“Adaptation to climate change through management and restoration of European estuarine ecosystems”.

C3.6: Report about saltmarsh restoration projects in the Iberian Peninsula

Deliverable ID	**DC3.6**
Action	**C3**
Issue	**1.1**
Due Date of Deliverable	**31/03/2021**
Submission Date	**31/03/2021**
Dissemination level[1]	**PU**
Lead partner	**FIHAC**
Contributors	
Grant Agreement No.	
Call ID	

With the contribution of the LIFE Programme of the European Union

[1]PU = Public; CO = Confidential, only for members of the consortium (including the Commission Services); CL = Classified, as referred to in Commission Decision 2001/844/EC

C3.6: Report about saltmarsh restoration projects in the Iberian Peninsula

Prepared by	Reviewed by	Approved by
Recio, M., Jimenez, M.	Neto, J., Juanes, J.	Juanes, J.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Saltmarshes provide multiple ecosystem services to societies, including maintaining healthy water, protecting the coastal area from flooding and erosion, providing nurseries, and supporting recreational activities, among others. Nevertheless, their integrity has long been threatened by human actions and 50% of saltmarshes are either lost or degraded worldwide (Orth et al . 2006; UNEP, 2006).

Over the last decades, the disappearance of part of these ecosystems, combined with the collective awareness of local populations, the greater scientific knowledge, as well as new European environmental policies, have highlighted the values of these natural habitats and enhanced the implementation of environmental restoration actions.

Historically, the restoration actions were designed to give a natural appearance to the degraded coastal areas. Over time, actions for the restoration and recovery of coastal habitats achieved increasingly promising and satisfactory results regarding biodiversity enhancement and cultural and recreational services, but without taking into account other potential co-benefits. The quantification of these additional services would allow to remark the importance of estuarine restoration actions and to adapt their design to take full advantage of all the ecosystem services that these communities may provide.

Therefore, this work will try to provide an analysis of the climate co-benefits associated with the restoration and conservation of natural estuarine habitats, with particular attention to saltmarsh communities.

2 OBJECTIVE

The main goal of this subaction is to analyze how historical estuarine restoration actions in the Peninsula Iberica may have increased the coastal protection benefits of these ecosystems.

To achieve this goal, a compilation of saltmarshes restoration actions on the Atlantic coast of the Iberian Peninsula has been conducted in order to analyze changes in saltmarshes communities over the years. Considering the results of action A2 (*Climate Change Ecosystem Services: Development of a standardized protocol for the quantification of CC services provided by EU estuaries*), coastal protection benefits derived from those restoration actions have been estimated.

3 STUDY AREAS

The study area integrates the Atlantic coast of the Iberian Peninsula (Portugal and Spain).

According to the revision of scientific and grey literature, in the last 20 years it was possible to identify specific saltmarshes restoration actions at the following locations (Table 1, Figure 1):

Country	Region	Estuary	Year	Action	Description
Spain	Cantabria	Oyambre	2020	Removal of Invasive Alien Species	Removal of Baccharis halimifolia
			2019	Restoration of hydrodynamic conditions	Removal of a dike
		Bahía de Santander	2009-2011	Restoring natural vegetation	
				Removal of Invasive Alien Species	*Cortaderia selloana*
				Landclaim recovery	New coastal lagoon
				Actions for public use	Network of walkways Noticeboards, public services
		Marismas de Santoña	2007	Landclaim recovery	
				Removal of Invasive Alien Species	
		Joyel	2016-2020	Removal of Invasive Alien Species	
				Removal of algae blooms	
				Restoration of tidal dynamics	
		Tina Menor	2016-2018	Removal of Invasive Alien Species	*Baccharis halimifolia*
				Removal of Invasive Alien Species	*Baccharis halimifolia*
	Galicia	A Xunqueira do Areal	2015-2016	Landclaim recovery	Removal of 30,000 m³ of anthropic fills and restoration of 1 ha of vegetation.
				Removal of Invasive Alien Species	
				Restoring natural vegetation	
				Wastewater treatment	
				Actions for public use	Walkway (1500 m) for public use and protection of marshes
		Baldaio	1997	Actions for public use	Implementation of new Public services (access, cleaning…)
			2006	Landclaim recovery	
				Channel realignment	
				Dune restoration	
				Land use management	
	Andalucía	Marismas del Odiel	2003-2006	Removal of dikes	
				Restoring riparian vegetation	

Country	Region	Estuary	Year	Action	Description
				Landclaim recovery	New coastal lagoon (7ha)
				Actions for public use	Bird observatory and walkway
				Wastewater treatment	
			2012	Restoration of marshes	Ecological restoration of *Spartina maritima*
				Actions for public use	Pedestrian paths, noticeboards
		Bahía Cádiz	2003-2006	Restoration of tidal dynamics	Dikes removal
				Actions for public use	
			?	Landclaim recovery	Dredge and restoration of estuarine main channel
				Restoration of hydraulic network	New channel network
				Tidal control	Construcción de compuertas de marea según la técnica salinera tradicional
		Doñana	2005	Dikes oppening	
				Restoring natural vegetation	
				Landclaim recovery	
				Removal of Invasive Alien Species	
				Actions for public use	
				Wastewater treatment	
				Tidal regulations	
				Restoration of hydraulic network	
	País Vasco	Urdaibai	2010-2014	Removal of dikes	Rotura de diques y apertura de munas
				Actions for public use	Pedestrian paths and activities to highlight the cultural heritage
				Removal of Invasive Alien Species	*Baccharis halimifolia*
			2010-2014	Plantationg of natural vegetation	
				Landclaim recovery	
				Removal of Invasive Alien Species	*Baccharis halimifolia*
				Actions for public use	Dissemination material, recreative actions
		Txingudi	2013	Removal of Invasive Alien Species	*Baccharis halimifolia*

Country	Region	Estuary	Year	Action	Description
		Zarautz	2020	Removal of dikes	Removal of reinforcements
			2010	Removal of Invasive Alien Species	
				Dikes removal	
				Restoration of natural vegetation	
Portugal	Centro	Ria de Aveiro	2020	Inclusion of saltmarshes in the Carbon Neutrality Roadmap 2050	
		Figueira da Foz	1997/98	Restoration of hydrodynamic connexions	
	Lisboa	Estuário do Tejo	2013	Actions for public use	Activities to promote the importance of saltmarshes and the need to preserve it
		Estuário do Sado	2019	Pedestrian paths	Construction of piers to avoid walking on the marsh. (Neto et al., 2019)
	Algarve	Ria de Alvor	2007	Saltmarshes revegetation	
				Topographic restoration and sediment suppy	
		Ria Formosa	2006	Creation of public parks	
				Pedestrian paths	
				Saltmarshes revegetation	

Table 1. Study sites at the Atlantic coast of the Iberian Peninsula.

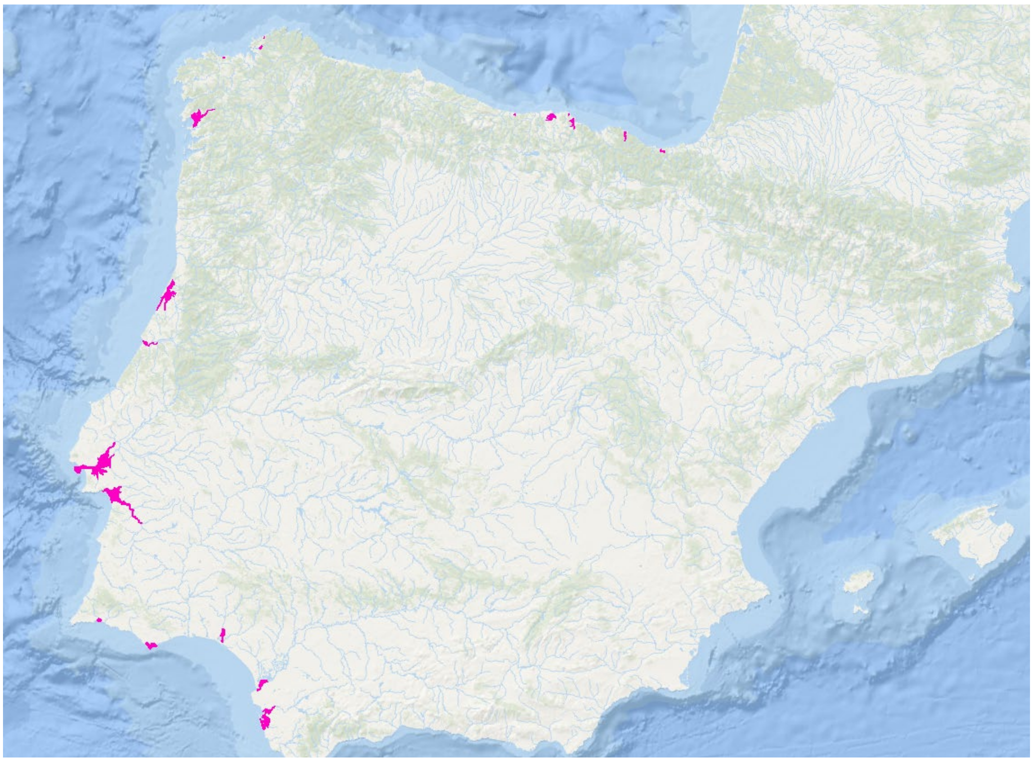

Figure 1. Location of study sites.

4 SALTMARSHES EVOLUTION

In general, there is no available homogenous information about the evolution of estuaries after the restoration actions. Therefore, the evolution of the saltmarshes communities after the implementation of these restoration measures has been analysed using information from European databases (i.e. Corine Land Cover data) and information from remote sensors (satellite imagery).

In general, this work monitors the estuarine evolution based on the analysis of changes in the land uses, according to the information from the Copernicus land monitoring service from the European Union (Corine Land Cover data). Nevertheless, taking into account that the minimum mapping unit of Corine Land Cover inventory is about 5 ha, the LIFE AdaptaBlues project has developed a new methodological approach to analyze the changes in the saltmarsh communities of smaller estuarine areas based on the analysis of remote sensing imageries. This approach is shown in Annex I.

The main results for each estuarine system are described in the following headings.

4.1 Oyambre

The estuary of Oyambre (1 km^2) suffered different restoration actions in 2018-2019 by the removal of an estuarine dike and the control of the invasive alien species *Baccharis halimifolia* (CONVIVE LIFE project, www.convivelife.es). These actions lead to changes in the hydromorphological estuarine characteristics and estuarine communities' distribution.

Following the methodological approach described in Annex I, it was possible to define the changes in the estuarine vegetation distribution due to remote sensing data (images from Sentinel 2A) and calculates the evolution of their surface, which has been increased during the last four years (Figure 2, Figure 3).

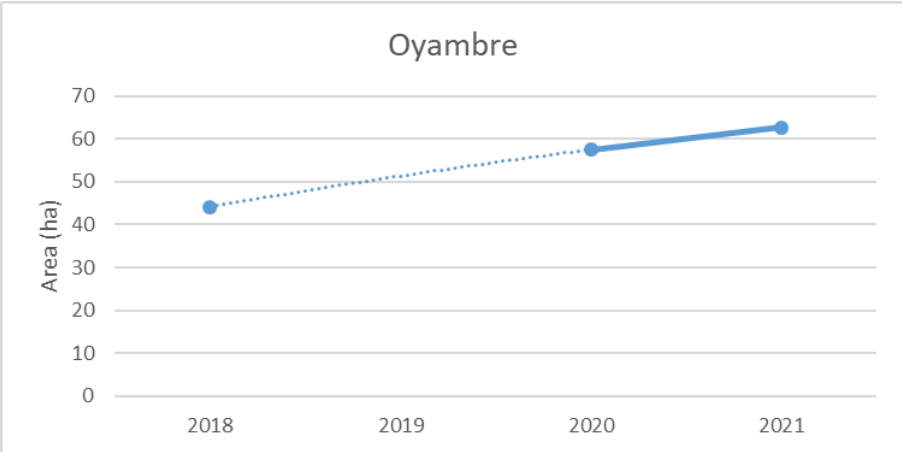

Figure 2. Evolution of saltmarsh surface in Oyambre between 2018 and 2021.

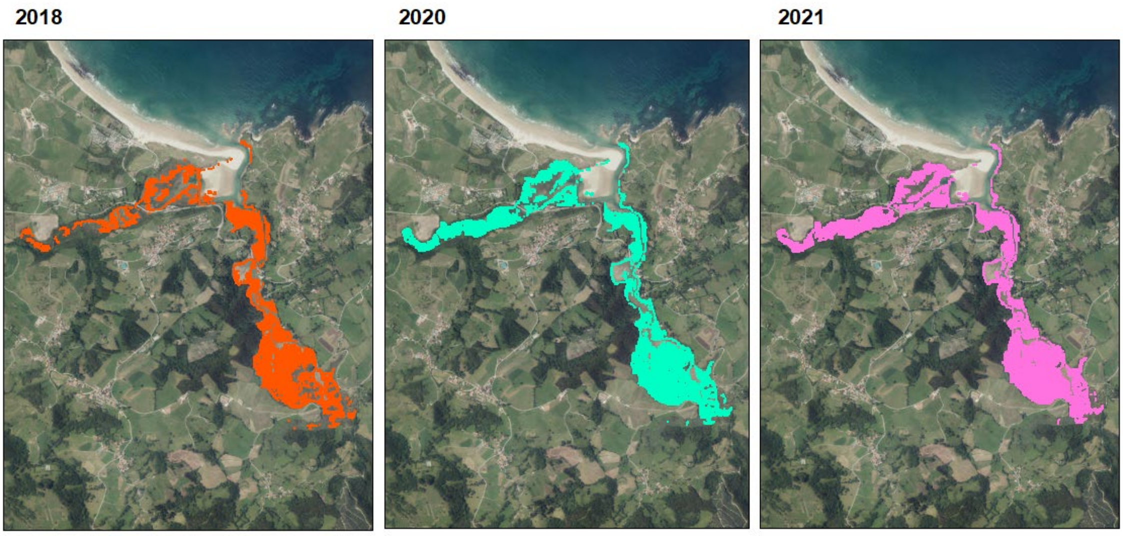

Figure 3. Distribution of saltmarsh communities in Oyambre between 2018 and 2021 according to the methodological approach described in Annex I.

It is important to note that these results are consistent with the information from the monitoring actions carried out by the LIFE CONVIVE project (LIFE14 NAT/ES/001213), which developed the habitat cartography of this estuarine system both in 2018 and 2020. Those cartographies also showed an increase in the natural estuarine vegetation.

4.2 Bahía de Santander

Santander Bay is the biggest estuary of Cantabria (22.7 km^2). It is an estuary confined by a sandy spit in the mouth ("Somo" spit), which gives it important protection against sea storms. As a result, the Santander Bay surface is a harbor area.

During 2000-2011 different restoration actions have been implemented in the inner estuarine area, at the *Marismas Blancas* (Figure 4). It is a small area (15 ha) in which different restoration projects have been implemented by the environmental NGO SeoBirdlife and the municipality. It was a landclaim area that was recovered as a freshwater coastal lagoon. Invasive Alien Species were removed and degraded areas were recovered.

Figure 4. Emplacement of the study site.

There is no cartographical information about the evolution of this area over the last 15 years, but the analysis of Landsat imageries shows that restoration actions led to a quick increase in the vegetated area (2007-2009). Since then, the vegetated area has remained stable (Figure 5, Figure 6). It is important to note that the small variation shown in Figure 5 can be attributed to changes in tide level between the different images.

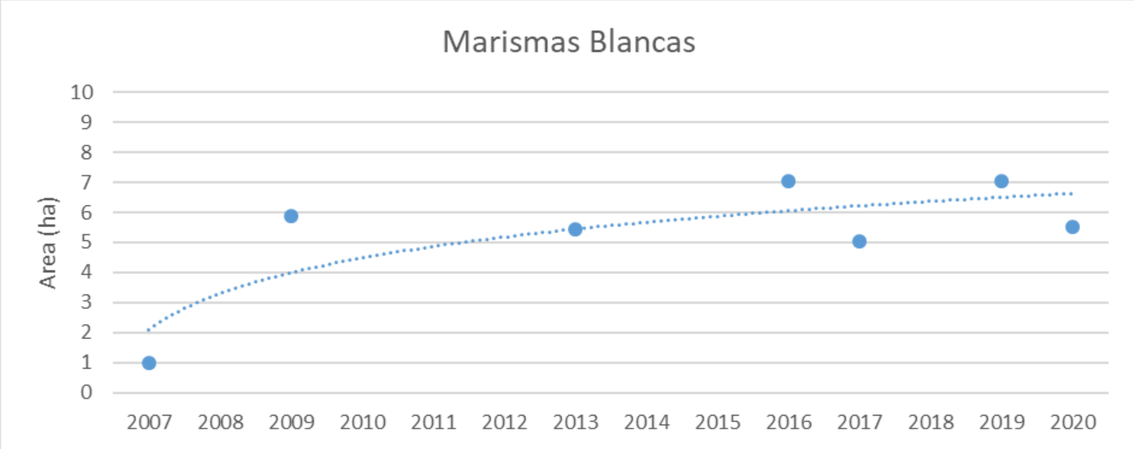

Figure 5. Evolution of the vegetal communities' surface in the Marismas Blancas (Santander Bay) between 2007 and 2020.

