REPORT

Action A1 from project Ilhas Barreira.

Invasive plants on the five barrier islands

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Action A1 Report from project Ilhas Barreira. Invasive plants on the five barrier islands

SPEA

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Reference
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Index

Summary

Coastal ecosystems are one of the most threatened and affected by the invasion of alien plants, especially shore dunes, saltmarshes and cliffs. These habitats, especially the dunes, experience significant pressure from human activities, which favours the expansion of some of these species.
Invasive plant patches found were identified and mapped on the five barrier islands. Initially, the mapping was carried out by photo-interpretation of aerial photos. Later, each patch was validated in the field using a GPS. Only on Barreta Island, all spots were measured to quantify the area occupied by the different species.
To assess the chemical variations that occur in the soil, due to the presence of invasive plants, soil samples were collected from four different areas: i) area occupied by *Carpobrotus edulis*, ii) area occupied by *Agave americana*, iii) area occupied by *Acacia saligna*, and iv) control area.
The work carried out along the five barrier islands revealed the presence of eight species of invasive plants. The islands with the lowest number of invasive species were Barreta and Culatra (three species) and, the island with the highest number was Tavira (eight species).
The analyzes carried out on the soil indicate the existence of some differences between the four areas, especially regarding some parameters as phosphorus, potassium, magnesium and the C/N ratio.

Resumo

Os ecossistemas costeiros são um dos mais ameaçados e afetados pela presença de plantas invasoras, em particular nas dunas costeiras, sapais e falésias. Esses habitats, principalmente as dunas, sofrem forte pressão das atividades antrópicas, o que favorece a expansão de algumas dessas espécies.
As manchas de plantas invasoras encontradas, foram identificadas e mapeadas nas cinco ilhas barreira. Inicialmente, o mapeamento foi realizado por fotointerpretação de fotos aéreas, mas posteriormente, cada mancha foi validada no campo por meio de um GPS. Somente na Ilha da Barreta, todas as manchas foram medidas para quantificar a área ocupada pelas diferentes espécies.
Para avaliar as variações químicas que ocorrem no solo, devido à presença de plantas invasoras, foram recolhidas amostras de solo em quatro áreas distintas: i) área ocupada por *Carpobrotus edulis*, ii) área ocupada por *Agave americana*, iii) área ocupada por *Acacia saligna* e iv) área de controlo.
O trabalho realizado ao longo das cinco ilhas barreira revelou a presença de oito espécies de plantas invasoras. As ilhas com menor número de espécies invasoras foram Barreta e Culatra (três espécies) e, a ilha com maior número foi Tavira (oito espécies).
As análises realizadas no solo indicam a existência de algumas diferenças entre as quatro áreas, principalmente no que se refere a alguns parâmetros como fósforo, potássio, magnésio e relação C/N.

1 | Introduction

Non-native ornamental and cultivated plants have become invasive in many ecosystems around the world (Vitousek et al., 1997). Some species have restricted distributions and low establishment rates in their native habitats but show explosive population growths once they arrive to new sites (Lockwood et al., 2001). Conditions and resources provided by the new habitat could mediate this invasive behaviour by improving the population growth rates of alien species. In other words, the alien species finds a niche dimension in the new habitat that enhances its reproduction or establishment rate (Shea & Chesson, 2002).

Many invasive plant species are able to transform ecosystems (Richardson et al., 2000; Ortega & Pearson, 2005), resulting in losses of biodiversity, altered ecosystem functioning and a changed capacity to provide services (e.g. Vitousek et al., 1997; Levine et al., 2003; Pejchar & Mooney, 2009; Vilà et al., 2010).

Coastal ecosystems are one of the most threatened and affected by the invasion of alien plants, especially shore dunes, saltmarshes and cliffs. These habitats, especially the dunes, experience significant pressure from human activities, which favours the expansion of some of these species such as *Arctotheca calendula, Cortaderia selloana, Carpobrotus edulis* (Campos et al., 2004). Their high sensitivity to alien establishment seems to be related to natural and anthropogenic factors such as habitat heterogeneity, intensive propagule pressure from ancient times, and frequent and diverse disturbances (Acosta et al., 2007). In recent years, coastal dune ecosystems have been extensively transformed as a result of urban expansion, agricultural and forestation spread, and industrial and harbour development (Schlacher et al. 2007). Population increase and the growing demand for recreation opportunities are the ultimate drivers of escalating pressure on sandy beaches.

Dunes offer unique ecological services, for example filtration of seawater, nutrient recycling, flood control, and storm protection which are closely associated with well preserved ecosystems (Barbier et al. 2011).

Dune plant communities form very dynamic ecosystems, with many open spaces that allow the quick settlement of some invasive species. Some of these species have short life-histories and grow very fast, in such a way that they create a significant seed bank that ensures the survival of the population (*Arctotheca calendula*). Others grow more slowly by means of rhizomes, stolons, etc., so that with time they succeed in excluding any possible competition (*Carpobrotus edulis*). The continuous human flow in these habitats, especially in summer, ensures the constant arrival of propagules from many different habitats (Campos et al., 2004).

Some of these invasive species are able to transform the environmental conditions and processes and the structure of littoral ecosystems, thus they have a strong impact on coastal vegetation. They are the so-called ‘transformers’ (Campos et al., 2004).

The main objective of this report is to evaluate the actual situation at the Barrier islands regarding the dispersion of invasive plants. This document aims to be an instrument to guide future works on the control of invasive plants, indicating priority areas to work. The focus of this mapping was, especially, the most common invasive species on these islands (*Carpobrotus edulis, Acacia saligna* and *Agave americana*), although whenever found, other species were also recorded.

1.1 *Agave americana*

Agave species (Agavaceae) have characteristic nocturnal stomatal opening and tissue succulence. The family Agavaceae ranges from western North America to South America and Caribbean Islands. Species in the genus *Agave* are found in deserts, grasslands, and oak-pine woodlands, growing on well-drained, rocky slopes (Arizaga & Ezcurra, 2002). Most Agave species are monocarpic (i.e. die after fruiting) and deplete their sugar reserves to produce a high number of seeds (Arizaga & Ezcurra, 2002).

Although produced seeds have high germination capacity, most seedlings die 8–9 days after germination (Arizaga & Ezcurra, 2002). Agaves also have clonal mechanisms of reproduction. Throughout their life span, agaves produce rhizomes, the apical meristems which give rise to new individuals (Arizaga & Ezcurra, 2002). Another clonal mechanism of reproduction occurs in floral stems, where bulbils develop from sterile meristems (Arizaga & Ezcurra, 2002).

In the Iberian Peninsula, several species of Agave were introduced in the 1940s as ornamental and cultivated plants, and recent field observations indicate that these species are spreading into new habitats, mainly on coastal sandy soils (Badano & Pugnaire, 2004).

In general, competition for space is the main negative effect of invasive plants on native species (Almasi, 2000), but competition for water and nutrients is also important (Shea & Chesson, 2002). *A. americana* tends to occupy the space with a dense network of rhizome offshoots that could draw resources and hence affect the status of native species (Badano & Pugnaire, 2004).

The *A. americana* was rated 18, according to a protocol adapted from the Australian Weed Risk Assessment. Values above 13 mean that the species is at risk of invasive behaviour in the Portuguese territory (Invasoras, 2021).

1.2 *Acacia saligna*

Australian acacias have a wide range of impacts on ecosystems that increase with time and disturbance, transform ecosystems and, alter and reduce ecosystem service delivery. A shared trait is the accumulation of massive seed banks, which enables them to become dominant after disturbances (Le Maitre et al., 2011).

These species were introduced for ornamental purposes and erosion control in coastal dunes. Acacia species induce simultaneous changes in the above- and below-ground communities, microclimates, soil moisture regimes and soil nutrient levels (Marchante et al., 2008; Yelenik et al., 2004). Many changes are directly attributable to key traits of Acacia species such as *i*) their rapid growth rates and ability to out-compete native plants, *ii*) their capacity to accumulate high biomass, *iii*) large, persistent seed banks, and *iv*) their capacity to fix nitrogen. These features enable them to dominate competitive interactions with native species (Le Maitre et al., 2011).

Acacia saligna produces large numbers of long-lived, hard-coated seeds that can remain dormant in the soil (Milton & Hall, 1981), and seed banks over 40,000 per m^2 have been recorded (Holmes et al., 1987). Small mammals can consume all the seeds of scattered trees, but these can also be removed by ants that take them below ground in their nests, safe from predation (Le Maitre et al., 2011). The species also reproduce vegetatively, forming vigorous sprouts from the stump and the roots (Invasoras, 2021).

The main impact of *A. saligna* is the formation of very dense populations inhibiting the development of native vegetation and the production of nitrogen-rich litter, which promotes soil change (Invasoras, 2021).

The *A. saligna* was rated 24, according to a protocol adapted from the Australian Weed Risk Assessment (Invasoras, 2021).

1.3 *Carpobrotus edulis*

This succulent plant of the Aizoaceae family seems to be well-adapted to the harsh conditions found in dunes and cliffs. It is a drought-resistant plant, which thrives in places with a warm temperate or dry climate, and grows both in acidic, alkaline and saline soils and in poorly nutritious soils (Campos et al., 2004).

This species, of South African origin, is very common as a garden plant and is often used to fix dunes and slopes (Invasoras, 2021). It frequently appears naturalized in dune ecosystems, eliminating the native species by competition (Campos et al., 2004).

Its impressive capacity for vegetative propagation, and seed production, led the *C. edulis* to quickly colonize large areas, becoming an invasive plant in the places introduced. The uncontrolled expansion of the *C. edulis* occurred, especially, in places with suitable climates such as southwestern Australia, California, the central Chilean coast and the Mediterranean basin. Nevertheless, also where climatic conditions are not so favourable, such as the British Isles, Ireland and New Zealand (Campos et al., 2004).

Once established, the *C. edulis* continues to grow and, the mats gradually become thicker, increasing the organic matter. These results in the change of the chemical properties of the soil (increased nitrogen and carbon content and reduced pH), which, in turn, has serious consequences for the germination, survival, growth and reproduction of other plants. In the diverse coastal habitats of Portugal and the Mediterranean basin, *C. edulis* forms nearly impenetrable mats, which eliminate the autochthonous vegetation (Campos et al., 2004).

The *C. edulis* was rated 23, according to a protocol adapted from the Australian Weed Risk Assessment (Invasoras, 2021). Currently, the *C. edulis* is one of the 100 worst invasive species in the world.

2 | Methodology

The barrier islands are included in the Ria Formosa SPA (PTZPE0017). The Ria Formosa is a complex coastal lagoon system, enclosed by five barrier islands (Barreta, Culatra, Armona, Tavira and Cabanas) and two peninsulas (Ancão and Cacela), which extends over 60 km. Ria Formosa is also classified as Natural Park and SCI (PTCON0013).

The Barrier Island system of the Algarve exhibits several unique characteristics that differ from more widely studied systems (Pilkey et al. 1989). From a geomorphological point of view, this system is unique in Europe. The islands are exceptional in both their physiographic setting and in the particular combination of environmental parameters responsible for their origin and evolution. The existence of this unusual chain of barrier islands is related to the presence of a shallow platform bounded by a relatively steep scarp or protuberance on the inner continental shelf. As a result, the Algarve barrier islands exist in equilibrium between island-degrading spring tides and the various processes of island construction.

The barrier islands and, in particular, the dune zones, are areas of high flora and fauna interest. Besides their intrinsic importance, these islands are home to several endemic plant species, priority bird species as well as priority habitats.

2.1 Mapping invasive plants

All invasive plant patches were identified and mapped on the five islands. Initially, to locate the different areas with invasive plants, the mapping was carried out by photo-interpretation of aerial photos. Later, each patch was validated in the field using a GPS. A photo of each patch was taken and, their location was recorded with GPS. Due to the large extension of the islands of Culatra, Armona, Tavira and Cabanas and the high number of invasive plants patches, it was not possible to quantify the area occupied by each species. Only its presence and location were recorded.

Only on Barreta Island, all spots were measured, with a measuring tape, to quantify the area occupied by the different species.

The final adjustments and the final calculation of the area were made using GIS analysis tools. Since the invasive plants in Barreta are distributed throughout the entire island, and to avoid duplication of effort in mapping the invasive patches, each patch was immediately controlled (under action C1) after mapping.

