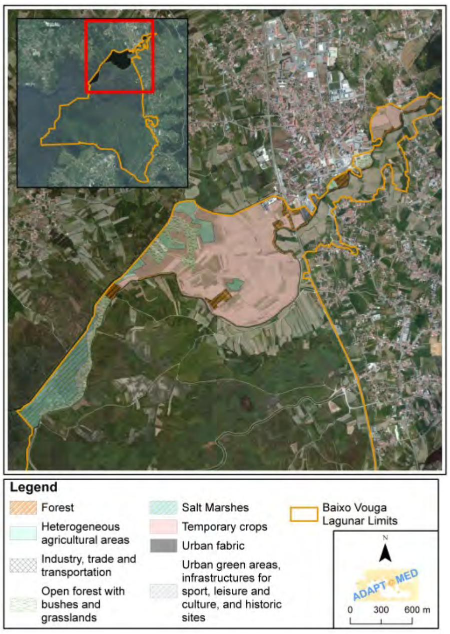


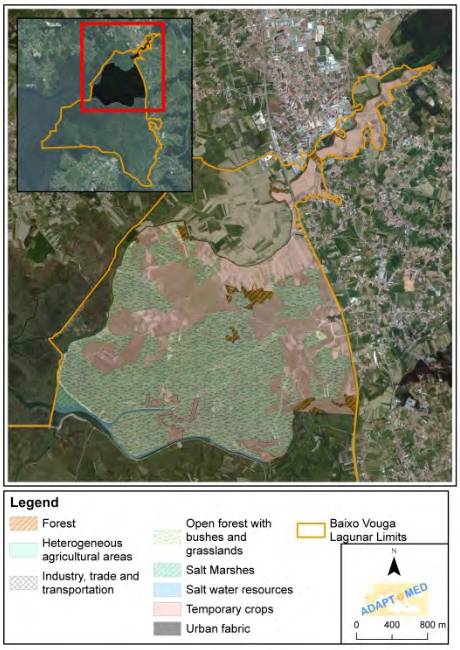
Figure 18 - Land Use in *Baixo Vouga Lagunar* (sources: IGP, 2014a; IGP, 2014b; Andresen & Curado, 2001b)

The following illustrates the land use per parish that comprises the BVL:

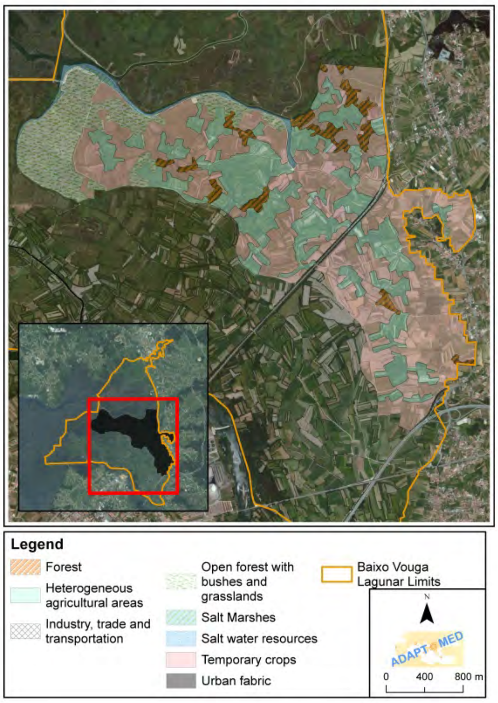
*Beduído**



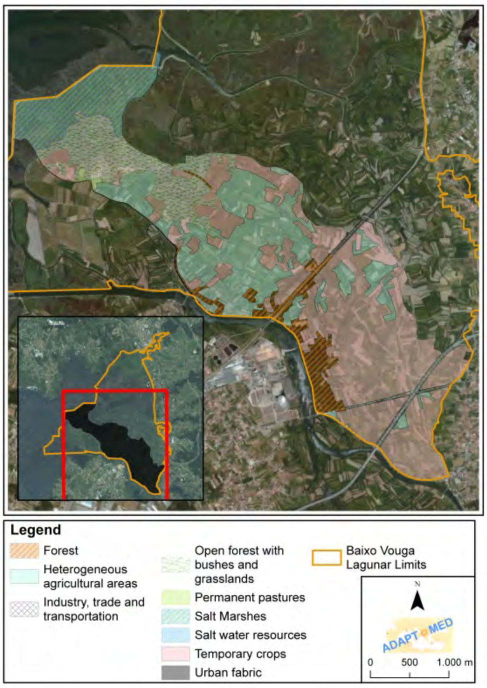
Salreu



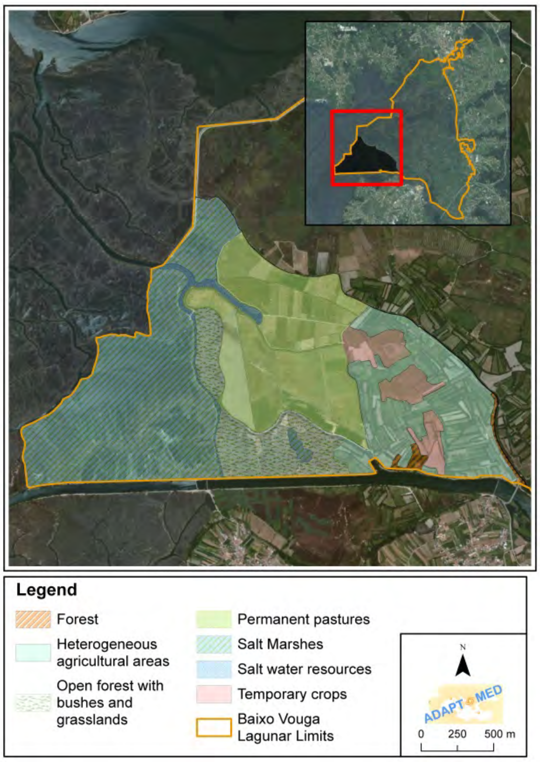
União das Freguesias de Canelas e de Fermelã



Angeja



Cacia



*Note: presently the considered *Beduíno* 'parish' is part of the *União das Freguesias de Beduído e Veiros*.

3.3 Landscape units

Baixo Vouga Lagunar is the result of a man-shaped landscape, which evolved mainly with the agriculture activities and with the cultural and historical evolution. It results in a very heterogeneous scenario gathering several biotopes for fauna and flora, with highly ecologic value. Nevertheless, the topography is rather homogeneous with few human infrastructures (Andresen & Curado, 2001c; Pinho, 2010).

As previously described, *Baixo Vouga Lagunar* includes three homogeneous landscape units: **open fields**, **wetlands** and the ***'Bocage'*** smallholdings. Figure 19 shows the evolution of these three landscape units between 1947 and 1995.

It is clear the increase of wetlands extension along the years, replacing the existing open fields. Between these years, the open field's area decreased from 904 ha to 555 ha and the wetlands area increased from 474 ha to 767 ha. During the same period, the *'Bocage'* landscape area remained approximately the same, around 1 280 ha.

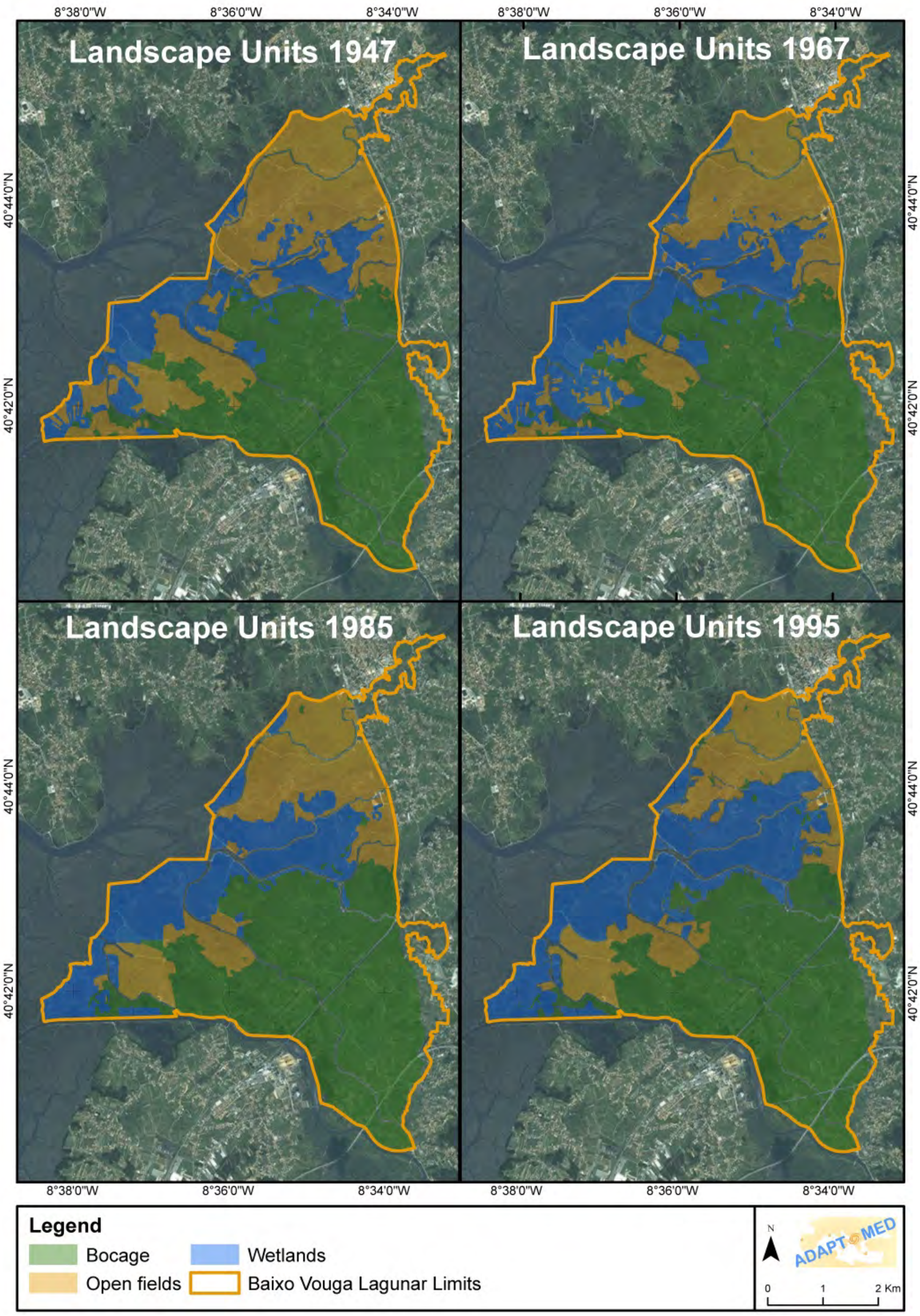


Figure 19 - Landscape units evolution (Source: Andresen & Curado, 2001c)

Open field

The open fields occur in two distinct areas: at north, in *Beduído area* (part of the União das Freguesias de Beduído e Veiros parish) and *Salreu* parish; and at southwest, in *Cacia* and *Angeja* parishes (Figure 20).

Figure 20 - Wetlands and Open Field in *Cacia*

In the north, the open fields are mainly used for forage production (silage maize and hay). These areas occur in slightly higher elevations and offer easier access to the fields.

In the southwest, permanent pastures are sown as a result of a soil recovery program, where there is higher salinity. These areas were previously rice-fields and currently work as a barrier to the saline wedge advance, towards '*Bocage*' areas.

The open fields do not have living hedges dividing the plots, which results in a wide homogeneous landscape contrasting with the surroundings, namely '*Bocage*' (Andresen & Curado, 2001c).

'Bocage'

'Bocage' occurs in *União das Freguesias de Canelas e de Fermelã, Angeja* and *Cacia* parishes. It is a very compartmentalized landscape due to the living-hedges, formed by bushes and trees. These barriers have a multifunctional purpose like: providing shelter for cattle and for crops; stabilization of the banks, dikes, slopes and ditches; and providing firewood and cattle-bed materials (Figure 21).

Figure 21 – *'Bocage'* aerial view and detail of a *'Bocage'* smallholding

In Portugal, nowadays *'Bocage'* only occurs in *Baixo Vouga Lagunar*. The lack of labour supply has contributed to the *'Bocage'* degradation because this landscape requires high maintenance as it gathers not only a living-hedges network but also a hydraulic grid of ditches, channels, floodgates, banks and other water barriers. Some of these infrastructures were built in the 19th century in order to protect BVL from the tidal floods and its lack of maintenance is leading to draining issues and to the increase of salinity. So, these infrastructures are not only a cultural part of the landscape but also function as a part of an integrate management system. With the increase of the surface salinity intrusion, more tolerant species appear, like bulrushes, rushes and reeds.

The length of living-hedges formed by trees was 311 km in 1967, 306 km in 1985 and 199 km in 1995. For bush living-hedges the length was 88 km in 1967, 216 km in 1986 and 167 km in 1995. The decreasing of the living-hedges density and continuity is occurring mostly in the south part of BVL (*Cacia* parish). The traditional living-hedges are being replaced by the salt tolerant tamarisk *(Tamarix africana)*, as the salinity increases. In other areas, the land-abandonment led to eucalyptus plating inside the smallholdings, transforming *'Bocage'* into small eucalyptus forest areas (Andresen & Curado, 2001c; FACTS!, 2013).

Wetlands

Wetlands in BVL are mainly occupied by reeds (*Phragmites australis*) and rushes (*Juncus maritimus*) marshes, all along *Esteiro de Salreu* (north) to *Cacia* (Southwest) - Figure 22.