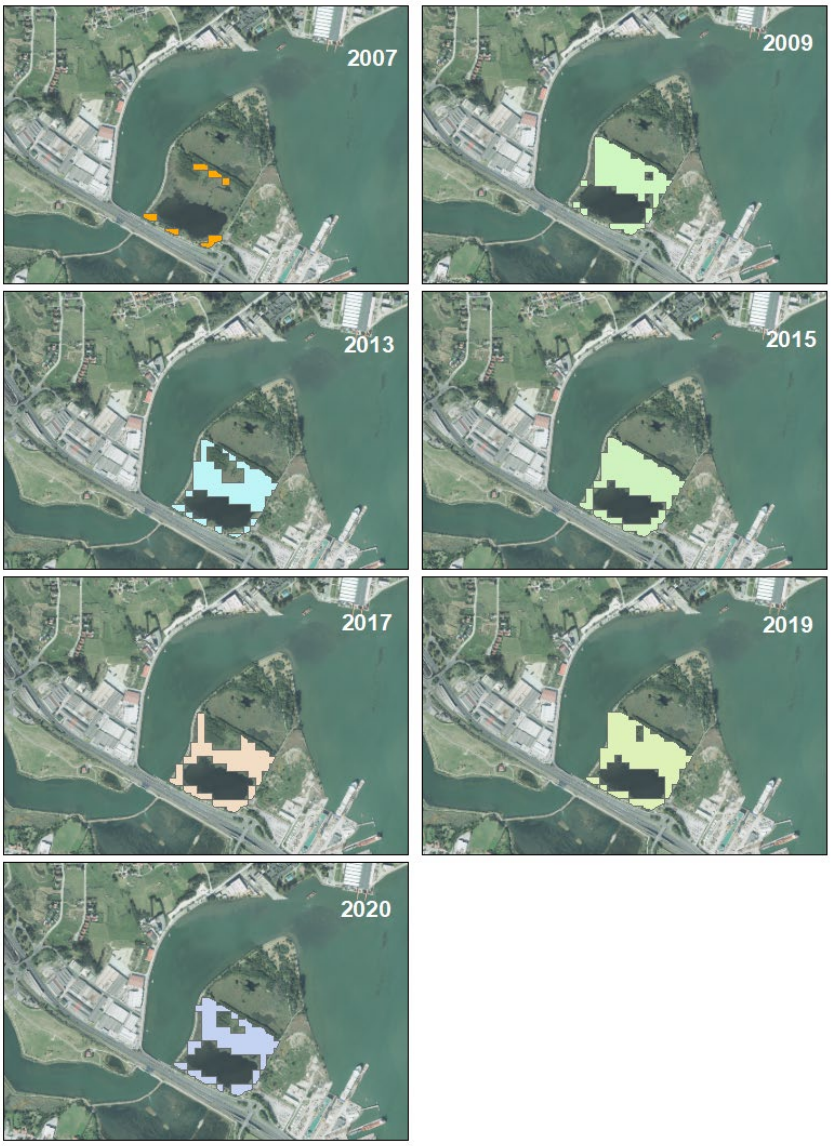

Figure 6. Distribution of saltmarsh communities in Santander Bay (Marismas Blancas) between 2007 and 2020 according to Landsat data.

4.3 Marismas de Santoña

In 2004, 13 ha of the estuarine surface were restored through the removal of a dike and the elimination of different invasive alien species in the Montehano marshes (Marismas de Santoña, Figure 7), in Cantabria.

Figure 7. Emplacement of the study site (Montehano marshes) inside the Santoña marshes.

Since then, some saltmarsh communities have developed around the edge of the marsh, but there is no continuous information available on the evolution of these communities.

Trying to analyze the evolution of these restoration actions by the methodological approach using by this work, the analysis of Landsat imageries (with a spatial resolution of 30 m) doesn't allow us to identify changes in the distribution of saltmarsh communities and their surface seems to be stable over time (Figure 8).

In the same way, information about Corine Land Cover program is not suitable for this monitoring due to their spatial resolution. Moreover, the Sentinel satellite was launched in 2015, so there are no earlier images from this.

Therefore, it is not possible to define the changes in the surface areas of these communities over the years using these remote sensing.

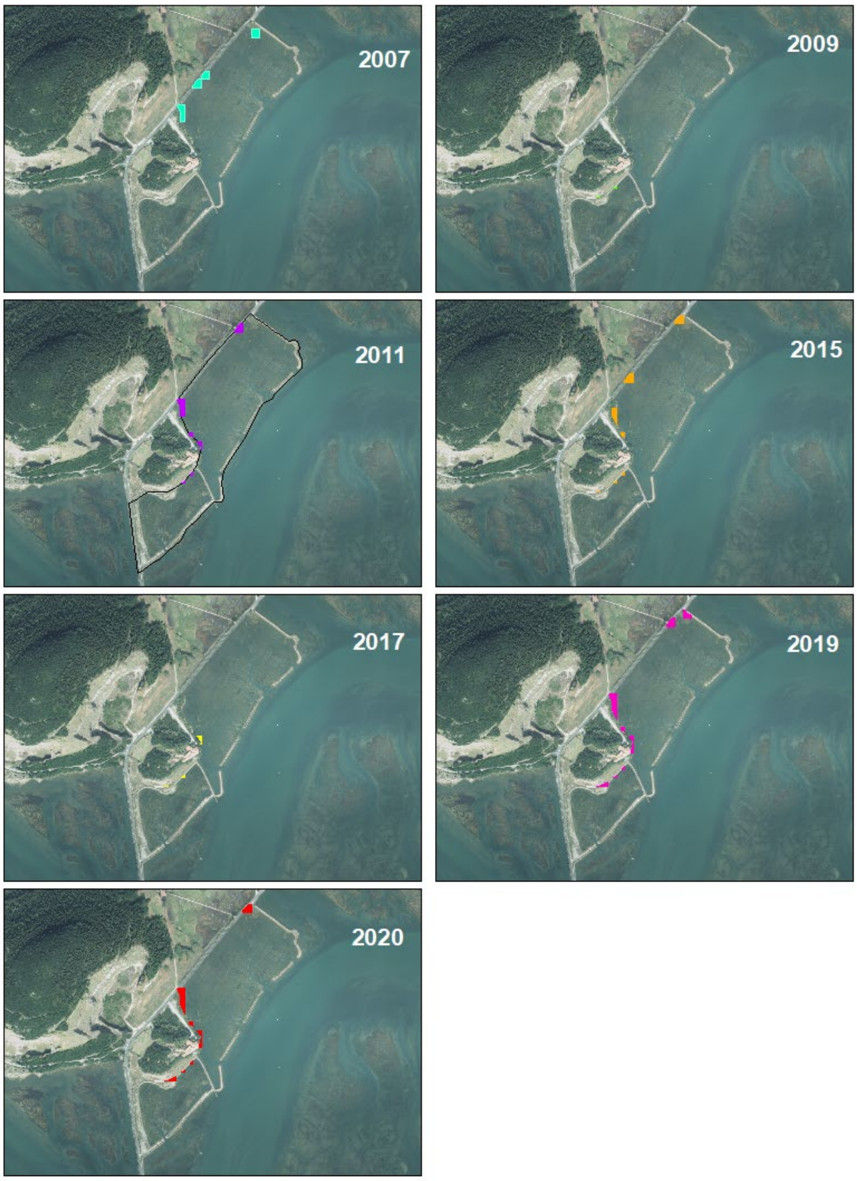

Figure 8. Evolution of the vegetal communities in Montehano (Santoña marshes) between 2007 and 2020 according to Landsat information.

4.4 Marismas de Joyel

Joyel marshes is a small estuarine area placed in the east of Cantabria. This estuary has suffered an important human impact due to the construction of isolating and fill dams, which led to the creation of two large lagoons inside the estuary. In order to decrease the degree of eutrophication of these lagoons, different restoration actions were implemented in 2017 (i.e. removal of green algae blooms and rehabilitation of the flooding dynamics in the Joyel pond) in the framework of the European CONVIVE LIFE project.

According to the information derived from satellite analysis (Sentinel), algae blooms have not been completely controlled and the vegetal area has been quite stable over the last few years

(Figure 9, Figure 10). As in the case of the estuary of Oyambre, these results are consistent with the monitoring results of the CONVIVE LIFE project, which analyzed the evolution of the saltmarsh communities of Joyel from 2016 to 2020.

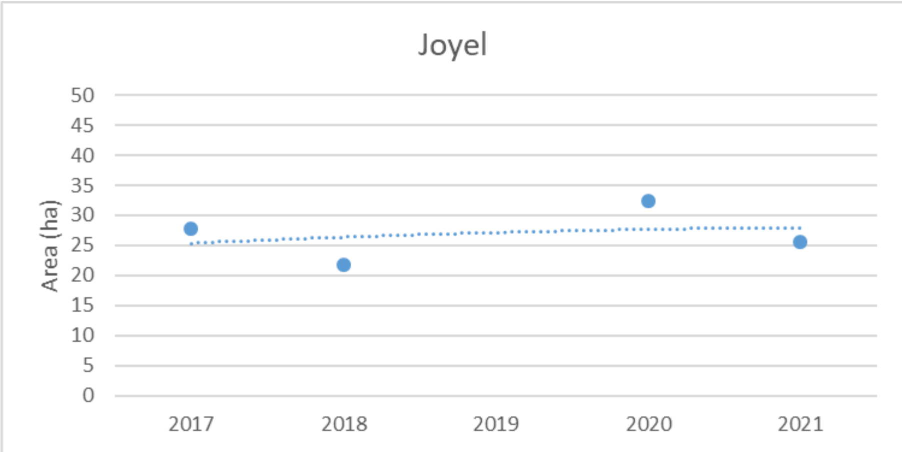

Figure 9. Evolution of the vegetal communities' surface in Joyel between 2017 and 2021.

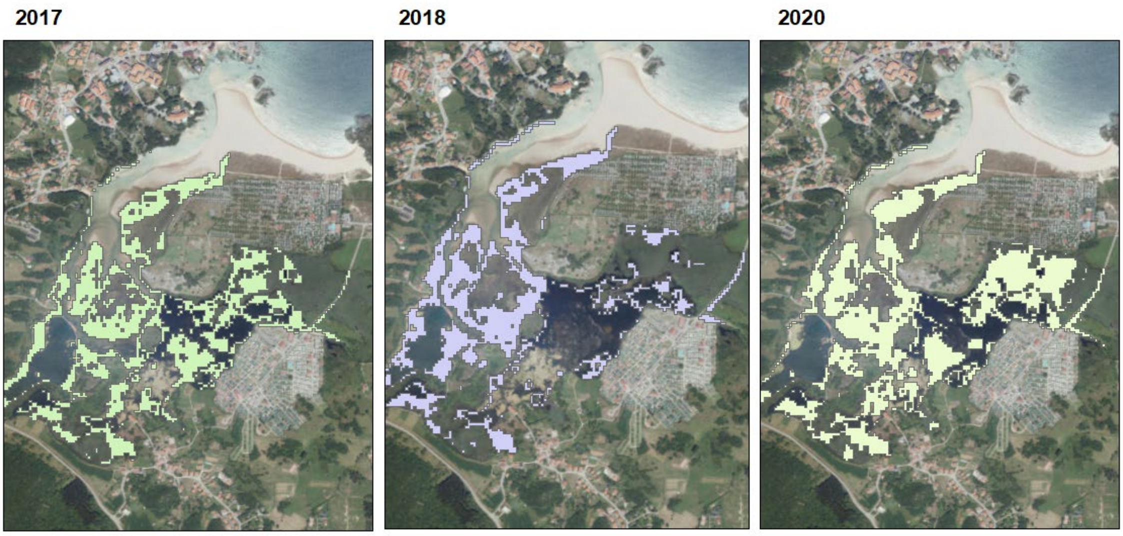

Figure 10. Distribution of vegetal communities in Joyel between 2017 and 2020.

4.5 Tina Menor

Following the restoration actions implemented by the CONVIVE LIFE project, a removal of invasive alien species (*Baccharis halimifolia*) was carried out in the estuarine area of Tina Menor during 2016-2018.

Based on the methodological approach described in Annex I, the imageries from Sentinel allows us to follow the evolution of saltmarsh communities in this estuarine area. As it is shown in Figure 11, after the removal of *Baccharis halimifolia*, saltmarshes increased their coverage over the years.

Due to the high cloud coverage during summer in the area of Tina Menor, there is no data about the years 2019 and 2020. The sentinel images taken during the low tide of these summer times were covered by clouds, so it is not possible monitoring the vegetation distribution from this remote information.

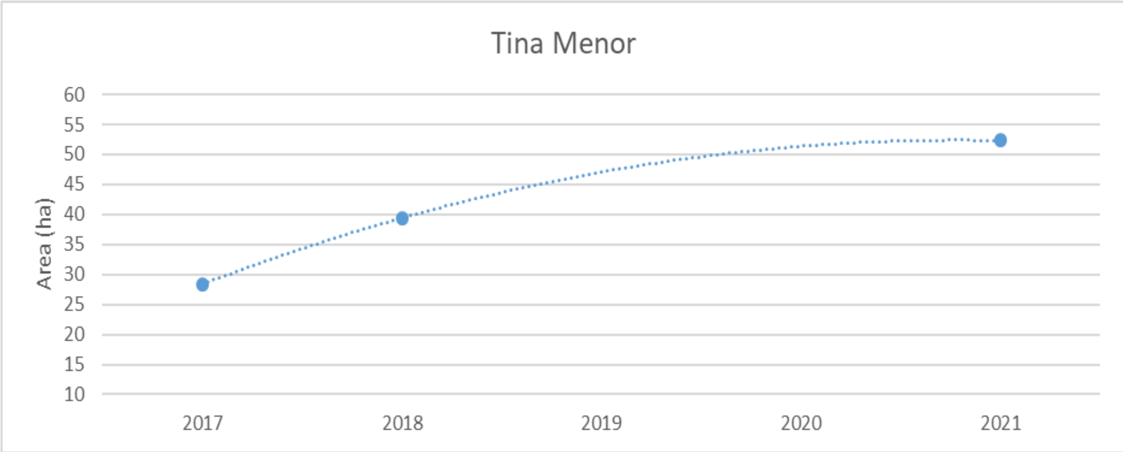

Figure 11. Evolution of the saltmarshes communities' surface in Tina Menor between 2017 and 2021

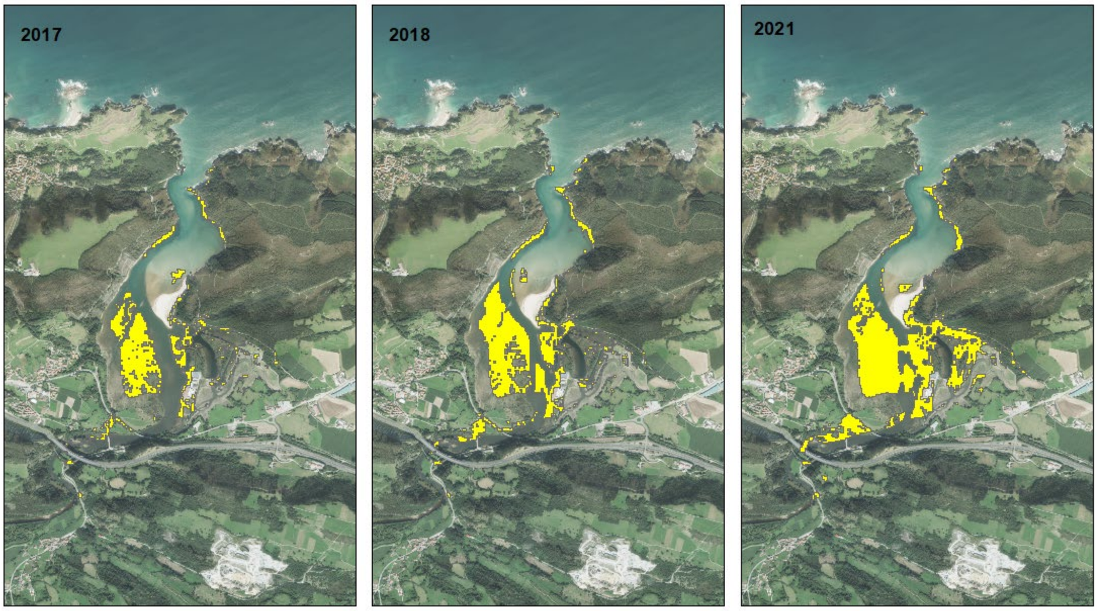

Figure 12. Distribution of saltmarshes in Tina Menor between 2017 and 2021 according to Sentinel data.

4.6 Baldaio

The coastal lagoon-dune system of Baldaio is placed on the northwest coast of Galicia. This natural area has suffered a historical degradation, with different sand mining processes that modified the morphology and hydrology of this coastal area due to the removal of sediments and the building of roads. Nevertheless, since the '90s, different environmental restoration actions were put in place (i.e. land claim recoveries and dune plantations) trying to recover the environmental value of the system.

As the first restoration actions were carried out before the Sentinel satellite was launched, the vegetation analysis has been done using information from the Corine Land Cover program. This data shows that the area covered by saltmarshes has been stable from 1990 to 2018, with a total surface close to 69 ha (Figure 13). Differences between 2006 and 2012 are mainly due to the changes in the Corine program for data analysis.