2.2 Collection of soil samples

To assess the chemical variations that occur in the soil due to the presence of invasive plants, in May 2020 soil samples were collected from four different areas: *i*) area occupied by *Carpobrotus edulis*, *ii)* area occupied by *Agave americana*, *iii*) area occupied by *Acacia saligna*, and *iv*) control area. Although distinct, these areas were located, whenever possible, close to each other, so that other biotic characteristics did not influence the results. Three samples were collected at each of the areas.

For each sample, referring to a homogeneous area, four to five sub-samples were collected at random, but close points. At each sampling point, the surface of the land was cleaned and, with a small shovel, a soil sample was collected from about 20-50 cm deep. The sub-samples were mixed and 500 g were removed and placed in a properly clean and labelled plastic bag (date of collection, collection area and sample number).
The analyzed parameters were field texture; pH; phosphorus, potassium, calcium and magnesium; percentage of nitrogen; percentage of organic matter; C/N ratio; electric conductivity; percentage of total limestone; calcium and magnesium exchange bases; ratio Ca exchange/Mg exchange; need in limestone. For this analysis, it was necessary to send the samples to the chemical analysis laboratory of the Instituto Superior de Agronomia.

3 | Results

The work carried out along the five barrier islands revealed the presence of eight species of invasive plants, although with different distributions and densities. The species detected were *Acacia sp., Agave americana, Arundo donax, Carpobrotus edulis, Cortaderia selloana, Eucalyptus globulus, Opuntia ficus-indica* and *Oxalis pes-caprae*.

3.1 Invasive plants on Barreta Island

As it was decided to carry out the mapping and control at the same time, the mapping of invasive plants on Barrreta Island is not yet finalized. The information included here will be updated annually, accordingly, the work carried out in the following months.
So far, the presence of three species has been identified: *A. saligna, A. americana* and *C. edulis*. The area occupied by each of the species can be seen in table 1.

Table 1 | Area occupied by each invasive species in Barreta Island, regarding data collected up to September 2021.

Species	Area (m^2)
Acacia saligna	618
Agave americana	67
Carpobrotus edulis	10928

The area occupied by each species is very different and is related to the removal effort (under Action C1) dedicated to each species. During 2020, the mapping was only directed to *C. edulis*. The mapping of *A. saligna* and *A. americana* only started, respectively, in May and September 2021. Figure 1 shows the distribution of different species along Barreta Island. A detailed map of different areas of the island can be found in Annex A.

Figure 1 | Distribution map of invasive plants on Barreta Island

We believe that up to September 2021, 80% of all patches of *A. saligna* were identified and about 75% of the *C. edulis* patches and 5% of *A. americana* total area.

3.2 Invasive plants on Culatra, Armona, Tavira and Cabanas Islands

The island with the lowest number of invasive species was Culatra (three species) and, the island with the highest number was Tavira (eight species). In table 2, we can find the different species present on each island.

Table 2 | Invasive plant species present on each island.

Species	Culatra	Armona	Tavira	Cabanas
Acacia sp.	X	X	X	X
Agave americana	X	X	X	X
Arundo donax			X	X
Carpobrotus edulis	X	X	X	X
Cortaderia selloana		X	X	
Eucalyptus globulus		X	X	
Opuntia ficus-indica			X	X
Oxalis pes-caprae		X	X	
Total	**3**	**6**	**8**	**5**

In Tavira and Armona islands, the invasive species are dispersed along all islands lengths (figure 2 and 3). Although in Cabanas we found five species, this island has the lowest number of invasive patches and, it is the island with less presence of invasive plants (figure 4). In Culatra Island, we found a strong relationship between the presence of invasive plants and the presence of houses (figure 5). A detailed map of different areas for each island can be found in Annexes B to E.

