MASTER SML

SCIENCES DE LA MER ET DU LITTORAL

MENTION

EXPERTISE ET GESTION DE

L'ENVIRONNEMENT LITTORAL

-

Emily ROBBINS

# Evolution and Resilience of barrier islands system in Ria Formosa, Portugal. Aerial photographs classification and laboratory work.

Mémoire de stage de Master *1*

Année Universitaire 2016-2017

Structure d'accueil : CIMA, Center of Marine Research of Faro

Tuteur universitaire: Alain Hénaff

Maître de stage : Ana MATIAS

## *AKNOWLEDGMENTS*

I am grateful to Ana Matias for having given me the opportunity to do this internship. I also want to thank all the EVEREST project team for your help during these two months. A special thank you to Katerina, Susana and Rita who took the time to understand my ArcGIS problems, I hope I didn't drive you crazy with it. Thank you Margarida to let me work on your laboratory, I really enjoyed it. "Poder feminino!"

## 1) INTRODUCTION

Barrier islands are coastal landforms, parallel to the mainland coast. They are made of sand with a dune system. This system, consisting of many islands, is usually separated from the mainland coast by areas of protected waters and wetlands.

Those islands are subject to change during storms or other action by creating new inlets for example. This coastal landform is protecting the coastline by absorbing the energy of the waves.

The EVREST project is mainly based at the CIMA (Centre of marine research) at the University of Algarve. The main objective of the project is to identify barrier resilience mechanisms and evolution in the Ria Formosa system. The timeframe for this study is the medium-to long-term. Four main geomorphological environments are studied: sandy barrier islands, dunes, salt marshes and pristine stable zones unaffected directly by tidal inlets.

This report is about trying to produce a vegetation map by using supervised or unsupervised classification on ArcGIS on orthophotographys of 2014 and 2008.

Culatra island has been chosen because of its particularity: during last decades the barrier embayment on the lagoon side of Culatra Island presents the environmental succession from sandy shore to saltmarsh. That is why this area is really interesting for the Everest project. Describing and understanding this evolution could be a great help understanding the mechanism of the barrier island system there.

## 2) PROJECT AREA:

- Location and regional setting


*Figure 1: Location map (Carrasco, 2006)*

Located in Algarve, south of Portugal, Ria Formosa was Classified as a Natural Park in 1987 and was included in the list of wetlands of world-wide interest defined by the Ramsar Convention. It encompasses an area of about 18 000 hectares. This Barrier islands system is large (55km long and 6km wide), composed of a series of five sandy islands and two peninsulas that separate the lagoon from the Atlantic and restrict water exchange. The lagoon is shallow, from 1.5m average to 3.5m in the channels. Most of the water in the lagoon part gets flushed out and replaced during a tidal cycle.

The shape of Ria Formosa produces two different areas in terms of wave exposure: The West and East areas. The west side is mostly exposed to W-SW wind and storms. The East side (Culatra) is directly exposed only to the "Levante" conditions (E–SE wind and waves) (A.R. Carasco and al., 2008).

The islands of Ria Formosa are now full of property, and the majority of the houses are under extreme risk of over washing for example.

The west part of Culatra Island is partially artificial (seawall, inlet jetty built in the early 1980's). The central part of the island used to be the location of an ancient inlet. The east side presents the development of curved sandy spits (Tiago Garcia and al.,2002). The old abandoned recurved spits have become low-energy environments where sediments get finer.

## Climate

In the Algarve region (south-western part of the Iberian Peninsula), the climate is strongly influenced by atmospheric circulation and topography. The studied area beneficiates of a Hot-Mediterranean climate: summers are warm to hot and sunny, the temperature goes between 27°C to 35°C during day time. During autumn and winter, the temperature goes from 8°C to 17°C. Precipitations events occur during winter months, the wettest months of the year is December with about 17% of total annual precipitation. Rain is really rare between June and September. The driest months are July and August with less than 1% of annual precipitation. That is why during that period the lagoon of the Ria Formosa doesn't get much fresh water. The annual rainfall is around 500 mm. The temperature of the sea surface is from 15°C in January and rises to 25°C in August.

## Vegetation

The embayment studied on Culatra Island presents the salt marsh habitat. This habitat is one of the highest productive areas on earth. Salt marshes are nursery places for many marine species. In this area the soil is soft because of the slow deposition of the sediment. Some plants of this area are totally immersed during high tide and emerged on low tide. The low-level part of the salt marsh is usually colonized by small cord-grass (*Spartina maritima*). This plant supports long immersion periods.

The vegetation slows down the current and accelerates the sedimentation rates: the level of the soil raises. The consequence is that the time of immersion can be reduced as well as the salinity.

In the low salt marshes (higher level part) the *Spartina* appears along with *Arthrocnemum perenne*, or can also be associate with *Salicornia nitens*, *Suaeda maritime*, *Atriplex* and *Limonium Algavense* (Algarve endemism) or *Limoniastrum monopetalum*.

In the high salt marsh, the upper part can be represented with *Juncus spp*. and *Artemisia campestris*. One rare species may be found: *Cistanche phelypaea*. (DITTY project, 2003)

## Land use

<u>Shellfish culture</u>

The clam and oyster culture in the lagoon of the Ria Formosa represents a huge contribution to the Algarve's economy. The annual production of clams (species of high economical value, as well as oysters) represents 90% of the regional production. Approximately 10 000 workers are directly or indirectly involved in this activity (POOC, 1997). Since many years the production of clams is decreasing because of the high mortalities of these benthic organisms because of environmental factors such as anthropogenic inputs from urban areas and the system hydrodynamics.

Shellfish catch

Shellfish catch consists on taking the animals directly in its natural environment. This technique overcomes the production of shellfish culture (ICN, 1999).

Fishing

The lagoon of Ria Formosa, because of its environmental factors such as salt marshes represent a nursery place for juveniles of oceanic fish species. Between ⅓ and ½ of Algarve's fishery arrived in Ria Formosa ports but most of the fishes are caught in oceanic water, not in the lagoon.

Salt extraction

50% of the salt produced in Portugal comes from Algarve, and a significant part from Ria Formosa. Because of international competition, this activity is now declining.

*Figure 2 : Salt extraction (www.formosamar.com)*

Tourism

Seasonal tourism is really important in Faro. The Ria Formosa is one of the famous tourist activity to visit in Algarve. Every day, many ferry boats and little cruise boats cross the lagoon for the tourists and local residents to go on the islands of the park.

*Figure 3 : Ferry boats ( http://ilha-deserta.com)*

## 3) *METHODS*

### Data informations

The image classification is made on orthophotographs of 2008 and 2014, provided by DGT (Direção-Geral do Território) of Portugal.

An **orthophoto** is an aerial photograph that has been geometrically corrected or '**ortho-rectified**' such that the scale of the photograph is uniform and utilised in the same manner as a map. An ortho-photograph can be used to measure true distances of features within the photograph. Planimetric corrections have been applied to remove lens distortions and optics, camera angle, and differences in elevation (topographic relief) through a process of measuring ground control points to 'tie' the photo to the ground, in a drawing-pin like manner. An orthophoto is an accurate representation of the Earth' s surface. Orthophotos have the benefits of high detail, timely coverage combined with the benefits of a map including uniform scale and true geometry.

