SUPPORTING INFORMATION I

CASE STUDY DESCRIPTION

The Baixo Vouga Lagunar remarkable characteristics permit a strong and balanced relationship between man, land and water, being characterized by three different landscape units: open fields; wetlands; and 'Bocage' (Andresen & Curado, 2001). '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. 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 the context of climate change, the Baixo Vouga lagunar (BVL) area is connected with Ria de Aveiro lagoon, that is a tidal dominated system (Lopes & Dias, 2007), which means that sea level rise is felt in the whole ecosystem, as flooding, saltwater intrusion, coastal erosion and habitat loss (Picado et al., 2010; Lopes et al., 2013; ADAPT-MED, 2015). This coastal lagoon system is also a flood prone system, from oceanic and riverine origin (Lopes et al., 2013). In BVL, with heavy precipitation, Vouga and Antuã rivers flow rates increase and overtopping of the riverbanks occurs. The combination of ocean storm surges with spring tides and extreme precipitation events has also led to major flooding (both freshwater and brackish). The resilience of the BVL to flooding is dependent on human activities, as maintenance and repair of riverbanks, watercourses, small dikes, and the continuation of the economic activities are vital for the protection and of great importance for the overall landscape maintenance (Lopes et al., 2013; ADAPT-MED, 2015; Fidélis & Carvalho, 2015). Flooding episodes have been recorded not only due to extreme weather events but also due to the decline of conservation and maintenance of traditional shoreline infrastructure's and the dredging activities by the Port of Aveiro, which have changed the geomorphology of the lagoon (Picado et al., 2010; Lopes et al., 2013). BVL watercourses are connected to the Atlantic Ocean through the Aveiro Lagoon allowing a permanent, saltwater, and tidal-dependent flow within BVL. Therefore, changes in sea water level, and consequently the lagoon's water level, might affect the BVL through the upstream extension of the surface saltwater intrusion. Possible direct impacts of sea level rise are the flooding of coastal areas, saltwater intrusion in estuaries and aquifers, coastal erosion, and habitat loss (Lopes et al., 2013; ADAPT-MED, 2015). However, in this particular case, as the ecosystem has been shaped and managed by man, factors other than climate change appear to also be responsible for changes in tide dynamics — namely, the lack of conservation and maintenance of coastal systems (e.g., abandonment of salt ponds), as well as changes in geomorphologic configuration. Indeed, over the last three decades, the dredging activities in the Aveiro harbour, which were performed in order to improve navigability, changed the geomorphology of the lagoon (Picado et al., 2010; Lopes et al., 2013). In this line, a sensitivity analysis confirmed that the alterations in bathymetry are mostly responsible for the observed changes in the tidal cycle, specifically in terms of tidal amplitude and tidal prism, thus having clear implications in surface saltwater intrusion in BVL (Picado et al., 2010; ADAPT-MED, 2015). The Aveiro lagoon is considered to be a flood-prone region, not only due to downstream oceanic events, but also due to upstream extreme weather events (Lopes et al., 2013). River banks, in particular, frequently collapse, causing an infiltration of salt water in the fields used for agriculture (ADAPT-MED, 2015).

The coastal zone between Esmoriz and Vagueira settlements is part of a dune system bordering the lagoons of Esmoriz and Aveiro. It has multiples resources that have been explored and attract population since longtime ago (Pinho, 2012). This area is characterized by a remarkable deficit of sediment nourishment, by the degradation of the sand-dune system and by the immense human pressure that is accentuated during the summer (Pinho et al., 2012). Originally coastal settlements were fishermen haylofts. They were occasionally used, mainly in summer, as support of fish activities. Following the global tendency of tourism massive expansion in developed countries, in the 70's of the 20th century, those places suffer a densification of buildings, mainly for seasonal tourism purposes, that are actually still increasing (Pinho, 2012). The urban expansion was made by occupying the dune system space, reducing or breaking the transversal shift of sand between the dunes and the beaches. Tourism and leisure activities became an important source of family revenues, complementing and sometimes substituting the traditional exclusivity of coastal fishing ("arte xávega"), lagoon fishing and agriculture (Pinho, 2012). Additionally to the mentioned changes of soil use that can be responsible for the unbalanced evolution of the coastline, it is important to register the harbour development occurring along the Portuguese coast, both up north and in the area. The construction of the Leixões