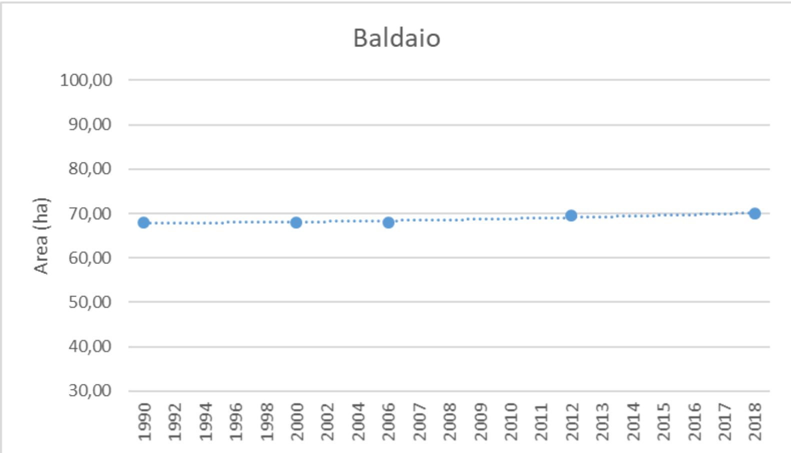

Figure 13. Evolution of the saltmarshes communities' surface in Baldaio between 1990 and 2018.

4.7 A Xunqueira do Areal (Ría de Arousa)

The Ría de Arousa is the biggest estuary of Galicia, with a surface of 23000 ha. Although this estuarine area is dominated by open waters, the estuarine margins show a great development of saltmarsh communities, dune habitats, and natural grasslands.

During 2016 different restoration actions have been implemented in a small area (5 ha) close to Pobla do Caramiñal, which is placed inner the estuarine area (Figure 14). These actions included land claim recoveries and the removal of invasive alien species.

Figure 14. Location of the study area inside the Ría de Arousa.

Taking into account that Corine land cover data doesn't recognize the changes of this small area, which is classified as *Urban fabric*, the analysis of this estuary has been made using the methodological approach based on the interpretation of images from the Sentinel satellite.

Therefore, according to the Sentinel data, the study area suffered a change between 2015 and 2016 which resulted in an increase in the area occupied by saltmarshes of about 0.5 ha (Figure 15 and Figure 16). After this increase, the surface area of saltmarshes seems to be stable over time.

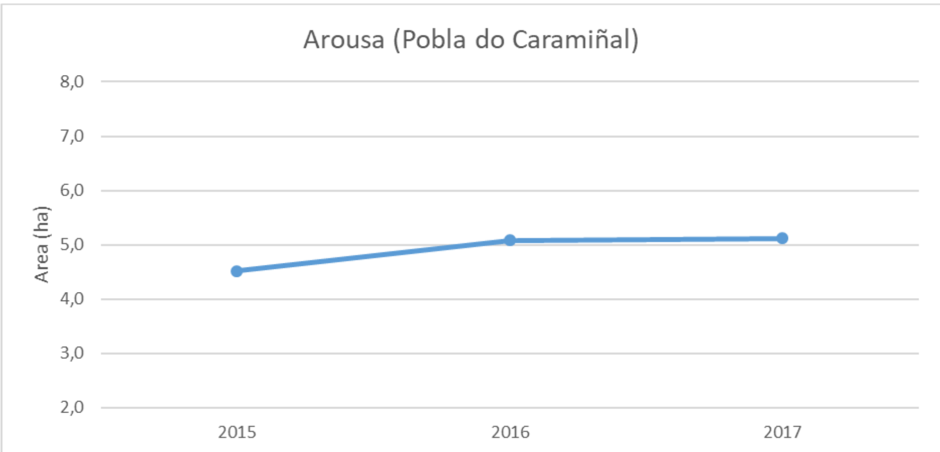

Figure 15. Evolution of the saltmarshes communities' surface close to Pobla do Caramiñal between 2015 and 2017.

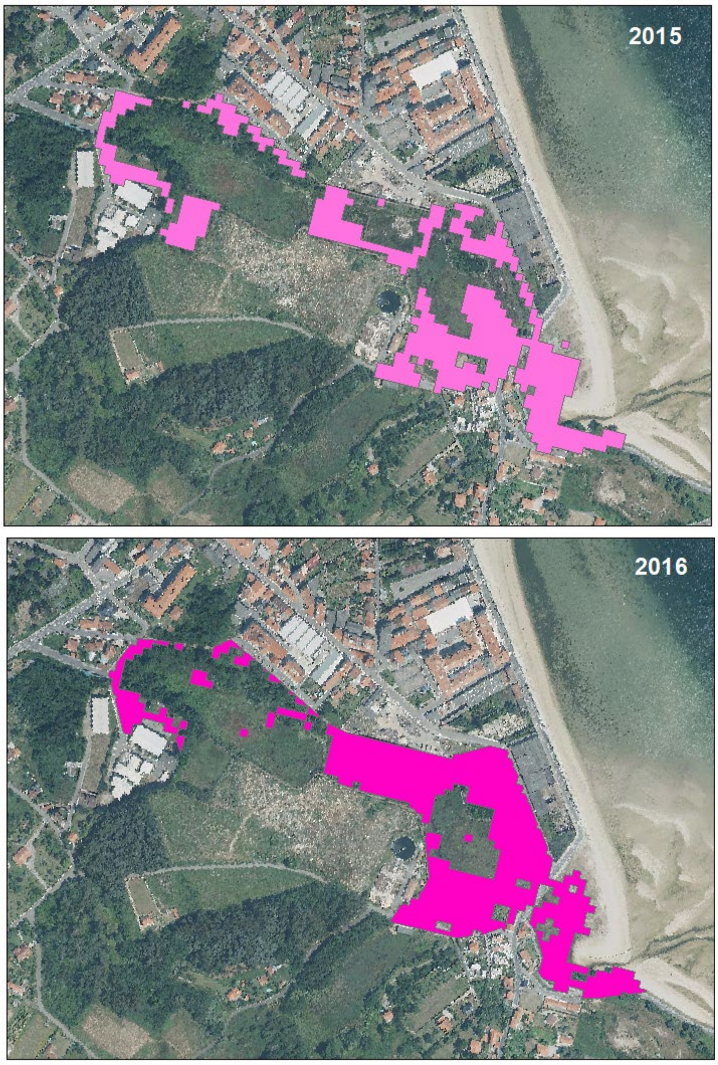

Figure 16. Distribution of estuarine vegetal communities close to Pobla do Caramiñal between 2015 and 2016 according to the process of Sentinel images.

4.8 Marismas del Odiel

The Odiel marshes is the second biggest wetland in the province of Huelva (after Doñana). This protected area is located at the confluence of the rivers Tino and Odiel, and it was declared a Biosphere Reserve due to its importance for protected birds.

Around 2006, different restoration actions were carried out in this protected area: the removal of dikes, the control of invasive alien species, and the recovery of land claim areas, among others. Moreover, in 2012, the Port of Huelva launched an environmental restoration plan which implied the restoration of saltmarsh communities (i.e. *Spartina maritima*) and the development of public infrastructures.

Taking into account the information of Corine Land Cover (1990-2018), it was possible to calculate the losses and gains of the marsh area in Odiel. Therefore, the restoration actions of 2006-2012 implied an increase in the saltmarshes surface which has been sustained over the years (Figure 17).

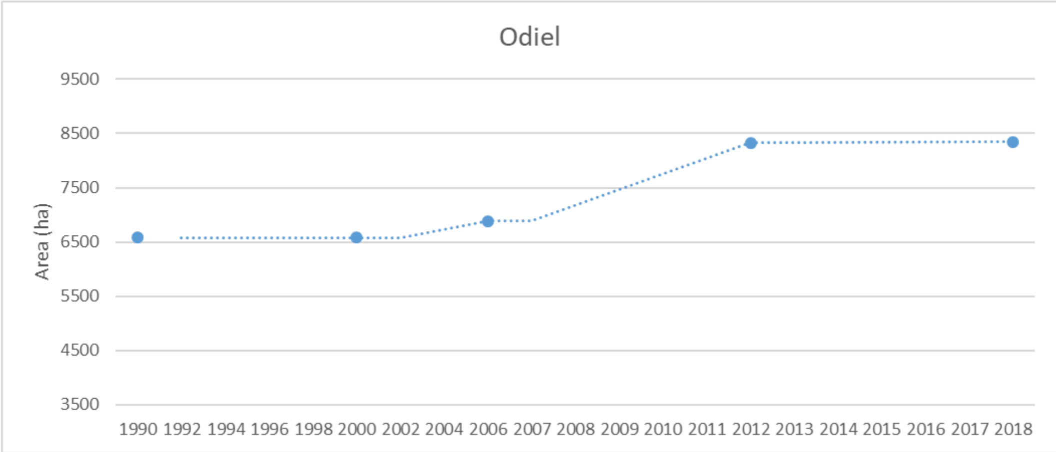

Figure 17. Evolution of the saltmarshes communities' surface in Odiel marshes between1990 and 2018.

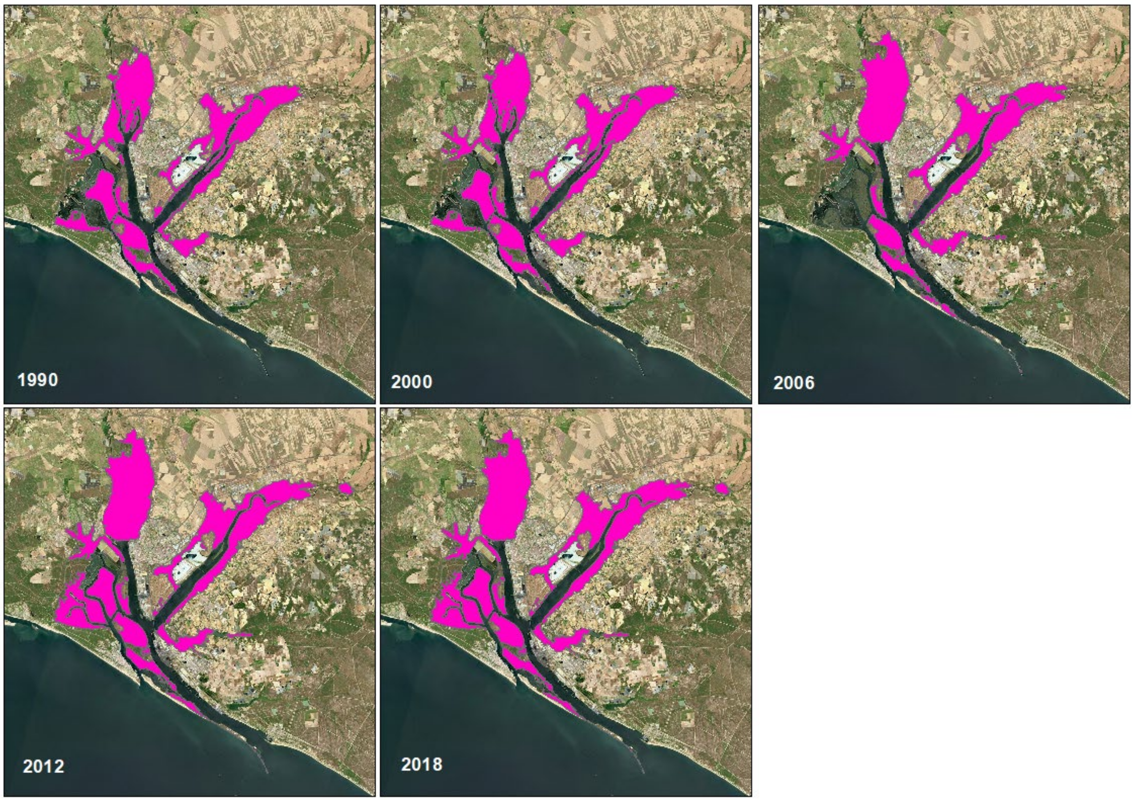

Figure 18. Evolution of the distribution of saltmarshes in Odiel between1990 and 2018 according to Corine Land Cover data.

4.9 Bahía de Cadiz

Following the restoration actions taken place in other coastal areas of Andalucía, in 2003-2006 different restoration activities were carried out in the Bay of Cadiz (i.e. LIFE03 NAT/ES/000054 project). This estuarine area, placed on the south Atlantic coast of the Iberian Peninsula is characterized by the presence of a high number of saltpans. The historical transformation of these wetlands for salt extraction was already documented several centuries ago and the result was a complex area of saltpans, natural marshes and channels.

The restoration actions carried out before 2006 included the restoration of abandoned saltpans, the recovery of hydrodynamic conditions by the removal of dikes and the restoration of natural vegetation (mostly dune communities). The analysis of the Corine Land Cover data allows us to identify the results of these activities. Thus, just after the implementation of the different restoration activities, it is possible to identify a response in the marsh communities, which increases their surface during the restoration period and seems to stabilize after them (Figure 19).

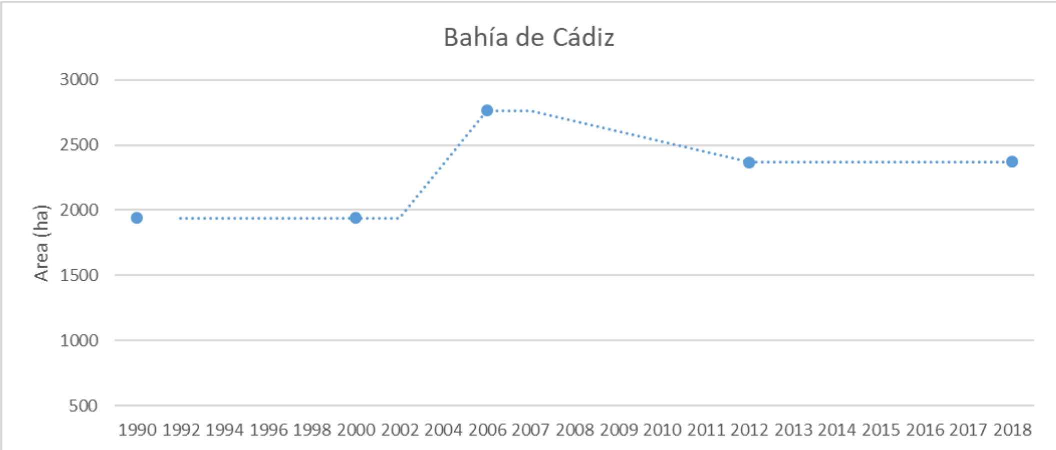

Figure 19. Evolution of the saltmarshes communities' surface in the Bahía de Cádiz between1990 and 2018.

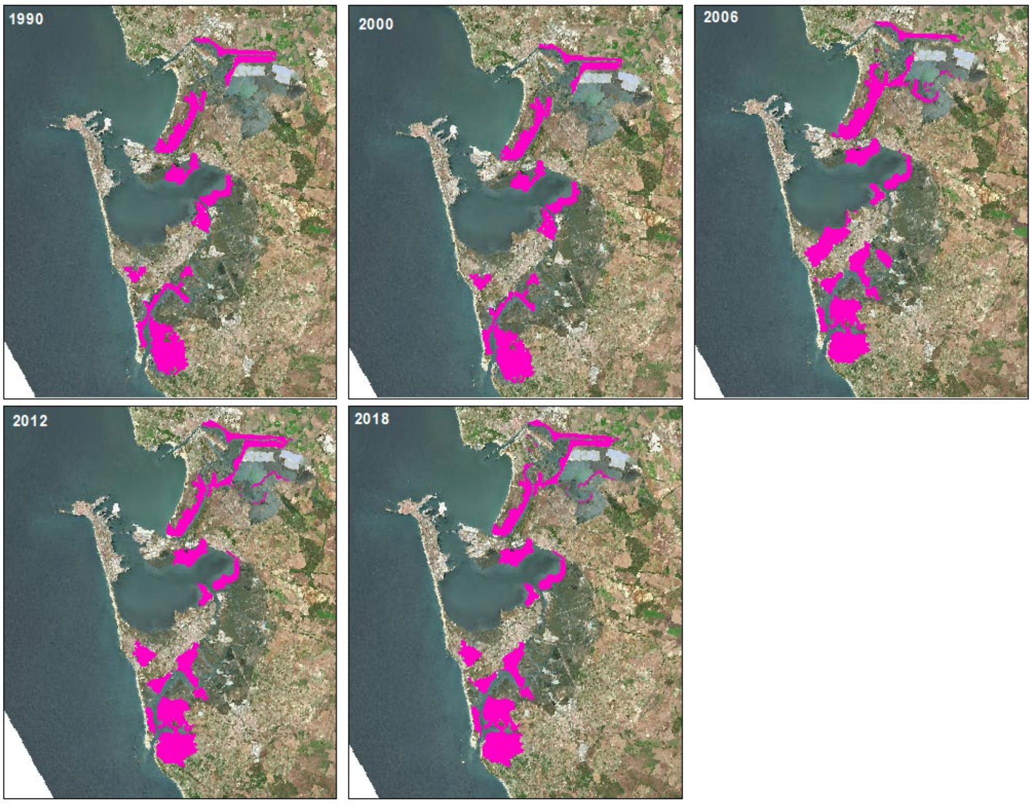

Figure 20. Evolution of the distribution of saltmarsh communities in the Bay of Cadiz between1990 and 2018.

4.10 Doñana

The wetland of Doñana (National Park, Ramsar site, UNESCO Biosphere reserve, Nature Reserve and Natura 2000 site), placed on the south Atlantic coast of the Iberian Peninsula, is one of the most valuable wetlands of the European coastal area. Despite of its environmental importance, this ecosystem has been under constant threat along time, by agricultural uses (draining marsh areas), water pollution, tourism and mining.