www.photomapping.com

- Orthophotos of 2014

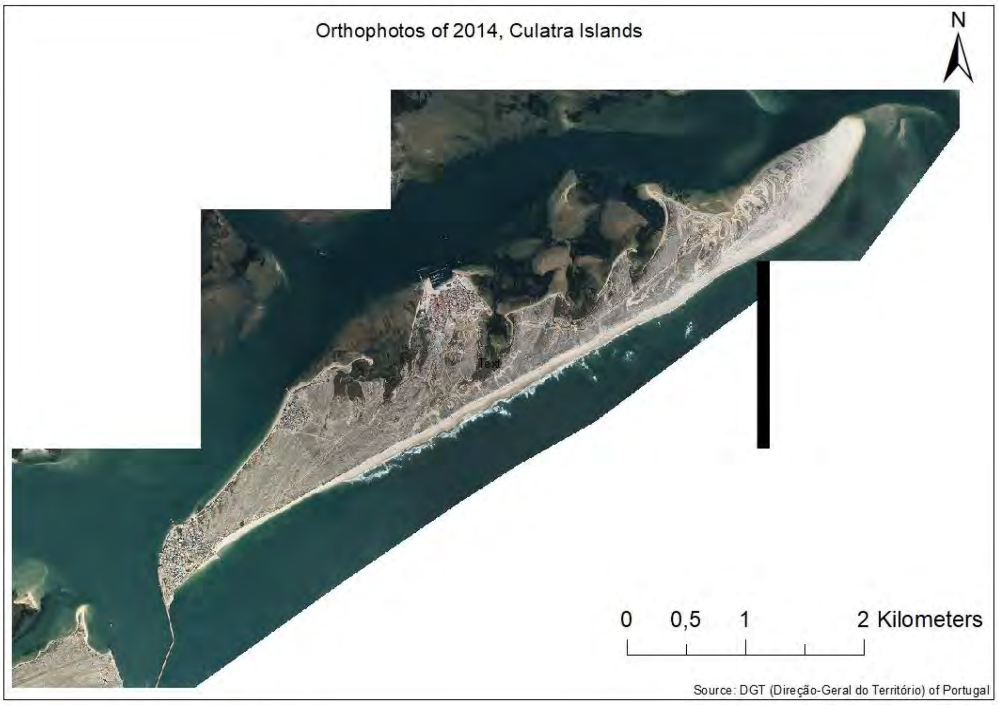



*Figure 4 : Orthophotos of 2014, Culatra Island*

- Orthophotos of 2008

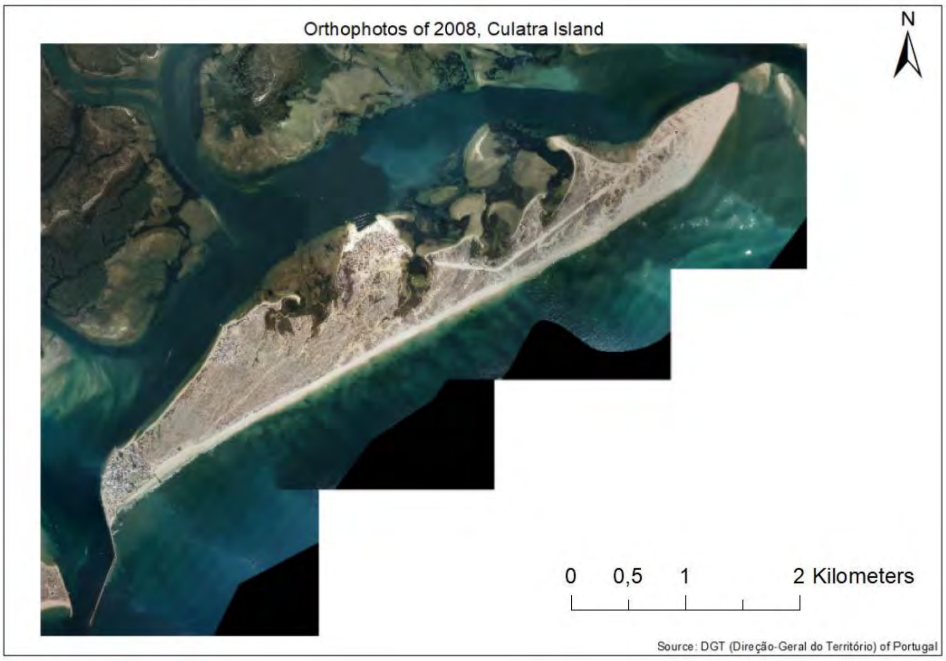



*Figure 5 : Orthophotos of 2008, Culatra Island*

In order to make the image classification easier and faster, a mosaic of the different orthophotogs has been made. The polygon that delimits the studied area has been made using a Trimble R6 Clobal Navigation Satellite System (GNSS) Receiver. The idea was to walk along the purple bushes of *Limoniastrum monopetalum* to create the shape of the studied area.

*Limoniastrum monopetalum* presents grey/green leaves sometimes rough to the touch due to salty exudates. The flowers are purple arranged at the top of the stems, rather large (1.5 cm diameter). The plants flower from June to September.

This plant is common in desert zones, on unstable sand of north and south coasts of the Mediterranean. It also penetrates the Sahara. (http://plants.jstor.org)


*Figure 8 : Shape of the studied area*

*Figure 6 : Limoniastrum monopetalum*

*Figure 7 : Bushes of Limoniastrum monopetalum*

The classification of the vegetation is made on ArcGIS, the tools used are available with Spatial Analyst license.

## Field data collection

Two days of field work was required from the 1st to the 2nd of June 2017. The measurements and sampling where made on the studied area of Culatra Island. The data collected about the embayment concerned topographic mapping of the area, sediment sampling and identification of mud and tidal flat vegetation.

- **Equipment and measurements:**

The elevation profile was made using a Trimble R6 Clobal Navigation Satellite System (GNSS) Receiver.


*Figure 9 : Trimble R6 Clobal Navigation Satellite System (GNSS) Receiver. (http://evrest.cvtavira.pt)*

During the field work, position data were collected for the sediment samples and vegetation. A total of 25 sediment samples were collected during the field work and taken to the laboratory. Each sample weight at least 200g.


*Figure 10 : Position of the samples (http://evrest.cvtavira.pt)*


*Figure 11 : Plants on the studied area*

It can be noted from the photos that the dominant species in the muddy areas of the tidal flat and low marsh is *Zostera noltei* with dense meadows in some parts. Around the embayment we found floating vegetation such as Ulva and dead vegetation mixed with Ulva. The upper part of the marsh is vegetated with a succession of *Spartina maritima*, *Salicornia sp.* and *Limoniastrum monopetalum*. Some parts of the upper part of the marsh were sparse vegetated.

## Laboratory work: Particle size distribution, Measurements techniques

The samples collected on the field are analysed in the laboratory during five work steps:

1- Ttriaging

2- Destroy organic matter

3- Separate the sand from the fine sediment

4- Sieve analysis

5- Sedimentation method

### Triaging

This step consists in choosing the right weight of sediment to process the sample: If it's a sample with fine sediments and sand, take 130g of it. If the sample contains only sand, 70g will be enough

- In a first place, dry the sample during 12 hours at a temperature between 76°C and 80°C.
- Then, every samples are weighed again to measure the percentage of water in each of them.

### Destroy organic matter

This step consists in destroying the organic matter of the samples using Hydrogen Peroxide during 4 days. One bottle of Hydrogen Peroxide represent 130 vol. Distillate water is used to dilute the Hydrogen Peroxide.

- First day: Put 10 vol. of Hydrogen Peroxide in one litre of distillate water
- Second day: Put 30 vol. of Hydrogen Peroxide in one litre of distillate water
- Third day: Put 60 vol. of Hydrogen Peroxide in one litre of distillate water
- Fourth day: Put 130 vol. (one bottle) of Hydrogen Peroxide

And then, put the samples in a bath at 80.7°C in order to destroy the rest of the organic matter.

- **Separate sand from fine sediment**

This step consists in separating sand and fine sediment by using a filter (aquarium filter) with 00.00001 µm porosity to take out only the water, and using a 63 µm sieve to separate the sand. Deionized water is used to separate the sample.

*Figure 13: Sand triaging with a 63 µm sieve*

*Figure 12: Water taken out with the aquarium filter*

*Figure 14: Sieves from 8mm to 63 µm*

- **Sieve analysis**

This steps consists in separating the grain of the sample by size using a sieve shaker (brand: Retsch) and weighing the amount collected on each sieve to determine the percentage weight in each size fraction.

- Shake each sample during 20 minutes with an amplitude of 100, on series of sieves from 8mm to 63 µm
- Then take the weight of each sieves and report to the sheet from the sieve analysis (Annex 1)

If some samples are finer than 63 µm, put it back with the rest of the fine sediment that correspond to the same sample.

- **Sedimentation method**

This sedimentation method is based on the measurement of the rate of setting the powder particles (fine sediment) uniformly dispersed in a fluid. The wetting agent added to ensure complete dispersion of the particles is sodium hexametaphosphate. During this method, six pipets will be taken in the sample.

- First pipet represents the total sediment
- Second pipet represents the very corse silt
- Third pipet represents the corse silt
- Fourth pipet represents the medium silt
- Fifth pipet represents the fine silt
- Sixth pipet represents the clay

First, prepare the sample one day before. Shake the sample for the fine sediment to be uniformly dispersed in the fluid. Put 3.04g of sodium hexametaphosphate in 1L of deionised water and take 70ml of this to put in the sample. Add deionised water to the sample to fill it until 1L. Then, shake again 2 min. Don't move the sample anymore.

<u>The sedimentation technique:</u>

**1)** Take the temperature of the samples to know how deep you have to put the pipet in the sample: 8°C = 6cm; 10°C = 6.5cm ;12°C = 7cm; 14°C = 7.5cm; 16°C = 8cm; 18°C = 8.5cm; 20°C =9 cm; 22°C = 9.5cm; 24°C = 10cm; 26°C = 10.5cm; 28°C = 11 cm, 30°C = 12cm

**2)** Take 6 pipets of 20ml:

- 0.00 min represents the total sample

- 1.45min represents the very coarse silt (<63-32< µm)

- 7.00 min represents the coarse silt (<32-16< µm)

- 28.00 min represents the medium silt (<16-8< µm)

- 1h.45min represents the fine silt (<8-4< µm)

- Take the temperature of the sample 30 min before the last pipet

-7h28min represents the clay (<4-2< µm)

**3)** Then dry the 6 sample during 12 hours at 100°C

**4)** After drying, weight the sample and its plate and report to the sheet of the sedimentation method (Annex 2)

**5)** Enter the results in the <u>*Gradistats*</u> (particle size analysis software)

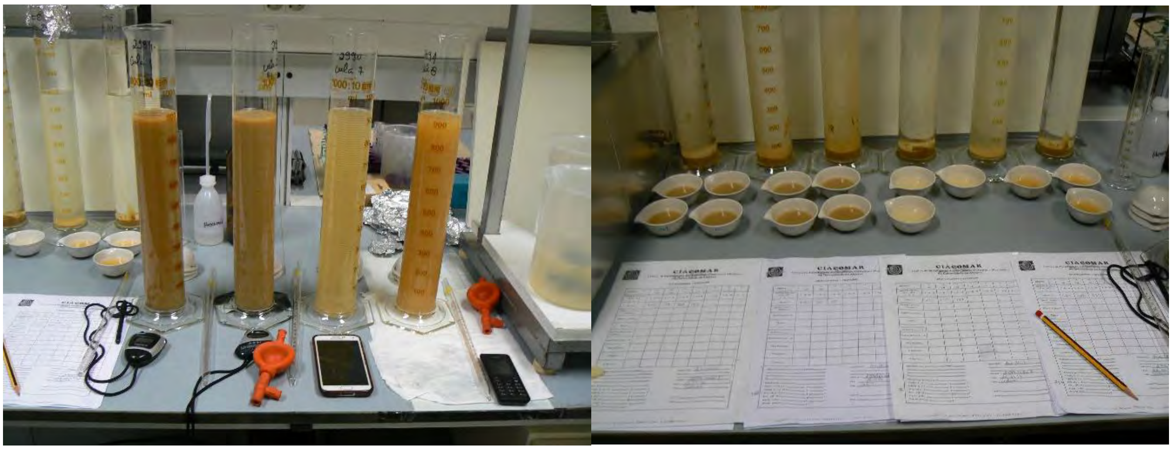


*Figure 15: Sedimentation method*

### Vegetation Classification

In order to realise the classification, the study has been divided in two part. The first part was to try to classify the aerial picture in two final classes:

- Vegetated Area
- Non vegetated area

The second part of the study was to try to classify the vegetated part along with the different environment and species:

- High marsh
- Low marsh
- Tidal flat

The method followed for each year is:

1) Classify the aerial photography in two final classes: Vegetated/Non vegetated

- Using *the Iso Cluster Unsupervised Classification*

> The Iso Cluster Unsupervised Classification tool automatically finds the clusters in an image and outputs a classified image. This tool is based on the Iso Cluster tool. The Iso Cluster tool only outputs a signature file, while the Iso Cluster Unsupervised Classification tool outputs a signature file and a classified image.
>
> desktop.arcgis.com

- Using the *Interactive Supervised Classification tool*

| |
|---|
| The Interactive Supervised Classification tool accelerates the maximum likelihood classification process. It works the same as the Maximum Likelihood Classification tool with default parameters. All the bands from the selected image layer are used by this tool in the classification. The classified image is added to ArcMap as a raster layer. |
| desktop.arcgis.com |

For the two orthophotos of 2014 and 2008, we can use the NDVI function:

| |
|---|
| The Normalized Difference Vegetation Index (NDVI) is a standardized index allowing you to generate an image displaying greenness (relative biomass). This index takes advantage of the contrast of the characteristics of two bands from a multispectral raster dataset—the chlorophyll pigment absorptions in the red band and the high reflectivity of plant materials in the near-infrared (NIR) band. |
| desktop.arcgis.com |

This function will help us to see if the classification is correct or not.

2) Classify the vegetated area along with the different environment and species present
- Using *the Iso Cluster Unsupervised Classification* on the whole area
- Using *the Iso Cluster Unsupervised Classification* inside the vegetated area created during the first part
- Using *Interactive Supervised Classification tool* inside the vegetated area created during the first part

## 4) RESULTS

### Laboratory work results

"A computer program called GRADISTAT has been written for the rapid analysis of grain size statistics from any of the standard measuring techniques, such as sieving and laser granulometry. Mean, mode, sorting, skewness and other statistics are calculated arithmetically and geometrically (in metric units) and logarithmically (in phi units) using moment and Folk and Ward graphical methods. Method comparison has allowed Folk and Ward descriptive terms to be assigned to moments statistics. Results indicate that Folk and Ward measures, expressed in metric units, appear to provide the most robust basis for routine comparisons of compositionally variable sediments. The program runs within the Microsoft Excel spreadsheet package and is extremely versatile, accepting standard and non-standard size data, and producing a range of graphical outputs including frequency and ternary plots.” (SIMON J. BLOTT and al.,2001)

- SAMPLE STATISTICS

| | | 2984.Cul.1 | 2985.Cul.2 | 2986.Cul.3 | 2987.Cul.4 | 2988.Cul.5 |
|---|---|---|---|---|---|---|
| | ANALYST AND DATE: | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 |
| | SIEVING ERROR: | | | | | |
| | SAMPLE TYPE: | Unimodal, Poorly Sorted | Unimodal, Poorly Sorted | Unimodal, Poorly Sorted | Unimodal, Moderately Sorted | Unimodal, Poorly Sorted |
| | TEXTURAL GROUP: | Slightly Gravelly Muddy Sand | Slightly Gravelly Muddy Sand | Slightly Gravelly Sand | Slightly Gravelly Sand | Slightly Gravelly Sand |
| | SEDIMENT NAME: | Slightly Very Fine Gravelly Muddy Medium Sand | Slightly Medium Gravelly Muddy Medium Sand | Slightly Very Fine Gravelly Medium Sand | Slightly Very Fine Gravelly Medium Sand | Slightly Fine Gravelly Medium Sand |
| METHOD OF MOMENTS Arithmetic (□m) | MEAN $(\bar{x}_a)$: | 519,3 | 526,7 | 454,0 | 464,1 | 548,6 |
| | SORTING $(\sigma_a)$: | 516,6 | 990,5 | 314,1 | 326,1 | 909,9 |
| | SKEWNESS $(Sk_a)$: | 5,263 | 7,269 | 3,706 | 2,840 | 6,997 |
| | KURTOSIS $(K_a)$: | 54,53 | 61,92 | 37,62 | 17,79 | 58,58 |
| METHOD OF MOMENTS Geometric (□m) | MEAN $(\bar{x}_g)$: | 252,9 | 228,3 | 305,5 | 349,6 | 312,0 |
| | SORTING $(\sigma_g)$: | 6,009 | 5,765 | 3,737 | 2,677 | 3,807 |
| | SKEWNESS $(Sk_g)$: | -1,919 | -1,794 | -2,920 | -3,376 | -2,429 |
| | KURTOSIS $(K_G)$: | 5,727 | 5,842 | 11,77 | 19,24 | 10,99 |
| METHOD OF MOMENTS Logarithmic (□) | MEAN $(\bar{x}_\phi)$: | 1,983 | 2,131 | 1,711 | 1,516 | 1,680 |
| | SORTING $(\sigma_\phi)$: | 2,587 | 2,527 | 1,902 | 1,421 | 1,929 |
| | SKEWNESS $(Sk_\phi)$: | 1,919 | 1,794 | 2,920 | 3,376 | 2,429 |
| | KURTOSIS $(K_\phi)$: | 5,727 | 5,842 | 11,77 | 19,24 | 10,99 |
| FOLK AND WARD METHOD (□m) | MEAN $(M_G)$: | 398,2 | 346,0 | 389,1 | 386,1 | 374,7 |
| | SORTING $(\sigma_G)$: | 3,916 | 3,694 | 2,688 | 1,759 | 2,720 |
| | SKEWNESS $(Sk_G)$: | -0,380 | -0,308 | -0,359 | 0,095 | -0,206 |
| | KURTOSIS | 2,996 | 3,373 | 2,657 | 1,069 | 2,644 |
| FOLK AND WARD METHOD (□) | MEAN $(M_Z)$: | 1,329 | 1,531 | 1,362 | 1,373 | 1,416 |
| | SORTING $(\sigma_I)$: | 1,969 | 1,885 | 1,427 | 0,815 | 1,444 |
| | SKEWNESS $(Sk_I)$: | 0,380 | 0,308 | 0,359 | -0,095 | 0,206 |
| | KURTOSIS $(K_G)$: | 2,996 | 3,373 | 2,657 | 1,069 | 2,644 |
| FOLK AND WARD METHOD (Description) | MEAN: | Medium Sand | Medium Sand | Medium Sand | Medium Sand | Medium Sand |
| | SORTING: | Poorly Sorted | Poorly Sorted | Poorly Sorted | Moderately Sorted | Poorly Sorted |
| | SKEWNESS: | Very Fine Skewed | Very Fine Skewed | Very Fine Skewed | Symmetrical | Fine Skewed |
| | KURTOSIS: | Very Leptokurtic | Extremely Leptokurtic | Very Leptokurtic | Mesokurtic | Very Leptokurtic |
| | MODE 1 (□m): | 427,5 | 302,5 | 427,5 | 302,5 | 302,5 |
| | MODE 2 (□m): | | | | | |
| | MODE 3 (□m): | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| MODE 1 (□): | 1,247 | 1,747 | 1,247 | 1,747 | 1,747 |
| MODE 2 (□): | | | | | |
| MODE 3 (□): | | | | | |
| D10 (□m): | 8,057 | 9,221 | 184,8 | 197,0 | 183,9 |
| D50 (□m): | 417,8 | 345,5 | 399,9 | 371,1 | 364,4 |
| D90 (□m): | 982,8 | 838,0 | 740,2 | 835,6 | 853,1 |
| (D90 / D10) (□m): | 122,0 | 90,88 | 4,006 | 4,242 | 4,638 |
| (D90 - D10) (□m): | 974,7 | 828,8 | 555,4 | 638,6 | 669,1 |
| (D75 / D25) (□m): | 2,458 | 2,203 | 2,084 | 2,093 | 2,083 |
| (D75 - D25) (□m): | 385,5 | 285,5 | 296,8 | 292,2 | 283,3 |
| D10 (□): | 0,025 | 0,255 | 0,434 | 0,259 | 0,229 |
| D50 (□): | 1,259 | 1,533 | 1,322 | 1,430 | 1,456 |
| D90 (□): | 6,955 | 6,761 | 2,436 | 2,344 | 2,443 |
| (D90 / D10) (□): | 277,9 | 26,52 | 5,613 | 9,044 | 10,66 |
| (D90 - D10) (□): | 6,930 | 6,506 | 2,002 | 2,085 | 2,214 |
| (D75 / D25) (□): | 3,086 | 2,218 | 2,309 | 2,272 | 2,208 |
| (D75 - D25) (□): | 1,298 | 1,139 | 1,059 | 1,065 | 1,059 |
| % GRAVEL: | 1,1% | 2,1% | 0,4% | 0,5% | 2,0% |
| % SAND: | 85,3% | 84,8% | 92,8% | 96,5% | 91,8% |
| % MUD: | 13,6% | 13,1% | 6,8% | 3,0% | 6,2% |
| % V COARSE GRAVEL: | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| % COARSE GRAVEL: | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| % MEDIUM GRAVEL: | 0,0% | 0,8% | 0,0% | 0,0% | 0,4% |
| % FINE GRAVEL: | 0,3% | 0,6% | 0,1% | 0,0% | 1,1% |
| % V FINE GRAVEL: | 0,8% | 0,7% | 0,3% | 0,5% | 0,5% |
| % V COARSE SAND: | 8,3% | 4,6% | 3,2% | 5,1% | 5,0% |
| % COARSE SAND: | 29,6% | 20,1% | 29,9% | 24,6% | 21,7% |
| % MEDIUM SAND: | 38,8% | 46,5% | 47,2% | 50,0% | 49,7% |
| % FINE SAND: | 8,4% | 13,4% | 12,2% | 16,4% | 15,1% |
| % V FINE SAND: | 0,2% | 0,3% | 0,3% | 0,3% | 0,3% |
| % V COARSE SILT: | 0,7% | 0,7% | 0,6% | 0,2% | 0,4% |
| % COARSE SILT: | 1,3% | 1,2% | 0,5% | 0,3% | 0,4% |
| % MEDIUM SILT: | 1,6% | 1,6% | 0,8% | 0,3% | 0,7% |
| % FINE SILT: | 2,1% | 1,9% | 0,8% | 0,4% | 0,8% |
| % V FINE SILT: | 2,0% | 2,0% | 0,9% | 0,4% | 0,9% |
| % CLAY: | 5,8% | 5,7% | 3,2% | 1,5% | 3,0% |