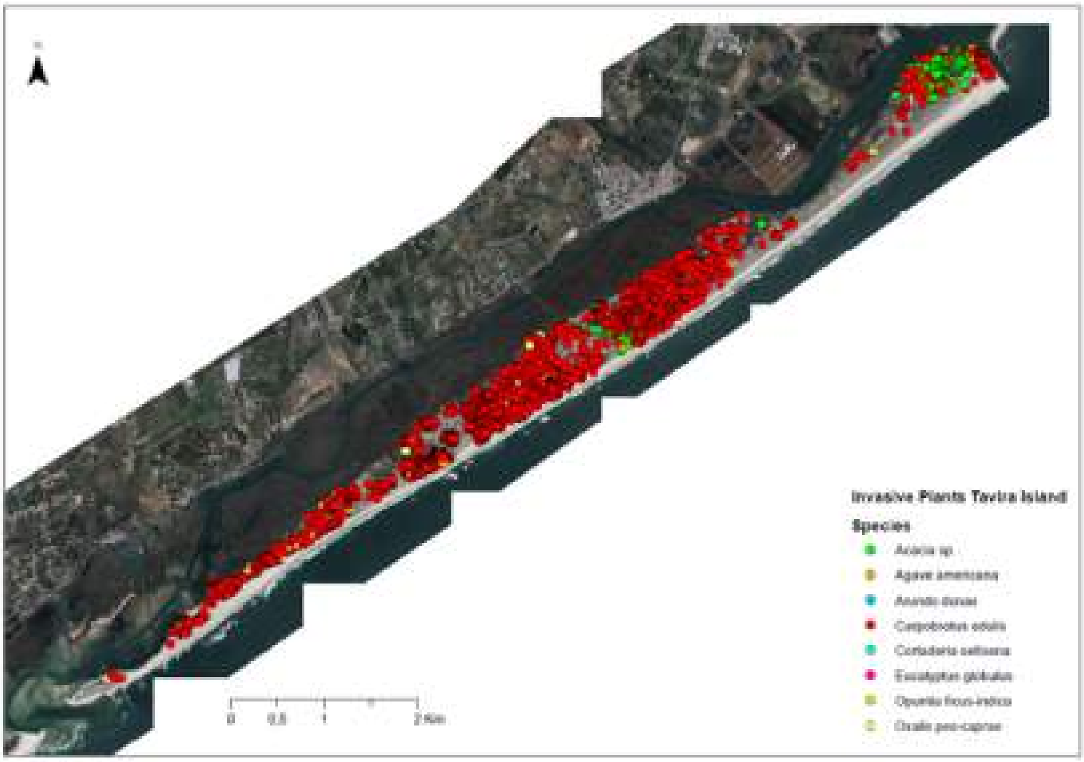

Figure 2 | Distribution map of invasive plants on Tavira Island

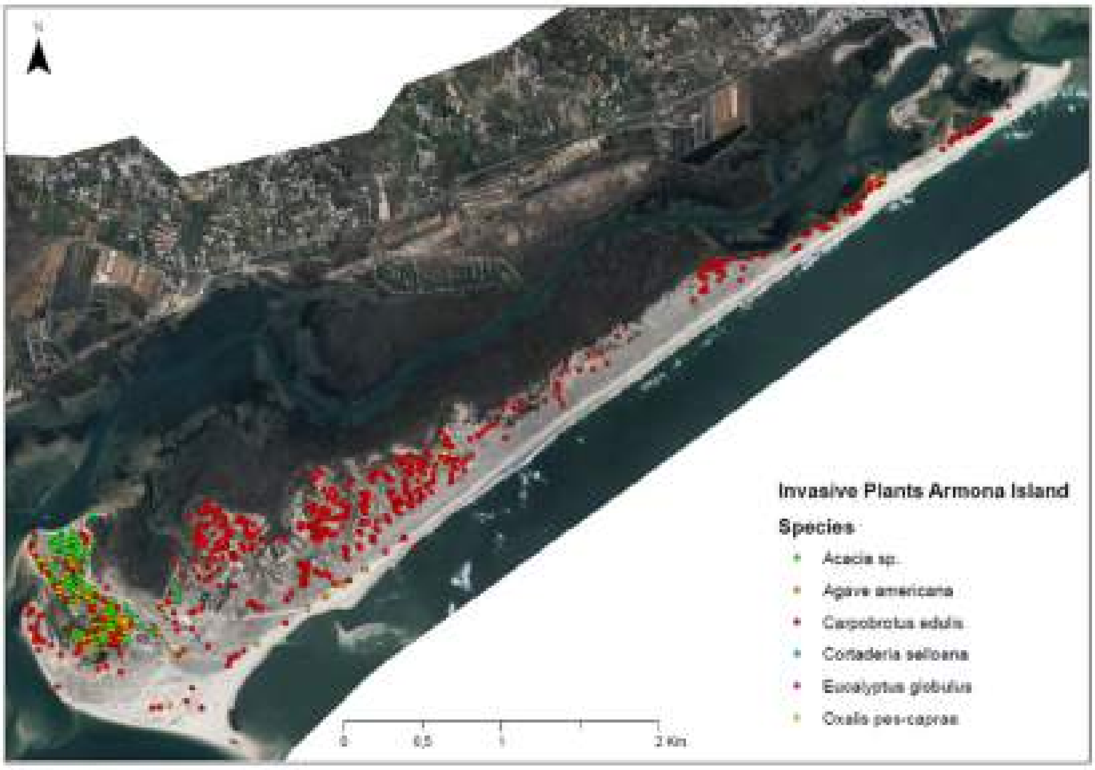

Figure 3 | Distribution map of invasive plants on Armona Island

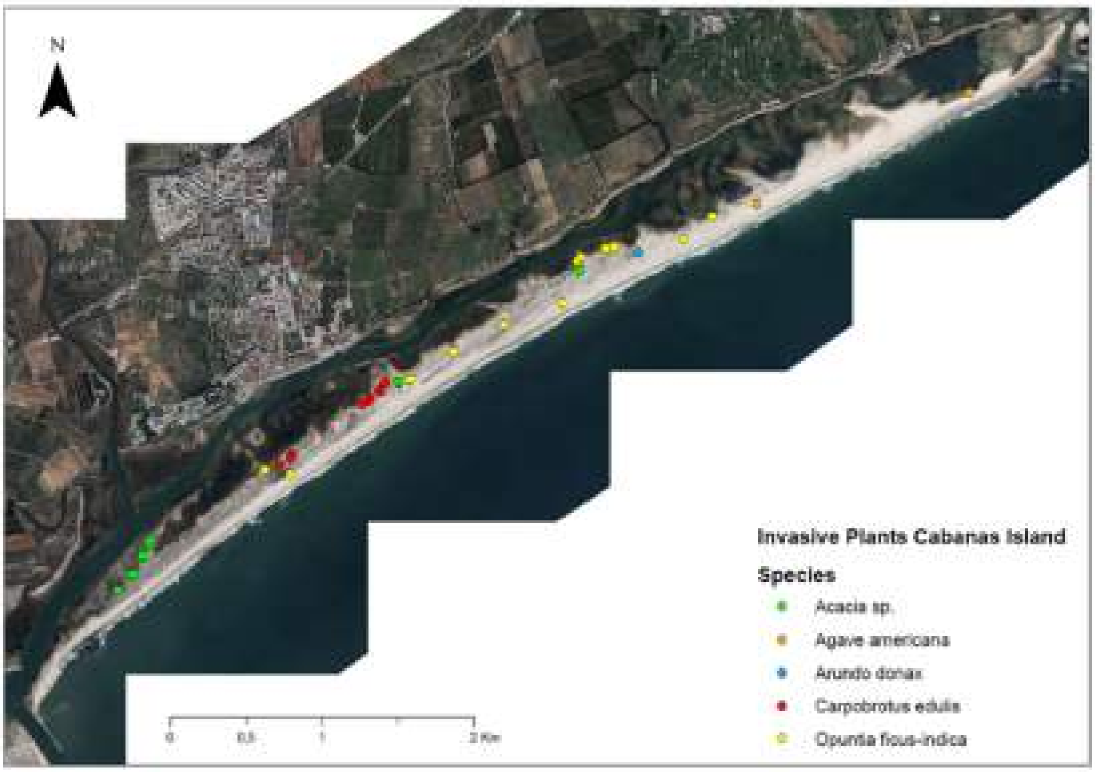

Figure 4 | Distribution map of invasive plants on Cabanas Island

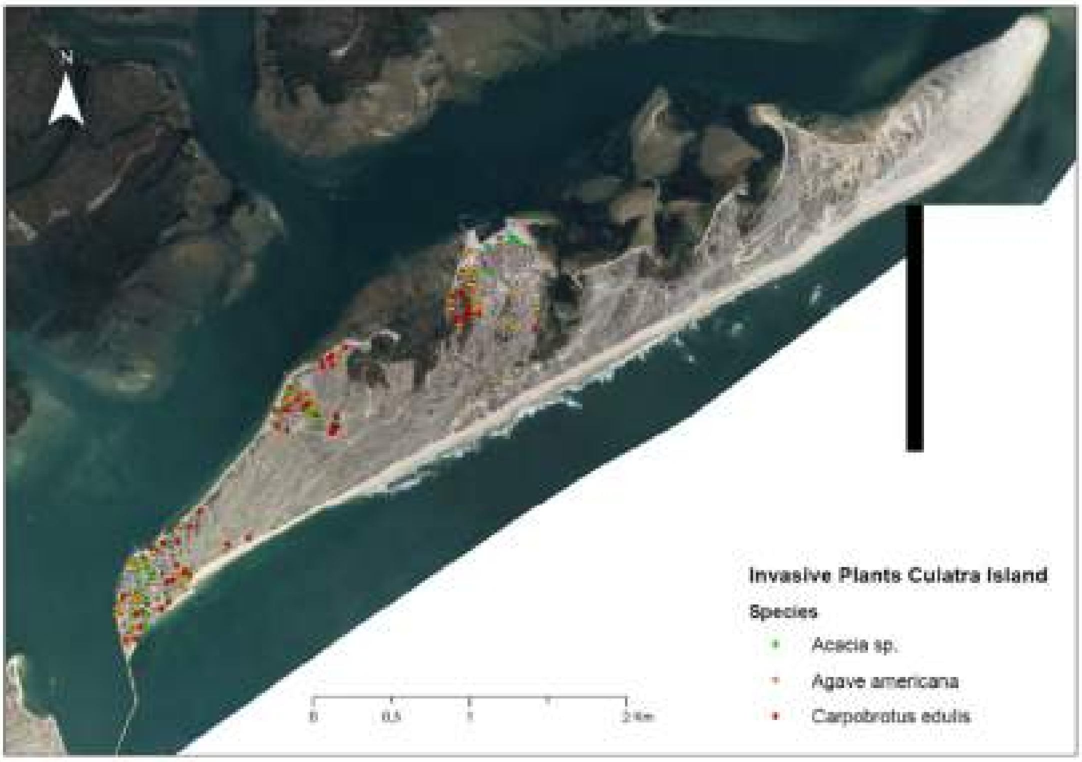

Figure 5 | Distribution map of invasive plants on Culatra Island

3.2 Soil samples analyses

The analyzes carried out on the soil, indicate the existence of some differences between the four areas. However, it should be noted that these analyzes are only indicative of differences between the soils occupied by the different invasive species. The final objective will be the comparison with the samples collected at the end of the project, to verify the changes in the soil after the habitat restoration is carried out.

The full results can be found in Annexes F to I, but the main differences found were:

Extractable phosphorus: this macronutrient presents low values in the control area (42, fertility index 2), while in the areas occupied by *C. edulis* and *A. saligna*, it presents high values (respectively 103 and 107, fertility index 4). In areas with *A. americana*, the value is medium (73), but also with a fertility index of 4.

Extractable potassium: this macronutrient presents low values in the areas with *A. americana* (35) and *A. saligna* (37, fertility index 2), but in the control areas, the values are very low (17, fertility index 1).

Extractable Magnesium: This macronutrient also varies. In areas with invasive plants, this macronutrient appears at low values (between 37 and 57, fertility index 2) but in the control area, the values are very low (22, fertility index 1).

C/N ratio: The highest differences are found between the control areas and the areas occupied by *A. saligna* and, it results from the organic matter content. Areas with *A. saligna* have higher values (Normal, 11), while control areas have a low value (5.25). This difference is related to the greater number of microorganisms that degrade the organic matter existing in areas with Acacia. It should be noted that, although the areas with *C. edulis* and *A. americana* present low values, for both areas the values are higher than those in the control areas, respectively 6.9 and 9.86.

4 | Discussion

We, as the main cause of exotic species introductions, must also be the main actor to fight this threat. Deepening the knowledge of the ecology of invasive species and the biological communities they affect, is essential to define the basis for the implementation of actions to eradicate invasive plants.

The invasive species found on the five barrier islands are the most common in the dune systems. However, we were surprised by their high dispersion, particularly on Tavira Island. This island has the highest number of invasive species (eight) and, the expansion of *C. edulis* throughout the entire island and the high number of Acacia trees present in the extreme east of the island is worrying. Although the situation on Armona Island is a little better, the higher presence of invasive species close to the housing nucleus and the high dispersion of *C. edulis* throughout the entire island is also a reason for concern.

The main objective of carrying out this mapping is to present to the competent entities (namely the municipalities) the reality on each island and, seek solutions for future control of these plants and also prevention to further introductions. Several public and private entities have been carrying out some specific actions to control invasive plants. It would be vital to create a network of entities that working together, in collaboration with island residents, could aim to remove these invasive plants from barrier islands. The maps provided in this report could be used to guide the work. Unfortunately, the proportion of invasive species present on the barrier islands is high and can harm the future conservation of native species in the dunes. Thus, it is important to define control measures for all islands, as well as priority intervention sites.

As mentioned in the results, the map referring to Barreta Island is not definitive and, it will be updated annually. This could lead to the identification of other invasive species. However, considering that on this island the *A. saligna, A. americana* and *C. edulis* are being removed, the work developed on Barreta Island can be used as an example and replicated to other sites.

Regarding the soil samples, our data indicate some variations in the values of macronutrients such as phosphorus, potassium and magnesium between the areas with the presence of invasive plants and the control area. It will be interesting to find out the variations obtained at the end of the project after the total removal of the invasive plants.

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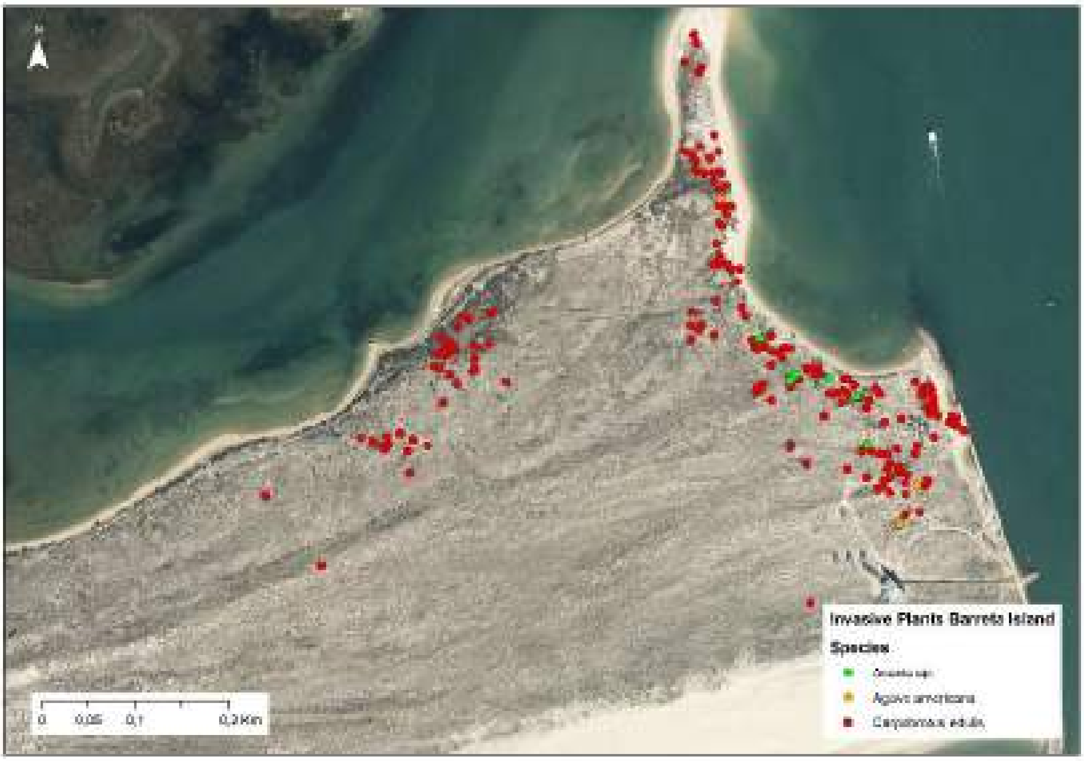
ANNEX

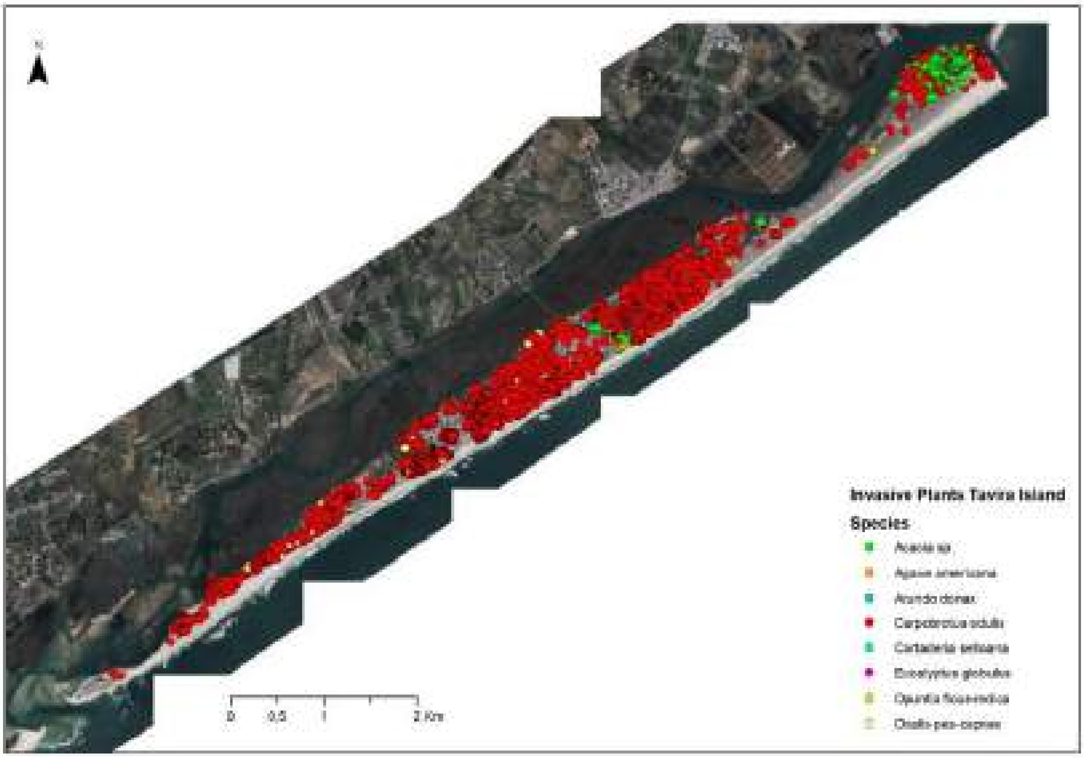
A – Detailed maps of Barreta Island and invasive plants distribution

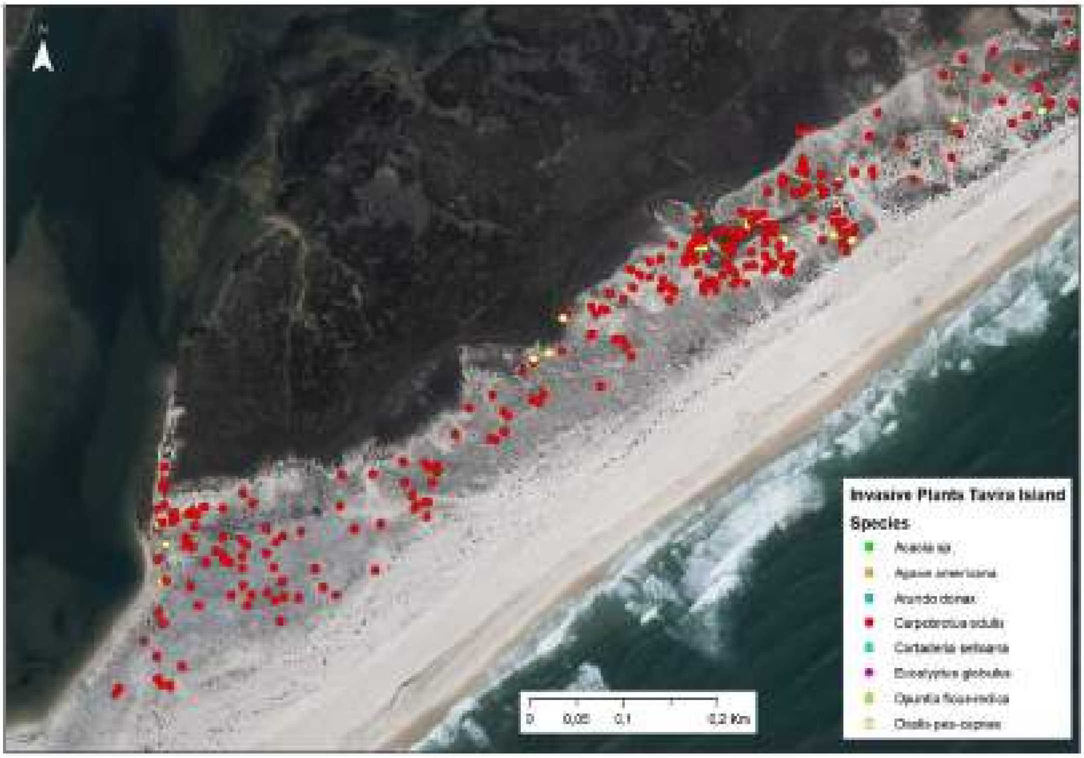

Invasive Plants Barreta Island
Species
0 0,05 0,1 0,2 Km


Invasive Plants Barreta Island
Species
0 0,05 0,1 0,2 Km


Invasive Plants Barreta Island
Species
Agave americana
Carpobrotus edulis
0
0,05
0,1
0,2 Km