After the mining environmental catastrophe of Aznalcóllar (1998), the Spanish ministry of environment promoted a restoration program ("Doñana 2005") with the aim to regenerate the environmental value of this wetland. It is important to note that this restoration project included both hydrological and ecological restoration activities, such as the recovery of flooding areas, the control of aquifer overexploitation, the restoration of abandoned agricultural lands and the introduction of endangered species (i.e. Imperial eagle and Iberian lynx).

These restoration actions led to a significant increase in the saltmarsh communities' surface which, based on the Corine Land Cover data, amounted 30000 ha (Figure 21, Figure 22).

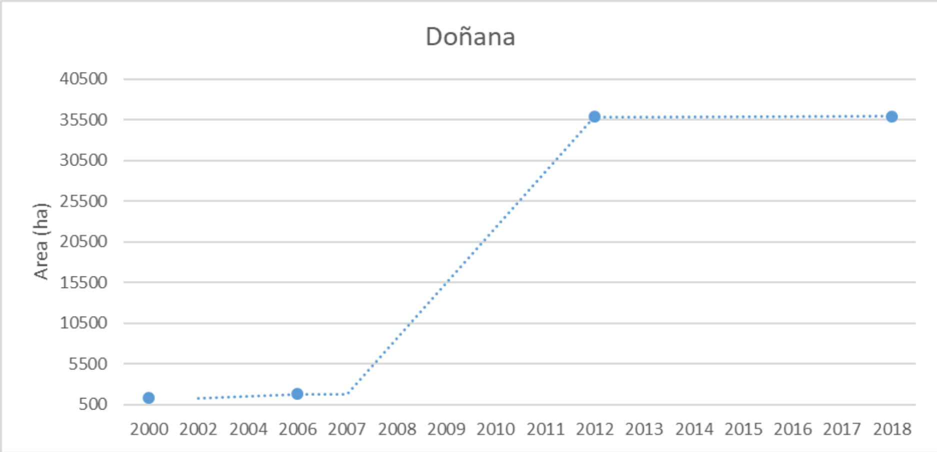

Figure 21. Evolution of the saltmarshes communities' surface in Doñana between2000 and 2018.

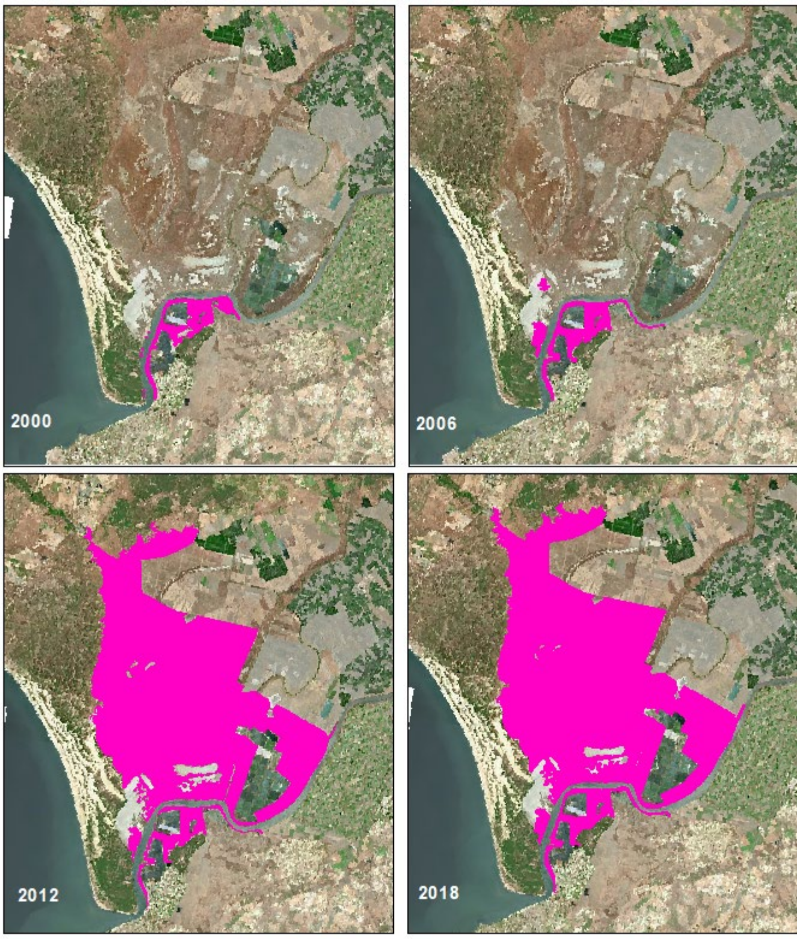

Figure 22. Evolution of the distribution of saltmarsh communities in Doñana 2000 and 2018.

4.11 Urdaibai

The Urdaibai wetland (also named Oka estuary), that is placed in northern Spain, was declared a biosphere reserve in 1984 because of their extraordinary biodiversity. Indeed, this wetland was included in the Ramsar Convention in 1996 and it was declared a Natura 2000 site in 1994.

Despite its environmental value, Urdaibai suffered substantial degradation in the past, due to conflicts between public and private interests, and historical land uses, among others. In order to reverse this situation different restoration actions have been implemented during the last decades, such as the elimination of 190 ha of *Baccharis halimifolia* during 2011 (LIFE+ project LIFE08 NAT/ES/000055), the restoration of coastal dune vegetation during 2001-2007 (LIFE04 NAT/ES/000031), or the restoration of tidal dynamics due to inner dikes opening (2010).

The restoration activities and the management plans of this protected area allowed to restore a large area of saltmarshes. According to Corine Land Cover data, this surface tripled in size from the 2000s (Figure 23).

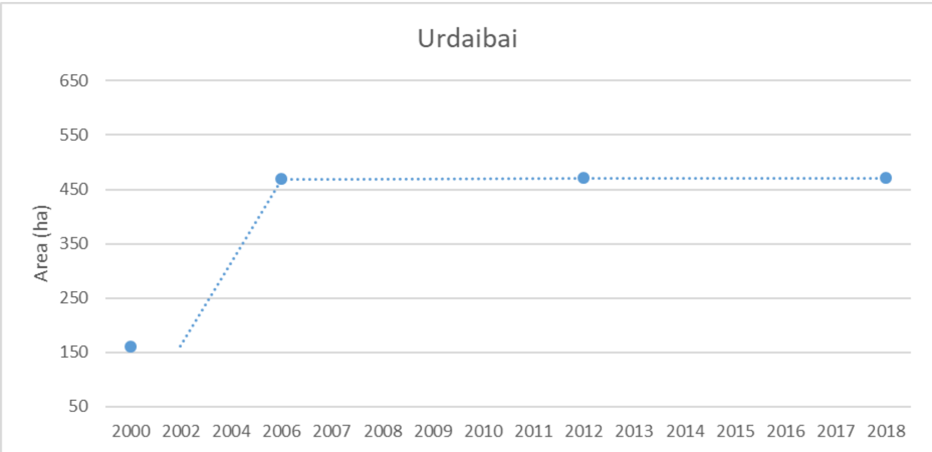

Figure 23. Evolution of the saltmarshes communities' surface in Urdaibai between2000 and 2018.

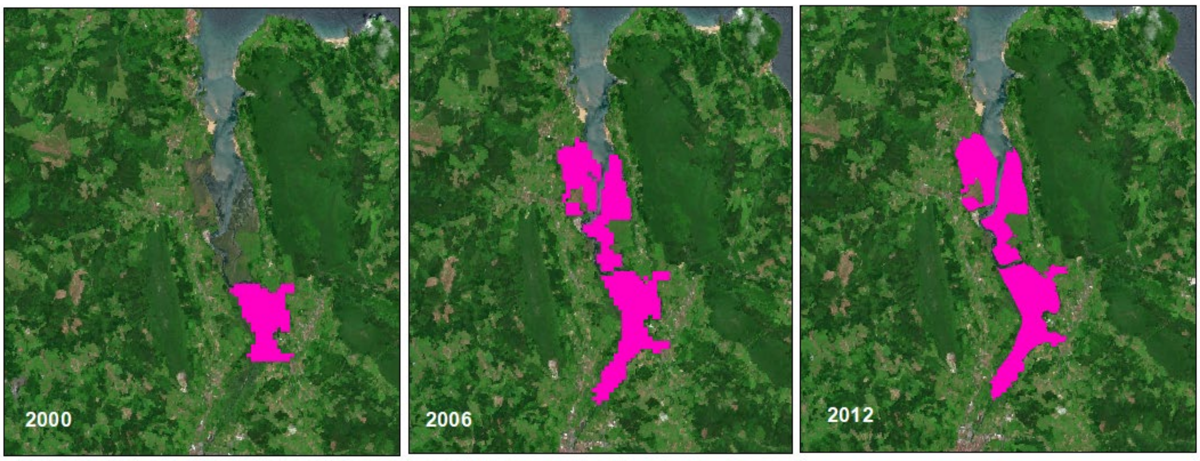

Figure 24. Evolution of the distribution of saltmarsh communities in Urdaibai between 2000 and 2012.

4.12 Txingudi

The bay of Txingudi constitutes a natural frontier with France. This estuarine area suffered different restoration actions in the framework of some European LIFE projects, which led to the removal of IAS in a total area of 4 ha at Santiagoaurra's island. These areas have been recolonized by saltmarsh communities, which have significantly increased their extension (Figure 25).

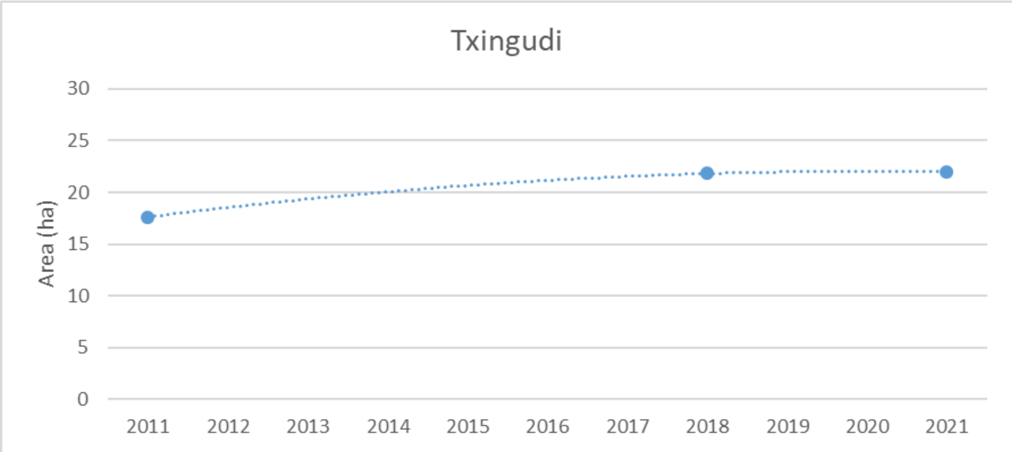

Figure 25. Evolution of saltmarsh surface at Santiagoaurra's island (Bay of Txingudi) between 2011 and 2022.

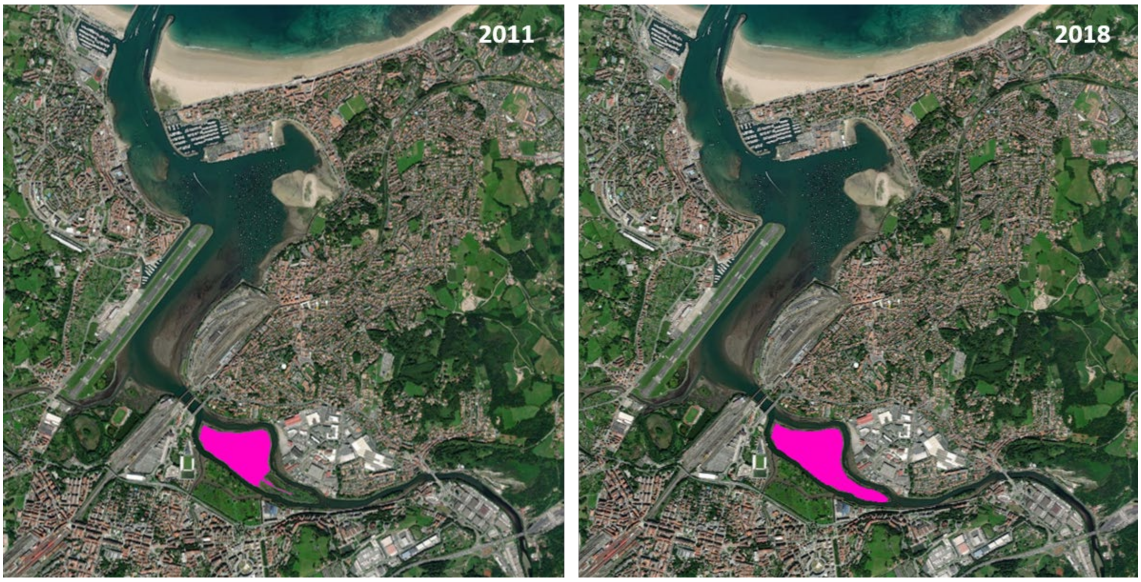

Figure 26. Evolution of the distribution of saltmarsh communities in Txingudi (Santiagoaurras Island) between 2011 and 2018.

4.13 Zarautz

The estuary of Zarautz, a small estuarine area which is placed in northern Spain, suffered different restoration actions in 2010 and 2020 regarding the removal of dikes and the control of IAS.

Due to these hydrodynamic and environmental interventions, the saltmarsh communities have been widely spread (Figure 27). As it is shown in Figure 28, estuarine vegetation has occupied the areas where tidal flow was previously limited and its area has more than doubled in size.

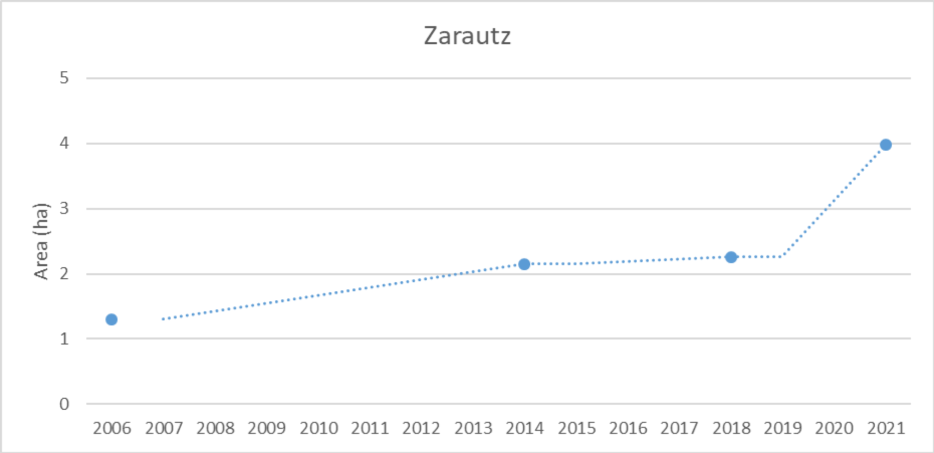

Figure 27. Evolution of saltmarsh surface in Zarautz between 2006 and 2022.

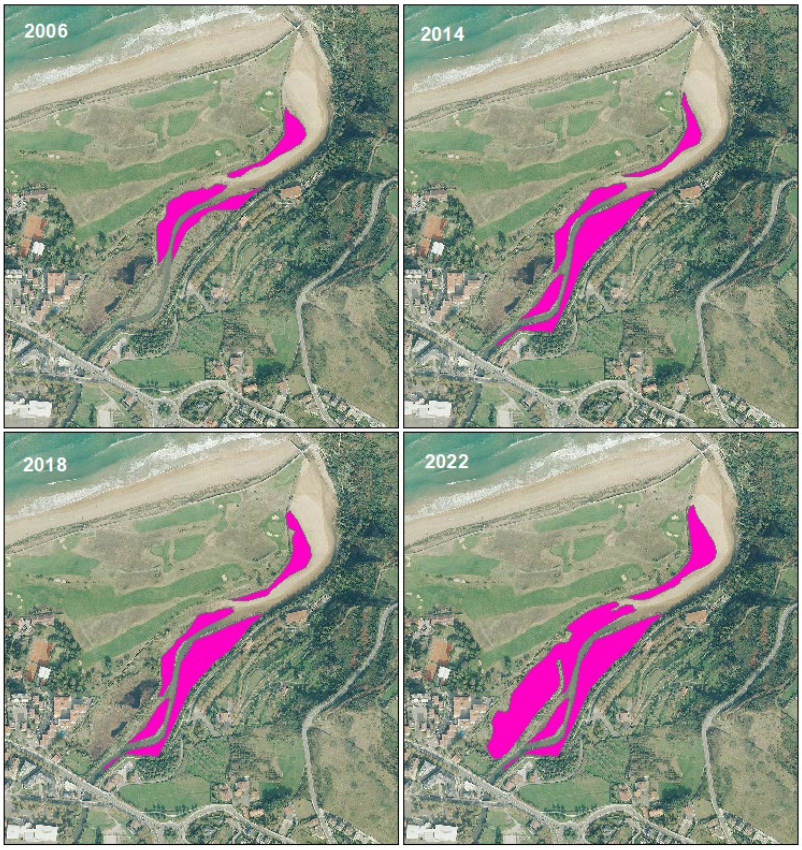

Figure 28. Distribution of saltmarsh communities in Zarautz between 2006 and 2018.