Figure 22 - Salt-marshes and *Baixo Vouga Lagunar* wetland

The rushes are more prevailing next to the concrete dike (both sides, where the salinity is higher) and reeds are more dominant along *Esteiro de Salreu* and *Esteiro de Canelas*, following the decrease in salinity. Other species like shedges (*Cyperus sp.*) and bulrushes (*Bolbochoenus maritimus*) also occur.

In *Salreu*, there remains a small area of rice fields around 90 ha (Figure 23). The rice extension was larger, but the areas have evolved to reed-beds due to the land abandonment.

Figure 23 – Wetlands in preparation for rice, in *Salreu*

Wetlands are frequently under human management, farmers often chop the vegetation for the cattle beds and the cattle itself eat some of the marsh vegetation. However, grazing is not a stressor for this marsh area.

As the wetlands are also used for farming purposes, its quality, biodiversity and appearance is highly dependent of human activities. Nevertheless, in the last 70 years the BVL wetland extension has increased from 800 ha to 1 200 ha (Andresen & Curado, 2001c; Pinho, 2010).

3.4 Urban infrastructures

The urban infrastructures in BVL are few and sparse, because this area is mainly used for farming and then is mainly occupied by natural (and semi-natural) landscapes. The urban infrastructures occur essentially next to the borders of BVL as it can be seen in Figure 24.

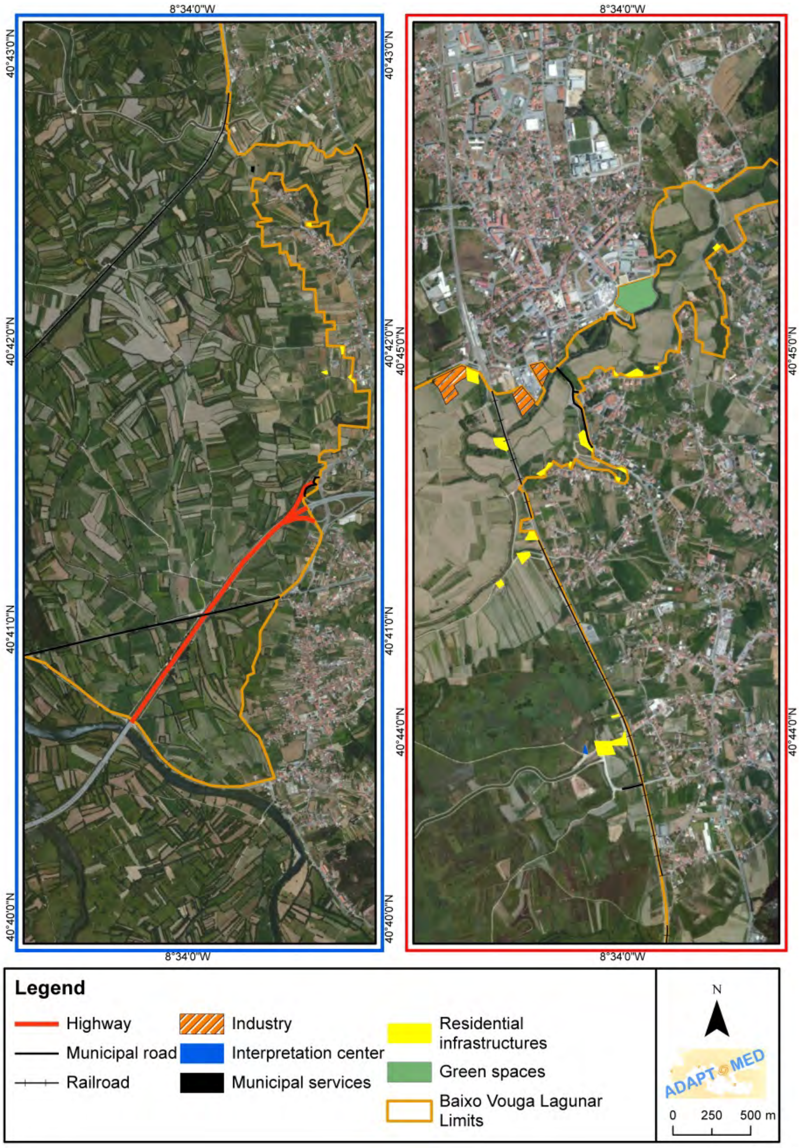


Figure 24 - Urban infrastructures in *Baixo Vouga Lagunar* (source: adapted and completed from CEAP, 2013)

3.5 Socio-economic development

The *Baixo Vouga* Region represents 3.5 % of Portuguese Gross Domestic Product (mainland) distributed by several sectors (INE, 2011b). In Table 6 it is shown that the **manufacturing industries** are the most productive, from which most corresponds to

metallurgy sector (19 %). In the first subclass 52 % of GVA is due to fishery and to fish farming and 34 % for agriculture, livestock production and hunting.

Table 6 – Gross Value Added (GVA) for *Baixo Vouga* (NUTS-III) in 2012, by Economic Activity (CAE Rev.3 – Subclass) (source: INE, 2011b)

Subclass	Economic Sector	GVA (2012) M€
1	**Agriculture, livestock production, hunting and forestry**	54
2	**Mining and quarrying (2011)**	5
3	**Manufacturing (food, textile, paper, pharmaceutic, etc.)**	1281
4	**Electricity, gas, steam, cold and hot water and cold air**	27
5	**Water abstraction, treatment and distribution; sewerage, waste management and remediation activities**	40
6	**Construction**	108
7	**Wholesale and retail trade; repair of motor vehicles and motorcycles**	396
8	**Transportation (people and goods) and storage (goods)**	N/A
9	**Accommodation and food service activities**	67
10	**Information and communication activities**	28
11	**Real estate activities**	20
12	**Consultancy, scientific and technical activities**	93
13	**Administrative and support service activities**	86
14	**Education**	14
15	**Human health and social work activities**	86
16	**Arts, entertainment, sports and recreation activities**	8
17	**Other service activities**	16
	Total	2328

In terms of number of companies Figure 25 shows their distribution by sector, in the six parishes that comprises the BVL (INE, 2013).

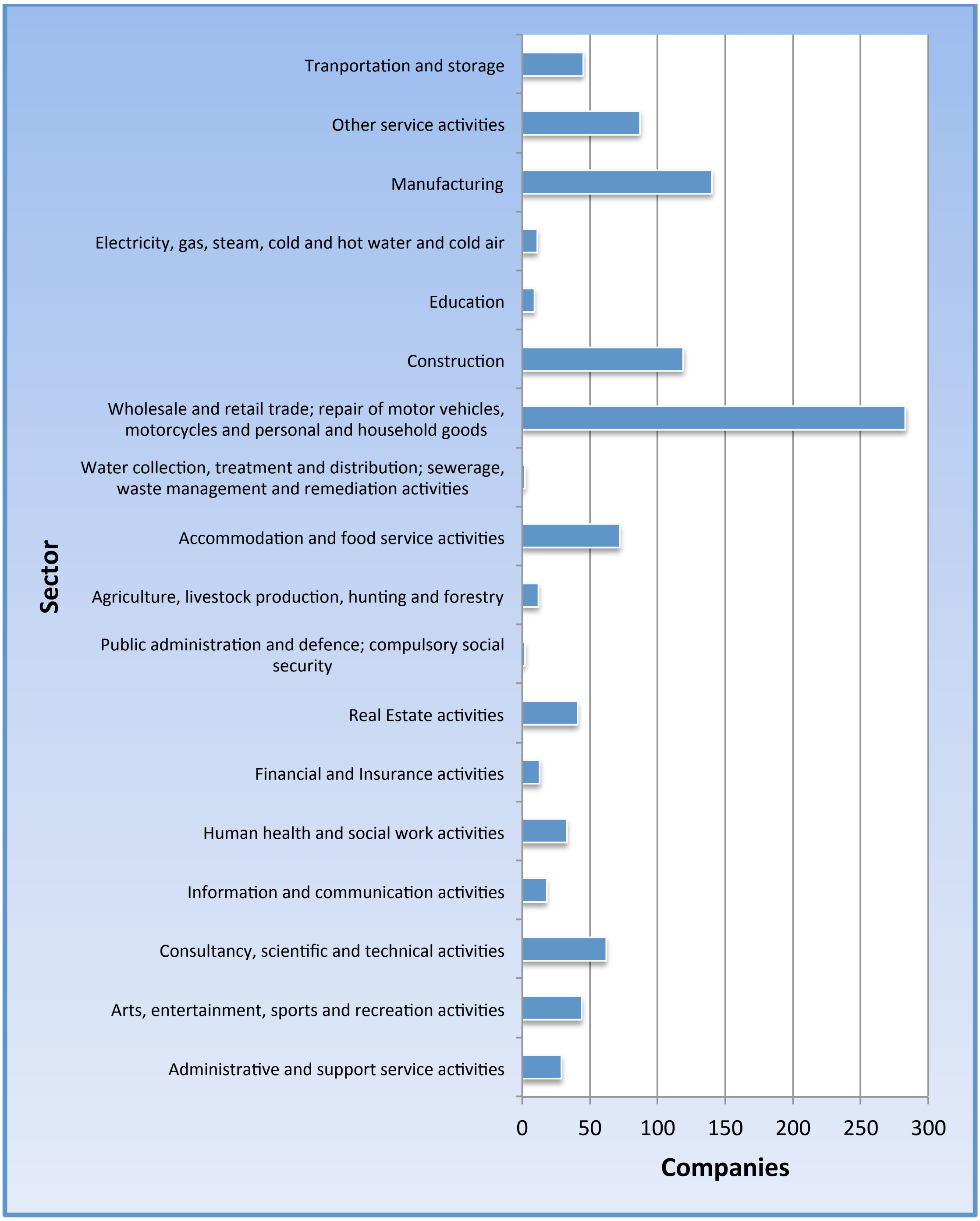


Figure 25 - Number of companies in *Angeja, Cacia, Salreu, Beduído* area (part of the *União das Freguesias de Beduído e Veiros*) and *União das Freguesias de Canelas e de Fermelã*, by sector in 2011 (Source: adapted from IRN, 2011)

When looking to the BVL, most of the companies are in the wholesale and retail trade category, followed by manufacture and construction. However these results correspond to the parishes full extend, including the industrial and residential areas. BVL is essentially a rural area, where the main economic activity is agriculture.

Agriculture is quite important in BVL as it offers income for the population. Even though only 3.2 % of the population works permanently in “agriculture, livestock production, hunting and forestry”, more than half of the families owns or work in a farm.

Around BVL borders, there are several industry activities like the metalworking, paper pulp manufacture, wood and cork production. In the 1930's, the chemical industry was established in *Estarreja* municipality. Nowadays, the *Estarreja* Chemical Complex - *Quimiparque* - gathers several of chemical companies like *CUF* (aniline, benzene, ammonia, sodium chloride and hydrogen manufacture) and *UNITECA* (Chloride, soda, hydrogen and derivatives manufacture) (AIDA, 2011; Baía do Tejo, 2014; CIRA, 2014a).

3.6 Population

Baixo Vouga Lagunar is included in *Aveiro*, *Albergaria-a-Velha* and *Estarreja* municipalities and comprises six parishes. The 2001 and 2011 population census is indicated in Table 7.

Table 7 - 2001 and 2011 census for BVL parishes (source: INE, 2013)

	2001				2011			
Parish	Density (Nº km^{-2})	Total	Male	Female	Density (Nº km^{-2})	Total	Male	Female
Angeja	110.95	2271	1124	1147	97.6	2011	966	1045
Cacia	186.56	6771	3323	3448	205.7	7059	3424	3635
Beduído **(area of the** ***União das Freguesias de Beduído e Veiros*****)**	387.77	7462	3569	3893	367	7179	3399	3780
União das Freguesias de Canelas e de Fermelã	129.05	2903	1384	1519	120.3	2664	1268	1396
Salreu	251.02	4062	1915	2147	230.7	3709	1752	1957
	Total	23469	11315	12154	Total	22622	10809	11813

In general, the population decreased between 2002 and 2011, with the exception of *Cacia* where the population increased 4.3 %. In *Angeja* the population decrease was over 10%. Regarding the distribution by gender, the percentage of females was slightly higher (51-52%), in both periods. In most cases the population density is higher than the average for Portugal (114.5 people·km^{-2}). *Angeja* has the lowest population density, with 97.6 people·km^{-2} and *Beduído* area the highest, with 367 people·km^{-2}. The population distribution by age bracket in 2001 and 2011 is indicated in Figure 26.

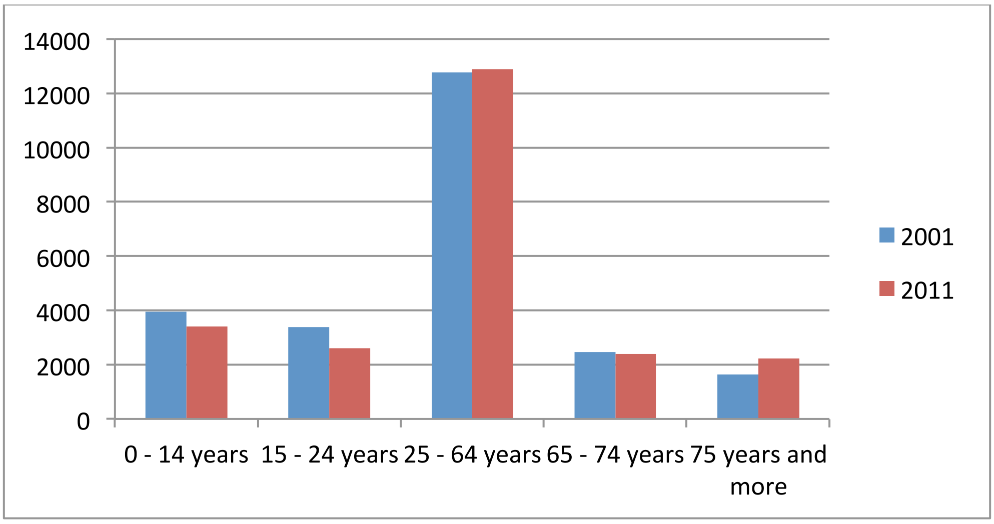


Figure 26 - Population distribution per age, in BVL parishes (source: INE, 2014)

Most of the population is between 25-64 years (>54 %) and in general, between 2001 and 2011, the population has become older. *Salreu* has the oldest population (26 % with 65 years or over) and *Beduído* area has the youngest population (27 % with 24 years or below). (INE, 2014; INE, 2013).