B – Detailed maps of Tavira Island and invasive plants distribution




Invasive Plants Tavira Island
Species
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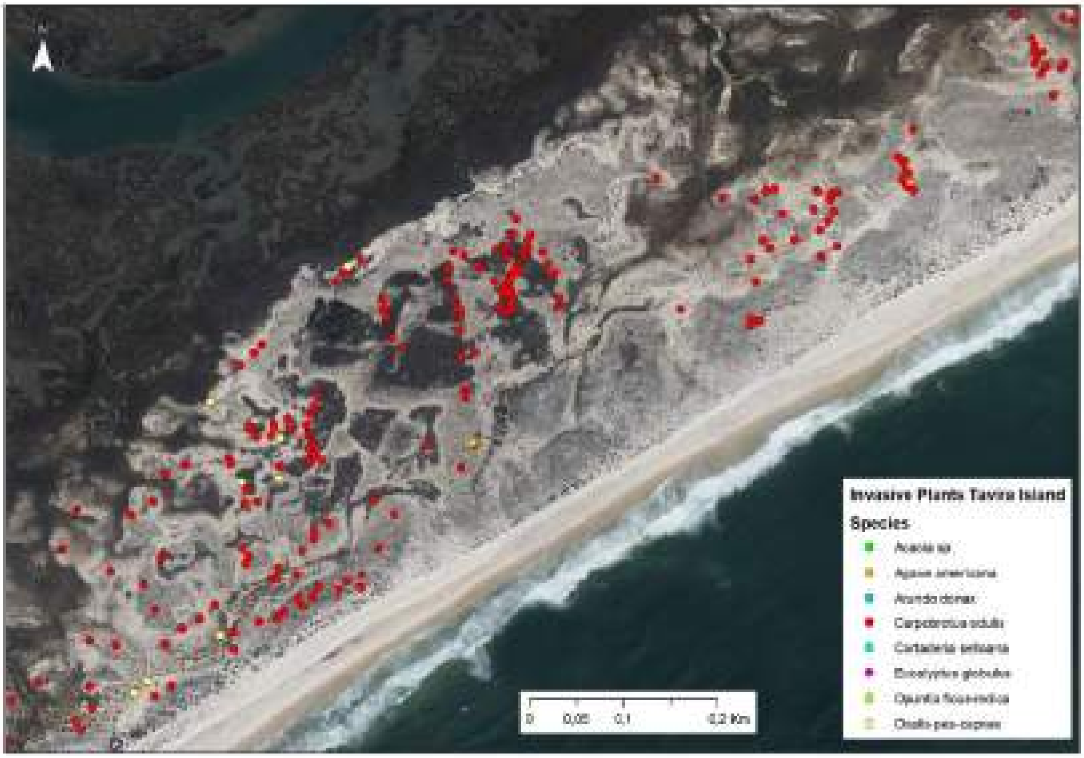
Invasive Plants Tavira Island
Species
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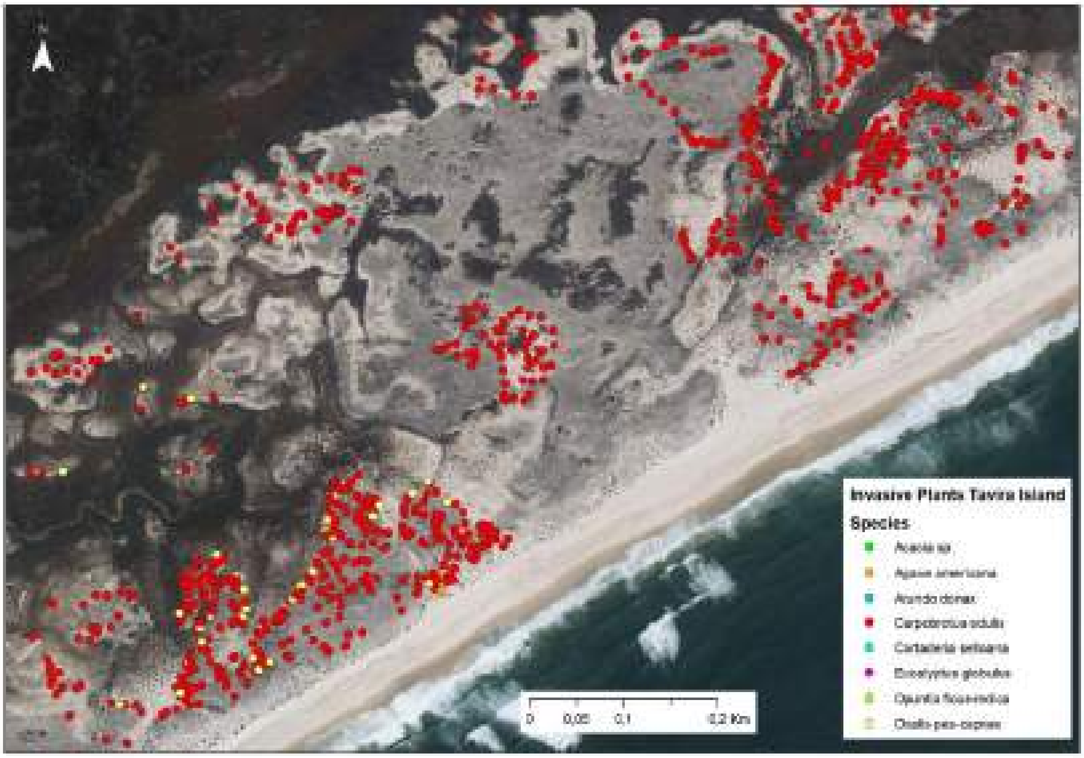
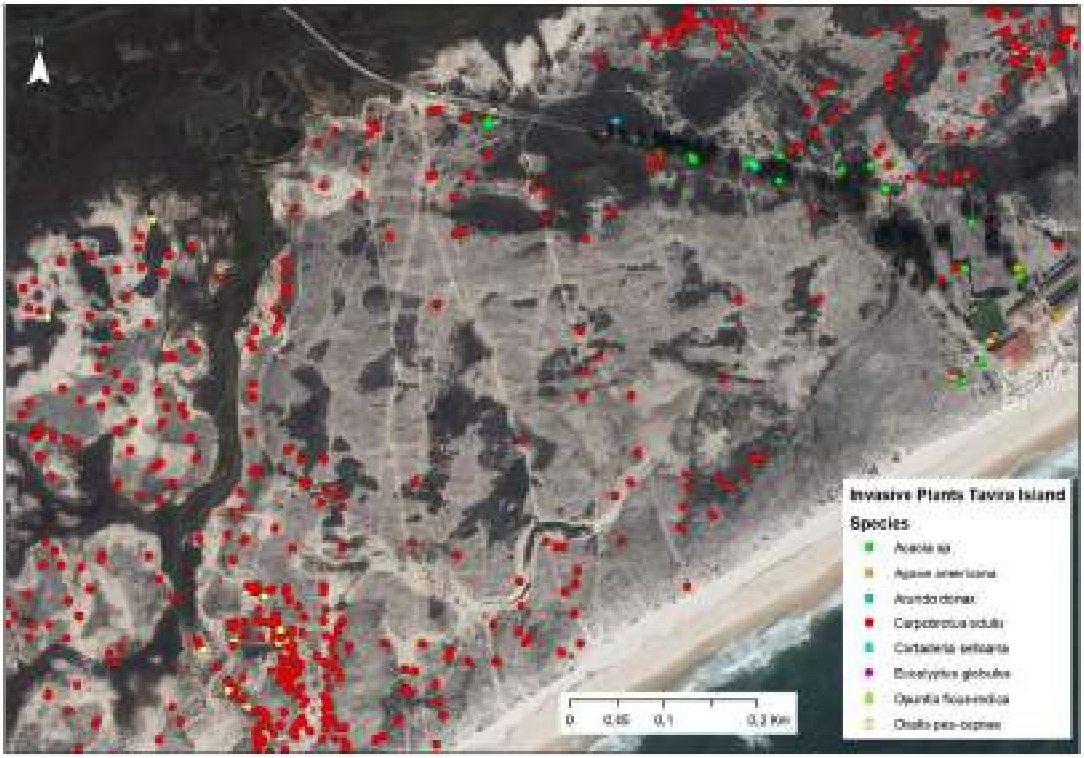
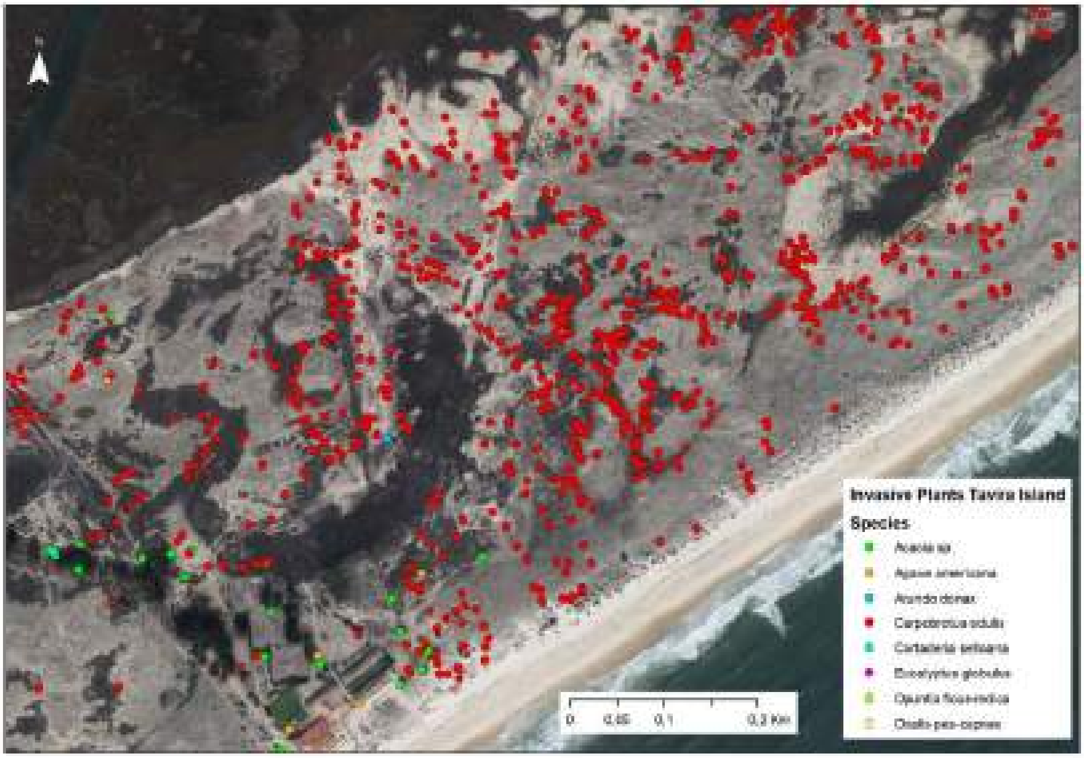
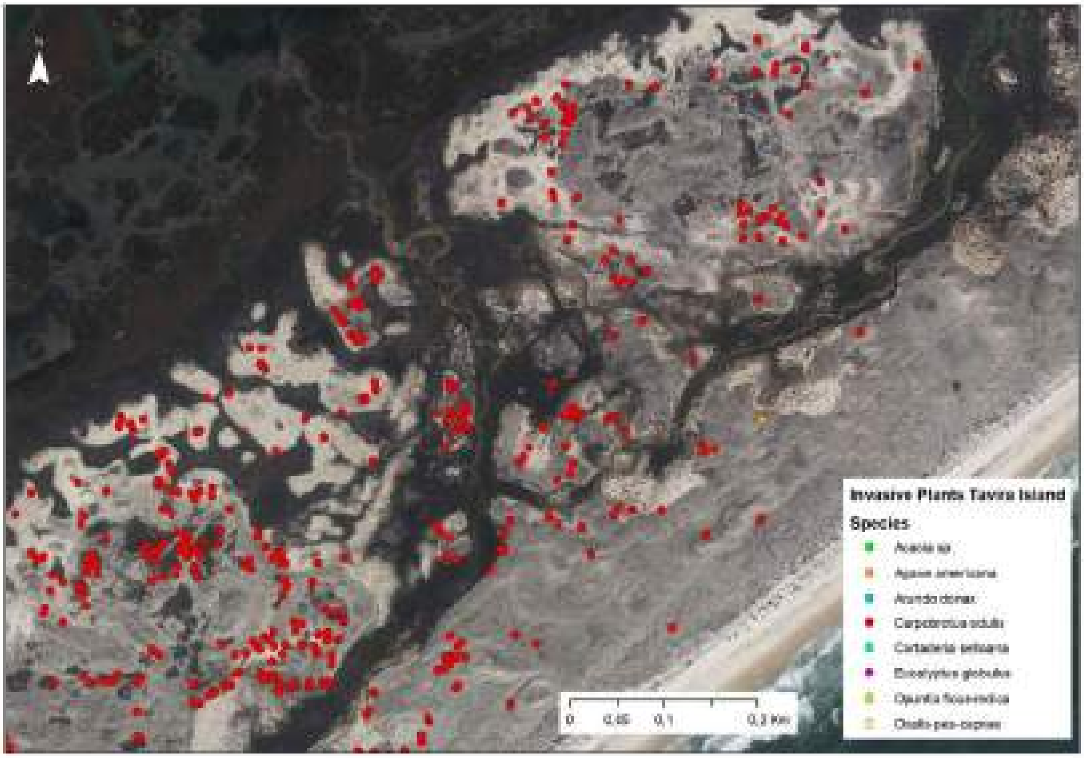