4.14 Caminha

The estuary of Caminha (40 km^2) is the estuary of the Minho River. It is a mesotidal-stratified estuary, with a tidal range of 2 meters and a residence time of 1.5 days (Ferreira et al., 2005).

Although there were no specific restoration actions, the restriction of agricultural activities over time, as well as land use reclassifications, has resulted in an increase of the area occupied by the saltmarshes present in the Minho estuary.

According to the information of Corine Land Cover, the area of saltmarshes is constant between 1990 and 2006 (Gonçalves et al. 2016), close to 91 ha. This area is increasing to 273 ha in the year 2006, but there is a decrease to 229 ha in 2012 (Figure 29).

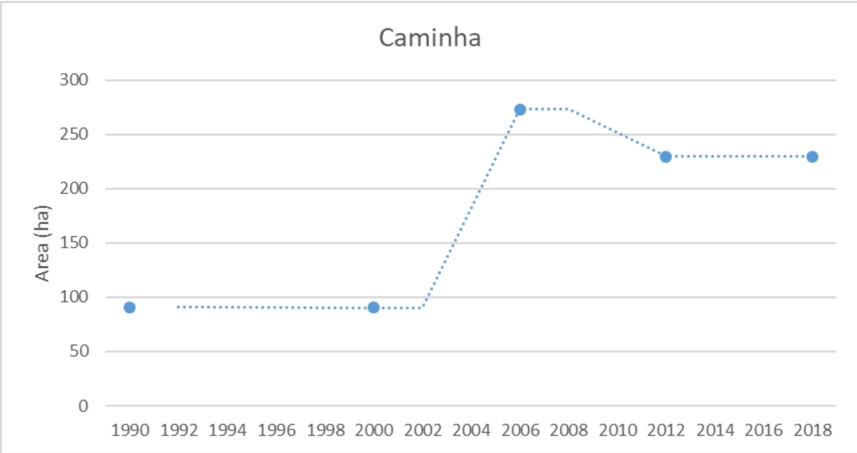

Figure 29. Evolution of saltmarsh surface in Caminha between 1990 and 2018.

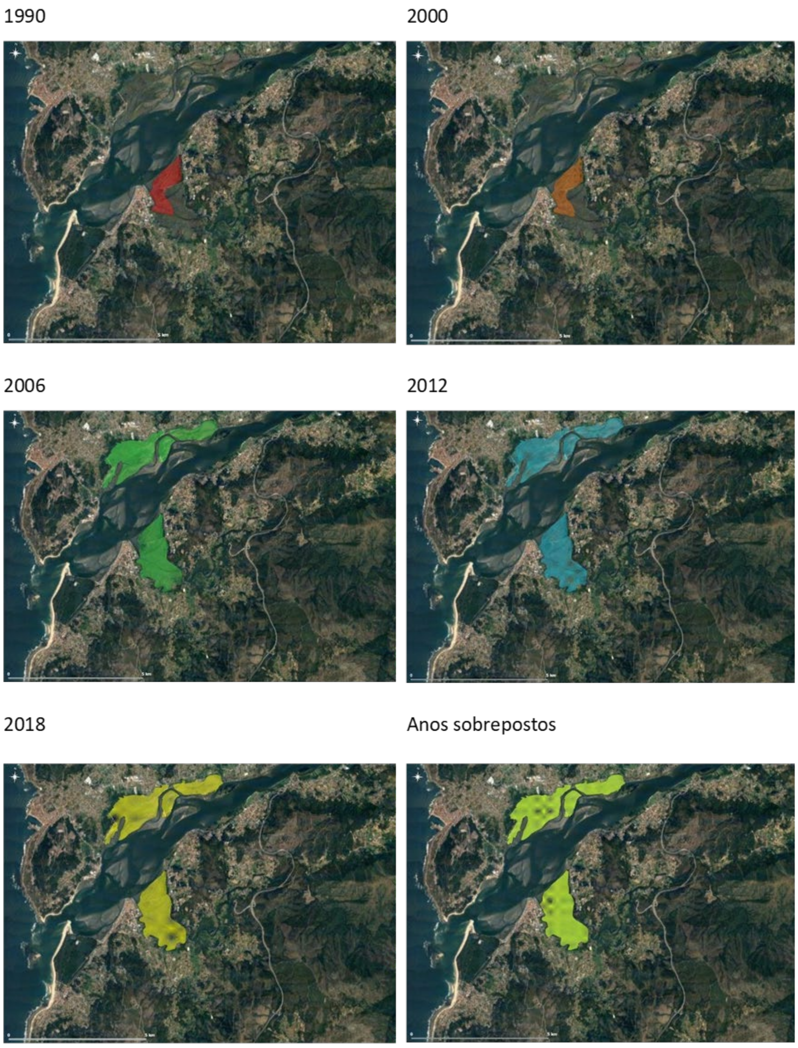

Figure 30. Distribution of saltmarsh communities in Caminha between 1990 and 2018.

4.15 Ria de Aveiro

The Ria de Aveiro is a wide, shallow estuary, with a configuration that resembles a coastal lagoon.

The saltmarshes of the Ria de Aveiro have suffered a process of regression since the 1980s. Changes in the hydrodynamics of the system (Silva, Duck, 2001, Silva et al., 2009), resulting from port activities, also led to a generalized loss of biodiversity (Duck, Silva, 2012). Nevertheless, the movement to put in value natural ecosystems, with proposals to reverse trends of decline, has also occurred in this estuary.

Taking into account the information of Corine Land Cover (1990-2018), it was possible to calculate losses and gains of the marsh area (Figure 31) and to produce maps about saltmarshes distribution (Figure 32). An increase is observed from 1990 to 2000, mainly northwest of the estuary and to the east. This value is reduced in 2006, and further reduced in 2012. The following phase, until 2018, the saltmarsh shows signs of recovery and reaches 6,242 ha. From the maps of the overlapping years, one can see what was lost in terms of area and spatial form, in the year 1990 (in red) and in the year 2000 (in brown), not having been recovered

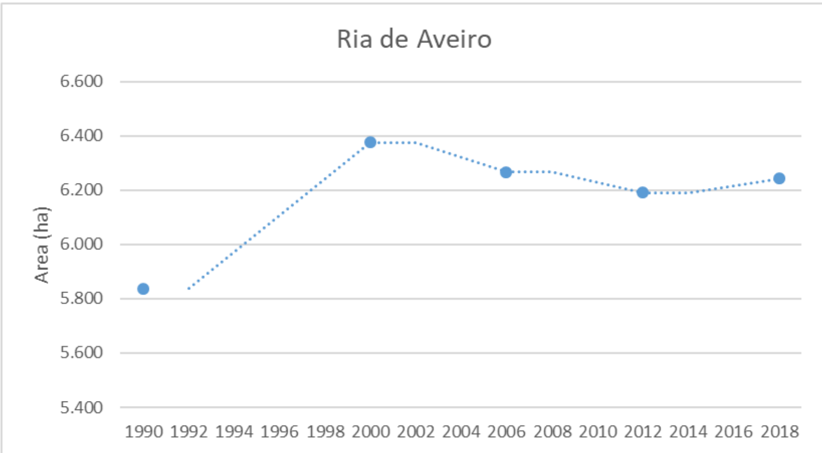

Figure 31. Evolution of saltmarsh surface in Aveiro between 1990 and 2018 based on Corine land cover data.

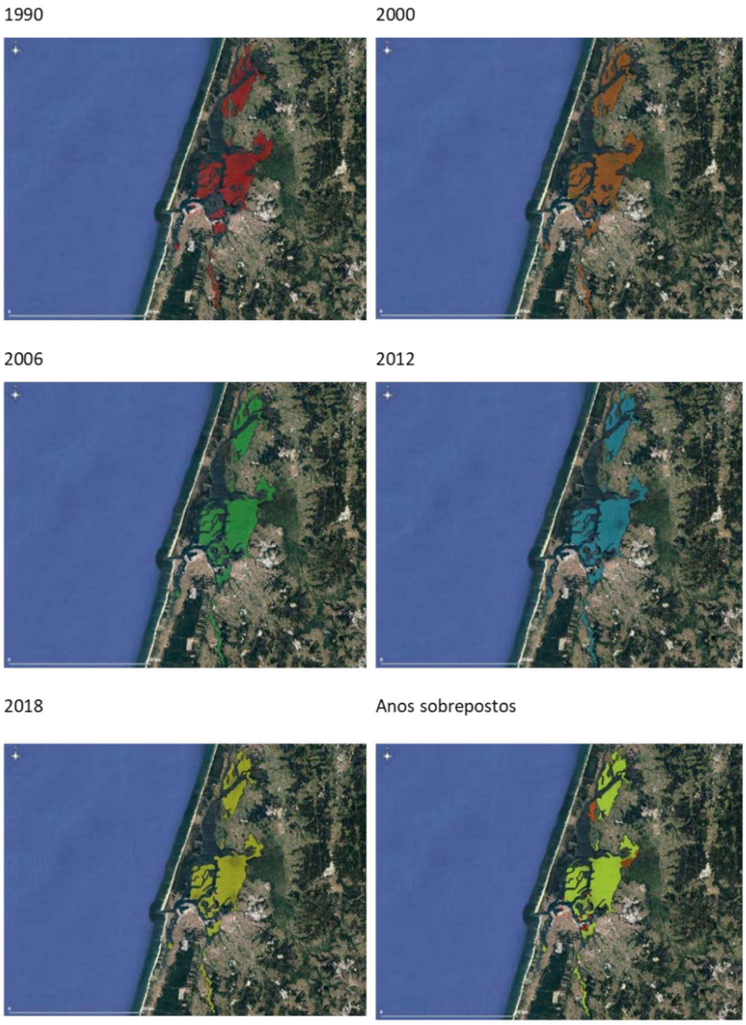

Figure 32. Distribution of saltmarsh communities in Aveiro between 1990 and 2018.

4.16 Figueira da Foz

The marshes of Figueira da Foz are placed in the estuary of the Mondego river, mostly in the intertidal zone around the Morraceira's Island. Saltmarshes are distributed in both estuarine branches, with the largest areas located in the southern arm.

Due to human development and the economic activities linked to saltponds and the port activities, the estuarine area has been historically degraded and it has lost over the 17% of the marsh area.

In 1997/98 different restoration activities were launched trying to protect the marshes and seagrass beds from human disturbance. Some of these actions integrated the re-establishment of the communication between the two estuarine branches, which were previously isolated. After that, an increase in saltmarsh area is observed for the years 2000 and 2006. Figure 33 shows an annual growth of the saltmarsh area until 2006, which is maintained until 2018, with 17.22% annual rate of change, which represents an important increase for the region.

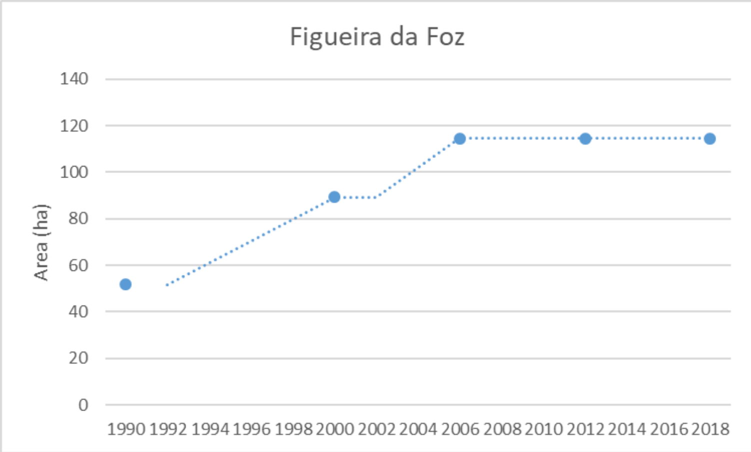

Figure 33. Evolution of saltmarsh surface in Mondego estuary between 1990 and 2018 according to Corine Land Cover data.

Figure 34. Distribution of saltmarsh communities in the Mondego estuary between 1990 and 2018 according to Corine Land Cover data.

4.17 Estuário do Tejo

The Tagus estuary is located on the western coast of the Iberian Peninsula. The north estuarine area shows a higher occupation rate due to the development of urban and industrial areas. For instance, the city of Lisbon is located at the mouth of Tagus estuary, on the north margin. Anyway, the inner estuarine area is characterized by a distribution of sediments that support the development of saltmarsh communities on both shores.

Some interesting initiatives have been launched regarding the recovery of marshes, such as the initiative of the Corroios marsh. It has been promoting the importance of the marsh to the community since 2013 and the need to preserve it. Approximately 50 activities have been included in this program, from bird watching, through exhibitions, biodiversity recovery through waste collection, artistic and literary exhibitions, to walks across the estuary.

According to Corine Land Cover data, from 1990 to 2018 the saltmarsh communities have increased their surface area (Figure 35) thanks to actions such as the one described above.

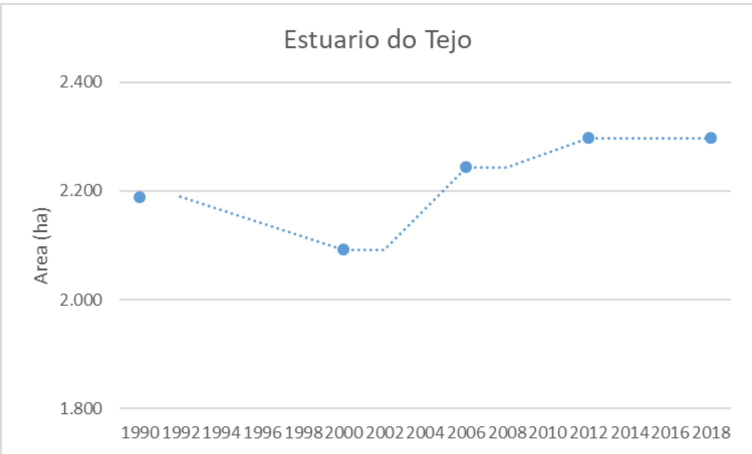

Figure 35. Evolution of saltmarsh surface in the Tagus estuary between 1990 and 2018 according to the Corine Land Cover data.

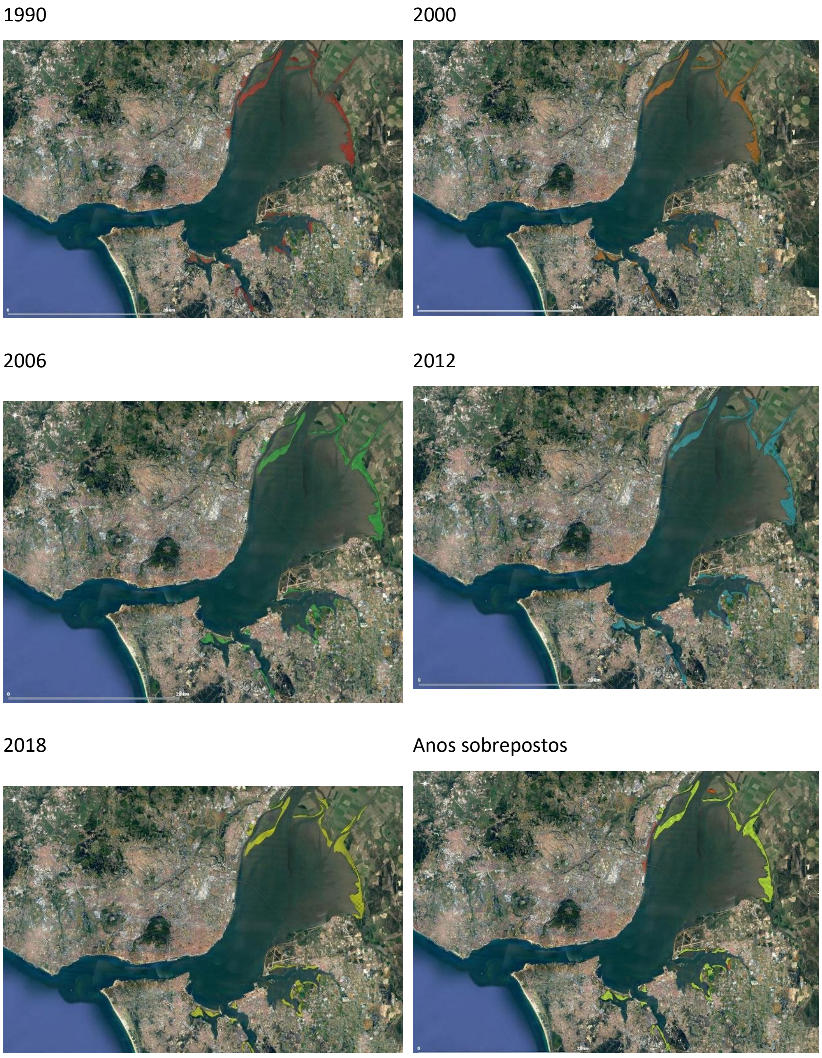

Figure 36. Distribution of saltmarsh communities in the Tagus estuary between 1990 and 2018 according to Corine Land Cover data.

4.18 Estuário do Sado

The Sado estuary is located south of the Tagus estuary. Due to the proximity to Lisbon (40 km away) and the city of Setubal, the estuary registers a great human activity. The navigability conditions have determined that the industrial and urban development were higher in the northern estuarine area, while the southern margins are mostly preserved from anthropogenic pressures. Nevertheless, saltmarshes just occupy the 11.5% of the estuarine margins and there are numerous land-claim areas for the installation of salt ponds, which have been transformed into fish-farmers or industrial areas. Moreover, some saltmarsh areas have been filled for the construction of dikes for the activity of the Setubal's port.