harbour between 1882 e 1892 induced some impacts in coastal dynamics. Also the opening of Aveiro's bar in 1808 influenced coastal dynamics to south, first in 1950 with the construction of groins and since then to nowadays with the maintenance and expansion of groins related with the Aveiro harbour maritime activity. The effects of sediments deficit are enhanced by the shortage of sediment supply from Douro's river due to its retention in the dams, along the river (Pinho, 2012). A study carried out by AMRIA in 2007, mentioned in Pinho (2012), showed the influence of coastline distance in the increasing of vulnerability, with a very high vulnerability in the first 20 m near the coastline, diminishing inland to very low values at 5000 m. The natural and social dynamics of the area between Esmoriz and Vagueira settlements resulted in the development of coastal defence infrastructures to avoid or diminish the impact of erosion and coastline retreat. Those defence works have been maintained and improved until now, combining them with other type of works, namely beach nourishment, dune rehabilitation and reinforcement of dune system. Long-time expected retreat strategies have also been implemented, as the reallocation of part of the Bairro dos Pescadores population.

In what concerns the Portuguese Territorial Management System, in the Aveiro region, the integration of governance and the water resources management constitutes 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, as illustrated in Figure 1.

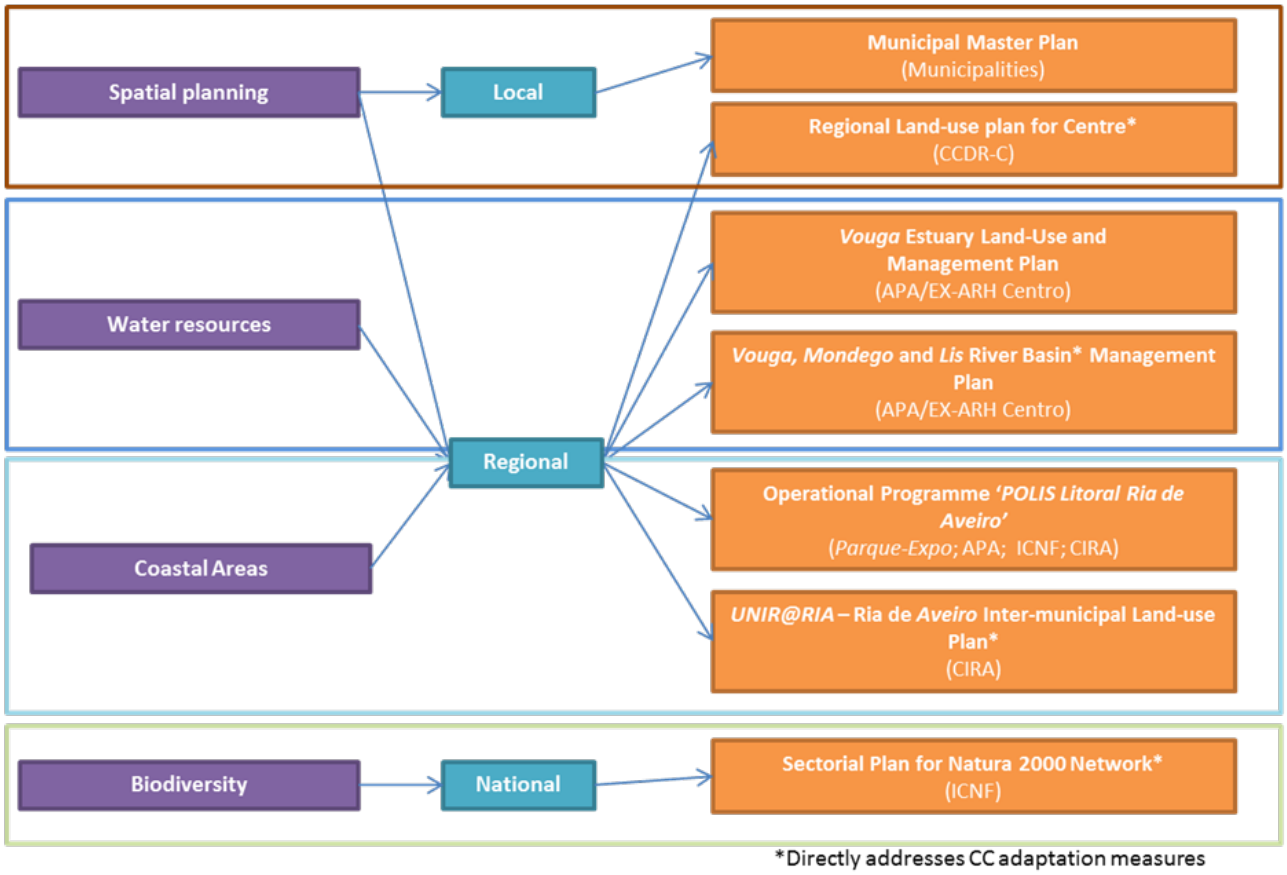

Figure 1 – Spatial planning regulations with application in BVL.

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