Invasive Plants Tavira Island
Species
0 0,05 0,1 0,2 Km


Invasive Plants Tavira Island
Species
0 0,05 0,1 0,2 Km

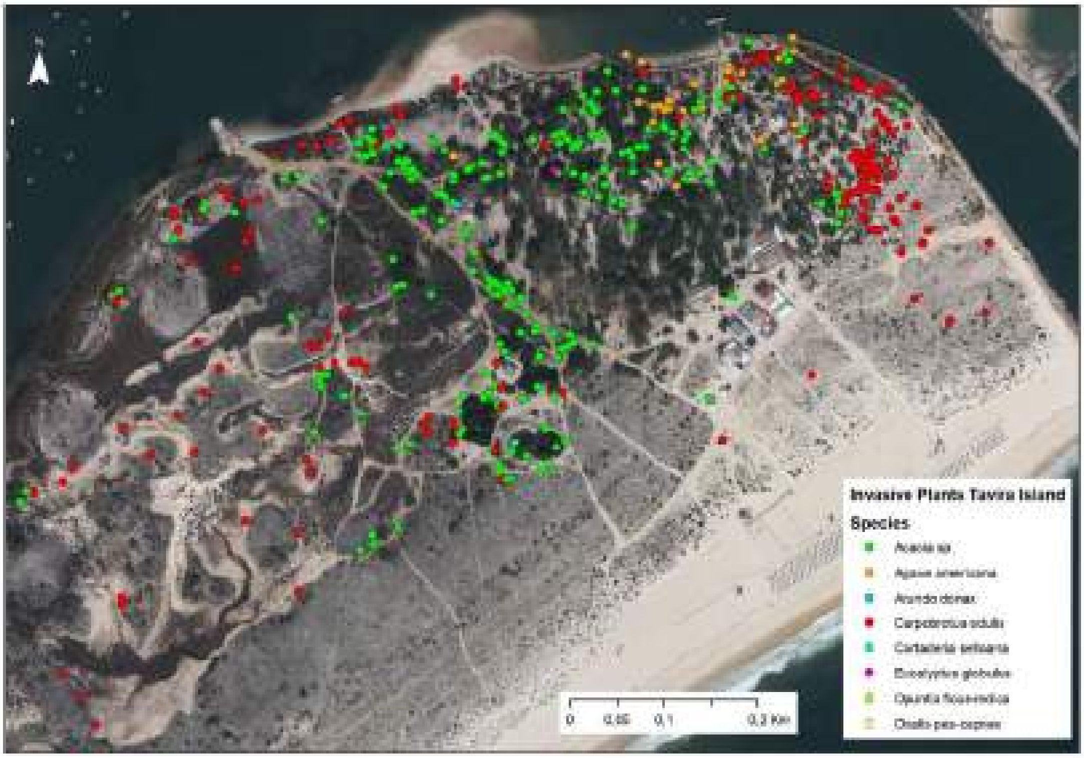

Invasive Plants Tavira Island
Species
Acacia sp.
Agave americana
Arundo donax
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Opuntia ficus-indica
Oxalis pes-caprae
0 0,05 0,1 0,2 Km


Invasive Plants Tavira Island
Species
Acacia sp.
Agave americana
Arundo donax
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Opuntia ficus-indica
Oxalis pes-caprae
0 0,05 0,1 0,2 Km