| | | 2989.Cul.6 | 2990.Cul.7 | 2991.Cul.8 | 2992.Cul.9 | 2994.Cul.10 |
|---|---|---|---|---|---|---|
| | ANALYST AND DATE: | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 |
| | SIEVING ERROR: | | | | | |
| | SAMPLE TYPE: | Bimodal, Poorly Sorted | Unimodal, Moderately Sorted | Unimodal, Moderately Sorted | Trimodal, Very Poorly Sorted | Bimodal, Very Poorly Sorted |
| | TEXTURAL GROUP: | Gravelly Sand | Slightly Gravelly Sand | Slightly Gravelly Sand | Slightly Gravelly Sandy Mud | Slightly Gravelly Muddy Sand |
| | SEDIMENT NAME: | Very Fine Gravelly Coarse Sand | Slightly Medium Gravelly Medium Sand | Slightly Very Fine Gravelly Coarse Sand | Slightly Fine Gravelly Medium Sandy Mud | Slightly Very Fine Gravelly Muddy Medium Sand |
| METHOD OF MOMENTS Arithmetic (mm) | MEAN $(\bar{x}_a)$: | 1330,0 | 653,0 | 644,3 | 204,3 | 430,5 |
| | SORTING $(\sigma_a)$: | 1982,9 | 813,5 | 404,0 | 683,2 | 528,5 |
| | SKEWNESS $(Sk_a)$: | 3,420 | 9,211 | 2,126 | 8,296 | 3,914 |
| | KURTOSIS $(K_a)$: | 14,18 | 100,7 | 11,61 | 78,88 | 29,17 |
| METHOD OF MOMENTS Geometric (mm) | MEAN $(\bar{x}_g)$: | 721,7 | 514,8 | 523,9 | 16,98 | 105,9 |
| | SORTING $(\sigma_g)$: | 3,350 | 1,861 | 2,070 | 10,95 | 11,37 |
| | SKEWNESS $(Sk_g)$: | -1,765 | -0,801 | -2,893 | 0,486 | -0,834 |
| | KURTOSIS $(K_g)$: | 12,08 | 18,76 | 23,83 | 1,761 | 2,071 |
| METHOD OF MOMENTS Logarithmic (f) | MEAN $(\bar{x}_\phi)$: | 0,471 | 0,958 | 0,933 | 5,880 | 3,239 |
| | SORTING $(\sigma_\phi)$: | 1,744 | 0,896 | 1,050 | 3,453 | 3,507 |
| | SKEWNESS $(Sk_\phi)$: | 1,765 | 0,801 | 2,893 | -0,486 | 0,834 |
| | KURTOSIS $(K_\phi)$: | 12,08 | 18,76 | 23,83 | 1,761 | 2,071 |
| FOLK AND WARD METHOD (mm) | MEAN $(M_G)$: | 739,8 | 510,8 | 537,9 | 15,97 | 84,56 |
| | SORTING $(\sigma_G)$: | 2,472 | 1,715 | 1,774 | 10,41 | 11,97 |
| | SKEWNESS $(Sk_G)$: | 0,102 | 0,060 | 0,004 | 0,386 | -0,676 |
| | KURTOSIS $(K_G)$: | 1,297 | 0,971 | 0,922 | 0,527 | 0,682 |
| FOLK AND WARD METHOD (f) | MEAN $(M_Z)$: | 0,435 | 0,969 | 0,895 | 5,969 | 3,564 |
| | SORTING $(\sigma_I)$: | 1,306 | 0,778 | 0,827 | 3,380 | 3,581 |
| | SKEWNESS $(Sk_I)$: | -0,102 | -0,060 | -0,004 | -0,386 | 0,676 |
| | KURTOSIS $(K_G)$: | 1,297 | 0,971 | 0,922 | 0,527 | 0,682 |
| FOLK AND WARD METHOD (Description) | MEAN: | Coarse Sand | Coarse Sand | Coarse Sand | Coarse Silt | Very Fine Sand |
| | SORTING: | Poorly Sorted | Moderately Sorted | Moderately Sorted | Very Poorly Sorted | Very Poorly Sorted |
| | SKEWNESS: | Coarse Skewed | Symmetrical | Symmetrical | Very Coarse Skewed | Very Fine Skewed |
| | KURTOSIS: | Leptokurtic | Mesokurtic | Mesokurtic | Very Platykurtic | Platykurtic |
| | MODE 1 (mm): | 855,0 | 427,5 | 605,0 | 1,500 | 427,5 |
| | MODE 2 (mm): | 9600,0 | | | 302,5 | 1,500 |
| | MODE 3 (mm): | | | | 6,000 | |
| | MODE 1 (f): | 0,247 | 1,247 | 0,747 | 9,466 | 1,247 |
| | MODE 2 (f): | -3,243 | | | 1,747 | 9,466 |
| | MODE 3 (f): | | | | 7,466 | |
| | $D_{10}$ (mm): | 269,3 | 265,4 | 263,5 | 1,260 | 1,590 |
| | $D_{50}$ (mm): | 744,7 | 503,1 | 537,6 | 7,890 | 339,4 |
| | $D_{90}$ (mm): | 2191,5 | 1036,6 | 1153,4 | 467,7 | 932,3 |
| | $(D_{90} / D_{10})$ (mm): | 8,137 | 3,906 | 4,377 | 371,1 | 586,3 |
| | $(D_{90} - D_{10})$ (mm): | 1922,2 | 771,3 | 889,9 | 466,4 | 930,7 |
| | $(D_{75} / D_{25})$ (mm): | 2,889 | 2,088 | 2,268 | 143,2 | 62,09 |

| | | | | | |
|---|---|---|---|---|---|
| $(D_{75} - D_{25})$ (mm): | 817,1 | 381,9 | 455,5 | 253,5 | 585,6 |
| $D_{10}$ (f): | -1,132 | -0,052 | -0,206 | 1,096 | 0,101 |
| $D_{50}$ (f): | 0,425 | 0,991 | 0,895 | 6,986 | 1,559 |
| $D_{90}$ (f): | 1,893 | 1,914 | 1,924 | 9,632 | 9,297 |
| $(D_{90} / D_{10})$ (f): | -1,672 | -36,885 | -9,344 | 8,785 | 91,97 |
| $(D_{90} - D_{10})$ (f): | 3,025 | 1,966 | 2,130 | 8,536 | 9,195 |
| $(D_{75} / D_{25})$ (f): | -3,759 | 3,368 | 4,998 | 4,636 | 8,958 |
| $(D_{75} - D_{25})$ (f): | 1,530 | 1,062 | 1,181 | 7,162 | 5,956 |
| % GRAVEL: | 10,9% | 0,9% | 0,8% | 1,1% | 1,3% |
| % SAND: | 86,6% | 98,8% | 98,3% | 31,4% | 67,5% |
| % MUD: | 2,4% | 0,3% | 0,9% | 67,5% | 31,2% |
| % V COARSE GRAVEL: | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| % COARSE GRAVEL: | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| % MEDIUM GRAVEL: | 4,6% | 0,7% | 0,0% | 0,0% | 0,0% |
| % FINE GRAVEL: | 1,3% | 0,0% | 0,0% | 0,9% | 0,6% |
| % V FINE GRAVEL: | 5,0% | 0,2% | 0,8% | 0,2% | 0,7% |
| % V COARSE SAND: | 24,3% | 9,9% | 13,6% | 1,1% | 6,8% |
| % COARSE SAND: | 34,5% | 39,6% | 40,3% | 6,3% | 24,2% |
| % MEDIUM SAND: | 22,4% | 42,8% | 37,9% | 17,0% | 29,7% |
| % FINE SAND: | 5,3% | 6,4% | 6,4% | 6,6% | 6,6% |
| % V FINE SAND: | 0,1% | 0,1% | 0,1% | 0,4% | 0,3% |
| % V COARSE SILT: | 0,2% | 0,1% | 0,1% | 2,7% | 1,4% |
| % COARSE SILT: | 0,2% | 0,0% | 0,1% | 6,6% | 2,4% |
| % MEDIUM SILT: | 0,3% | 0,0% | 0,1% | 8,4% | 3,5% |
| % FINE SILT: | 0,3% | 0,0% | 0,2% | 10,5% | 4,8% |
| % V FINE SILT: | 0,3% | 0,0% | 0,1% | 10,4% | 4,7% |
| % CLAY: | 1,1% | 0,1% | 0,4% | 28,9% | 14,4% |