As it is showed in Figure 37, the saltmarsh communities reduced their extension from 1990 (1491 ha) to 2006 (1279 ha), but some of this coverage has been recovered in the last 10 years, up to 1347 ha in 2018.

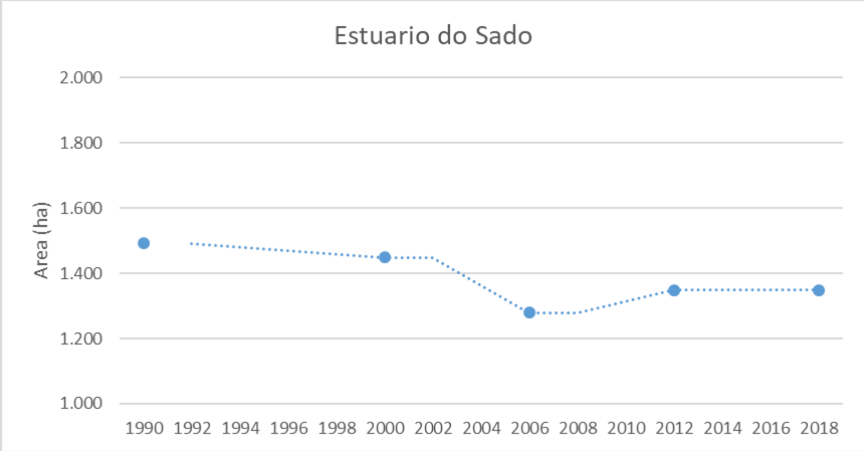

Figure 37. Evolution of saltmarsh communities in the Sado estuary from 1900 to 2018 according to Corine Land Cover data.

Figure 38. Distribution of saltmarsh communities in the Tagus estuary from 1990 to 2018 according to Corine Land Cover data.

4.19 Ria de Alvor

This coastal lagoon is a small mesotidal area, placed in the Bay of Lagos (south of Algarve).

Between 1997 and 2000 this coastal area showed a relevant urban expansion regarding tourism centres (hotels, apartments, camping sites) as well as industries linked to cement production, which led to a decrease in the marsh surface.

Trying to reverse this situation, some restoration actions were launched in 2000 to preserve the natural communities: recovery of the original topography, replacement of mud flats, and revegetation with saltmarsh species in an area of 2.1 ha. Moreover, an environmental information system for the public was implemented.

According to the Corine Land Cover data, the anthropogenic development resulted in a loss of saltmarsh surface between 1990 and 2001. As it is showed in Figure 39, the area of these communities has been maintained since then and the loss of the small area of saltmarsh, visible on the map of the overlays with the red color (Figure 40), has not been recovered again until 2018.

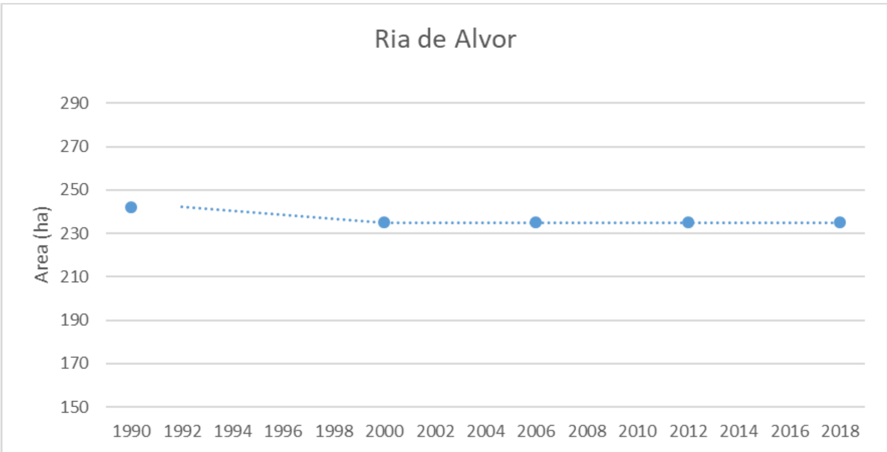

Figure 39. Evolution of saltmarsh communities in the Ria de Alvor from 1900 to 2018 according to Corine Land Cover data.

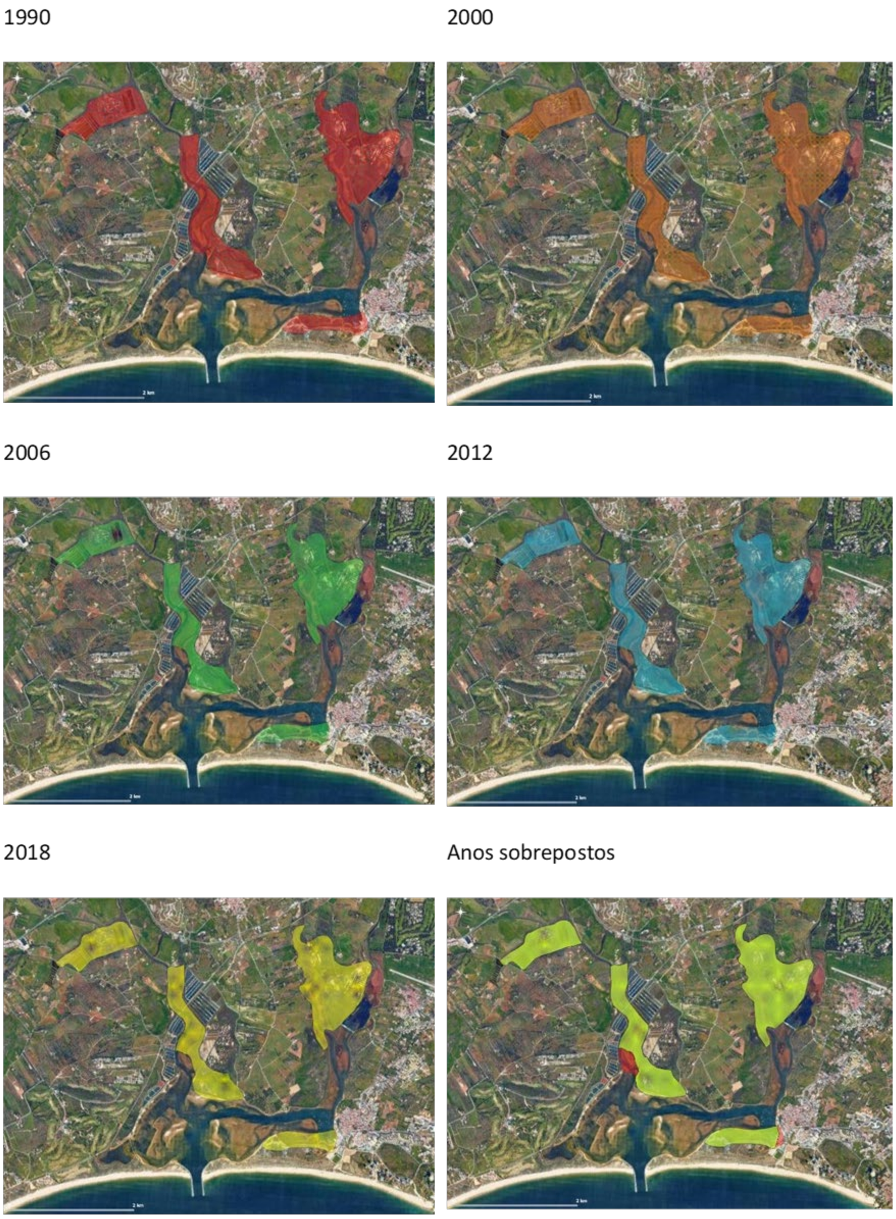

Figure 40. Distribution of saltmarsh communities in the Ría de Alvor from 1990 to 2018 according to Corine Land Cover data.

4.20 Ria Formosa

Ría Formosa is a coastal lagoon, placed in the western Algarve. It is classified as a Natural Park and Ramsar site.

According to Portela (2002), in 1979, the area of saltmarshes within the protected area of the Ría Formosa was about 1300 ha, in 1986 it was 1876 ha, and the surface area of these communities increased to 1998 ha in 1991. This growth may be related to the management actions regarding the Nature Reserve declaration (1970) as well as the accumulation of sediment in the middle and upper estuary.

Nevertheless, the data of Corine Land Cover shows a decline in the total surface of saltmarshes in the Ría de Formosa since the 90s, maintaining this reduction pattern until 2012. Therefore, there was a significant loss of saltmarsh communities between 1990 and 2006 (Figure 41, Figure 42).

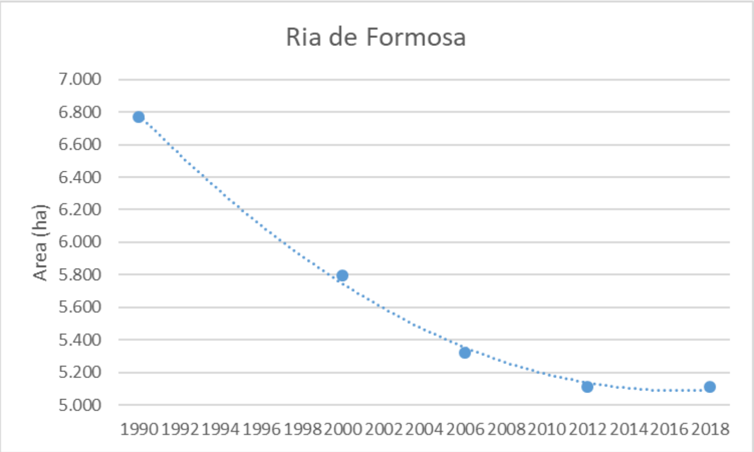

Figure 41. Evolution of saltmarsh communities in the Ría Formosa from 1900 to 2018 according to Corine Land Cover data.

Figure 42. Distribution of saltmarsh communities in the Ría Formosa from 1990 to 2018 according to Corine Land Cover data.

5 CONTRIBUTION TO CLIMATE CHANGE ADAPTATION

Once the evolution of saltmarsh communities has been quantified in the estuaries where restoration actions have been taken place, next sections shows an analysis of the climate services provided by the results of those restoration actions.

5.1 Change rates in the restoration projects

The evolution of the saltmarsh communities after the implementation of the restoration measures has been analysed in Section 4 using information from European databases. In order to evaluate the changes in the restoration projects, the total surface and the rates of change of these ecosystems (ha/y) are calculated (Table 2, Figure 43).

Estuary	Changes in saltmarsh surface (ha)	Rate (ha/y)	Date of restoration actions (year)	Land use change
Oyambre	18,46	6.15	2019	Baccharis to saltmarshes
Bahía de Santander	4,56	0.35	2009	Landclaim to saltmarshes
Marismas de Santoña	*No change*	-	2007	-
Marismas de Joyel	4,62	-0.51	2016	Baccharis to saltmarshes
Tina Menor	23,94	6.24	2016	Baccharis to saltmarshes
Baldaio	*No change*	-	2006	-
A Xunqueira	0,6	0.29	2015	Landclaim to saltmarshes
Marismas de Odiel	1764,51	63.02	2003	Landclaim/Mudflats to saltmarshes
Bahía de Cádiz	431,67	15.42	2003	Saltponds to saltmarshes
Doñana	34556	1920	2005	Agricultural to saltmarshes
Urdaibai	309,38	17.22	2010	Landclaim/Baccharis to saltmarshes
Txingudi	4,38	0.43	2013	Baccharis to saltmarshes
Zarautz	2,67	0.18	2010	Landclaim to saltmarshes
Caminha	138,9	5.07		Agricultural to saltmarshes
Ría de Aveiro	404,83	14.64	2020	
Figueira da Foz	62,71	2.18	1997	Saltponds to saltmarshes
Estuario do Tajo	108,96	3.89	2013	Mud/Sandflats to saltmarshes
Estuario do Sado	-143,44	-5.11	2019	-
Ría de Alvor	-7,22	-0.32	2009	-
Ría Formosa	-1658	-55.54	2006	-

Table 2. Total change of saltmarsh surface area in the restored estuarine systems.

The estuary with the highest rate of change is Doñana estuary (an increase per year of 1920 ha/y). It should be noted that the recovered hectares are located within the delimitation of the Doñana Natural Park (1 of the 16 National Natural Parks in Spain). This increase in the restoration area occurs in the framework of the restoration program "Doñana 2005" with the aim to regenerate the environmental value of this wetland. This estuary is a special protection area, which means that the management of the area has special characteristics. The application of the approach selected in this Section is not suitable for this type of special protection areas, since each one has its own special characteristics and the necessary information (coefficients) is not available to apply the BT approach in a reliable way. Figure 44 shows the rates of change for the estuaries analyzed. As can be seen, the estuaries of Ria de Alvor, Ria Formosa, Joyel and Estuário do Sado have reduced the area of saltmarsh communities in the period analyzed. Ria Formosa is the estuary with the greatest loss of these ecosystems (55 ha/y). The estuaries of Joyel and Ría de Alvor show a very constant behavior over time, but with a net loss of 0.51 ha/y and 0.32 ha/y, respectively. In the rest of the estuaries, restoration projects have increased the extent of saltmarsh communities.

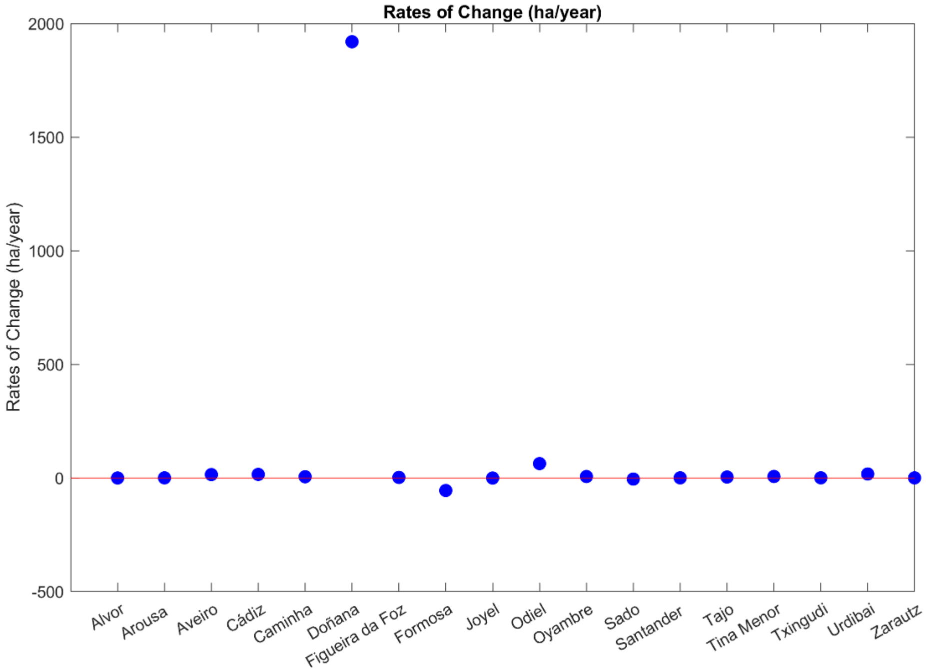

Figure 43. Evolution rate (ha/y) of area recovered/loss of saltmarsh communities in the estuaries analyzed.

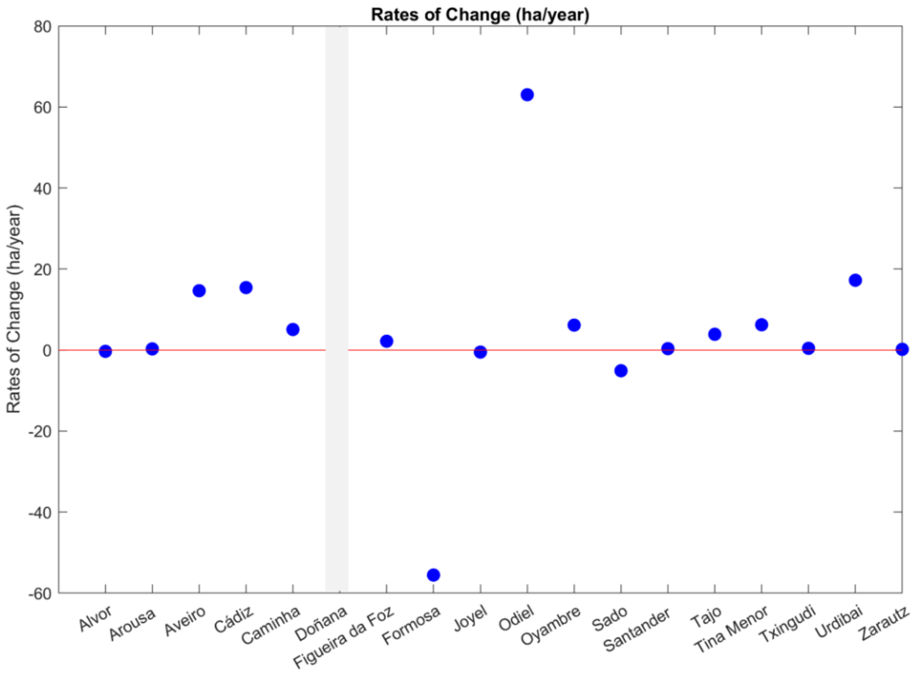

Figure 44. Evolution rate (ha/y) of area recovered/loss of saltmarsh communities in the estuaries analyzed.