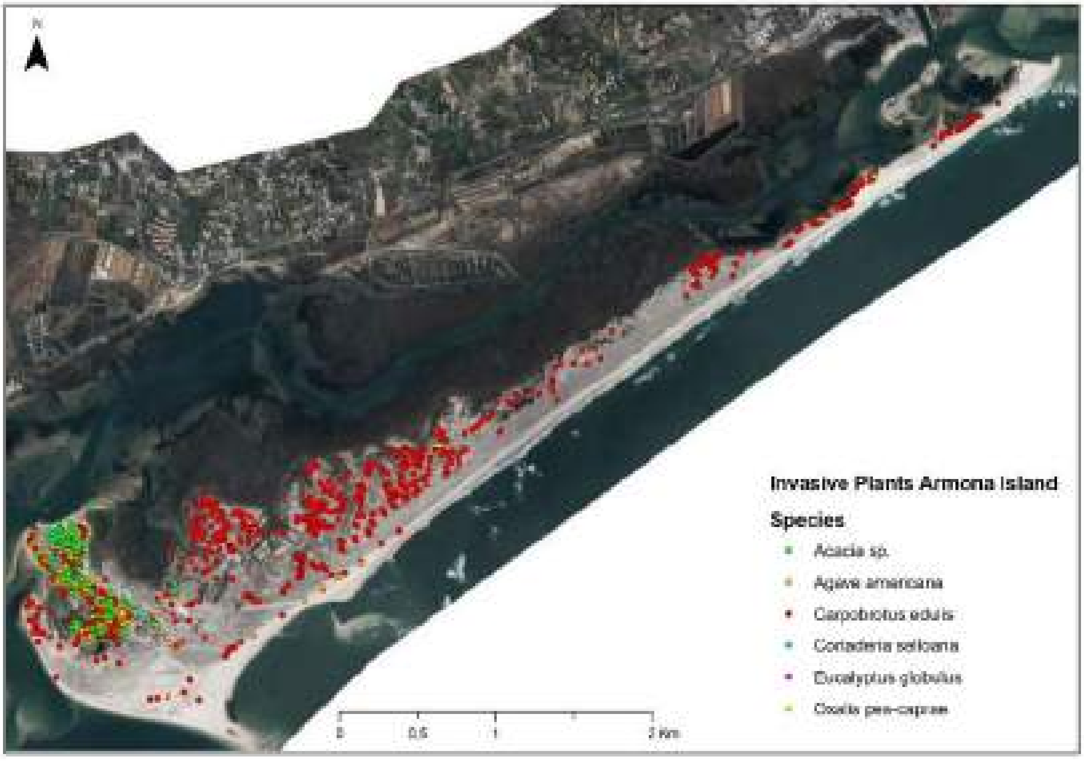

Invasive Plants Tavira Island
Species
0 0,05 0,1 0,2 Km

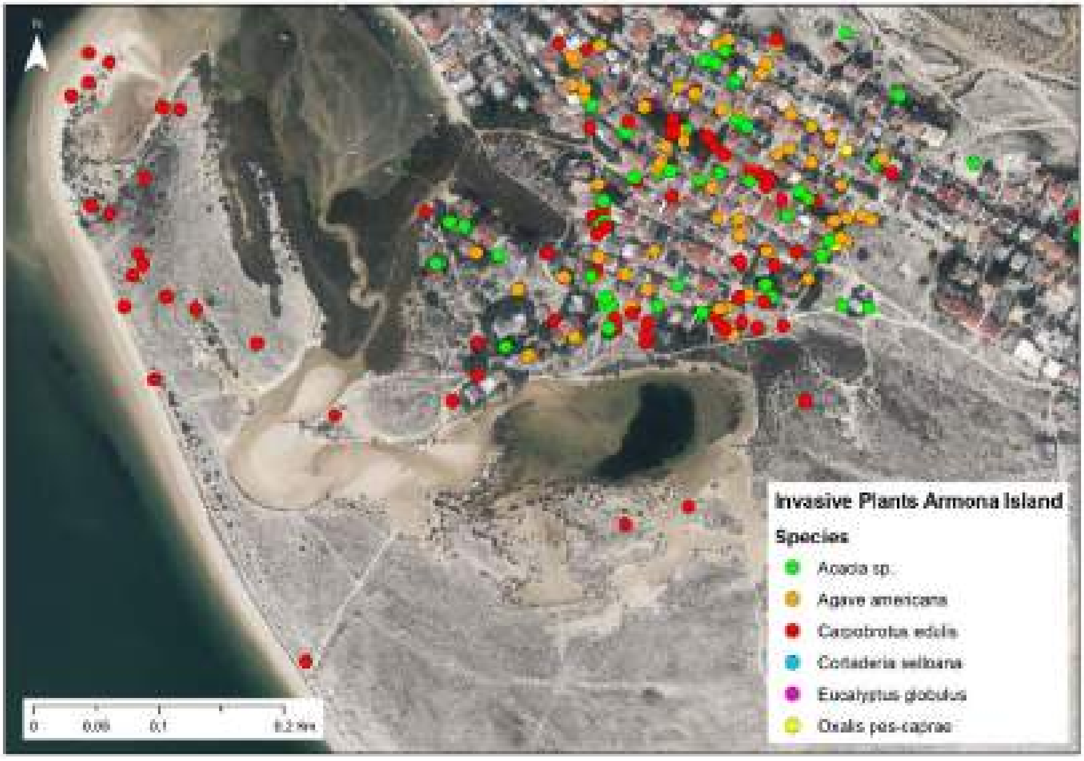

Invasive Plants Tavira Island
Species
0 0,05 0,1 0,2 Km

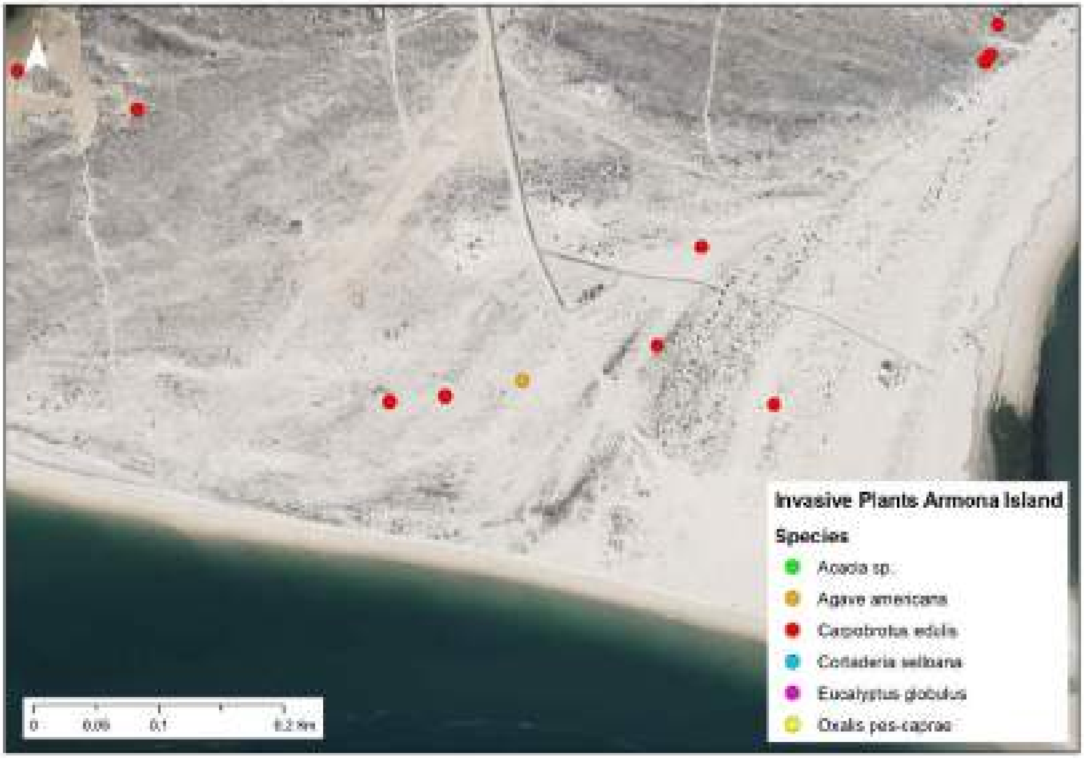

Invasive Plants Tavira Island
Species
0 0,05 0,1 0,2 Km

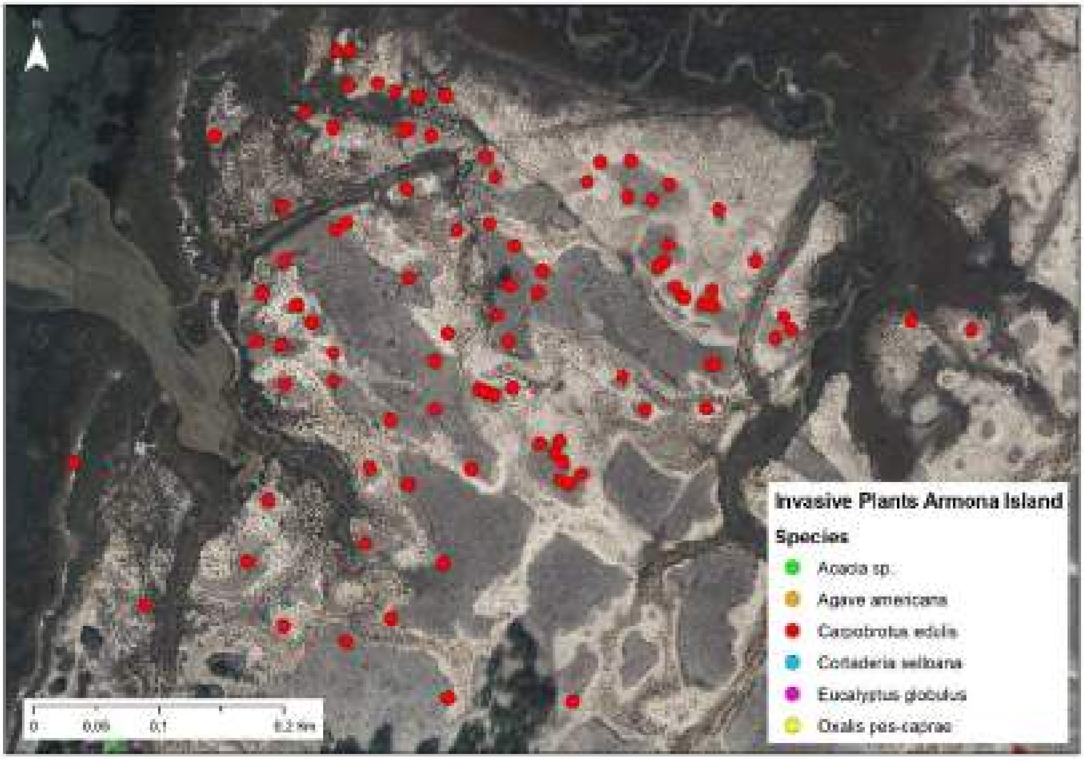

Invasive Plants Tavira Island
Species
0 0,05 0,1 0,2 Km

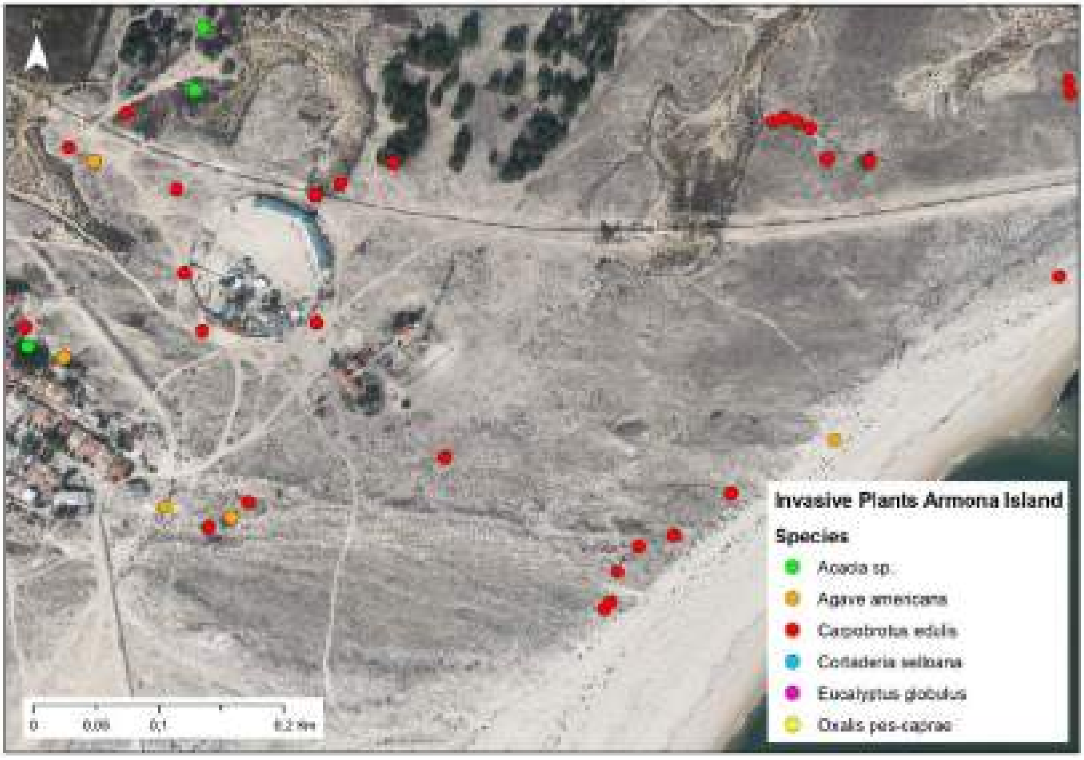
C – Detailed maps of Armona Island and invasive plants distribution