| | | 2995.Cul.11 | 2996.Cul.12 | 2997.Cul.13 | 2993.Cul.14 | 2998.Cul.14A |
|---|---|---|---|---|---|---|
| | ANALYST AND DATE: | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2018 |
| | SIEVING ERROR: | | | | | |
| | SAMPLE TYPE: | Unimodal, Moderately Sorted | Polymodal, Very Poorly Sorted | Unimodal, Very Poorly Sorted | Unimodal, Poorly Sorted | Bimodal, Very Poorly Sorted |
| | TEXTURAL GROUP: | Slightly Gravelly Sand | Gravelly Muddy Sand | Slightly Gravelly Muddy Sand | Slightly Gravelly Sand | Slightly Gravelly Muddy Sand |
| | SEDIMENT NAME: | Slightly Very Fine Gravelly Medium Sand | Medium Gravelly Muddy Medium Sand | Slightly Fine Gravelly Muddy Medium Sand | Slightly Medium Gravelly Medium Sand | Slightly Very Fine Gravelly Muddy Medium Sand |
| METHOD OF MOMENTS Arithmetic (mm) | MEAN $(\bar{x}_a)$: | 537,7 | 1028,4 | 425,0 | 721,1 | 434,9 |
| | SORTING $(\sigma_a)$: | 336,6 | 2387,9 | 645,1 | 1557,8 | 560,9 |
| | SKEWNESS $(Sk_a)$: | 2,654 | 3,189 | 7,387 | 7,568 | 7,112 |
| | KURTOSIS $(K_a)$: | 17,37 | 11,55 | 68,97 | 62,08 | 74,49 |
| METHOD OF MOMENTS Geometric (mm) | MEAN $(\bar{x}_g)$: | 457,6 | 132,6 | 184,8 | 395,6 | 187,8 |
| | SORTING $(\sigma_g)$: | 1,686 | 13,01 | 6,313 | 3,532 | 6,621 |
| | SKEWNESS $(Sk_g)$: | 0,427 | -0,548 | -1,676 | -2,407 | -1,644 |
| | KURTOSIS $(K_g)$: | 3,084 | 2,261 | 4,811 | 12,70 | 4,585 |
| METHOD OF MOMENTS Logarithmic (f) | MEAN $(\bar{x}_\phi)$: | 1,128 | 2,915 | 2,436 | 1,338 | 2,413 |
| | SORTING $(\sigma_\phi)$: | 0,753 | 3,702 | 2,658 | 1,821 | 2,727 |
| | SKEWNESS $(Sk_\phi)$: | -0,427 | 0,548 | 1,676 | 2,407 | 1,644 |
| | KURTOSIS $(K_\phi)$: | 3,084 | 2,261 | 4,811 | 12,70 | 4,585 |
| FOLK AND WARD METHOD (mm) | MEAN $(M_G)$: | 454,3 | 100,9 | 235,0 | 461,1 | 218,5 |
| | SORTING $(\sigma_G)$: | 1,707 | 14,96 | 4,427 | 2,081 | 5,116 |
| | SKEWNESS $(Sk_\phi)$: | 0,134 | -0,444 | -0,564 | -0,086 | -0,571 |
| | KURTOSIS $(K_\phi)$: | 0,964 | 0,932 | 3,256 | 1,489 | 2,910 |
| FOLK AND WARD METHOD (f) | MEAN $(M_G)$: | 1,138 | 3,309 | 2,089 | 1,117 | 2,194 |
| | SORTING $(\sigma_g)$: | 0,772 | 3,903 | 2,146 | 1,057 | 2,355 |
| | SKEWNESS $(Sk_G)$: | -0,134 | 0,444 | 0,564 | 0,086 | 0,571 |
| | KURTOSIS $(K_G)$: | 0,964 | 0,932 | 3,256 | 1,489 | 2,910 |
| FOLK AND WARD METHOD (Description) | MEAN: | Medium Sand | Very Fine Sand | Fine Sand | Medium Sand | Fine Sand |
| | SORTING: | Moderately Sorted | Very Poorly Sorted | Very Poorly Sorted | Poorly Sorted | Very Poorly Sorted |
| | SKEWNESS: | Coarse Skewed | Very Fine Skewed | Very Fine Skewed | Symmetrical | Very Fine Skewed |
| | KURTOSIS: | Mesokurtic | Mesokurtic | Extremely Leptokurtic | Leptokurtic | Very Leptokurtic |
| | MODE 1 (mm): | 427,5 | 302,5 | 302,5 | 427,5 | 302,5 |
| | MODE 2 (mm): | | 9600,0 | | | 1,500 |
| | MODE 3 (mm): | | 1,500 | | | |
| | MODE 1 (f): | 1,247 | 1,747 | 1,747 | 1,247 | 1,747 |

| | | | | | |
|---|---|---|---|---|---|
| MODE 2 (f): | | -3,243 | | | 9,466 |
| MODE 3 (f): | | 9,466 | | | |
| D10 (mm): | 248,3 | 1,699 | 4,278 | 209,5 | 3,626 |
| D50 (mm): | 435,4 | 323,2 | 323,9 | 447,5 | 336,0 |
| D90 (mm): | 946,4 | 1323,2 | 681,2 | 1004,1 | 793,8 |
| (D90 / D10) (mm): | 3,812 | 778,7 | 159,2 | 4,792 | 218,9 |
| (D90 - D10) (mm): | 698,2 | 1321,5 | 677,0 | 794,6 | 790,1 |
| (D75 / D25) (mm): | 2,111 | 48,35 | 2,211 | 2,217 | 2,493 |
| (D75 - D25) (mm): | 341,6 | 604,6 | 259,6 | 370,0 | 310,6 |
| D10 (f): | 0,079 | -0,404 | 0,554 | -0,006 | 0,333 |
| D50 (f): | 1,199 | 1,629 | 1,626 | 1,160 | 1,574 |
| D90 (f): | 2,010 | 9,201 | 7,869 | 2,255 | 8,107 |
| (D90 / D10) (f): | 25,31 | -22,772 | 14,21 | -378,258 | 24,33 |
| (D90 - D10) (f): | 1,931 | 9,605 | 7,315 | 2,261 | 7,774 |
| (D75 / D25) (f): | 2,729 | 9,041 | 2,063 | 3,019 | 2,391 |
| (D75 - D25) (f): | 1,078 | 5,595 | 1,144 | 1,148 | 1,318 |
| % GRAVEL: | 0,4% | 8,2% | 1,5% | 2,3% | 1,0% |
| % SAND: | 99,6% | 61,2% | 82,5% | 92,8% | 82,7% |
| % MUD: | 0,0% | 30,6% | 16,0% | 5,0% | 16,3% |
| % V COARSE GRAVEL: | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| % COARSE GRAVEL: | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| % MEDIUM GRAVEL: | 0,0% | 6,9% | 0,0% | 1,3% | 0,0% |
| % FINE GRAVEL: | 0,0% | 0,3% | 0,8% | 0,3% | 0,5% |
| % V FINE GRAVEL: | 0,4% | 1,0% | 0,7% | 0,7% | 0,5% |
| % V COARSE SAND: | 7,7% | 5,0% | 1,9% | 7,8% | 4,5% |
| % COARSE SAND: | 31,9% | 18,9% | 18,2% | 32,1% | 20,9% |
| % MEDIUM SAND: | 49,8% | 29,1% | 47,9% | 43,9% | 42,3% |
| % FINE SAND: | 10,1% | 8,0% | 14,2% | 8,7% | 14,4% |
| % V FINE SAND: | 0,0% | 0,2% | 0,3% | 0,2% | 0,5% |
| % V COARSE SILT: | 0,0% | 1,5% | 0,7% | 0,4% | 0,7% |
| % COARSE SILT: | 0,0% | 2,9% | 1,2% | 0,5% | 1,2% |
| % MEDIUM SILT: | 0,0% | 3,9% | 2,0% | 0,6% | 1,7% |
| % FINE SILT: | 0,0% | 5,9% | 2,5% | 0,6% | 2,3% |
| % V FINE SILT: | 0,0% | 3,7% | 2,9% | 0,7% | 3,3% |
| % CLAY: | 0,0% | 12,6% | 6,7% | 2,1% | 7,0% |