In all the parishes less than 50 % of the population is economically active (Note: Total population between the ages 15 to 64 is the number of people who could potentially be economically active). Nevertheless, the employability is over 87 % for all parishes and *Salreu* has the highest employability - 90 %. Regarding the economic sectors, 1-4 % of the population works in the primary sector (farming, fishery, etc.), 37-49% in the secondary sector (transformation, industry, etc.), 17-18 % in the social sector (tertiary) and 29-38 % in economy sector (tertiary) (INE, 2014).

3.7 Governance

Integrating the governance and the water resources management is effectively a challenge, since all the regulations must be accept by a wide range of perspectives and stakeholders. The different policies and planning instruments are conceived out of different scientific contexts and even if combined in an integrated land use and water resources planning is still difficult to apply it in a practical sense (Fidélis & Roebeling, 2014).

The Portuguese spatial planning framework has been established by the Law nº48/98 (altered by Law nº54/2007, updated by Decrees Law nº280/99, nº 316/2007 and nº46/2009). It defines the main planning objectives, the institutions responsibilities and articulates three spatial planning levels: **national**; **regional**; and **municipal**. The legal framework also establishes how spatial planning should be coordinated on each level and defines the rules for preparation, approval, implementation and evaluation. Table 8 resumes the Portuguese land-use and water resources planning instruments (Fidélis & Roebeling, 2014).

Table 8 - Portuguese land-use and water resources planning regulations (source: adapted from Fidélis & Roebeling, 2014)

	Land-use planning		**Water resources planning**
Level	Strategic	Regulatory	Strategic
National	National Land-use Policy Programme Sector Plans		National Water Plan
Regional	Regional Land-use Plans	Protected Areas Plans Coastal Management Plans Public Water Reservoir Plans Estuary Land-use and Management Plans	River Basin Management Plans
Local	Inter-municipal Land-use Plans	Municipal Master Plans Urbanization Plans Detailed Plans	Specific Water Management Plans

Baixo Vouga Lagunar is surrounded by a complex coastal lagoon, *Ria de Aveiro*, which includes the *Vouga* estuary, wetlands with coastal, trasitional and freshwater resources integrated in the *Vouga* river basin. It also includes several ecosystems and protected areas, including Natura 2000 areas, which are balanced with human activities, such as agriculture, fishery, industry, tourism, etc. Therefore, there is a "*complex framework*" between public institutions, and their responsibilities, and management levels so planning becomes challenging in BVL and in *Ria de Aveiro* (Fidélis & Roebeling, 2014). BVL stakeholders have also recognized this challenge during the interviews taken under the scope of the DADPT-MED project.

In Table 9 it illustrates the Spatial Planning and Water Management Regulations applied to *Baixo Vouga Lagunar*, then followed by a description.

Table 9 – Spatial Planning Regulations with application in BVL

Regulations		Application	Entities
a)	***Vouga, Mondego* and *Lis* River Basin Management Plan**	Strategic	Portuguese Environment Agency (APA, I.P.), Ex-Administration of Hydrographic Region for Centre (Ex-ARH Centro)
b)	**Regional Land-use plan for Centre**	Strategic (waiting for approval)	Centro Regional Coordination and Development Commission (CCDRC)
c)	**Sectorial Plan for Natura 2000 Network**	Strategic with management measures	The national Institute for the Conservation of Nature and Forest (ICNF, I.P.)
d)	***Vouga* Estuary Land-Use and Management Plan**	In preparation	APA, I.P. (former-ARH Centro)
e)	**Municipal Master Plan**	Zoning and regulatory plan ; under revision	Municipalities
f)	***UNIR@RIA* – Ria de *Aveiro* Inter-municipal Land-use Plan**	Strategic; Guidelines for regional development	CIRA
g)	**Operational Programme '*POLIS Litoral Ria de Aveiro'***	Rehabilitation and recovery interventions	*Sociedade de Requalificação e Valorização da Ria de Aveiro S.A.* (*Parque-Expo*; APA; ICNF; CIRA)

The *Vouga, Mondego* and *Lis* River Basin Management Plan was elaborated by former-ARH Centro (former-Administration of Hydrographic Region of Centre), part of APA (Portuguese Environment Agency), as a management instrument established in the Portuguese Water Law (Law nº58/2005). For each River Basin District (territorial water management unit) a management plan was made in order to (APA, 2014a):

- Support and guide the water protection and management, according to its purposes and availability;
- Guarantee the water sustainable use, that is, supply this generation but not compromising its future availability and quality;
- Manage the water allocation according to the different purposes, dealing with the regional development, the sectorial policies, the individual rights and the local interests.
- Regulate the water quality and define the water evaluation criteria.

The BVL is part of *Vouga, Mondego* and *Lis* River Basin District. The current plan bases its works in a water-monitoring network, defining this way the classification for the water quality. The plan generally gives strategic measures and defines objectives for the management of the basin - see Box 3 (ARH Centro, 2012a).

Box 3. Main objectives for *Vouga*, *Mondego* and *Lis* River Basin Management Plan

- Water quality (protect groundwater and surface water quality)
- Water quantity (promote the efficient use of water)
- Risk management and water resources valorisation (protection and valorisation of the hydrographic network and coastal water; prevent and minimize the natural and anthropogenic threats regarding the water resources)
- Legal framework (adapt the legal framework in order to plan and manage the water resources, with the participation of the different stakeholders)
- Economic and Financial framework (sustainability using the polluter/user-payer principle and recover the water management cost using hydroelectric facilities and from pumping licenses)
- Monitoring, research and knowledge (improve the scientific knowledge and a monitoring system for water quality and use)
- Communication and leadership (improve the society awareness for the water environmental value and promote the stakeholders interactivity)

The monitoring network that permits the evaluation for the water quality is located all over the basin (ARH Centro, 2012g). As shown in Figure 27, and according to the WFD criteria for the ecological status, most of the *Vouga* river basin has good status, exceptions are *Vouga* river itself, Á*gueda* river and *Cértima* river which are in bad status. Other watercourses are in moderate and in poor status (ARH Centro, 2012b; LAGOONS, 2013).

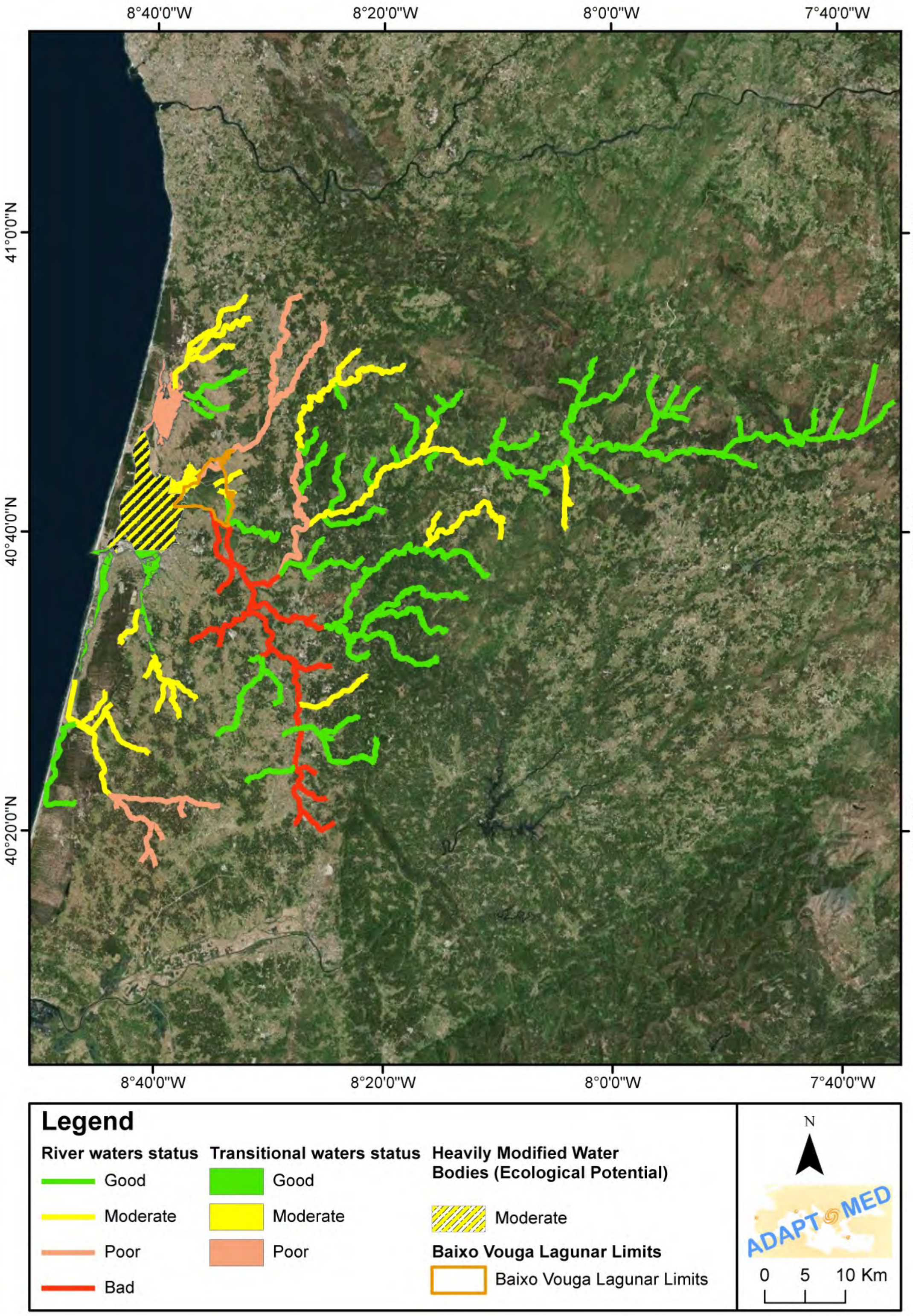


Figure 27 - Ecological status for Vouga basin (source: ARH Centro, (2012b); LAGOONS, (2013))

Particularly for *Baixo Vouga Lagunar* (Figure 28) it includes heavily modified water bodies with **moderate ecological potential**, which extends upstream to *Vouga* river. The transitional water bodies have **moderate ecological status**, the *Antuã* river has **poor ecological status,** the *Fontão* riverside has **good ecological status** and the remaining rivers in BVL have **moderate ecological status.**

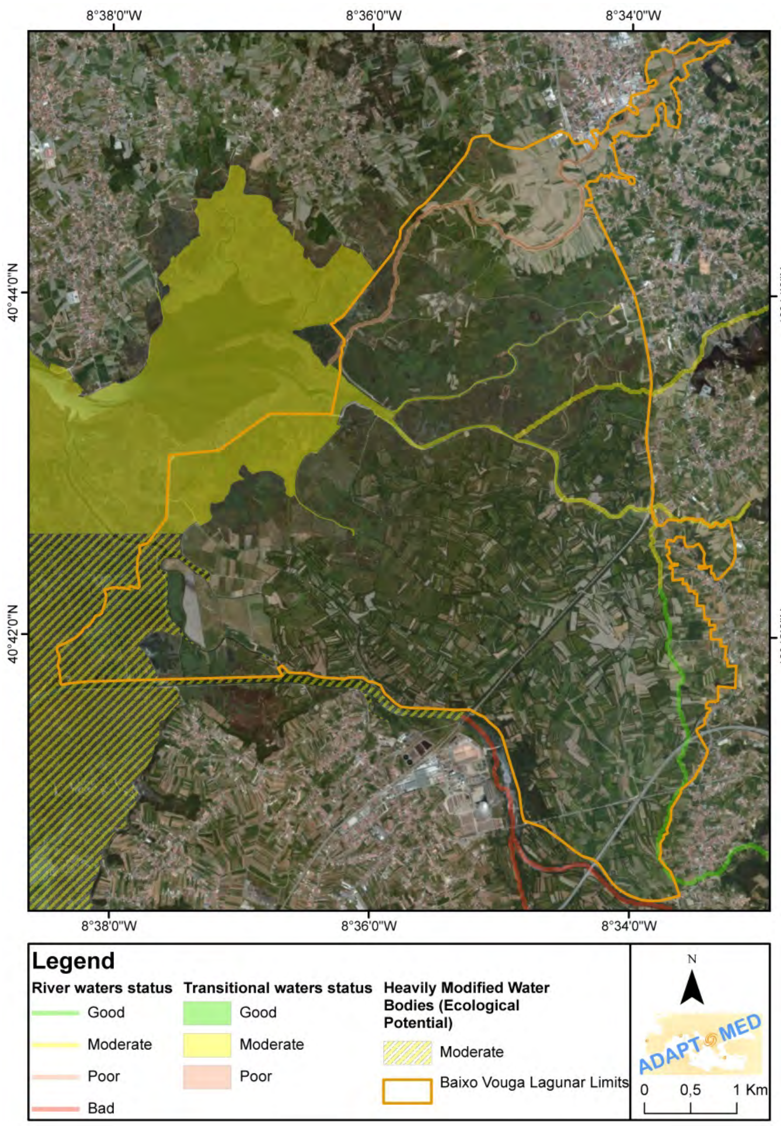


Figure 28 - Water ecological status in *Baixo Vouga Lagunar* (source: ARH Centro, (2012b); LAGOONS, (2013))

For *Vouga* river basin there are 43 measures in the management plan, including the completion of the BVL protecting dike (see section 5.3). Other is the sediment transference from the *Aveiro* navigation channel to the shoreline, which could influence the BVL tidal dynamics as well as applications for small hydroelectric plants (ARH Centro, 2012a; ARH Centro, 2012d).