5.2 Carbon sequestration service

Taking into account the analysis of carbon sequestration developed by the preparatory actions of this LIFE project (see results of Action A2; Deliverable A2.1), the amount of CO_2 sequestered by saltmarshes per surface area varies across the vegetal communities (Figure 45).

The average value of carbon storage in saltmarsh communities has been defined as 50±2 Mg C_{org} ha^{-1} in the top 30 cm of soil, which corresponds to 183 Mg CO_2 ha^{-1} sequestered in the soil compartment. On the other hand, the unvegetated mudflats and sandflats soil stocks per surface area about 40 Mg C_{org} ha^{-1} (136 Mg CO_2 ha^{-1}), while communities of *Baccharis halimifolia* and *Juncus maritimus* showed the largest stocks in the top 30 cm of sediment per surface area (65-100 Mg Corg ha^{-1}; 226-368 Mg CO2 ha^{-1}).

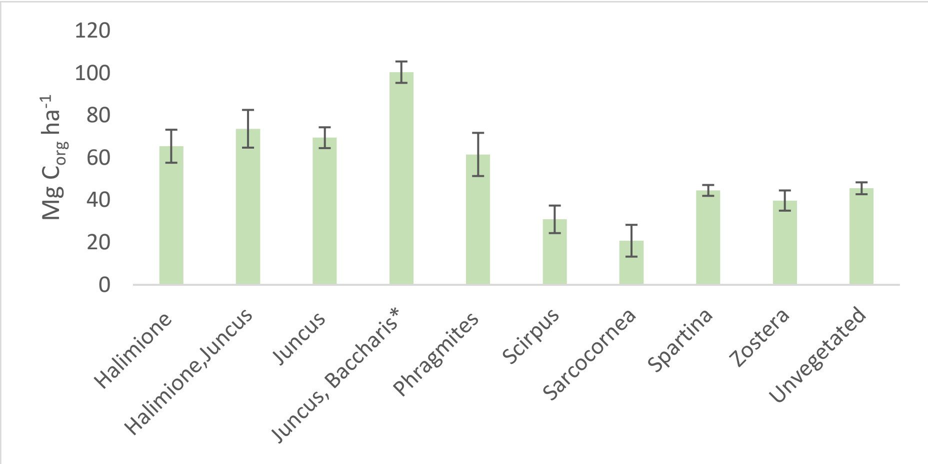

Figure 45. Average of top 30 cm soil C_{org} stocks across dominant species in the estuarine communities (source: LIFE AdaptaBlues)

Therefore, the analysis of the carbon sequestration value must take into account the increase in the surface area of saltmarshes, but also the change in land use that has occurred. As it is described in Section 5.1, most of the restored estuarine systems increased the surface area of saltmarshes (Table 2). Thus, it would be possible to assume that there has been an increase in the carbon sequestration service. However, it is important to note that, sometimes, the increase in saltmarshes is due to the removal of invasive alien species, such as *Baccharis halimifolia*, which showed one of the highest carbon sequestration value (higher than average for marsh vegetation).

Taking into account all these issues, it would be possible to consider that there has been an increase of carbon sequestration in the estuarine areas of Bahía de Santander, A Xunqueira, Bahía de Cádiz, Doñana, Urdaibai, Zarautz, Caminha, Figueira da Foz and Tagus estuary, where the saltmarsh communities increased due to the restoration actions. On the other hand, the estuaries of Sado, Ría de Alvor and Ría Formosa, which lost saltmarsh surface area, would have decreased their estuarine carbon stock. Likewise, the estuarine areas of Oyambre, Joyel, Tina

Menor and Txingudi would have decrease their carbon sequestration capacity due to changing vegetal communities from *Baccharis halimifolia* to other saltmarsh species.

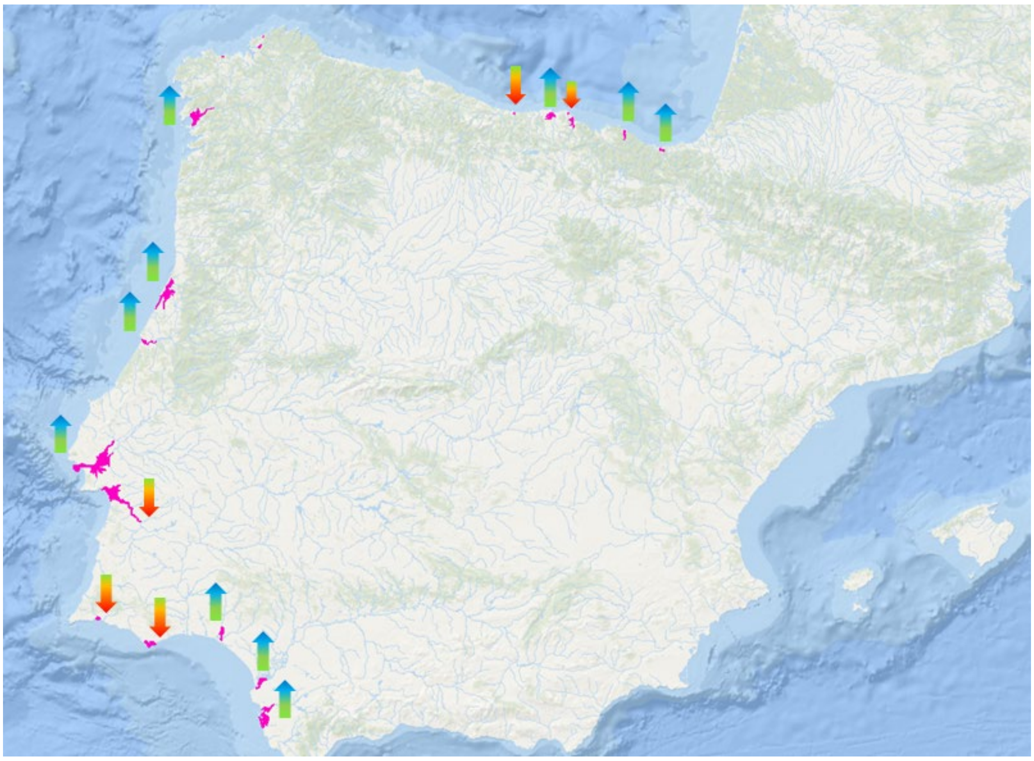

Figure 46. Changes in carbon sequestration.

5.3 Coastal protection services

The valuation of ecosystem services in a particular area helps to quantify the economic benefits that these services provide to the community. There are several methods to perform this quantification. In many situations, to avoid the full cost of primary data collection, value estimates may be applied from secondary sources in a process known as a "*benefit transfer, BT*". In other words, the benefit transfer approach is used to transfer benefits estimated by previous studies in a similar context to the policy context of interest (Bartczak et al., 2008). This method takes two different approaches. In direct value transfer a value for an ecosystem service is directly transferred to the studied site. Ideally the two sites have similar characteristics. The other approach uses transfer functions.

Badamfirooz et al. (2021) study several approaches to assess the economic valuation of wetland ecosystem services. One of them is the BT approach. If the benefit transfer approach is chosen; then, the value coefficients of Costanza et al. (2014) or De Groot et al. (2012) can estimate each land use/land cover type's ecosystem service value through Eq. (1). The total value of ecosystem services for the years considered is calculated by multiplying the area of a certain land-use type and the adjusted coefficients of the value of ecosystem services, derived from the weight coefficients of ecosystem services per hectare of each biome.

$$ESV = \sum (Ak * V\ Ck)) \qquad (1)$$

where;

ESV= Estimated total value of the ecosystem service, Ak=area (ha), and VCk= Value coefficient for the desired ecosystem (€/hectare/year), for example, for the land use type k. The percentage change in ESVS in the studied years is calculated based on Eq. (2), as below.

$$P\ ercantage\ ESV = (\ Vt2 - ESVt1/ESVt1) \times 100 \qquad (2)$$

Where; ESV t2 (€/ha/year) = estimated value of ecosystem services in recent years, and ESV t1 (€/ha/year)= estimated value of ecosystem services in the previous year. Positive values indicate an increase in ESVS, while negative values show a decrease in ESVS.

In this study, BT will be used for the quantification of coastal protection services provided by this type of vegetated ecosystems.

5.3.1 Quantification of coastal protection

The results obtained from action A2 (*Climate Change Ecosystem Services: Development of a standardized protocol for the quantification of CC services provided by EU estuaries*) provide the coastal protection benefits of the Portuguese and Spanish analyzed estuaries. The application of the BT approach considering the results of A2 and the analysis of the evolution of saltmarshes communities provides us some useful information about the quantification of coastal protection. This classification is based on the exposure and vulnerability of each estuary:

- Estuaries with high exposure and low vulnerability (e.g. Santander Bay and Mondego estuary).
- Estuaries with high exposure and high vulnerability (e.g. Santoña Marshes).
- Estuaries with low exposure and low vulnerability (e.g. Oyambre estuary.

Each restoration project was identified in a category and the annual protection values obtained in action A2 in the estuary identified in each category was assigned. Table 3 shows the results obtained. Each restoration project was identified in a category and the annual protection values obtained in action A2 in the estuary identified in each category was assigned. Table 3 shows the results obtained.

	Name	Rate (ha/y)	Protected population (people/ha/y)	Protected building assess (€/ha/y)	Country
1	Alvor	-0.32	-5	-6,187 €	Portugal
2	Arousa	0.29	53	9,690 €	Portugal
3	Aveiro	14.64	103	20,837 €	Portugal
4	Cádiz	15.42	2868	522,333 €	Spain
5	Caminha	5.07	36	7,217 €	Portugal
7	Figueira da Foz	2.18	405	73,812 €	Portugal
8	Formosa	-55.54	0	-13,051 €	Portugal
9	Joyel	-0.51	0	-119 €	Spain
10	Odiel	63.02	945	1,212,999 €	Spain
11	Oyambre	6.15	0	1,446 €	Spain
12	Sado	-5.11	-77	-98,304 €	Portugal
13	Marismas Blancas	0.35	5	6,642 €	Spain
14	Tejo	3.89	58	74,876 €	Portugal
15	Tina Menor	6.24	0	1,466 €	Spain
16	Txingudi	0.43	6	8,229 €	Spain
17	Urdibai	17.22	3203	583,502 €	Spain
18	Zarautz	0.18	3	3,438 €	Spain

Table 3. Protected population and protected building assess in each restoration project.

Table 4 shows the results of coastal protection that saltmarshes communities provide to the population and buildings, aggregated by country. As can be seen, restoration policies in Spain have provided a greater benefit in terms of protection of the population and buildings against flood events. It should be mentioned that the analysis performed in Action 2 shows that the Spanish estuarine ecosystems presents a higher protection capacity than the Portuguese estuarine ecosystems.

Country	Mean proteced population (people\ha\y)	Mean protected building asses (€\ha\y)
Portugal	72	8,611.14 €
Spain	781	259,992.79 €

Table 4. Total change of saltmarsh surface area in the restored estuarine systems.

Figure 47 and Figure 48 show a bar diagram of protected population and protected building assess per unit area of restored estuarine ecosystem.

Odiel marshes, Cádiz bay and Urdaibai estuary have restored a higher number of hectares and therefore they provide greater protection than other estuaries. The loss of intertidal cosystems in some estuaries (Estuario do Sado and Alvor) produces a reduction in the protection against flooding over 77 and 5 people, respectively.

The restoration of saltmarsh ecosystems has provided the protection of several infrastructures against flooding events. This protection has been quantified in 1.21 million € in Odiel estuary, while in the Urdaibai estuary and the Cádiz marshes this quantification is around 0.5 million of €.

Figure 47 and Figure 48 show a bar diagram of protected population and protected building assess per unit area of restored estuarine ecosystem.

Odiel marshes, Cádiz bay and Urdaibai estuary have restored a higher number of hectares and therefore they provide greater protection than other estuaries. The loss of intertidal ecosystems in some estuaries (Estuario do Sado and Alvor) produces a reduction in the protection against flooding over 77 and 5 people, respectively.

The restoration of saltmarsh ecosystems has provided the protection of several infrastructures against flooding events. This protection has been quantified in 1.21 million € in Odiel estuary, while in the Urdaibai estuary and the Cádiz marshes this quantification is around 0.5 million of €.

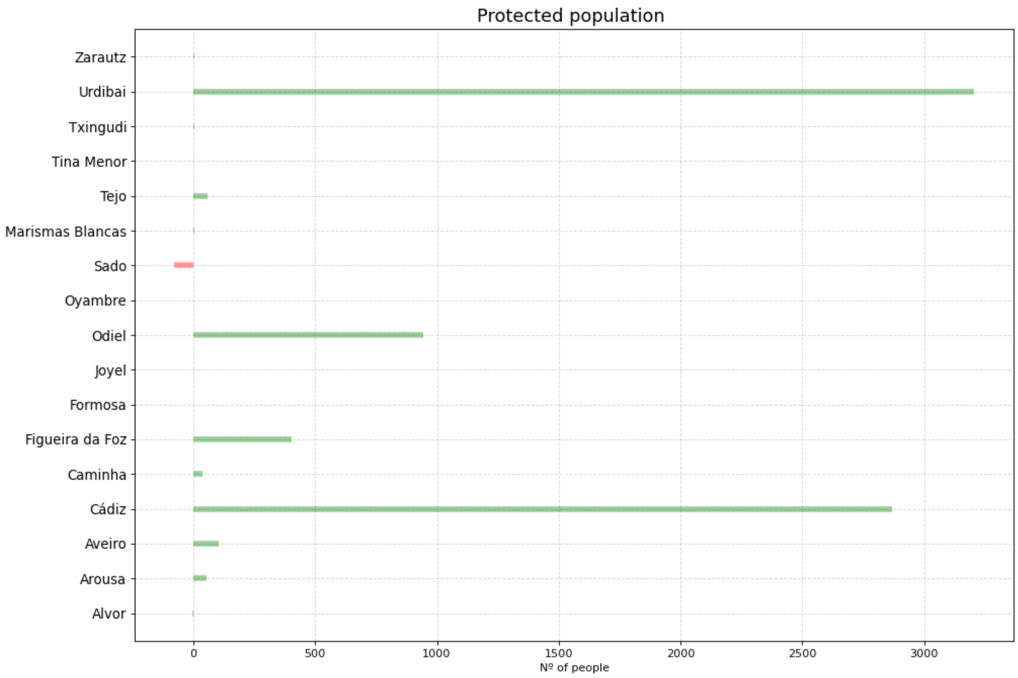

Figure 47. Bar diagram of protected population in each restoration project.

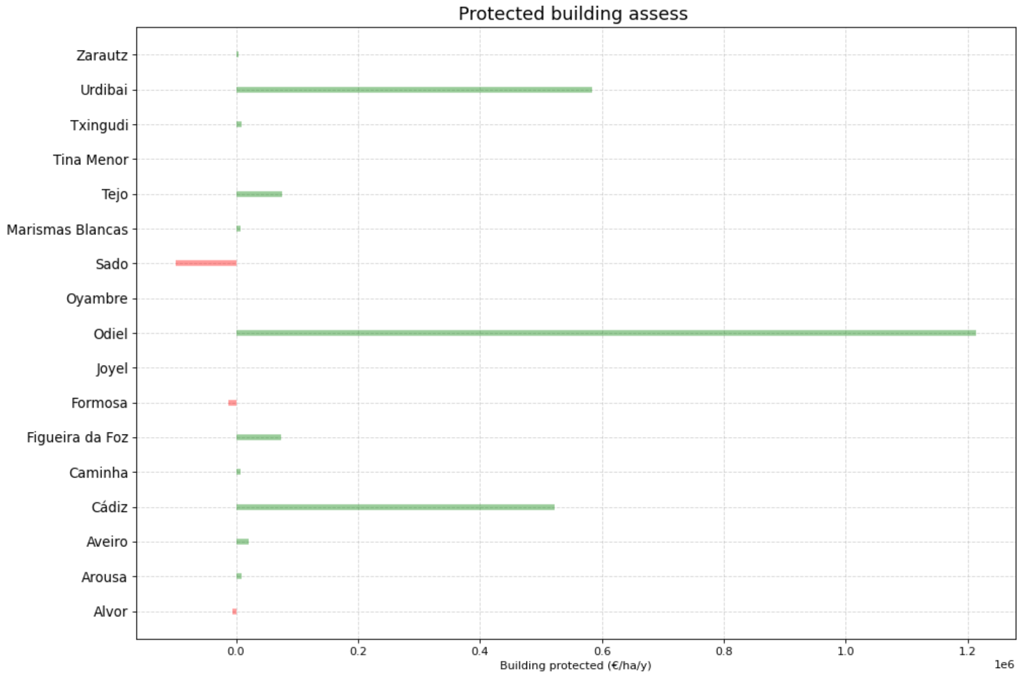

Figure 48. Bar diagram of protected building assess of saltmarsh communities in each restoration project.

5.4 Other ecosystem services.

Estuarine ecosystems provide different services. Several studies (Constanza et al., 1997; de Groot et al.,2012) estimated the value of these services for more than 10 biomes (open oceans, coral reefs, coastal systems, coastal wetlands, inland wetlands, lakes, tropical forests, temperate forest, Woodlands and Grasslands) and an aggregated value expressed in monetary units. These monetary units have been used in the quantification of the estuarine restoration projects analysed in this study. Table 5 presents the summary of monetary values for each service per biome in each restoration project.