| | | 2999.Cul.15 | 3000.Cul.16 | 3001.Cul.17 | 3002.Cul.18 | 3003.Cul.19 |
|---|---|---|---|---|---|---|
| | ANALYST AND DATE: | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 |
| | SIEVING ERROR: | | | | | |
| | SAMPLE TYPE: | Unimodal, Poorly Sorted | Bimodal, Very Poorly Sorted | Trimodal, Very Poorly Sorted | Bimodal, Very Poorly Sorted | Bimodal, Very Poorly Sorted |
| | TEXTURAL GROUP: | Slightly Gravelly Sand | Slightly Gravelly Muddy Sand | Slightly Gravelly Muddy Sand | Slightly Gravelly Muddy Sand | Slightly Gravelly Muddy Sand |
| | SEDIMENT NAME: | Slightly Medium Gravelly Medium Sand | Slightly Fine Gravelly Muddy Medium Sand | Slightly Very Fine Gravelly Muddy Medium Sand | Slightly Very Fine Gravelly Muddy Medium Sand | Slightly Very Fine Gravelly Muddy Medium Sand |
| METHOD OF MOMENTS Arithmetic (µm) | MEAN $(\bar{x}_a)$: | 792,0 | 336,5 | 377,6 | 481,0 | 374,1 |
| | SORTING $(\sigma_a)$: | 1544,1 | 585,9 | 725,2 | 496,8 | 303,9 |
| | SKEWNESS $(Sk_a)$: | 4,737 | 7,861 | 5,698 | 2,781 | 2,174 |
| | KURTOSIS $(K_a)$: | 25,51 | 82,61 | 45,31 | 17,18 | 13,97 |
| METHOD OF MOMENTS Geometric (µm) | MEAN $(\bar{x}_g)$: | 392,5 | 79,05 | 64,13 | 156,2 | 172,4 |
| | SORTING $(\sigma_g)$: | 3,678 | 10,68 | 12,20 | 9,463 | 6,566 |
| | SKEWNESS $(Sk_g)$: | -1,930 | -0,722 | -0,431 | -1,191 | -1,668 |
| | KURTOSIS $(K_g)$: | 11,23 | 1,916 | 1,618 | 2,870 | 4,414 |
| METHOD OF MOMENTS Logarithmic (ϕ) | MEAN $(\bar{x}_\phi)$: | 1,349 | 3,661 | 3,963 | 2,679 | 2,536 |
| | SORTING $(\sigma_\phi)$: | 1,879 | 3,416 | 3,609 | 3,242 | 2,715 |
| | SKEWNESS $(Sk_\phi)$: | 1,930 | 0,722 | 0,431 | 1,191 | 1,668 |
| | KURTOSIS $(K_\phi)$: | 11,23 | 1,916 | 1,618 | 2,870 | 4,414 |
| FOLK AND WARD METHOD (µm) | MEAN $(M_G)$: | 437,3 | 67,10 | 63,59 | 115,0 | 162,0 |
| | SORTING $(\sigma_G)$: | 2,029 | 10,77 | 11,90 | 9,982 | 5,961 |
| | SKEWNESS $(Sk_\phi)$: | 0,141 | -0,691 | -0,605 | -0,695 | -0,659 |
| | KURTOSIS $(K_\phi)$: | 1,399 | 0,643 | 0,618 | 2,260 | 3,108 |
| FOLK AND WARD METHOD (ϕ) | MEAN $(M_G)$: | 1,193 | 3,898 | 3,975 | 3,120 | 2,626 |
| | SORTING $(\sigma_g)$: | 1,021 | 3,430 | 3,573 | 3,319 | 2,575 |
| | SKEWNESS $(Sk_G)$: | -0,141 | 0,691 | 0,605 | 0,695 | 0,659 |
| | KURTOSIS $(K_G)$: | 1,399 | 0,643 | 0,618 | 2,260 | 3,108 |
| FOLK AND WARD METHOD (Description) | MEAN: | Medium Sand | Very Fine Sand | Very Fine Sand | Very Fine Sand | Fine Sand |
| | SORTING: | Poorly Sorted | Very Poorly Sorted | Very Poorly Sorted | Very Poorly Sorted | Very Poorly Sorted |
| | SKEWNESS: | Coarse Skewed | Very Fine Skewed | Very Fine Skewed | Very Fine Skewed | Very Fine Skewed |
| | KURTOSIS: | Leptokurtic | Very Platykurtic | Very Platykurtic | Very Leptokurtic | Extremely Leptokurtic |
| | MODE 1 (µm): | 427,5 | 302,5 | 302,5 | 427,5 | 302,5 |
| | MODE 2 (µm): | | 1,500 | 1,500 | 1,500 | 1,500 |
| | MODE 3 (µm): | | | 2400,0 | | |
| | MODE 1 (ϕ): | 1,247 | 1,747 | 1,747 | 1,247 | 1,747 |

| | | | | | |
|---|---|---|---|---|---|
| MODE 2 (ϕ): | | 9,466 | 9,466 | 9,466 | 9,466 |
| MODE 3 (ϕ): | | | -1,243 | | |
| $D_{10}$ (μm): | 201,0 | 1,564 | 1,498 | 1,942 | 3,595 |
| $D_{50}$ (μm): | 413,8 | 267,4 | 237,4 | 399,3 | 326,7 |
| $D_{90}$ (μm): | 1061,6 | 658,6 | 738,1 | 948,9 | 693,7 |
| ($D_{90}$ / $D_{10}$) (μm): | 5,282 | 421,1 | 492,8 | 488,5 | 193,0 |
| ($D_{90}$ - $D_{10}$) (μm): | 860,6 | 657,0 | 736,6 | 946,9 | 690,2 |
| ($D_{75}$ / $D_{25}$) (μm): | 2,215 | 65,93 | 100,1 | 3,469 | 2,307 |
| ($D_{75}$ - $D_{25}$) (μm): | 347,7 | 421,8 | 426,1 | 447,2 | 272,5 |
| $D_{10}$ (ϕ): | -0,086 | 0,603 | 0,438 | 0,076 | 0,528 |
| $D_{50}$ (ϕ): | 1,273 | 1,903 | 2,075 | 1,325 | 1,614 |
| $D_{90}$ (ϕ): | 2,315 | 9,321 | 9,383 | 9,008 | 8,120 |
| ($D_{90}$ / $D_{10}$) (ϕ): | -26,847 | 15,47 | 21,42 | 118,9 | 15,39 |
| ($D_{90}$ - $D_{10}$) (ϕ): | 2,401 | 8,718 | 8,945 | 8,932 | 7,592 |
| ($D_{75}$ / $D_{25}$) (ϕ): | 2,744 | 5,939 | 6,464 | 3,677 | 2,142 |
| ($D_{75}$ - $D_{25}$) (ϕ): | 1,148 | 6,043 | 6,646 | 1,795 | 1,206 |
| % GRAVEL: | 4,9% | 0,8% | 3,4% | 2,2% | 0,2% |
| % SAND: | 90,5% | 65,6% | 57,1% | 74,2% | 82,4% |
| % MUD: | 4,6% | 33,6% | 39,5% | 23,6% | 17,4% |
| % V COARSE GRAVEL: | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| % COARSE GRAVEL: | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| % MEDIUM GRAVEL: | 2,1% | 0,0% | 0,0% | 0,0% | 0,0% |
| % FINE GRAVEL: | 1,8% | 0,6% | 0,9% | 0,2% | 0,0% |
| % V FINE GRAVEL: | 1,0% | 0,2% | 2,5% | 2,0% | 0,2% |
| % V COARSE SAND: | 5,9% | 2,8% | 2,9% | 6,3% | 3,0% |
| % COARSE SAND: | 25,9% | 14,1% | 12,8% | 29,1% | 19,3% |
| % MEDIUM SAND: | 47,2% | 36,1% | 29,3% | 32,4% | 45,5% |
| % FINE SAND: | 11,3% | 12,2% | 11,9% | 6,2% | 14,4% |
| % V FINE SAND: | 0,2% | 0,3% | 0,3% | 0,2% | 0,2% |
| % V COARSE SILT: | 0,2% | 1,4% | 1,3% | 0,7% | 0,8% |
| % COARSE SILT: | 0,4% | 2,2% | 2,6% | 1,2% | 1,2% |
| % MEDIUM SILT: | 0,6% | 3,6% | 4,8% | 2,7% | 2,0% |
| % FINE SILT: | 0,6% | 5,3% | 6,7% | 4,5% | 3,1% |
| % V FINE SILT: | 0,7% | 6,2% | 7,5% | 4,4% | 3,1% |
| % CLAY: | 2,1% | 15,0% | 16,6% | 10,1% | 7,3% |