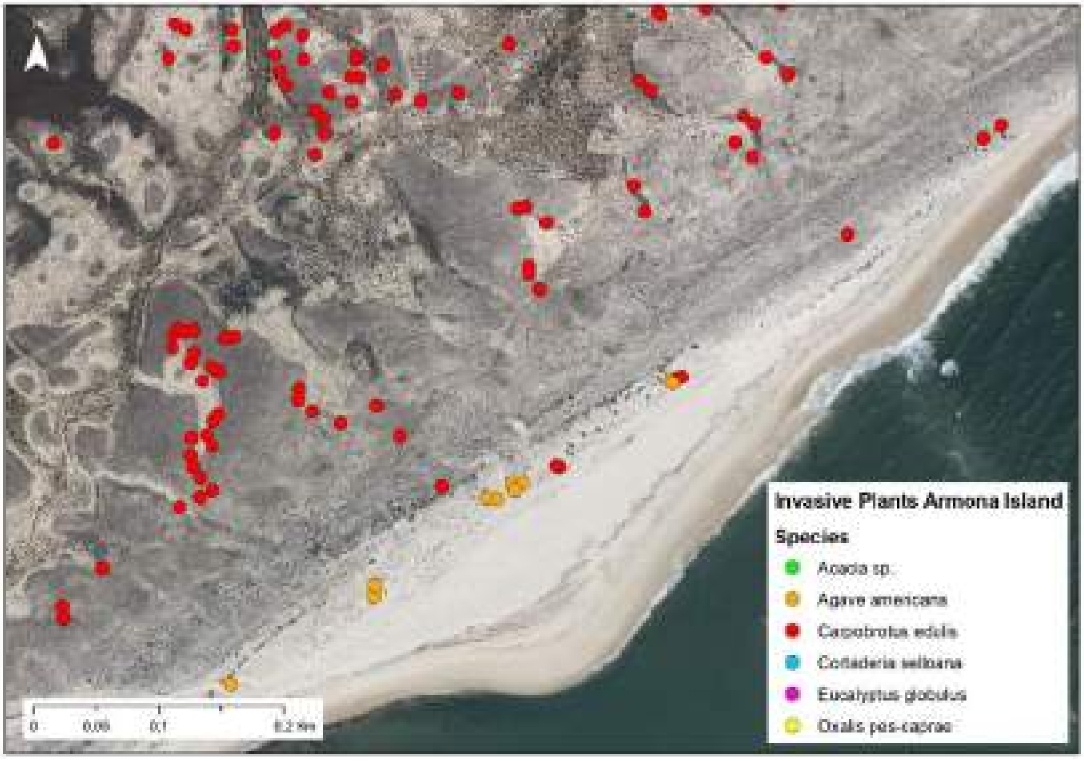


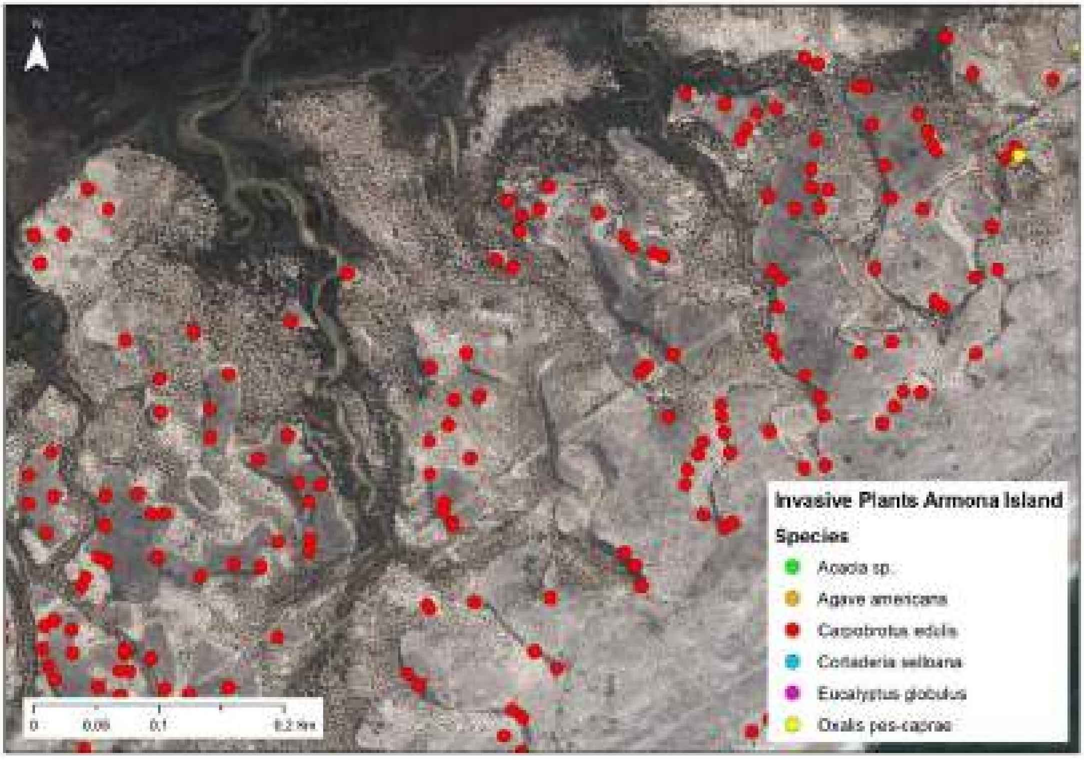

Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae


Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae


Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae
0
0,05
0,1
0,2 km


Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae
0
0,05
0,1
0,2 km


Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae
0
0,05
0,1
0,2 km


Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae
0
0,05
0,1
0,2 km


Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae
0
0,05
0,1
0,2 km

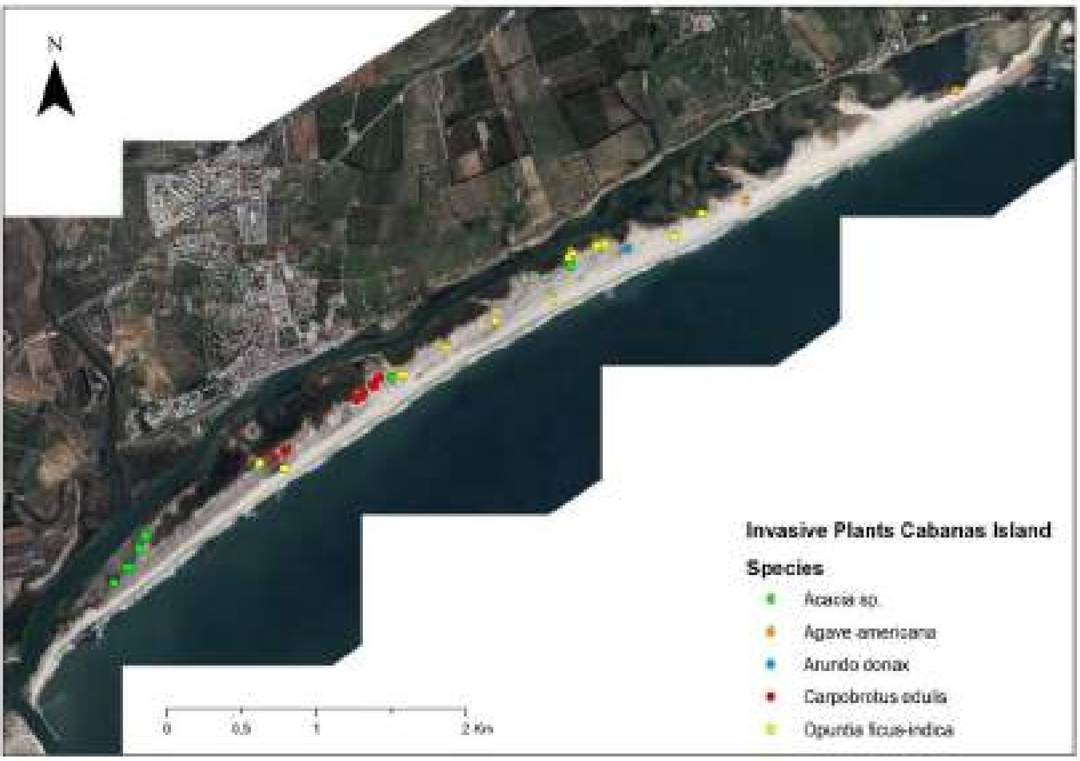

Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae
0
0,05
0,1
0,2 km

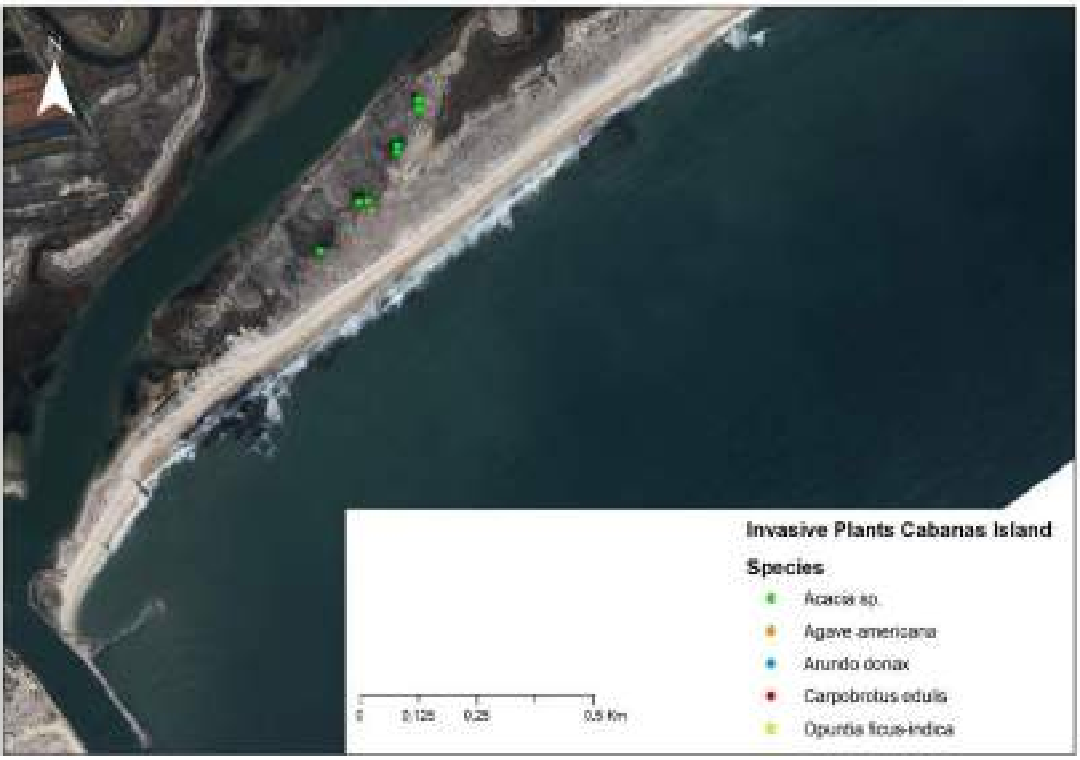

Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae
0
0,05
0,1
0,2 km


Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae
0
0,05
0,1
0,2 km


Invasive Plants Armona Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
Cortaderia selloana
Eucalyptus globulus
Oxalis pes-caprae

D – Detailed maps of Cabanas Island and invasive plants distribution



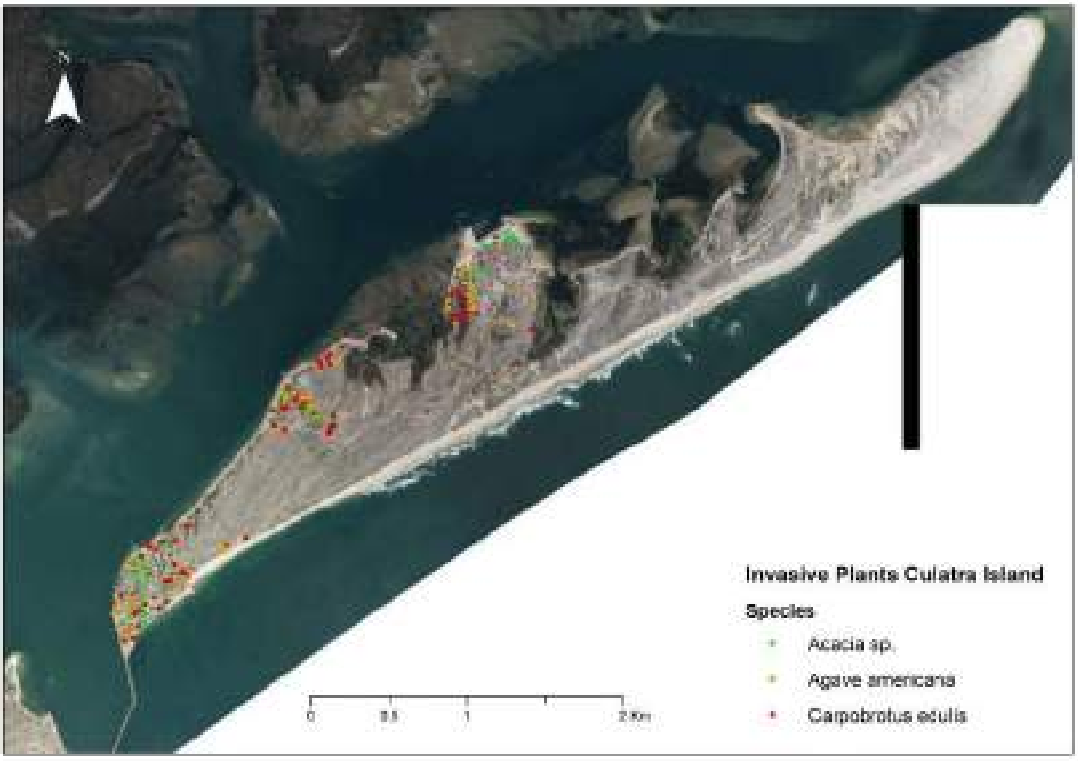



N
Invasive Plants Cabanas Island
Species
Acacia sp.
Agave americana
Arundo donax
Carpobrotus edulis
Opuntia ficus-indica


N
Invasive Plants Cabanas Island
Species
Acacia sp.
Agave americana
Arundo donax
Carpobrotus edulis
Opuntia ficus-indica

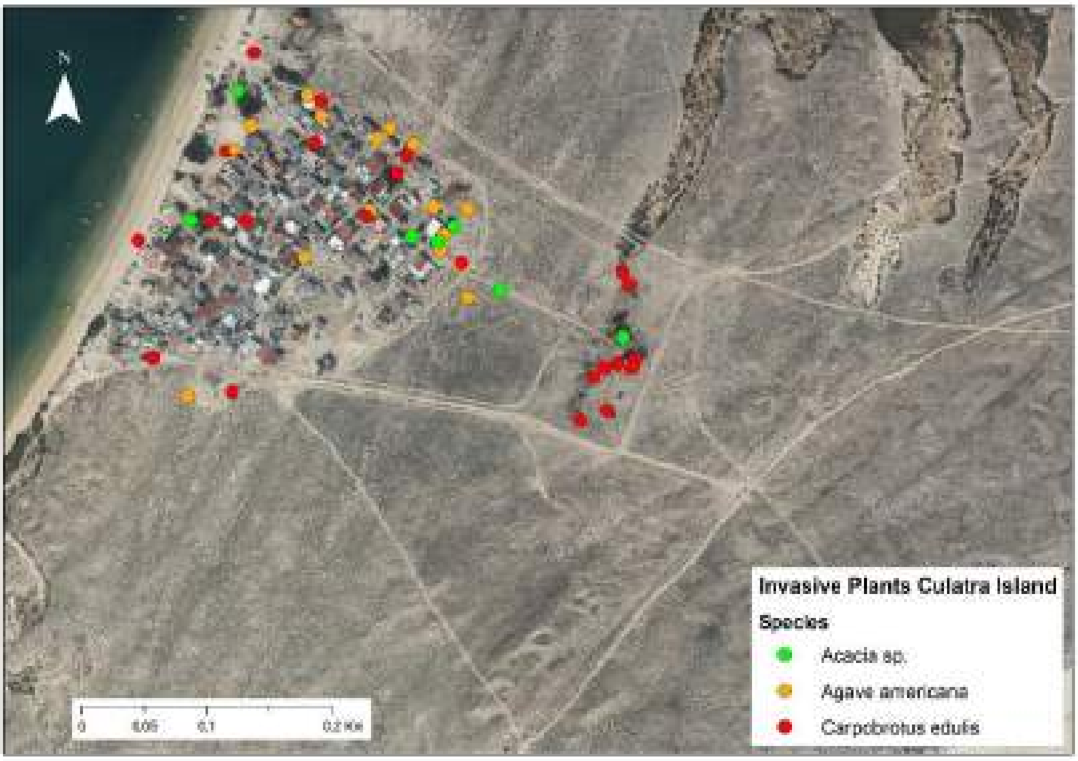

Invasive Plants Cabanas Island
Species
Acacia sp.
Agave americana
Arundo donax
Carpobrotus edulis
Opuntia ficus-indica
0 0.125 0.25 0.5 Km