The Regional Land-use Plan for Centre (PROTC) was elaborated by the Centro Regional Coordination and Development Commission (CCDRC), a public institution with large experience in multi-sector planning. The plan establishes a regional strategic vision and objectives at a bio-physical and demographic level, as well as for the structuring elements (urban, economic, tourism, environmental protection, risks, etc.). The water resources are mentioned as its quality needs improvement and, in some cases, total recovery.

The PROTC gives general guidelines for the territory management, as a whole, and gives other specific guidelines for each territorial unit. Namely, for *Ria de Aveiro* (and therefore BVL) it establishes that the Territorial Managing Instruments (TMI), e.g. municipal master plan, should aim for preventing and decreasing the coastal erosion, the floods and the surface saline intrusion. The TMI should also ensure the maintenance and the management of the affected areas. Other measures are: control and monitoring for dredging activities and for changes in superficial water flow; alert system for extreme marine events; guarantee the construction of *Ribeiradio* dam in order to control the *Vouga* river flows and supply water for irrigation; BVL Agricultural Project, namely to guarantee the conclusion of the tidal defence dike and the traditional dikes recovery, in order to prevent the floods; and the elaboration of the *Vouga* Estuary Land-Use and Management Plan (CCDRC, 2011a; CCDRC, 2011b; Fidélis & Roebeling, 2014).

The climate changes are directly addressed in the PROTC but only in terms of energy consumption and greenhouse gases emissions (mitigation actions). There are air quality monitoring stations and the main emissions sources are identified. PROTC does not directly establish climate change adaptation measures (including for BVL impacts) (CCDRC, 2011c).

The Sectorial Plan for Natura 2000 Network is a territorial management mechanism for promoting and protecting the Special Protected Sites and Areas, including the promotion for favourable species and habitats conservation. The defined measures are specific for each Natura 2000 habitat and are taken into account in the Municipal Master Plans and in the Special Master Plans (Territorial Managing Instruments). BVL (as part of *Ria de Aveiro*) is a Natura 2000 Special Protected Area (SPA) since 1988, due to its importance as feeding and reproduction site for several birds. Is in *Ria de Aveiro* where 60 % of purple heron (*Ardea purpurea*) Portuguese population nests (ICNF, 2014a).

Since June 2014, in a Council of Ministers Resolution, *Ria de Aveiro* was included in the National List of Sites in order to propose its classification as a Site of Community Interest. Contributing for this decision is the importance for the preservation of several ichthyofauna communities (*Petromyzon marinus, Lampetra planeri, Alosa alosa e Alosa fallax*) and of coastal and estuary habitats (estuaries, Atlantic salt-marshes, dunes with *Salix repens ssp. Argentea*) (CM, 2014; ICNF, 2014c)

The *Vouga* Estuary Land-Use and Management Plan is a specific Landscape Planning mechanism that should provide measures related to the water resources protection and valorisation and its sustainable use. This kind of plan is focused in transitional waters, including its banks, beds and ecosystems (< 500 m of the border). The *Vouga* Estuary Land-Use and Management Plan is the responsibility of the Portuguese Environmental Agency (APA, which includes the former ARH *Centro*). The terms of reference of the current plan were approved and the plan itself is now in elaboration (APA, 2014b).

There are three Municipal Master Plans, one per municipality that comprises the BVL – *Aveiro, Albergaria-A-Velha* and *Estarreja*. For *Aveiro*, BVL is classified as Nature Conservation Site (in Planning) and as Strict Protection Zone (in the Constraints). For *Albergaria-a-Velha*, BVL is classified as Natural Protected Site (in Planning) and Agricultural and Ecological National Reserve (in the Constraints). For *Estarreja*, BVL is classified as Existing Protected Agricultural Space (in Planning) and Agricultural and Ecological National Reserve (in the Constraints) (DGOTDU, 2008).

The Municipal Master Plans are in revision, except for *Estarreja* which was already concluded in July 2014 (CM Estarreja, 2014). Particularly for the water resources, *Estarreja* municipality establishes the requalification of the traditional piers as a strategic measure, as well as achieving ideas and projects to improve the farming activities, namely by the *Vouga* Hydro-Agricultural Project. The plan also previews the *Antuã* banks recovery, the protection and the defence of the lagoon area and the requalification of the damaged structures (Quero Vento, 2014). *Albergaria-A-Velha* 1999 master plan also highlights the importance of *Baixo Vouga* Hydro-Agricultural Plan, which should account the hydro-agricultural and the reparcelling legislation (CM, 1999).

The *UNIR@RIA* plan is an inter-municipal plan between 10 municipalities (including *Aveiro, Albergaria-A-Velha* and *Estarreja*) that aims for the management integration, in terms of landscape planning in *Ria de Aveiro* and in *Vouga* river basin. *UNIR@RIA* is a strategic plan between municipalities for social and for economical development, and for the environmental protection and qualification (CIRA, 2014a). For the BVL, the plan bases its interventions in previous studies, namely in measures like reducing the number of disperse plots per farmer, gathering it in larger continuous areas per farmer (reparcelling). The water related measures include interventions in the secondary draining network and in the irrigation infrastructures. These interventions aim for increasing the efficiency of the existing network and for new extensions. The *UNIR@RIA* plan gives other guidelines like defining Interesting Landscape Paths next to the wetlands (e.g. banks, roads) in order to promote nature related tourism and also the requalification and/or building of traditional berths (CPU, 2007).

The Operational Programme *'POLIS Litoral Ria de Aveiro'* is the responsibility of the Portuguese Government and CIRA (Inter-municipal Community of the Aveiro Region). The plan aims for interventions for the requalification and for the valorisation of *Ria de Aveiro*, in terms of the environment, urban structures, touristic and cultural activities, leisure and other activities with economic and social interest. The plan *POLIS Litoral Ria de Aveiro* also looks for the landscape preservation, decreasing the risk, increasing biodiversity and managing the natural ecosystem in a sustainable way. It is based in strategic plan, divided in four axes and one hundred and fifty actions - Figure 29 (POLIS LITORAL RIA DE AVEIRO, S.A., 2013).

Figure 29 - Axes and actions in Ria de Aveiro strategic plan (source: POLIS LITORAL RIA DE AVEIRO, S.A., 2013)

4 Ecosystem Services

ADAP-MED will follow CICES definitional structure for ecosystem services (ES) (Haines-Young & Potschin, 2013; Maes, et al., 2013; Maes, et al., 2014). At the highest-level, CICES hierarchical structure includes three categories:

Provisioning services	• All the nutritional, material and energetic outputs from the living systems.
Regulating and maintenance	• All the ways in which living organisms can mediate or moderate the environment, affecting human activities (ex: waste processing, physic-chemical and biological regulation, etc.)
Cultural services	• All the non-material and/or non-cosumptive ecosystem outputs that affect human physical and mental states.

Below these major 'Sections' in the classification are nested a series of 'Divisions', 'Groups' and 'Classes':

Division	• Splits sections categories into main types of outputs or process
Group	• Splits division categories by biological, physical or cultural type or process
Class	• Splits groups categories into further individual entities

In the scope of ADAP-MED we will identify the ES provided by BVL considering together the following ecosystems typologies: forests, agro-ecosystems, freshwater ecosystems and marine ecosystems. More specifically, for the BVL we will consider the '*Bocage*' living hedges; the cropland and grassland areas; the permanent freshwater inland surface waters, which includes freshwater wetlands; and the transitional waters, which correspond to aquatic ecosystems on the land-water interface under the influence of tides and with salinity higher than 0.5, including coastal wetlands and saltmarshes.

Baixo Vouga Lagunar ecosystems services

Provisioning services

Division: Nutrition

Group	Class	*Baixo Vouga Lagunar*
Biomass	Cultivated crops	Rice, maize, oat, alfalfa, ryegrass and permanent pastures (mixtures of several species – grasses and legumes)
	Reared animals and their outputs	*Marinhoa* cattle for meat; other cattle breeds for meat (Charolais, Limousine, crossbreed); Holstein Friesian cattle for dairy products like milk; and equine cattle.
	Wild plants, algae and their outputs, used in gastronomy, cosmetic, pharmaceutical…	Wild berries, Samphire.
	Wild animals and their outputs	Migratory fish species (Eel, lamprey, shad), wild ducks, quails and doves for food
	Plants and algae from in-situ aquaculture	N.A. (seaweed farming restricted to the lagoon area)
	Animals from in-situ aquaculture	N.A. (aquaculture restricted to the lagoon area)
Water	Surface water for drinking	N.A. to *Baixo Vouga Lagunar*
	Groundwater for drinking	N.A. to *Baixo Vouga Lagunar*

Division: Materials

Group	Class	*Baixo Vouga Lagunar*
Biomass	Fibers and other materials from plants, algae and animals for direct use or processing	Wood, timber, flowers, eucalyptus for industrial products such as cellulose for paper, reeds (harvested, from August to October, for traditional products/handcraft, mostly used in traditional festivities), Sea rush (harvested, from August to October and used as cattle bedding).
	Materials from plants, algae and animals for agricultural use	Sea rush cattle bedding compost is used as a fertilizer in agriculture.
	Genetic materials (DNA) from all biota	N.A. to *Baixo Vouga Lagunar*
Water	Surface water for non-drinking purposes	Abstracted surface water from the rivers *Vouga, Antuã*, and streams for irrigation, livestock consumption, industrial use (consumption and cooling)
	Groundwater for non-drinking purposes	Freshwater abstracted from groundwater layers by wells for irrigation

Division: Energy

Group	Class	*Baixo Vouga Lagunar*
Biomass	Biomass-based energy sources	'*Bocage*' living hedges are pruned for firewood
	Mechanical energy	Physical labour provided by *Marinhoa* cattle

Regulation and maintenance services

Division: Mediation of waste, toxics and other nuisances

Group	Class	*Baixo Vouga Lagunar*
Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	Bio-chemical detoxification / decomposition / mineralization in land / soil, freshwater and marine systems including sediments; decomposition / detoxification of waste and toxic materials
	Filtration/sequestration /storage/accumulation by micro-organisms, algae, plants, and animals	Biological filtration / sequestration / storage / accumulation of pollutants in land / soil, freshwater and biota, adsorption and binding of metals and organic compounds in biota
Mediation by ecosystems **(Combination of biotic and abiotic factors)**	Filtration/sequestration/storage/accumulation by ecosystems	Bio-physicochemical filtration / sequestration / storage / accumulation of pollutants in land / soil, freshwater and marine ecosystems, including sediments; adsorption and binding of metals and organic compounds in ecosystems
	Dilution by atmosphere, freshwater and marine ecosystems	Bio-physico-chemical dilution of gases, fluids and solid waste, wastewater in atmosphere, rivers and sediments
	Mediation of smell/noise/visual impacts	*'Bocage'* as green infrastructure to reduce the visual impact and the smell from a pulp mill industry

Division: Mediation of waste, toxics and other nuisances

Group	Class	*Baixo Vouga Lagunar*
Mass flows	Mass stabilization and control of erosion rates	*'Bocage'* living hedges, Vouga and Antuã rivers riparian vegetation, freshwater marshes and saltmarshes provide erosion, landslide and gravity flow protection.
	Buffering and attenuation of mass flows	*'Bocage'* living hedges, permanent pastures, freshwater marshes and saltmarshes provides attenuation of mass flows, contributing to settlement of particulate organic matter (POM).
Liquid flows	Hydrological cycle and water flow maintenance	*'Bocage'* living hedges and the associated drainage system ensures baseline flows for water supply (including freshwater groundwater recharge) and discharge; freshwater marshes and saltmarshes also contribute to the regulation of the hydrological cycle.
	Flood protection	*'Bocage'* living hedges, freshwater marshes and saltmarshes provide resilience to extreme weather events (floods) and acts as a physical buffering of climate change impacts (storm events).

Gaseous / air flows	Storm protection	*'Bocage'* living hedges serves as shelterbelts against the wind.
	Ventilation and transpiration	*'Bocage'* living hedges enables air ventilation and evapotranspiration

Division: Maintenance of physical, chemical, biological conditions

Group	Class	*Baixo Vouga Lagunar*
Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	Pollination by bees and other insects; seed dispersal by insects, birds and other animals.
	Maintaining nursery populations and habitats	BVL is a Natura 2000 site, which includes several habitats classified by the Habitats directive (e.g. 1130 - estuaries; 1150 – Coastal lagoons; 1310 - *Salicornia* and other annuals colonizing mud and sand).
Pest and disease control	Pest control	*Plants: (e.g.) Cortaderia selloana, Spartina versicolor*
	Disease control	N.A. to *Baixo Vouga Lagunar*
Soil formation and composition	Weathering processes	*'Bocage'* living hedges, freshwater marshes and saltmarshes contribute to soil formation and to the maintenance of bio-geochemical conditions of soils including fertility, nutrient storage, and soil structure
	Decomposition and fixing processes	*'Bocage'* living hedges, freshwater marshes and saltmarshes contribute to the maintenance of bio-geochemical conditions of soils/sediments by decomposition / mineralisation of organic mater, mediate the N cycle (e.g. N-fixation, nitrification, denitrification) etc.), and other bio-geochemical processes (e.g. P, Si, Fe and S cycles).
Water conditions	Chemical condition of freshwaters (Note: we are considering the ecological status in the scope of WFD)	In freshwater flows through BVL are classified as follow: *Vouga* river - 'Bad' ecological status, *Antuã* river - 'Poor' ecological status, *Jardim* river and *Fontão* river - 'Good' ecological status.
	Chemical condition of salt waters (Note: we are considering the ecological status in the scope of WFD)	In the scope of the WFD, Ria de Aveiro coastal lagoon is divided into 5 transitional water bodies (WB's). The WB's closer to the BVL are WB2 – A heavily modified water body corresponding to the central area of the lagoon. The water potential ecological status is "Moderate"; and WB4 – A natural (unmodified) water body that includes the *Murtosa* Channel and the *Laranjo* Basin. The water ecological status is "Moderate".
Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	*'Bocage'* living hedges, permanent pastures, freshwater marshes and saltmarshes contribute to global climate regulation by greenhouse gas/carbon sequestration
	Micro and regional climate regulation	*'Bocage'* living hedges increases local evapotranspiration, modify temperature, humidity and wind fields; *'bocage'* living hedges contributes to air quality.