| | | 3004.Cul.20 | 3005.Cul.21 | 3006.Cul.22 | 3007.Cul.23 | 3008.Cul.24 |
|---|---|---|---|---|---|---|
| | ANALYST AND DATE: | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 | Margarida, 07,07.2017 |
| | SIEVING ERROR: | | | | | |
| | SAMPLE TYPE: | Unimodal, Moderately Sorted | Unimodal, Poorly Sorted | Unimodal, Moderately Sorted | Unimodal, Moderately Well Sorted | Unimodal, Moderately Sorted |
| | TEXTURAL GROUP: | Slightly Gravelly Sand | Slightly Gravelly Sand | Slightly Gravelly Sand | Slightly Gravelly Sand | Slightly Gravelly Sand |
| | SEDIMENT NAME: | Slightly Very Fine Gravelly Medium Sand | Slightly Very Fine Gravelly Medium Sand | Slightly Very Fine Gravelly Medium Sand | Slightly Very Fine Gravelly Medium Sand | Slightly Fine Gravelly Medium Sand |
| METHOD OF MOMENTS Arithmetic (μm) | MEAN $(\bar{x}_a)$: | 529,1 | 406,2 | 705,5 | 389,0 | 507,4 |
| | SORTING $(\sigma_a)$: | 415,7 | 286,5 | 1146,5 | 215,2 | 541,2 |
| | SKEWNESS $(Sk_a)$: | 2,888 | 2,798 | 5,998 | 4,565 | 5,680 |
| | KURTOSIS $(K_a)$: | 14,91 | 19,65 | 42,91 | 43,51 | 43,37 |
| METHOD OF MOMENTS Geometric (μm) | MEAN $(\bar{x}_g)$: | 426,5 | 270,3 | 474,4 | 349,3 | 380,1 |
| | SORTING $(\sigma_g)$: | 1,809 | 3,726 | 2,049 | 1,491 | 2,220 |
| | SKEWNESS $(Sk_g)$: | 0,710 | -2,787 | 1,385 | 0,963 | -2,243 |
| | KURTOSIS $(K_g)$: | 3,325 | 11,00 | 6,112 | 5,289 | 19,83 |
| METHOD OF MOMENTS Logarithmic (ϕ) | MEAN $(\bar{x}_\phi)$: | 1,229 | 1,887 | 1,076 | 1,517 | 1,396 |
| | SORTING $(\sigma_\phi)$: | 0,855 | 1,898 | 1,035 | 0,576 | 1,150 |
| | SKEWNESS $(Sk_\phi)$: | -0,710 | 2,787 | -1,385 | -0,963 | 2,243 |
| | KURTOSIS $(K_\phi)$: | 3,325 | 11,00 | 6,112 | 5,289 | 19,83 |
| FOLK AND WARD METHOD (μm) | MEAN $(M_G)$: | 420,4 | 346,9 | 458,4 | 342,9 | 384,1 |
| | SORTING $(\sigma_G)$: | 1,803 | 2,765 | 1,907 | 1,450 | 1,762 |
| | SKEWNESS $(Sk_\phi)$: | 0,236 | -0,287 | 0,264 | 0,190 | 0,162 |
| | KURTOSIS $(K_\phi)$: | 1,014 | 3,108 | 1,043 | 1,120 | 0,936 |
| FOLK AND WARD METHOD (ϕ) | MEAN $(M_G)$: | 1,250 | 1,528 | 1,125 | 1,544 | 1,380 |
| | SORTING $(\sigma_g)$: | 0,850 | 1,467 | 0,931 | 0,536 | 0,818 |
| | SKEWNESS $(Sk_G)$: | -0,236 | 0,287 | -0,264 | -0,190 | -0,162 |
| | KURTOSIS $(K_G)$: | 1,014 | 3,108 | 1,043 | 1,120 | 0,936 |
| FOLK AND WARD METHOD (Description) | MEAN: | Medium Sand | Medium Sand | Medium Sand | Medium Sand | Medium Sand |
| | SORTING: | Moderately Sorted | Poorly Sorted | Moderately Sorted | Moderately Well Sorted | Moderately Sorted |
| | SKEWNESS: | Coarse Skewed | Fine Skewed | Coarse Skewed | Coarse Skewed | Coarse Skewed |
| | KURTOSIS: | Mesokurtic | Extremely Leptokurtic | Mesokurtic | Leptokurtic | Mesokurtic |
| | MODE 1 (μm): | 302,5 | 302,5 | 302,5 | 302,5 | 302,5 |
| | MODE 2 (μm): | | | | | |
| | MODE 3 (μm): | | | | | |
| | MODE 1 (ϕ): | 1,747 | 1,747 | 1,747 | 1,747 | 1,747 |
| | MODE 2 (ϕ): | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| MODE 3 (ϕ): | | | | | |
| $D_{10}$ (μm): | 212,0 | 161,1 | 221,3 | 217,3 | 197,3 |
| $D_{50}$ (μm): | 387,8 | 342,9 | 414,7 | 329,4 | 368,9 |
| $D_{90}$ (μm): | 995,4 | 694,0 | 1184,1 | 596,3 | 869,0 |
| ($D_{90}$ / $D_{10}$) (μm): | 4,696 | 4,308 | 5,350 | 2,744 | 4,404 |
| ($D_{90}$ - $D_{10}$) (μm): | 783,5 | 533,0 | 962,8 | 379,0 | 671,7 |
| ($D_{75}$ / $D_{25}$) (μm): | 2,208 | 1,920 | 2,344 | 1,627 | 2,235 |
| ($D_{75}$ - $D_{25}$) (μm): | 334,4 | 232,6 | 388,2 | 168,4 | 317,9 |
| $D_{10}$ (ϕ): | 0,007 | 0,527 | -0,244 | 0,746 | 0,203 |
| $D_{50}$ (ϕ): | 1,367 | 1,544 | 1,270 | 1,602 | 1,439 |
| $D_{90}$ (ϕ): | 2,238 | 2,634 | 2,176 | 2,202 | 2,342 |
| ($D_{90}$ / $D_{10}$) (ϕ): | 337,0 | 4,999 | -8,925 | 2,952 | 11,56 |
| ($D_{90}$ - $D_{10}$) (ϕ): | 2,232 | 2,107 | 2,420 | 1,456 | 2,139 |
| ($D_{75}$ / $D_{25}$) (ϕ): | 2,609 | 1,903 | 3,184 | 1,588 | 2,454 |
| ($D_{75}$ - $D_{25}$) (ϕ): | 1,143 | 0,941 | 1,229 | 0,702 | 1,160 |
| % GRAVEL: | 1,2% | 0,3% | 3,4% | 0,1% | 1,3% |
| % SAND: | 98,8% | 92,4% | 96,6% | 99,9% | 97,4% |
| % MUD: | 0,0% | 7,3% | 0,0% | 0,0% | 1,3% |
| % V COARSE GRAVEL: | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| % COARSE GRAVEL: | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% |
| % MEDIUM GRAVEL: | 0,0% | 0,0% | 1,0% | 0,0% | 0,0% |
| % FINE GRAVEL: | 0,0% | 0,0% | 1,0% | 0,0% | 1,1% |
| % V FINE GRAVEL: | 1,2% | 0,3% | 1,4% | 0,1% | 0,3% |
| % V COARSE SAND: | 8,7% | 3,2% | 9,9% | 1,9% | 5,1% |
| % COARSE SAND: | 23,8% | 19,5% | 24,9% | 12,7% | 25,1% |
| % MEDIUM SAND: | 49,3% | 53,0% | 47,5% | 69,1% | 45,5% |
| % FINE SAND: | 17,0% | 16,3% | 14,2% | 16,1% | 21,3% |
| % V FINE SAND: | 0,1% | 0,4% | 0,1% | 0,0% | 0,3% |
| % V COARSE SILT: | 0,0% | 0,5% | 0,0% | 0,0% | 0,1% |
| % COARSE SILT: | 0,0% | 0,6% | 0,0% | 0,0% | 0,2% |
| % MEDIUM SILT: | 0,0% | 0,8% | 0,0% | 0,0% | 0,1% |
| % FINE SILT: | 0,0% | 1,1% | 0,0% | 0,0% | 0,2% |
| % V FINE SILT: | 0,0% | 1,1% | 0,0% | 0,0% | 0,2% |
| % CLAY: | 0,0% | 3,1% | 0,0% | 0,0% | 0,6% |

## Vegetation classification

### A. Classification of 2014

Classify the aerial photography in two final classes: Vegetated/Non vegetated

- Using the *Iso Cluster Unsupervised Classification*
- Using the *Interactive Supervised Classification tool*
- Using the *Reclassify* tool on the NDVI version

Classify the vegetated area along with the different environment and species present

- Using the *Iso Cluster Unsupervised Classification* on the whole area
- Using the *Iso Cluster Unsupervised Classification* inside the vegetated area created during the first part
- Using *Interactive Supervised Classification tool* inside the vegetated area created during the first part

#### 1) Separate sand and vegetation

- **Create a mosaic and a clip of the area**

To create the mosaic of the embayment, the orthophotos **611_4_32_14.ecw** and **611_4_22_14.ecw** are used. The polygon **purple_plant_contour_Culatra_polygon** of the embayment made during field work is used as a mask.

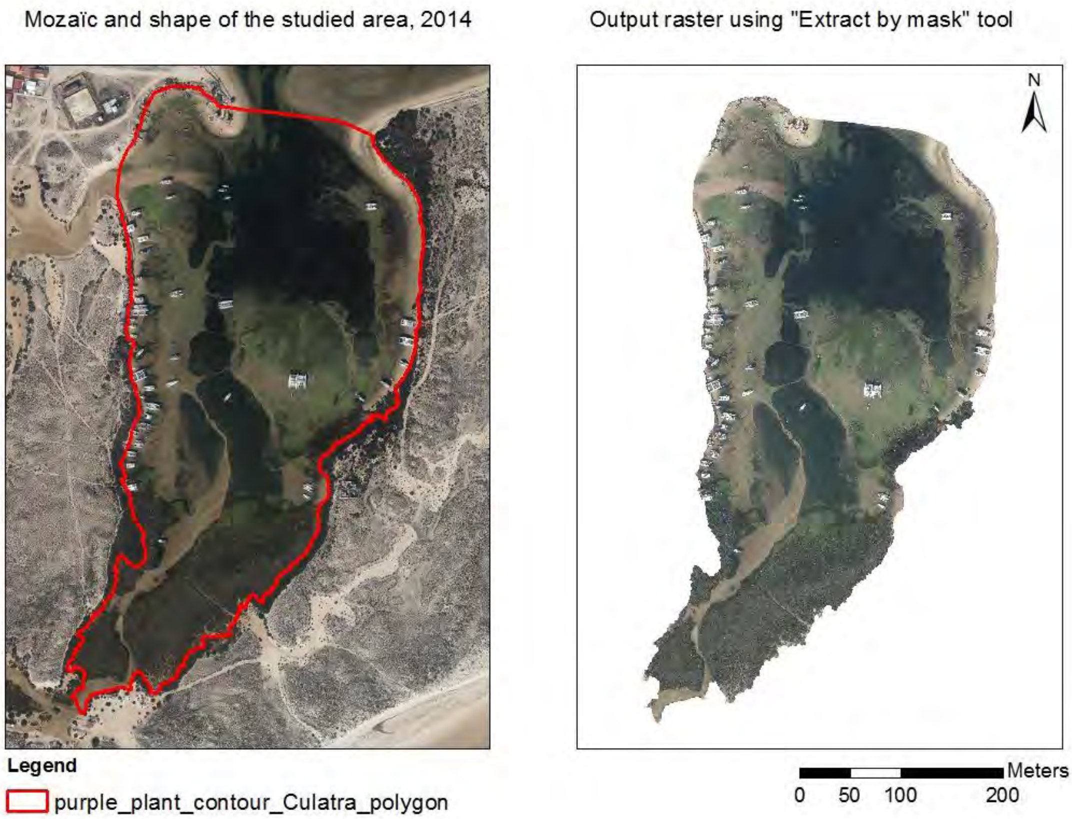



*Figure 16: Mosaic and shape of the studied area, 2014*

- Use the Iso Cluster Unsupervised Classification

Before any classification, the NDVI function is applied in order to have the correct vegetated area. This version of the studied area will be used as a model to see if the classification is right or wrong.