E – Detailed maps of Culatra Island and invasive plants distribution

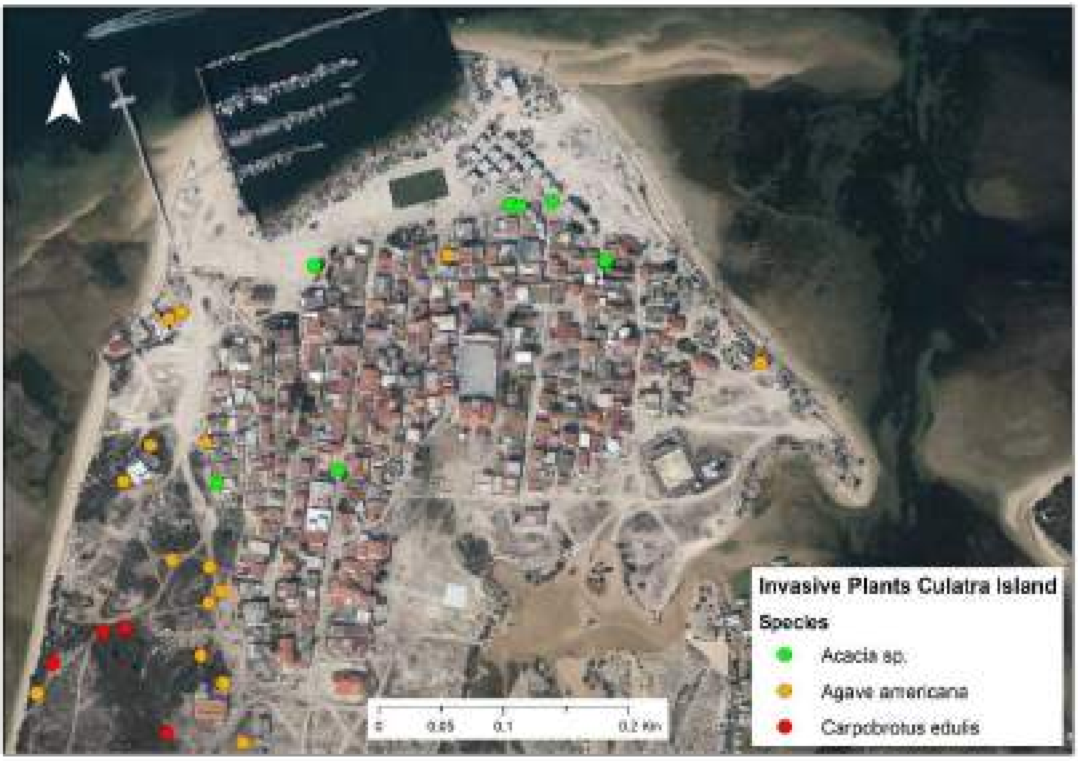


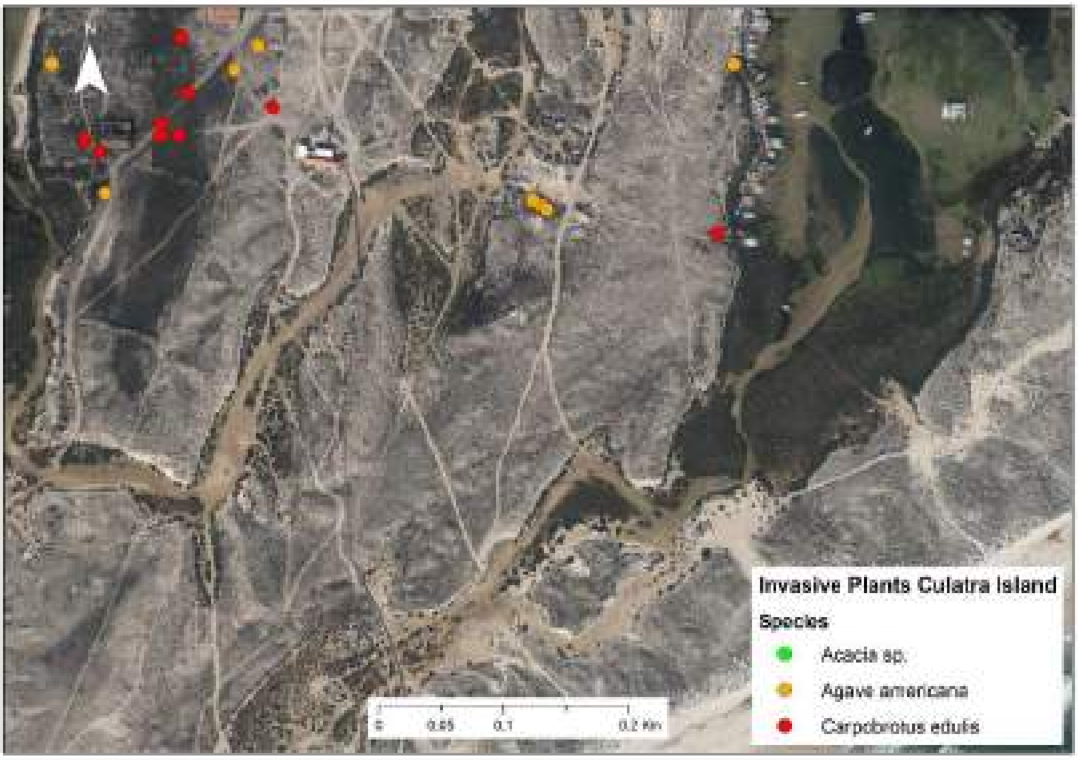

Invasive Plants Culatra Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis


Invasive Plants Culatra Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis


N
Invasive Plants Culatra Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
0
0,05
0,1
0,2 Km


N
Invasive Plants Culatra Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
0
0,05
0,1
0,2 Km


N
Invasive Plants Culatra Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
0 0.05 0.1 0.2 Km


N
Invasive Plants Culatra Island
Species
Acacia sp.
Agave americana
Carpobrotus edulis
0 0.05 0.1 0.2 Km

F - Soil sample results from areas with *Agave americana*

Parameter	Sample I	Notes	Sample II	Notes	Sample III	Notes
Texture	Sandy	Coarse	Sandy	Coarse	Sandy	Coarse
pH	9,1	Alkaline	9,1	Alkaline	9,5	Alkaline
Extractable phosphorus (mg/Kg)	37	Low (fertility rate 2)	92	Medium (fertility rate 4)	90	Medium (fertility rate 4)
Extractable potassium (mg/Kg)	30	Low (fertility rate 2)	30	Low (fertility rate 2)	45	Low (fertility rate 2)
Extractable calcium (mg/Kg)	823	Low	1316	Medium	1136	Medium
Extractable magnesium (mg/Kg)	16	Very Low (fertility rate 1)	33	Low (fertility rate 2)	88	Medium (fertility rate 3)
Nitrogen (N) %	0,022		0,028		0,039	
Organic matter %	0,22	Very Low	0,38	Very Low	0,48	Very Low
Ratio C/N	5,8	Low	7,87	Low	7,14	Low
Electric conductivity (mS/cm)	0,08	Non saline	0,06	Non saline	0,12	Non saline
Total limestone %	5	Little limestone	6,25	Little limestone	4,92	Little limestone
Calcium (exchange bases) cmol+/Kg	4,1	Low	6,57	Medium	5,67	Medium
Magnesium (exchange bases) cmol+/Kg	0,14	Very Low	0,27	Very Low	0,72	Low
Relation Ca exchange / Mg exchange	29,3	Very unfavorable, predominance of Ca over Mg	24,3	Very unfavorable, predominance of Ca over Mg	7,9	Unfavorable, predominance of Ca over Mg
Limestone requirement	0	Does not need liming	0	Does not need liming	0	Does not need liming

G - Soil sample results from areas with *Carpobrotus edulis*

Parameter	Sample IV	Notes	Sample V	Notes	Sample VI	Notes
Texture	Sandy	Coarse	Sandy	Coarse	Sandy	Coarse
pH	9,3	Alkaline	9,2	Alkaline	9,4	Alkaline
Extractable phosphorus (mg/Kg)	64	Medium (fertility rate 4)	>200	Very High (fertility rate 7)	45	Low (fertility rate 2)
Extractable potassium (mg/Kg)	26	Low (fertility rate 2)	24	Very Low (fertility rate 1)	13	Very Low (fertility rate 1)
Extractable calcium (mg/Kg)	1481	Medium	1448	Medium	1218	Medium
Extractable magnesium (mg/Kg)	31	Low (fertility rate 2)	41	Low (fertility rate 2)	38	Low (fertility rate 2)
Nitrogen (N) %	0,024		0,025		0,022	
Organic matter %	0,6	Very Low	0,4	Very Low	0,22	Very Low
Ratio C/N	14,5	High	9,28	Low	5,8	Low
Electric conductivity (mS/cm)	0,08	Non saline	0,07	Non saline	0,12	Non saline
Total limestone %	5,33	Little limestone	5,92	Little limestone	4,92	Little limestone
Calcium (exchange bases) cmol+/Kg	7,39	Medium	7,22	Medium	6,08	Medium
Magnesium (exchange bases) cmol+/Kg	0,25	Very Low	0,34	Very Low	0,31	Very Low
Relation Ca exchange / Mg exchange	29,6	Very unfavorable, predominance of Ca over Mg	21,2	Very unfavorable, predominance of Ca over Mg	19,6	Very unfavorable, predominance of Ca over Mg
Limestone requirement	0	Does not need liming	0	Does not need liming	0	Does not need liming

H - Soil sample results from areas with *Acacia saligna*

Parameter	Sample VII	Notes	Sample VIII	Notes	Sample IX	Notes
Texture	Sandy	Coarse	Sandy	Coarse	Sandy	Coarse
pH	9	Alkaline	8,9	Alkaline	8,6	Alkaline
Extractable phosphorus (mg/Kg)	99	Medium (fertility rate 4)	107	High (fertility rate 4)	117	High (fertility rate 4)
Extractable potassium (mg/Kg)	57	Medium (fertility rate 3)	19	Very Low (fertility rate 1)	35	Low (fertility rate 2)
Extractable calcium (mg/Kg)	1431	Medium	1274	Medium	1581	Medium
Extractable magnesium (mg/Kg)	52	Low (fertility rate 2)	28	Very Low (fertility rate 1)	89	Medium (fertility rate 3)
Nitrogen (N) %	0,046		0,027		0,062	
Organic matter %	0,9	Very Low	0,41	Very Low	1,34	Low
Ratio C/N	11,35	Normal	8,81	Low	12,54	High
Electric conductivity (mS/cm)	0,2	Non saline	0,1	Non saline	0,21	Non saline
Total limestone %	5,75	Little limestone	5,08	Little limestone	3,83	Little limestone
Calcium (exchange bases) cmol+/Kg	7,14	Medium	6,36	Medium	7,89	Medium
Magnesium (exchange bases) cmol+/Kg	0,43	Very Low	0,23	Very Low	0,73	Low
Relation Ca exchange / Mg exchange	16,6	Very unfavorable, predominance of Ca over Mg	27,7	Very unfavorable, predominance of Ca over Mg	10,8	Very unfavorable, predominance of Ca over Mg
Limestone requirement	0	Does not need liming	0	Does not need liming	0	Does not need liming

I - Soil sample results from control areas

Parameter	Sample X	Notes	Sample XI	Notes	Sample XII	Notes
Texture	Sandy	Coarse	Sandy	Coarse	Sandy	Coarse
pH	9,3	Alkaline	9,3	Alkaline	9,3	Alkaline
Extractable phosphorus (mg/Kg)	42	Low (fertility rate 2)	35	Low (fertility rate 2)	49	Low (fertility rate 2)
Extractable potassium (mg/Kg)	14	Very Low (fertility rate 1)	14	Very Low (fertility rate 1)	22	Very Low (fertility rate 1)
Extractable calcium (mg/Kg)	1260	Medium	965	Low	1045	Medium
Extractable magnesium (mg/Kg)	23	Very Low (fertility rate 1)	19	Very Low (fertility rate 1)	24	Very Low (fertility rate 1)
Nitrogen (N) %	0,023		0,021		0,024	
Organic matter %	0,05	Very Low	0,21	Very Low	0,36	Very Low
Ratio C/N	1,26	Low	5,8	Low	8,7	Low
Electric conductivity (mS/cm)	0,05	Non saline	0,06	Non saline	0,06	Non saline
Total limestone %	5	Little limestone	4,75	Little limestone	4	Little limestone
Calcium (exchange bases) cmol+/Kg	6,29	Medium	4,82	Low	5,21	Medium
Magnesium (exchange bases) cmol+/Kg	0,19	Very Low	0,16	Very Low	0,19	Very Low
Relation Ca exchange / Mg exchange	33,1	Very unfavorable, predominance of Ca over Mg	30,1	Very unfavorable, predominance of Ca over Mg	27,4	Very unfavorable, predominance of Ca over Mg
Limestone requirement	0	Does not need liming	0	Does not need liming	0	Does not need liming