Cultural services

Division: Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]

Group	Class	*Baixo Vouga Lagunar*
Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	*In-situ* landscape and bird watching
	Physical use of land-/seascapes in different environmental settings	Walking, diving, biking, sailing, boating, kayaking, swimming, leisure fishing (angling) and leisure hunting.
Intellectual and representational interactions	Scientific	BVL is subject matter for research, namely by the University of Aveiro.
	Educational	The natural and cultural heritage of the BVL is subject matter of education (e.g Science Activities in the Summer with the support of the University of Aveiro; BioRia Environmental Interpretation Centre).
	Heritage, cultural	N.A. to *Baixo Vouga Lagunar*
	Entertainment	Ex-situ viewing/experience of natural world through different media. There are several videos of the lagoon wildlife including BVL.
	Aesthetic	Sense of place, artistic representations of nature, inspiration for some painters and writers, interested in the history and heritage of the lagoon, including BVL, and its users

Division: Spiritual, symbolic and other interactions with biota, ecosystems, and land- /seascapes [environmental settings]

Group	Class	*Baixo Vouga Lagunar*
Spiritual and/or emblematic	Symbolic	N.A. to *Baixo Vouga Lagunar*
	Sacred and/or religious	N.A. to *Baixo Vouga Lagunar*
Other cultural outputs	Existence	Enjoyment provided by wild species, namely birds, *'Bocage'* landscape, and the diversity of biota in such a relatively small area
	Bequest	Willingness to preserve freshwater and saltmarshes and the *'Bocage'* landscape and to preserve biota, namely birds and migratory fish (e.g. lamprey and eel) for future generations.

5 Climate change

5.1 Evidences of sea level rise and climate change

Sea level rise is considered to be a direct consequence of climate change, inducing significant impacts on the society and ecosystems. For *Aveiro* region, recent studies recorded an increase of 1.15 +/- 0.68 mm per year, between 1976 and 2003 (Lopes, et al., 2011).

Possible direct impacts of sea level rise are: inundation of coastal areas, saltwater intrusion through estuaries and aquifers, shore erosion and habitat loss.

Baixo Vouga Lagunar watercourses are connected to the Atlantic Ocean through *Ria de Aveiro* coastal lagoon (see Figure 10), allowing a permanent saltwater, tidal dependent, flow within BVL. Meaning that changes in sea water level and consequently in Ria water level might affect BVL trough the upstream extension of surface saltwater intrusion (Lopes, et al., 2013).

In the last three decades, the geomorphology of the lagoon has changed due to the dredging activities in Aveiro Harbour, which were performed in order to improve navigability. The main dredges occurred in the 1990's, with clear effects on the system eco-hydrology (Silva et al., 2004, Picado et al., 2010). These effects include changes in the system water velocity and currents, changing the spatial patterns of erosion and sediment accretion, and the increase of the tidal prism, with clear implications in surface saltwater intrusion in BVL (Andresen & Curado, 2001c; Picado, et al., 2010). During the WP3 interviews, the BVL stakeholders acknowledged that the Aveiro Harbour dredging activities were/are mainly responsible for the surface saline intrusion events in BVL.

Picado et al., (2010) also acknowledges that other factors, rather than CC, are responsible for the changes related with the tidal dynamics, such as the lack of conservation and maintenance of coastal systems (e.g. saltpans abandonment) and changes in the geomorphologic configuration. Specifically for *Ria de Aveiro*, sensitivity analysis confirmed that the alterations in bathymetry is mostly responsible for the observed changes in the tidal cycle, namely in terms of tidal amplitude and tidal prism. Also changes in the lagoon bottom are responsible for increasing the currents and then increasing the erosion potential and the sediments export (Picado, Dias, & Fortunato, 2010)

Ria de Aveiro is considered to be a flood-prone region, not only due to downstream oceanic events but also due to upstream extreme weather events. Namely in BVL, due to heavy precipitation the *Vouga* river and *Antuã* river flows might increase in a way that water overtops the banks flooding the agricultural fields. During the WP3 interviews, it was stated that fluvial floods are usually beneficial for agriculture, as the water transports nutrients from upstream. However, extreme precipitation events have severe consequences in the 'Bocage' landscape and associated activities. In BVL, the most severe events occurred in *Estarreja* and *Albergaria-a-Velha*, that is, the flood events occurred more often and with the worst consequences for the ecosystem.

The combination of Ocean storm surges with spring tides and extreme precipitation events has lead to major floods (both saltwater and freshwater) and damages in BVL, requiring human intervention (Fidélis & Carvalho, 2013; Lopes, et al., 2013).

The translational waves that reach the shore transport a large amount of seawater and when these reach the lagoon ocean boundary at the inlet, they interact with the lagoon flows and therefore with the *Baixo Vouga Lagunar* water dynamics. The changes in the tidal dynamics reveal the fragile equilibrium between the environment, the human intervention and the development. This enhances the real challenge of dealing with the nature conservation and the economic development (Andresen & Curado, 2001c; Fidélis & Carvalho, 2013).

Figure 30 shows the great floods that occurred in *Baixo Vouga Lagunar* in 2001. These floods have been highlighted by Alves, et al., 2013b.

During storm surges and fluvial floods (that cause banks collapse) the surface saline occurs causing the salinization of the agricultural fields and 'Bocage' living-hedges death - Figure 31. Every year, several agricultural areas are lost (ARH Centro, 2012f; Alves, et al., 2013b).

Figure 30 - Flood events in Baixo Vouga Lagunar, in 2001 (storm surge).

Figure 31 - Consequences of soil salinization

Other consequence of severe flooding is the collapse of several infrastructures like dikes, roads and paths, bridges, among others, as highlighted in Figure 32. Every year the municipalities and the parishes repair these damages to ensure the mobility in *Baixo Vouga Lagunar* and for preventing the surface saline water entrance to the agricultural fields. The increase of the soil salinity content is leading to the establishment of halophytes, namely *Salicornia ramosissima* and the sea rush (*Juncus maritimus)* (Pinho, 2010).

Figure 32 - Damaged dikes during flood events

5.2 Evidences of coastal changes

Human action has contributed to the actual coastal morphology. In *Aveiro* Region the main intervention was the creation of an artificial inlet to the lagoon, in 1808. Then several other works were made to improve the *Aveiro* commercial harbour. The lagoon inlet needs to be constantly dredged in order to assure navigability. Namely, between 1988 and 1999 the inlet was dredged to assure the -10 m depth. Since then, only maintenance dredges occur to maintain the same depth (Andresen & Curado, 2001c; Rua, 2014).

Apart from the harbour interventions, the inlet region is very dynamic, suffering changes in the bathymetry very often with consequences to the nearby beaches, which alternates from strong deposition to mild erosion (Lopes, et al., 2011).

Other coastal changes are related to the extreme weather events that reach the shore. During the winter 2013-2014 the beaches next to *Aveiro* harbour suffered massive erosion, leading to the shoreline retreat.

The coastal phenomena are reflected in the lagoon, in a way that the changes in the tidal are felt in BVL, namely in the borders. As the tidal rises, the salt water is pushed upstream and the existing dikes and banks, in some situations, are not able to contain this effect and collapse. A concrete dike was built in order to contain the salt water advance (see 5.3), however not all the west border is protected by this dike, namely in the southwest where the traditional dike (in *Ilha Nova*) was not able to contain the tidal and then some land was lost. The increase of the saltwater flow brings also consequences to the transitional watercourses BVL, is common to observe the water overtopping the banks (*Esteiro de Salreu, Esteiro de Canelas*, etc.)

5.3 Existing grey infrastructures

In BVL there are grey infrastructures built for extreme weather events that could be adapted to reduce vulnerability to climate change impacts. Namely, since 1972, the *Vouga* Hydro-Agricultural Development Project has been responsible for several interventions to improve the water use efficiency and to provide protection against freshwater floods and surface saline intrusion. In 1992, the Execution Plan for the Tidal Protecting Dike was concluded, however the project was charged by non-governmental agencies and therefore never concluded. After the legal authorizations, the concrete dike medium section was built between 1995 and 1999. But still in 1995, an official complaint was made before the European Commission stating that the dike construction was not submitted through an Environmental Impact Assessment (EIA) and violated the Natura 2000 directives. Afterwards, an EIA was effectively made regarding the effects of the medium section dike construction, the dike itself and the future expansion. In 2002, the Declaration of Environmental Impact was emitted approving the 2nd alternative for the tidal defence dike (Andresen & Curado, 2001a; DGADR, 2008).

Effectively, the current grey infrastructures in BVL were built to deal with regular torrential events, but nowadays could also be considered to be part of climate change adaptation infrastructures. The grey infrastructures include the tidal defence system, that is the **main concrete dike** and other **traditional dikes** (in some cases working as roads as well), **which a**ct as water barriers to the fields. These water barriers exist in the right bank of *Vouga* river,

in *Velho* river, in *Ilha Nova*, in the banks of *Esteiro de Canelas*, *Esteiro do Barbosa*, *Esteiro de Salreu* and in the banks of *Antuã* river. Figure 33 and Figure 34 show the existing concrete dike and the proposed dike, approved in the Declaration of Environmental Impact (Andresen & Curado, 2001c).

Figure 33 - The existing tidal dike in BVL

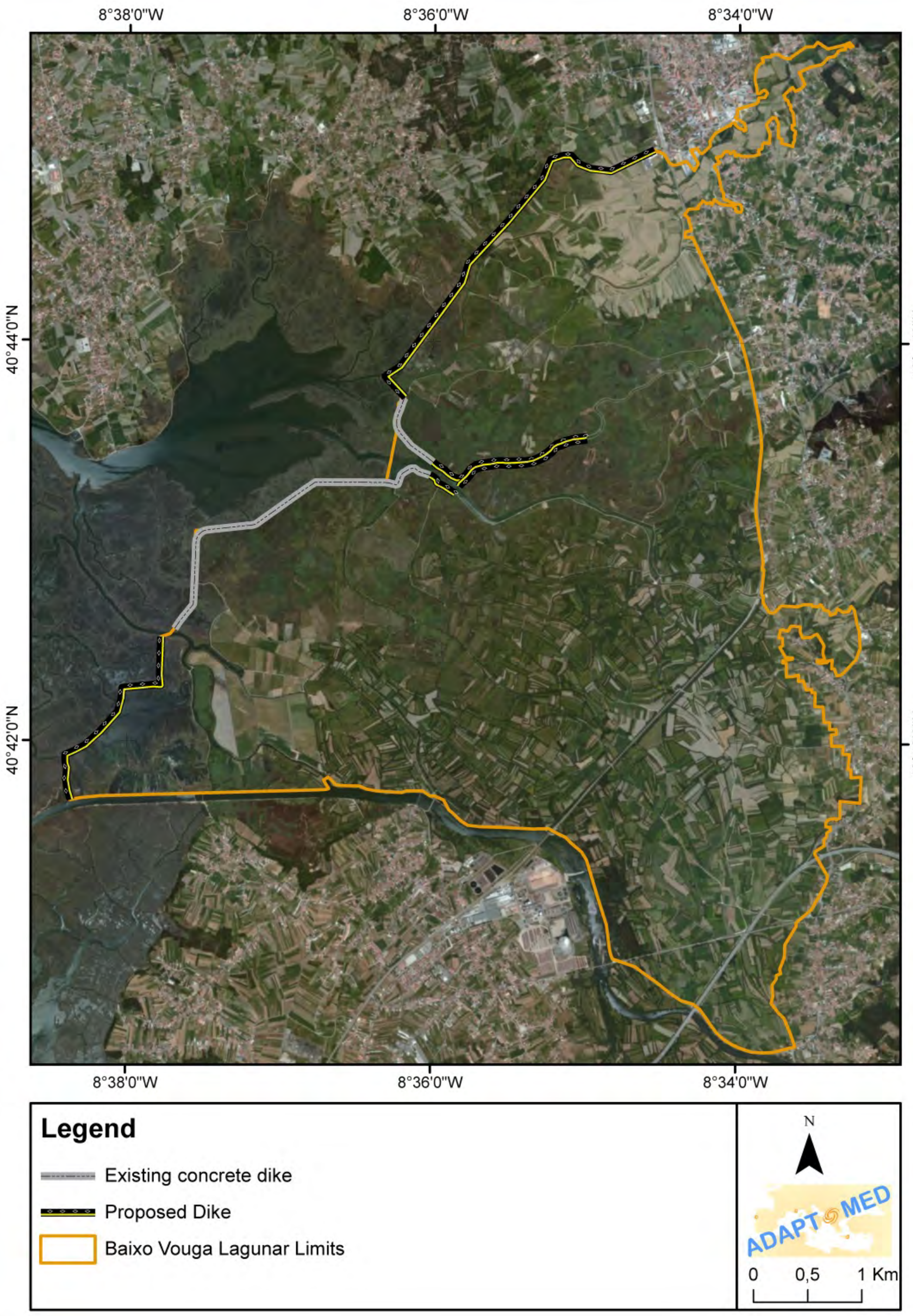


Figure 34 - The proposed and the existing tidal dike in BVL

Next to *Esteiro do Barbosa*, there was an autonomous water-gate that controlled the water flow between the BVL and *Ria de Av*eiro. Due to vandalism, the structure now operates now manually and with tidal water-gates – see Figure 35 (Magalhães-Crespo *personal communication*).