The percentage of the ecosystem service in each group defined in the Groot et al. (2012) and Groot et al.(2021) is showed in Figure 49. Regulating services as: regulation of water flows and erosion prevention present high monetary units per ha restored. Regulation of water flows represent 24.7% of the total economic value of this kind of ecosystem, while erosion prevention is 11.5% and other uses, as recreation, is 9.8%.

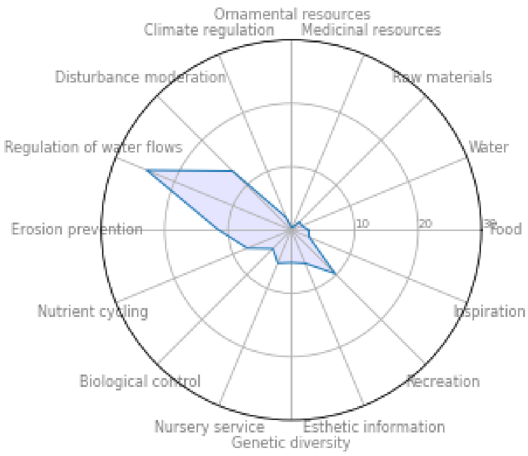

Figure 49 Percentage of each particular service over the total economic value in the Inland Wetlands ecosystems.

Figure 50 shows the total monetary values for all ecosystem services in each restoration project and Figure 51 shows the total monetary value grouped by country. In both figures, the Portuguese estuaries return less monetary value in the restoration projects. Our estimations show that estuaries such as Ría Alvor, Joyel Marshes, Ría Formosa and Estuário do Sado have lost between 7,000 – 1,250,000 €, while the restoration projects in estuaries such as Odiel marshes, Cádiz Bay and Urdibai estuary have provided benefits between 350,000 € - 1,250,000 €, approximately.

Estimates of the global accounting value of ecosystem services expressed in monetary units, like those in this study, are mainly useful to raise awareness about the magnitude of these services relative to others services provided by human built capital at the current point in time.

	Inland wetland	Alvor	Arousa	Aveiro	Cádiz	Caminha	Doñana	Figueira da Foz	Formosa	Joyel	Odiel	Oyambre	Sado	Santander	Tejo	Tina Menor	Txingudi	Urdibai	Zarautz
Provisioning services	**1,660 €**	**-531 €**	**481 €**	**24,302 €**	**25,597 €**	**8,416 €**	**3,187,200 €**	**3,619 €**	**-92,196 €**	**-847 €**	**104,613 €**	**10,209 €**	**-8,483 €**	**581 €**	**6,457 €**	**10,358 €**	**714 €**	**28,585 €**	**299 €**
1 Food	614 €	-196 €	178 €	8,989 €	9,468 €	3,113 €	1,178,880 €	1,339 €	-34,102 €	-313 €	38,694 €	3,776 €	-3,138 €	215 €	2,388 €	3,831 €	264 €	10,573 €	111 €
2 Water	408 €	-131 €	118 €	5,973 €	6,291 €	2,069 €	783,360 €	889 €	-22,660 €	-208 €	25,712 €	2,509 €	-2,085 €	143 €	1,587 €	2,546 €	175 €	7,026 €	73 €
3 Raw materials	425 €	-136 €	123 €	6,222 €	6,554 €	2,155 €	816,000 €	927 €	-23,605 €	-217 €	26,784 €	2,614 €	-2,172 €	149 €	1,653 €	2,652 €	183 €	7,319 €	77 €
4 Genetic resources					0 €	0 €													
5 Medicinal resources	99 €	-32 €	29 €	1,449 €	1,527 €	502 €	190,080 €	216 €	-5,498 €	-50 €	6,239 €	609 €	-506 €	35 €	385 €	618 €	43 €	1,705 €	18 €
6 Ornamental resources	114 €	-36 €	33 €	1,669 €	1,758 €	578 €	218,880 €	249 €	-6,332 €	-58 €	7,184 €	701 €	-583 €	40 €	443 €	711 €	49 €	1,963 €	21 €
Regulating services	**14,348 €**	**-4,591 €**	**4,161 €**	**210,055 €**	**221,246 €**	**72,744 €**	**27,548,160 €**	**31,279 €**	**-796,888 €**	**-7,317 €**	**904,211 €**	**88,240 €**	**-73,318 €**	**5,022 €**	**55,814 €**	**89,532 €**	**6,170 €**	**247,073 €**	**2,583 €**
7 Air quality regulation																			
8 Climate regulation	488 €	-156 €	142 €	7,144 €	7,525 €	2,474 €	936,960 €	1,064 €	-27,104 €	-249 €	30,754 €	3,001 €	-2,494 €	171 €	1,898 €	3,045 €	210 €	8,403 €	88 €
9 Disturbance moderation	2,986 €	-956 €	866 €	43,715 €	46,044 €	15,139 €	5,733,120 €	6,509 €	-165,842 €	-1,523 €	188,178 €	18,364 €	-15,258 €	1,045 €	11,616 €	18,633 €	1,284 €	51,419 €	537 €
10 Regulation of water flows	5,606 €	-1,794 €	1,626 €	82,072 €	86,445 €	28,422 €	10,763,520 €	12,221 €	-311,357 €	-2,859 €	353,290 €	34,477 €	-28,647 €	1,962 €	21,807 €	34,981 €	2,411 €	96,535 €	1,009 €
11 Waste treatment																			
12Erosion prevention	2,607 €	-834 €	756 €	38,166 €	40,200 €	13,217 €	5,005,440 €	5,683 €	-144,793 €	-1,330 €	164,293 €	16,033 €	-13,322 €	912 €	10,141 €	16,268 €	1,121 €	44,893 €	469 €
13 Nutrient cycling	1,713 €	-548 €	497 €	25,078 €	26,414 €	8,685 €	3,288,960 €	3,734 €	-95,140 €	-874 €	107,953 €	10,535 €	-8,753 €	600 €	6,664 €	10,689 €	737 €	29,498 €	308 €
14 Pollination																			
15 Biological control	948 €	-303 €	275 €	13,879 €	14,618 €	4,806 €	1,820,160 €	2,067 €	-52,652 €	-483 €	59,743 €	5,830 €	-4,844 €	332 €	3,688 €	5,916 €	408 €	16,325 €	171 €
Habitat services	**2,455 €**	**-786 €**	**712 €**	**35,941 €**	**37,856 €**	**12,447 €**	**4,713,600 €**	**5,352 €**	**-136,351 €**	**-1,252 €**	**154,714 €**	**15,098 €**	**-12,545 €**	**859 €**	**9,550 €**	**15,319 €**	**1,056 €**	**42,275 €**	**442 €**
16 Nursery service	1,287 €	-412 €	373 €	18,842 €	19,846 €	6,525 €	2,471,040 €	2,806 €	-71,480 €	-656 €	81,107 €	7,915 €	-6,577 €	450 €	5,006 €	8,031 €	553 €	22,162 €	232 €
17 Genetic diversity	1,168 €	-374 €	339 €	17,100 €	18,011 €	5,922 €	2,242,560 €	2,546 €	-64,871 €	-596 €	73,607 €	7,183 €	-5,968 €	409 €	4,544 €	7,288 €	502 €	20,113 €	210 €
Cultural services	**4,203 €**	**-1,345 €**	**430 €**	**61,532 €**	**64,810 €**	**21,309 €**	**8,069,760 €**	**9,163 €**	**-233,435 €**	**-2,144 €**	**264,873 €**	**25,848 €**	**-21,477 €**	**1,471 €**	**16,350 €**	**26,227 €**	**1,807 €**	**72,376 €**	**757 €**
18 Esthetic information	1,292 €	-413 €	132 €	18,915 €	19,923 €	6,550 €	2,480,640 €	2,817 €	-71,758 €	-659 €	81,422 €	7,946 €	-6,602 €	452 €	5,026 €	8,062 €	556 €	22,248 €	233 €
19 Recreation	2,211 €	-708 €	226 €	32,369 €	34,094 €	11,210 €	4,245,120 €	4,820 €	-122,799 €	-1,128 €	139,337 €	13,598 €	-11,298 €	774 €	8,601 €	13,797 €	951 €	38,073 €	398 €
20 Inspiration	700 €	-224 €	72 €	10,248 €	10,794 €	3,549 €	1,344,000 €	1,526 €	-38,878 €	-357 €	44,114 €	4,305 €	-3,577 €	245 €	2,723 €	4,368 €	301 €	12,054 €	126 €
21 Spiritual experience																			
22 Cognitive development																			

Table 5. Summary of monetary values for each service per biome in each restoration project

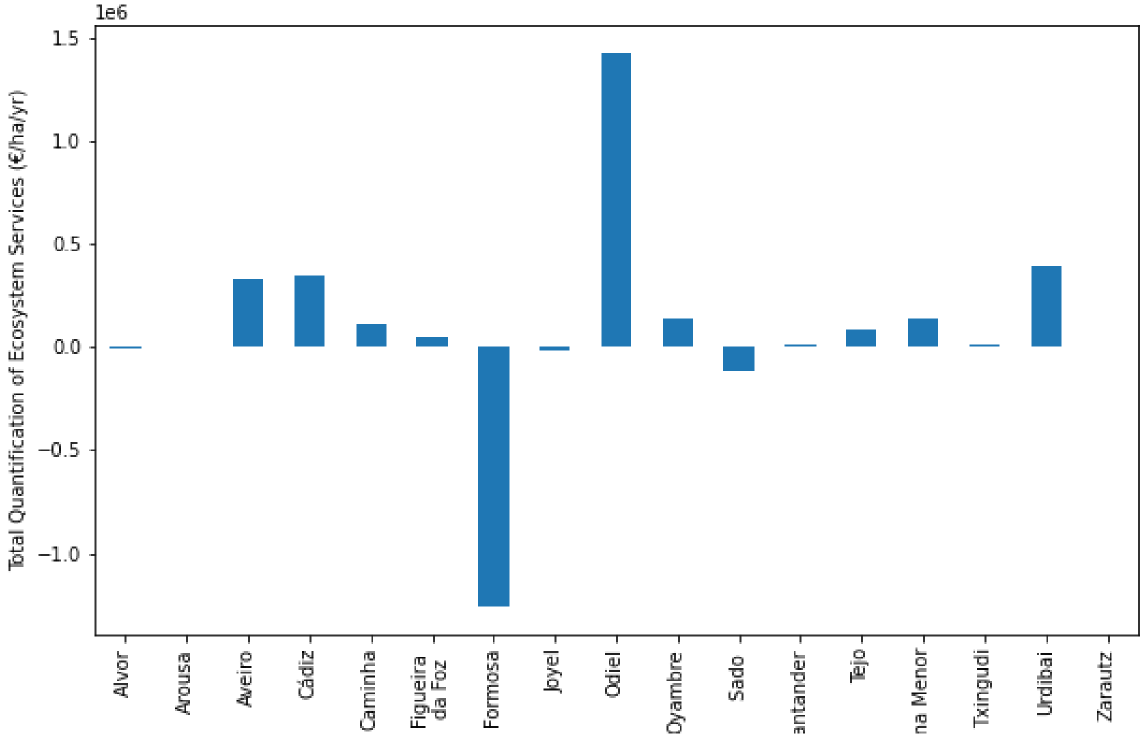

Figure 50. Total monetary values for all ecosystem services in each restoration project.

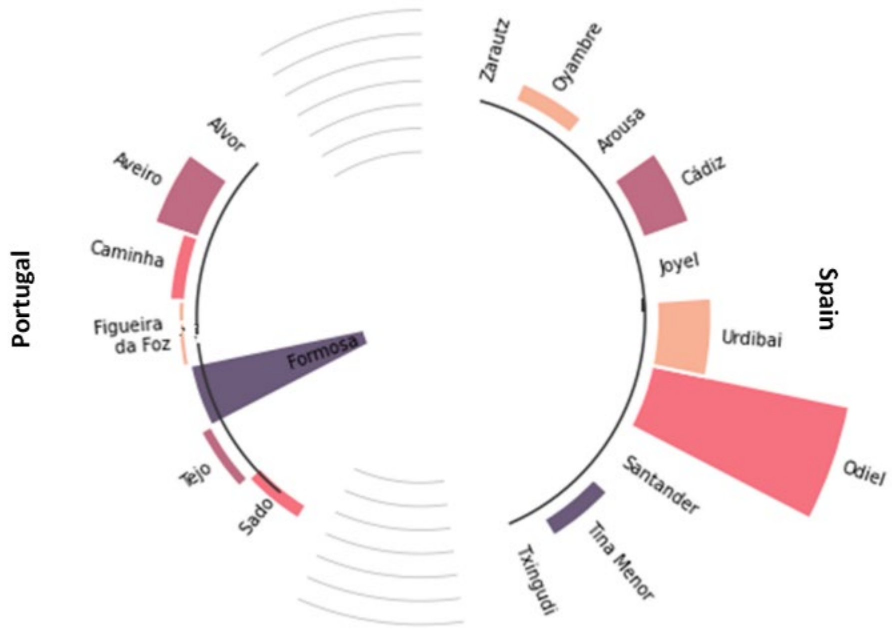

Figure 51. Distribution of restoration projects according the total monetary value group by country.

6 REFERENCES

Badamfirooz,J., Mousazadeh,R and Sarkheil, H. (2021). A proposed framework for economic valuation and assessment of damages cost to national wetlands ecosystem services using the benefit-transfer approach. Environmental Challenges. (2021). Volume 5. 100303.ISSN 2667-0100. https://doi.org/10.1016/j.envc.2021.100303.

Bartczak, Anna., Lindhjem, Henrik ., Stenger, Anne. (2008). Review of benefit transfer studies in the forest context. Scandinavian Forest Economics. 281-310.

Costanza, R., De Groot, R., Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S., Turner, R.K., 2014. Changes in the global value of ecosystem services. Glob.Environ. Change 26, 152–158. Doi:10.1016/j.gloenvcha.2014.04.002.

De Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M.,Crossman, N., Ghermandi, A., Hein, L., Hussain, S., Kumar, P., McVittie, A., Portela, R.,Rodriguez, L.C., ten Brink, P., van Beukering, P. (2012). Global estimates of the value of ecosystems and their services in monetary units. J. Ecosyst. Serv. 1 (1), 50–61. doi: 10.1016/j.ecoser.2021.07.005.

Groot, Rudolf., Brander, Luke., Lieshout, Joost., Solomonides, Stefanos., Guisado, Victoria., Stagner, Jan Philipp., Hoff, Vince., Stevens, Mire., Konovska, Iskra ., Siebers, Mieke .,Vliet, Arnold. (2021). Updating and Upgrading the Ecosystem Services Valuation Database (ESVD): a global database for valuing ecosystem services (with focus on data relevant for the Netherlands).

Ferreira, J.; Abreu, P.; Bettencourt, A.; Bricker, S.; Marques, J.; Melo, J.; Newton, A.; Nobre, A.; Patricio, J.; Rocha, F.; et al. 2005. Monitoring Plan for Portuguese Coastal Waters. Water Quality and Ecology. Development of Guidelines for the Applications of the European Union Water Framework Directive. IMAG-IMAR: Portugal.

Gonçalves, P.R.S. 2016. Os sapais em Portugal continental. Levantamento e evolução das suas envolventes desde 1990 a 2012. Lisboa: ISA, 73 p.

Halpern, B. S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., Fujita, R., Heinemann, D., Lenihan, H.S., Madin, E.M.P., Perry, M.T., Selig, E.R., Spalding, M., Steneck, R., Watson, R. 2008. A global map of human impacts on marine ecosystems. Science 319: 948– 952

Orth, R. J.,Carruthers, T.J.B., Dennison, W.C., Duarte, C.M., Fourqurean, J.W., Heck, K.L., Huges, A.R., Kendrick, G.A., Kenworthy, W.J., Olyarnik, S., Short, F.T., Waycott, M., Williams S.L. 2006. A global crisis for seagrass ecosystems. BioScience 56: 987– 996

UNEP. 2006. Marine and coastal ecosystems and human wellbeing: A synthesis report based on the findings of the Millennium Ecosystem Assessment. UNEP, Nairobi, Kenya.

ANNEX I

The methodology used for the analysis of the distribution of vegetation in the estuarine systems based on the interpretation of information derived from remote sensing is described below.

First, the study area is delimited based on the boundaries of the transitional water bodies established for the Water Framework Directive 2000/60/EC. Secondly, the tidal limits were established based on the calculation of the Normalized Difference Water Index (NDWI), which measures moisture content and is capable of detecting water masses (McFeeters et al., 1996):

$$NDWI = \frac{\mathrm{G} - \mathrm{NIR}}{\mathrm{G} + \mathrm{NIR}}$$

Where G and NIR are the reflectance in the green and near-infrared, respectively. From this index, a threshold was established to generate a water mask identifying the flooded study area (NDWI≥ -0.1).

Third, the vegetated area in the study areas was identified by calculating the Normalized Difference Vegetation Index (NDVI):

$$NDVI = \frac{\mathrm{NIR} - \mathrm{R}}{\mathrm{NIR} + \mathrm{R}}$$

Where NIR and R are the reflectances in the near-infrared and red, respectively.

Based on field data, images from drone flights, high resolution orthophotos and bibliographical information, thresholds were established that optimize the detection of plant communities characteristic of estuarine systems:

Vegetation	NDVI
No vegetated	< 0,2
Estuarine vegetation (saltmarshes)	0,2 - 0,6
Srubs and other vegetation	> 0,6