Figure 35 – *Esteiro do Barbosa* water gate

Along the *Baixo Vouga Lagunar* watercourses, there are also permanent weirs with **manual water gates** and **tidal water gates.** These operate to ensure freshwater supply and drainage, and also as salt water barrier (Figure 36).

Figure 36 – Permanent weirs and manual water gates in *Baixo Vouga Lagunar*.

5.4 Existing green infrastructures

The existing green infrastructures correspond essentially to the *'Bocage'* living-hedges. The main purpose is to bound the plots where could be permanent pastures or annual crops, but they also have a role in providing shelter for cattle, protecting and stabilizing the ditches, banks and slopes, and finally for producing biomass for burning. The living-hedges also take part in the water cycle regulation and containing the floods as they work as a natural-barrier for the water breakthrough. They also reduce the erosion potential as they offer protection and stabilization to the ditches margins and banks. The living-hedges have been used as part of the agricultural system, but currently they could also be considered for climate change adaptation. The main species in the living-hedges are black alder (*Alnus glutinosa)*, grey willow (*Salix atrocinerea*), common oak (*Quercus robur*), as shown in Figure 37 (Andresen & Curado, 2001c).

Figure 37 – Road with living-hedges in both sides; living-edge being pruned in a *'Bocage'* smallholding.

Like mentioned (see 3.3), living hedges have been disappearing along the years. The last living-hedges cartography was made during the Environmental Impact Assessment for the Tidal Protecting Dike and is illustrated in Figure 38 (Andresen & Curado, 2001b; DGADR, 2008).

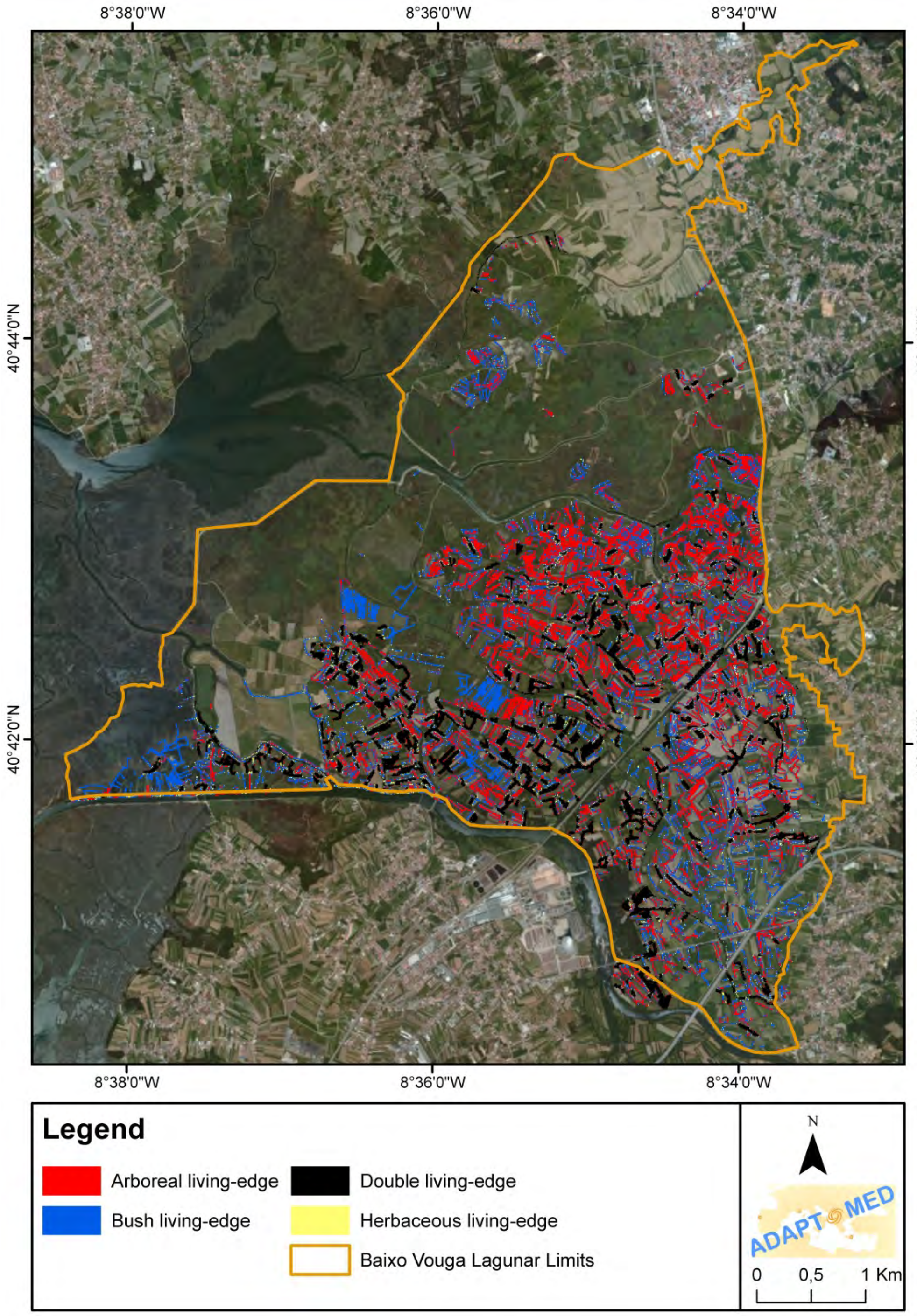


Figure 38 - Living hedges in *Baixo Vouga Lagunar* in 1995 (source: Andresen & Curado, 2001c).

The other green infrastructure consists in increasing the banks elevation in order to deal with higher water levels. The dirt used is this infrastructure is taken from the watercourse bed and placed on the bank (see Figure 39).

Figure 39 - Banks elevation in *Baixo Vouga Lagunar*

6 THE EXPECTED IMPACTS AND RISKS ATTRIBUTED TO FUTURE CHANGES

6.1 Projected climate evolution

For *Vouga* river basin, the climatic prediction scenarios[1] estimate a temperature increase between 2ºC to 6ºC and a precipitation decrease between 5 and 30 %. The runoff will also vary between +5 and -60% - see Figure 40 (ARH Centro, 2012e).

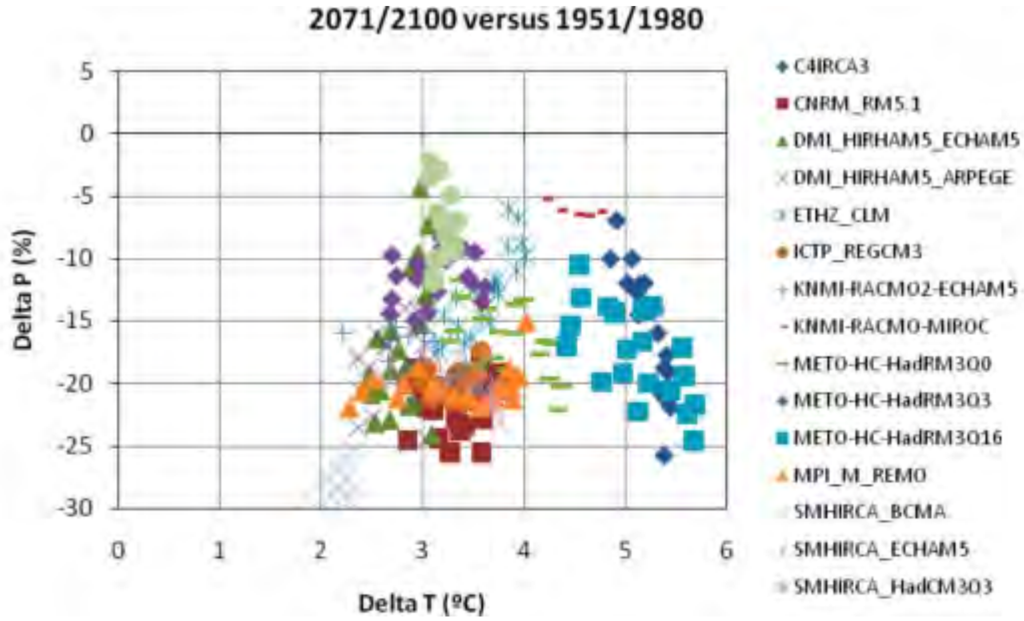


Figure 40 - Variation on the Annual Average Precipitation (%) vs. Variation on the Average Air Temperature (ºC), concerning the period between 2010-2071 with 1951-1980 has a reference (source: ARH Centro, 2012e)

The same projections show that also the seasonal distribution will change, particularly the precipitation will be more frequent in winter and less frequent in the remaining seasons. This effect will lead to drought events during the summer and floods during the winter. The precipitation decrease will also reduce the aquifer recharge capability and the salinity will increase, also due to sea level rise (ARH Centro, 2012e).

[1] The used climate change scenarios correspond to those obtained in ENSEMBLES project for the Iberian Peninsula (van der Linden & Mitchell, 2009). Please see the project websites: http://www.ensembles-eu.org/; http://www.cru.uea.ac.uk/projects/ensembles/ScenariosPortal/; http://www.siam.fc.ul.pt/SIAMExecutiveSummary.pdf

6.2 Freshwater resources

The climate change scenarios foresee changes in the water supply system, as the quality and availability will decrease mainly during spring, autumn and summer. So, the management of the water sources will have to be adapted. Table 10 shows the effects and consequences due to climate change, by sector (ARH Centro, 2012e).

Table 10 - Effects on climate change in Baixo Vouga Basin (source: ARH Centro, (2012e))

Sector	Causes/Effects	Possible consequences
Water supply and sewage services	Water availability decrease Coastal aquifers salinization Changes in the precipitation distribution Water temperature increase	Risk increase for water unavailability Risk increase for water contamination More advanced systems in water treatment Risk increase for facilities floods
Agriculture	Water availability decrease Coastal aquifers salinization Changes in the precipitation distribution Water temperature increase Water quality decrease	Increase of the irrigation needs Productivity decrease
Energy	Decrease in the supply Water temperature increase	Electricity production and power decrease Problems in operating power-plants Conflicts increase with the water management
Coastal areas	Mean sea level rise Recharge decrease Saline intrusion and aquifer salinization	Risk increase for coastal erosion Changes in the coastal morphology
Tourism	Air temperature increase Mean sea level rise Changes in the coastal morphology	Changes in the tourism attractiveness and demand Changes in tourism season flow and therefore pressure to water resources
Aquatic ecosystems	Water availability decrease Changes in the precipitation distribution and flow Water temperature increase Water quality decrease Pressure increase through water resources	Changes in marine and terrestrial ecosystems, in estuaries and coastal areas

Stefanova, et al., (2014) used the ENSEMBLE project climate changes scenarios to downscale and assess the CC impacts in *Ria de Aveiro* catchment area. Considering the reference period of 1971-2010 (p0), on average, there is a small discharge decrease to the lagoon in 2011-2040 (p1) and in 2041-2070 (p2), following the precipitation in those periods (-6 and -8 % respectively). In the 2071-2098 (p3) the flow decreases the most, also following the precipitation trend in this period (-16%). During the summer months, the total discharge to *Ria de Aveiro* will decrease from 5 to 10% in p1, 10 to 15% in p2 and 20 to 25% in p3, which will affect the freshwater supply in areas like BVL, as well as the salinity patterns (Stefanova, et al., 2014).

6.3 Marine/coastal environment

Based in the IPCC Special Report on Emissions Scenario A2[2], Lopes, et al., 2011, estimates a Sea Level Rise (SLR) of 0.42 m for the Portuguese coast, by the end of the 21st century. However, due to the uncertainty in the global circulation level and due to greenhouse gases emissions patterns the SLR could reach 0.64 m. For *Ria de Aveiro*, the flood extent would increase between 23 % and 35 % based in the two SLR estimates (the actual flooded area between the spring tide and the mean tide is 20 %). This means that the high tide coverage could increase from 88.6 km^2 to 107.5 km^2, with the 0.42 m scenario and to 118.6 km^2, with 0.64 m scenario (Lopes, et al., 2013). These predictions evidence the susceptibility of lower elevations, like the *Baixo Vouga Lagunar*. In these cases the surface salinity intrusion potential will increase, compromising the current infrastructures and activities, such as the residential areas and the agricultural fields (Lopes, et al., 2011; Coelho & Pereira, 2013; Lopes, et al., 2013).

In the scope of LAGOONS Project (http://lagoons.web.ua.pt,) the Delft3D and ELCIRC models were used to perform the flooding simulations for the climate change scenarios. The Delft3D-Flow model was developed and calibrated for *Ria de Aveiro* coastal lagoon in the scope of LAGOONS project, whilst the ELCIRC model was developed and improved during the ADAPTARIA project (http://climetua.fis.ua.pt/legacy/adaptaria/en/index.html). For the area of BVL, LAGOONS project used the ELCIRC model for the flooding simulations using the climate forcing conditions determined for the LAGOONS project (LAGOONS, 2014b).

The flood simulations were performed for the typical year, extreme flood and extreme surge in three reference periods: 1981 – 2010; 2011 – 2040; and 2071 – 2098. For each period:

- The correspondent values of humidity, air temperature, radiation, etc. were used;
- The extreme river flows (Q), with a 100 years return period, were extracted from fitting a distribution to each of the 30 years periods. That is, the Q_{100} is distinct in every period;
- It was considered the maximum equinoctial tide in each 30 year period.

The simulations are illustrated in Figure 41 (LAGOONS, 2014a; LAGOONS, 2014b; LAGOONS, 2014c).

[2] "A2 storyline and scenario family: a very heterogeneous world with continuously increasing global population and regionally oriented economic growth that is more fragmented and slower than in other storylines" in IPCC, 2014.

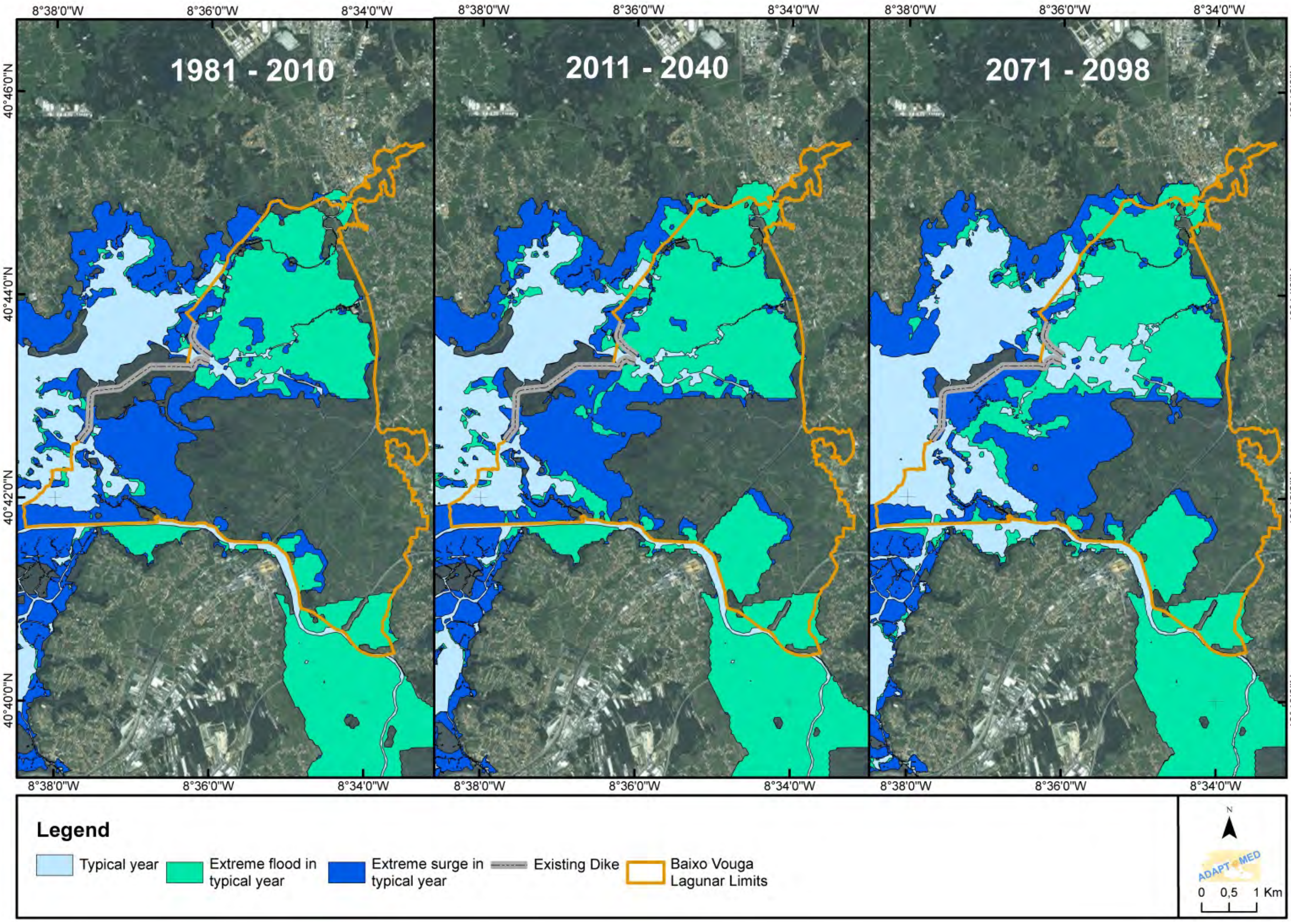


Figure 41 - Flood scenarios (source: LAGOONS, 2014)

In general, from Figure 41 is possible to observe that the flood extension increases, along the years, in the three different scenarios. The north of *Baixo Vouga Lagunar* has higher probability to floods, as both in extreme flood and in extreme surge is completely flooded. In the southwest there is an area which already floods in a typical year and its extension increases during extreme events. The southeast is only flooded in extreme events, but between the two first two periods the flooded area increases. In Dias, et al., 2013a flood scenarios, it is observed that highest flood levels occur in Vouga river margins area, with over 1.5 m.

The effect of the existing dike (grey infrastructure) in containing the water advance is quite observable in Figure 41. That is, the dike's nearby areas are less susceptible to floods when compared with the unprotected west borders of *Baixo Vouga Lagunar*.

In Alves & Sousa, 2013, it was possible to define risk maps for flooding in *Baixo Vouga Lagunar*, considering the **probability** for each flood scenario and the **vulnerability** of the territory. In Figure 42 it illustrates the risk map, considering the maximum flood extension in a future scenario where the SLR is 0.64 m.

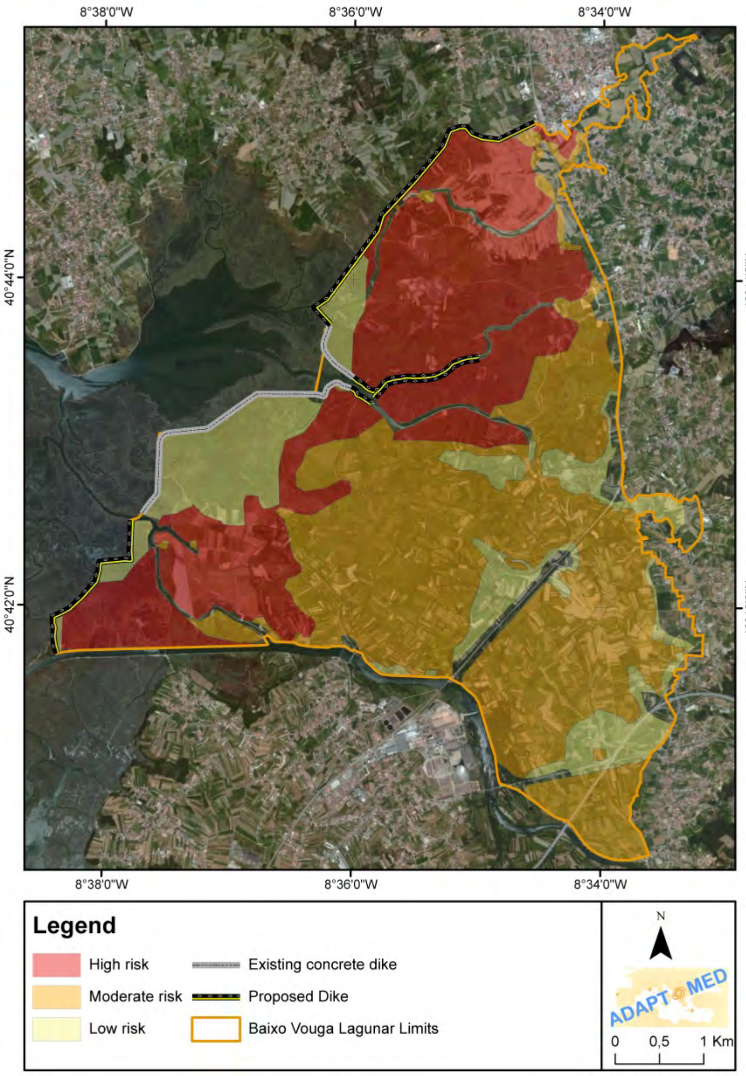


Figure 42 - Risk map for flooding in *Baixo Vouga Lagunar* (source: Alves, et al., 2013)

Most of the *Baixo Vouga Lagunar* area has **high** or **moderate risk for flooding** (> 2 200 ha). The effect of the existing dike is, again, quite noticeable in the nearby areas, which have low risk for flooding.

6.4 Urban infrastructure/ agglomerations

As seen in 3.4, there are few urban infrastructures and residential agglomerations in *Baixo Vouga Lagunar,* therefore the impact is expected to be low. Figure 41 shows the affected urban infrastructures under the flood scenarios for 2011-2040. The typical year flood does not have direct impact. However, in the case of extreme flood and in surge flood the highway and railway surroundings are affected. Some of the residential and industrial infrastructures in the northeast are flooded as well.

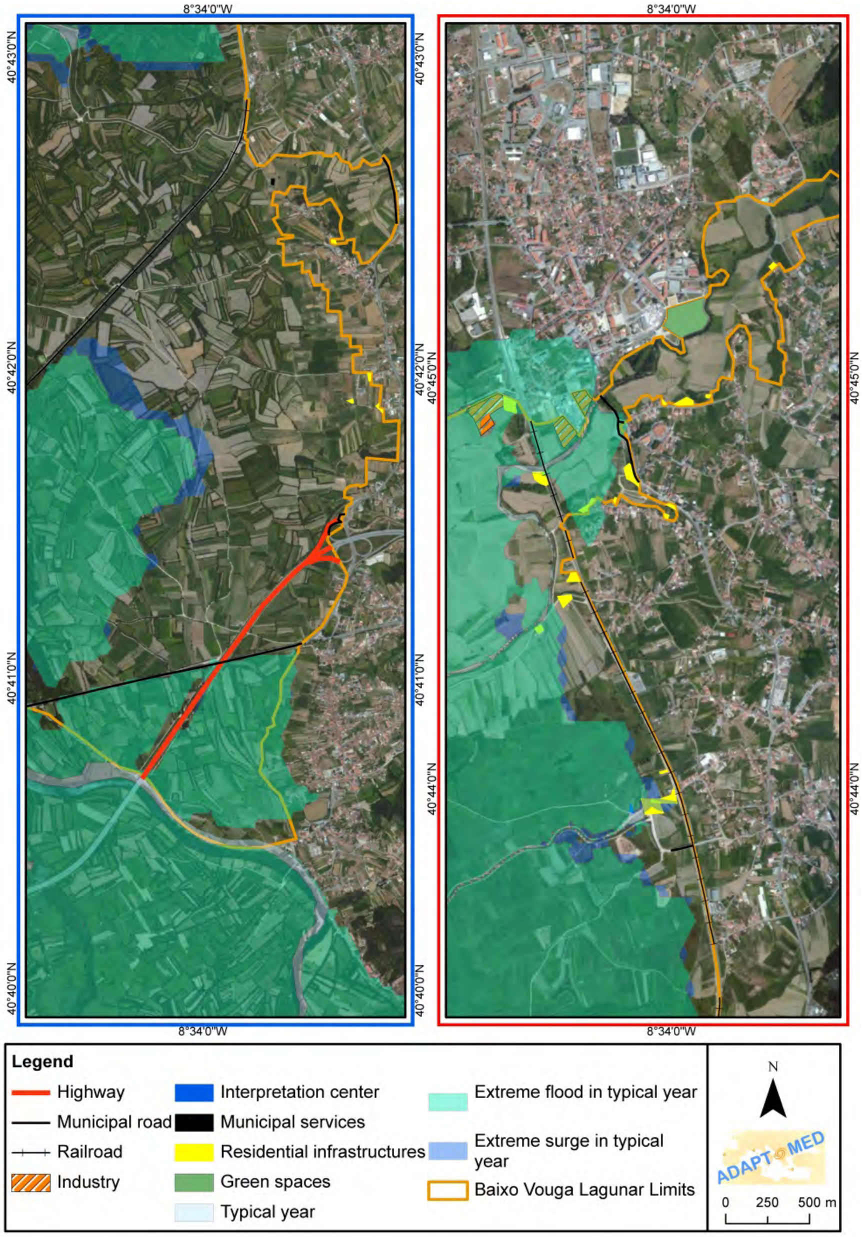


Figure 43 - Urban infrastructures under the floods scenarios for 2011 – 2040 (source: CEAP, 2013; LAGOONS, 2014; LAGOONS, 2014c)

Alves & Sousa, 2013 acknowledges that in BVL there is no risk for flooding in urban areas. However, there is risk for flooding (freshwater) and for surface saline intrusion in agricultural areas. The affected urban areas would be in the outside of the BVL, for example in *Aveiro* urban waterfront.

6.5 Ecosystem services

The BVL area includes four ecosystems typologies forests, agro-ecosystems, freshwater ecosystems and marine ecosystems that results from a strong relationship between **man,**

land and water. Foreseeing the provided ecosystem services, the landscape was shaped into three different landscape units: **open fields; wetlands; and '*Bocage*'**, which depend on the management of water resources. Meaning that the presence of these ecosystems typologies and the provided services is closely related to the mangement of water resources and the equilibrium between freshwater and transitional waters.

Considering the climate change scenarios, namely the increase in air and water temperatures the changes in precipitation patterns and the possible increase of surface saline intrusion, the hydrological cycle could be affected as well as the equilibrium between freshwater and transitional waters and therefore affecting ecosystems services as presently provided (see section 4). Namely, the possible increase of drought events during the summer, the reduction of aquifers recharge capability and increase evapotranspiration will affect the BVL hydrologic cycle and consequently the services provided by forests, agro-ecosystems and freshwater ecosystems. In addition, the increase of surface saltwater intrusion will primarily affect the '*Bocage*' and the freshwater wetlands and their associated services, increasing the areas under the influence of the transitional waters, which correspond to coastal wetlands and saltmarshes under the influence of tides and with salinity higher than 0.5.

6.6 The main sources of uncertainty in available knowledge

In general, uncertainty could be due to the **lack of information** and due to **disagreement** between the key-actors on the matter. In addition, when discussing uncertain events like the climate change other sources of uncertainty appear, like those associated with the **prediction models** for the climatic variables and for the hydrologic variables (tidal, fluvial flow, drainage, etc.).

The uncertainty could be decreased by increasing the knowledge but in a certain point is impracticable, so it could be done by increasing the adaptation resilience, that is, diversify the adaptation strategies to assure it covers the uncertainty (Mees & Kaufmann, 2014).

The Intergovernmental Panel on Climate Change (IPCC) was established in 1988, in order to assess the available scientific information regarding the effect of human activities in the climate change. While IPCC as an institution does not do scientific investigation and does not directly monitor climate-related data, leading and contributing authors of the reports are themselves directly involved in climate data monitoring and scientific investigations.. The IPCC gathers three working groups, which final objective is to provide the "state of knowledge in climate change", on a regular basis. Its reports are based on different scenarios in the published literature and the authors use an "Uncertainty Guide" to characterize the degree of certainty in the literature (see: http://www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf) (IPCC, 2007; IPCC, 2013).

Specifically for *Baixo Vouga Lagunar*, one of the main concerns of uncertainty regarding is **causality**, that is, which is the real cause for the increase of the tidal influence area. The most pointed reason is the dredging activities in *Aveiro* harbour, but the *Aveiro* Port Authority claims that the last dredge with consequences to the tidal was made in the 1990's. Therefore the recent events must be due to other causes, like the climatic change. (MEA, 2005; Rua, 2014; Vlassopoulos, 2014).

Vlassopoulos (2014) proposes a “*multi-layered safety concept*” for dealing with uncertainty in flood risk:

- Emergency management: security regions, evacuation plans, flood warnings. Civil Protection and water authorities’ responsibility.
- Sustainable spatial planning: compartimentation, water robust spatial planning. Municipalities and regional authorities’ responsibility.
- Protection: structural measures like the dike and increase the river width. Water authority responsibility.

There are other strategies to deal with uncertainty, one example is a type of “*iterative adaptive management*”, including the **no-** and **low-regret adaptation**. They are measures that benefit the current effects of the climate change and certain scenarios of future climate change. The no-regret options provide social and economic benefits whether the climate change occurs or not. The low-regret options, depends on who you ask. It could be like the no-regret but with opportunity/policy costs, or with some benefits in the present and in the future, or with options that benefits most scenarios, etc. Low-regret options include: early warning systems; sustainable land management; surveillance; irrigation and drainage systems climate-proofing infrastructure; better education and awareness; etc. The proposed measures for BVL fit in the low-regret concept (Watkiss & Hunt, 2014).

7 Highlights and Final Remarks

The objective of the current document is to build a knowledge database regarding *Baixo Vouga Lagunar* based in the available literature, which included scientific papers, conference proceedings, project reports and PhD thesis. The existing information was complemented with interviews to stakeholders taken under the scope of the ADAPT-MED project.

Baixo Vouga Lagunar represents a man-shaped landscape working in a dependent relationship between agricultural activities, wildlife and water regulation. BVL includes three main landscape units:

- **Wetlands** with natural and semi-natural vegetation like reeds and rushes, on which their distribution is highly dependent on the water salinity content; There are also small areas of rice fields, which have been decreasing along the years.
- ***'Bocage'*** it is a unique landscape in Portugal used for agriculture and livestock production. It represents small-holds bounded by living-hedges (e.g. grey willow, black alder, etc.) and water ditches. These water channels supply water for crop production and also assure the drainage when there is water in excess in the fields.
- **Open-Fields** are large agricultural areas with no arboreal vegetation.

Aveiro has been affected by extreme weather events which are responsible for fluvial floods in BVL (from upstream), as the drainage network is unable to guarantee the adequate flow. BVL stakeholders remark that fluvial floods have low negative impact (or even positive), unless when it causes margins and dikes collapse, enabling surface saline intrusion when the tide rises.

From downstream, the marine floods in BVL are mainly associated with the increase of the tidal prism (due to changes in the lagoon bathymetry as a result of dredging activities). The marine floods have negative consequences as the saltwater overtops the margins causing surface saline intrusion to occur and contaminating the fields.

The SLR and extreme weather events have been associated with the CC in coastal areas. However, the changes in the tidal prism and amplitude (that affect BVL) are related with the dredging activities in the *Aveiro* harbour. The BVL stakeholders remark that the surface saline intrusion is mainly caused by the tidal prism increase and not by the CC.

Nevertheless, considering the IPCC A2 emissions scenario the SLR for the Portuguese coast would be between 0.42 m to 0.64 m, by the end of the 21st century. For the *Ria de Aveiro*, this means that the tidal flooded area would increase 23 % to 35 %, increasing the surface saline intrusion potential and compromising the current infrastructures and activities.

In the BVL there are some infrastructures that were built in order to deal with extreme weather events that could be adapted to mitigate the effects of CC. Namely with the *Vouga* Hydro-Agricultural Development Project several interventions took place to improve the water use efficiency and to provide protection against freshwater floods and surface saline intrusion. The most noticeable intervention was the construction of a 4 km concrete dike in the west border of BVL; however the dike was never concluded due to a formal complaint presented to the European Commission. The effect of the constructed section is quite remarkable when comparing with the areas not covered by it. Particularly in the southwest part of BVL (in *Ilha* Nova) about 160 ha of agricultural land was lost due to the saline contamination. BVL farmers and other stakeholders are looking forward for the concrete dike conclusion, they stand it is the most needed solution for containing the surface saline intrusion.

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9 Glossary of terms

Term	Meaning	Reference
Ecological status	"Expression to designate the quality of the structure and functioning of aquatic ecosystems associated with surface waters. For transitional waters the quality elements for the classification of ecological status are: biological elements (phytoplankton, other aquatic flora, benthic invertebrate fauna and fish fauna), hydro-morphological elements supporting the biological elements (Morphological conditions and tidal regime), chemical and physico-chemical elements supporting the biological elements (general, including nutrient concentrations, and specific pollutants)." For more details see Annex W from WFD	(European Comission, 2000)
Extreme weather events	"an extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations."	(IPCC, 2013a)
Final ecosystem services	"*Final* ecosystem services *are the contributions that ecosystems make to human well-being"*	(Haines-Young & Potschin, 2013)
Natural capital	"the world's stocks of natural assets which include geology, soil, air, water and all living things"	(Scottish Wildlife Trust, 2014)
Drought	"*Drought is a natural phenomenon. It is a temporary, negative and severe deviation along a significant time period, and over a large region from average precipitation values (a rainfall deficit), which might lead to meteorological, agricultural, hydrological and socio-economic drought, depending on its severity and duration."*	(Schmidt, et al., 2012)
Water scarcity	*"Water scarcity is a man-made phenomenon. It is a recurrent imbalance that arises from an overuse of water resources, caused by consumption being*	(Schmidt, et al., 2012)

	significantly higher than the natural renewable availability. Water scarcity can be aggravated by water pollution (reducing the suitability for different water uses), and during drought episodes.	
Vulnerability	*"the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity"*	(IPCC, 2007b)
Adaptation	*"In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate."*	(IPCC, 2012)
Global Warming Potential (GWP)	*"An index, based on radiative properties of greenhouse gases, measuring the radiative forcing following a pulse emission of a unit mass of a given greenhouse gas in the present-day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide. The GWP represents the combined effect of the differing times these gases remain in the atmosphere and their relative effectiveness in causing radiative forcing. The Kyoto Protocol is based on GWPs from pulse emissions over a 100-year time frame."*	(IPCC, 2013a)
Climate Change	*"Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the*	(IPCC, 2013a)

	global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes."	
Emission scenario	*"A plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g., greenhouse gases, aerosols) based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their key relationships. Concentration scenarios, derived from emission scenarios, are used as input to a climate model to compute climate projections. In IPCC (1992) a set of emission scenarios was presented which were used as a basis for the climate projections in IPCC (1996). These emission scenarios are referred to as the IS92 scenarios. In the IPCC Special Report on Emission Scenarios (Nakićenović and Swart, 2000) emission scenarios, the so-called SRES scenarios, were published, some of which were used, among others, as a basis for the climate projections presented in Chapters 9 to 11 of IPCC (2001) and Chapters 10 and 11 of IPCC (2007). New emission scenarios for climate change, the four Representative Concentration Pathways, were developed for, but independently of, the present IPCC assessment."*	(IPCC, 2013a)
Flood	*"The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods."*	(IPCC, 2012)
Impacts	*"Effects on natural and human systems. In this report, the term 'impacts' is used to refer to the effects on natural and human systems of physical events, of disasters, and of climate change"*	(IPCC, 2012)
Biodiversity	*"The variability among living organisms from all*	(Verbruggen, et al.,

	sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, among species and of ecosystems."	2011).
Ecosystem	*"An ecosystem is a functional unit consisting of living organisms, their non-living environment, and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined: in some cases they are relatively sharp, while in others they are diffuse. Ecosystem boundaries can change over time. Ecosystems are nested within other ecosystems, and their scale can range from very small to the entire biosphere. In the current era, most ecosystems either contain people as key organisms, or are influenced by the effects of human activities in their environment."*	(IPCC, 2013a)
Saltwater intrusion	*"Displacement of fresh surface water or groundwater by the advance of saltwater due to its greater density. This usually occurs in coastal and estuarine areas due to reducing land-based influence (e.g., either from reduced runoff and associated groundwater recharge, or from excessive water withdrawals from aquifers) or increasing marine influence (e.g., relative sea-level rise")*	(IPCC, 2007b)
Sea level change	*"Sea level can change, both globally and locally due to (1) changes in the shape of the ocean basins, (2) a change in ocean volume as a result of a change in the mass of water in the ocean, and (3) changes in ocean volume as a result of changes in ocean water density. Global mean sea level change resulting from change in the mass of the ocean is called barystatic. The amount of barystatic sea level change due to the addition or removal of a mass of water is called its sea level equivalent (SLE). Sea level changes, both globally and locally, resulting from changes in water density are called steric. Density changes induced by temperature changes only are called thermosteric, while density changes induced by salinity changes are called halosteric.*	(IPCC, 2013a)

	Barystatic and steric sea level changes do not include the effect of changes in the shape of ocean basins induced by the change in the ocean mass and its distribution.”	
Stakeholder	*“A person or an organization that has a legitimate interest in a project or entity, or would be affected by a particular action or policy”* .	(IPCC, 2007b)
Dyke/dike	A human-made wall or embankment along a shore to prevent flooding of low-lying land.	(IPCC, 2007a)
Erosion	The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds and underground water.	(IPCC, 2007b)
Wetland	*“The (Ramsar) Convention uses a broad definition of wetlands. It includes all lakes and rivers, underground aquifers, swamps and marshes, wet grasslands, peatlands, oases, estuaries, deltas and tidal flats, mangroves and other coastal areas, coral reefs, and all human-made sites such as fish ponds, rice paddies, reservoirs and salt pans.”*	(Ramsar, 2014)
Environmental Impact Assessment	*“Environmental Impact Assessment (EIA) is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse.* *UNEP defines Environmental Impact Assessment (EIA) as a tool used to identify the environmental, social and economic impacts of a project prior to decision-making. It aims to predict environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and options to decision-makers. By using EIA both environmental and economic benefits can be achieved, such as reduced cost and time of project implementation and design, avoided treatment/clean-up costs and impacts of laws and*	(Convention on Biological Diversity - UNEP, N/A)

	regulations."	
Gross Domestic Product	Gross domestic product, abbreviated as GDP, is a basic measure of a country's overall economic health. As an aggregate measure of production, GDP is equal to the sum of the gross value added of all resident institutional units (i.e. industries) engaged in production, plus any taxes, and minus any subsidies, on products not included in the value of their outputs. Gross value added is the difference between output and intermediate consumption.	(Eurostat, 2013a)
Gross Value Added	*"Gross value added (GVA) at market prices is output at market prices minus intermediate consumption at purchaser prices; it is a balancing item of the national accounts' production account."*	(Eurostat, 2013b)
Special Protection Areas	*"Under the Birds Directive Member States select the most suitable sites and designate them directly as Special Protection Areas (SPAs). These sites then automatically become part of the Natura 2000 network."*	(European Comission, 2014)
Grey infrastructure	*"Grey infrastructure is manmade improvements that support and improve human settlement such as roads, power lines, water systems, schools and hospitals." (Note: constructed dikes is one of the considered example in this report)*	(European Environment Agency, 2011).
Green infrastructure	*"Green infrastructure is a concept addressing the connectivity of ecosystems, their protection and the provision of ecosystem services, while also addressing mitigation and adaptation to climate change. It contributes to minimizing natural disaster risks, by using ecosystem-based approaches for coastal protection through marshes/flood plain restoration rather than constructing dikes. Green infrastructure helps ensure the sustainable provision of ecosystem goods and services while increasing the resilience of ecosystems. The concept is central to the overall objective of ecosystem restoration, which is now part of the 2020 biodiversity target."*	(European Environment Agency, 2011).

Sustainable development	*"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*	(IPCC, 2013b).

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