The idea here is to see if the classification is able to map two final classes:

- Vegetated area
- Non vegetated area

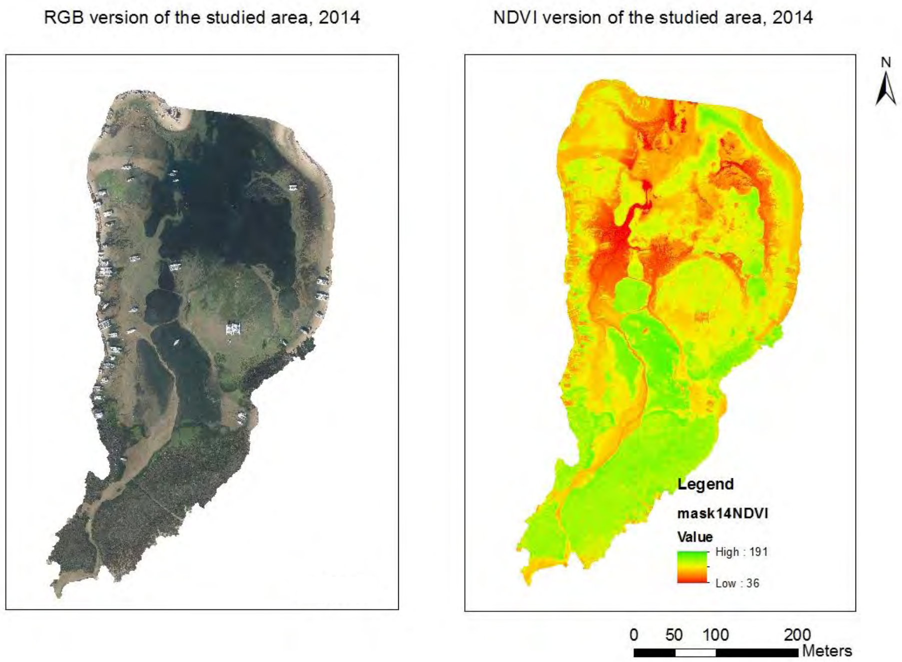



*Figure 17: RGB and NDVI versions of the studied area, 2014*

Firstly, the *Iso Cluster Unsupervised Classification* tool is used and asked to create **2 classes**:

- Vegetation
- Sand

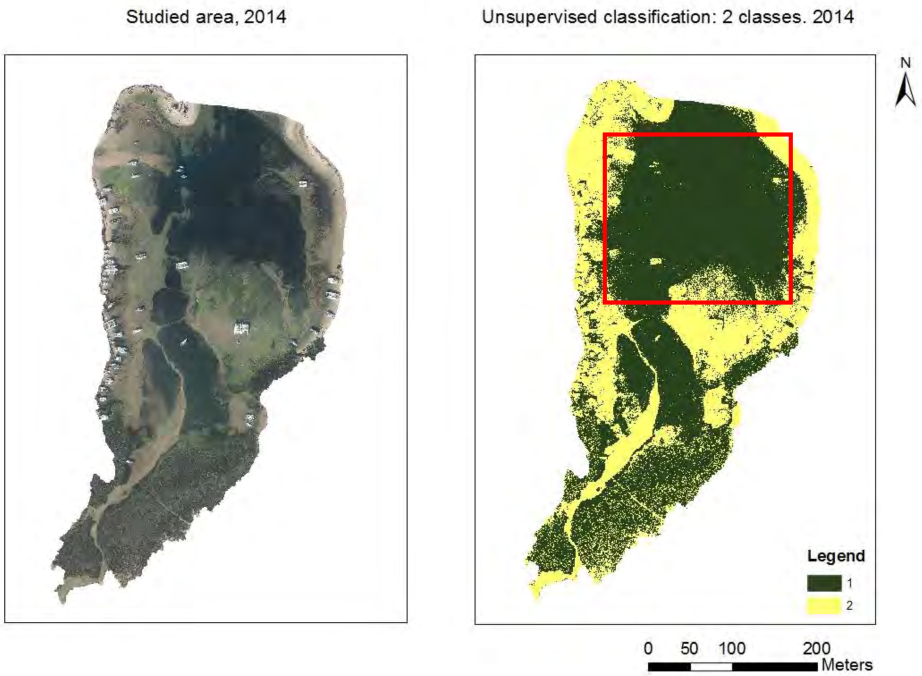



*Figure 18: Unsupervised classification: 2classes, 2014*

Thanks to the NDVI version of the embayment, we can clearly see that the upper part of the image is not well classified.

Secondly, the *Iso Cluster Unsupervised Classification* tool is used and asked to create 3 **classes**:

- Vegetation
- Sand
- No data (Boats)

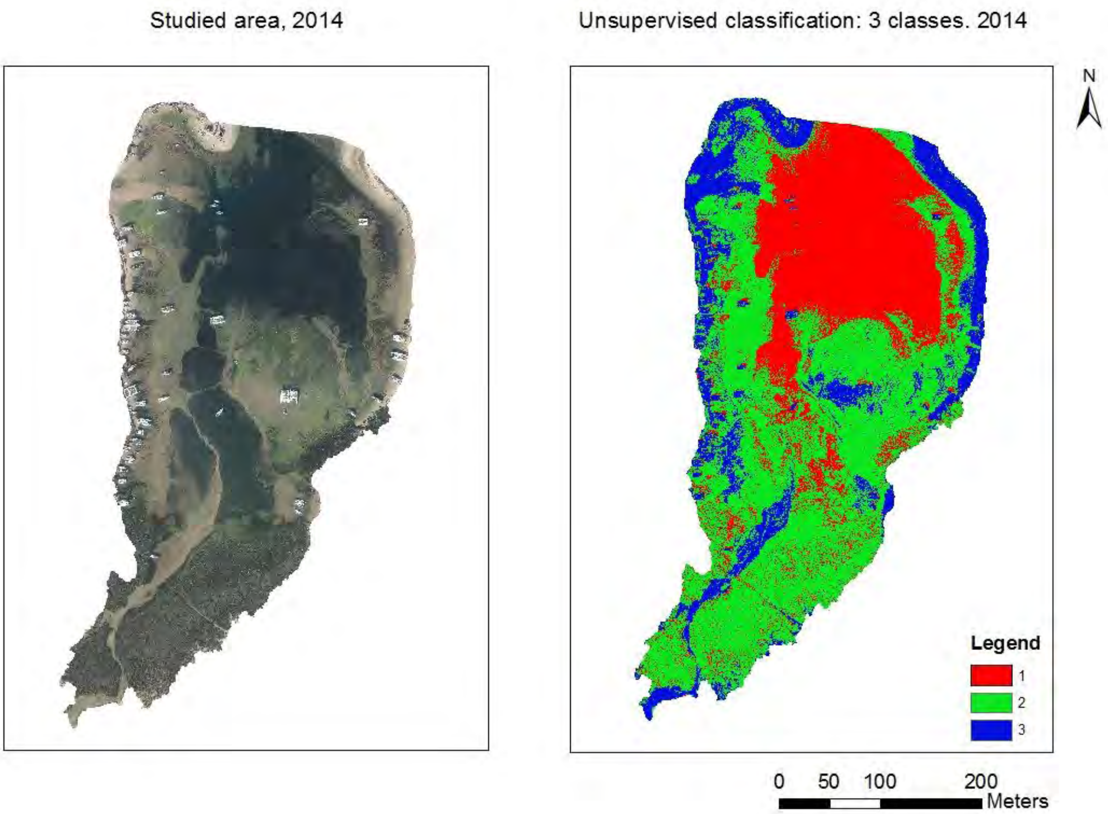



*Figure 19 : Unsupervised classification: 3 classes, 2014*

In this case, the image is not well classified. Looking at the RGB version of the embayment, we can see that the vegetated part is mixed with the sand, and the upper part of the image is still not well classified.
Thanks to the VDVI and RGB versions, we can clearly affirm that the *Iso cluster unsupervised Classification* tool is not working on the studied area.

- **Use the Interactive Supervised Classification tool**

The idea here is still the same: Is it possible to create a map with two final classes :

- Vegetated area
- Non vegetated area

Because the *Iso cluster unsupervised Classification* tool was not satifying on the orthophotos, we will now try to use the *Interactive Supervised Classification tool*.

To use this tool, you have to create your own samples of pixels with polygons and create some classes with them. Here, two classes of samples where made:

- Vegetation
- Sand

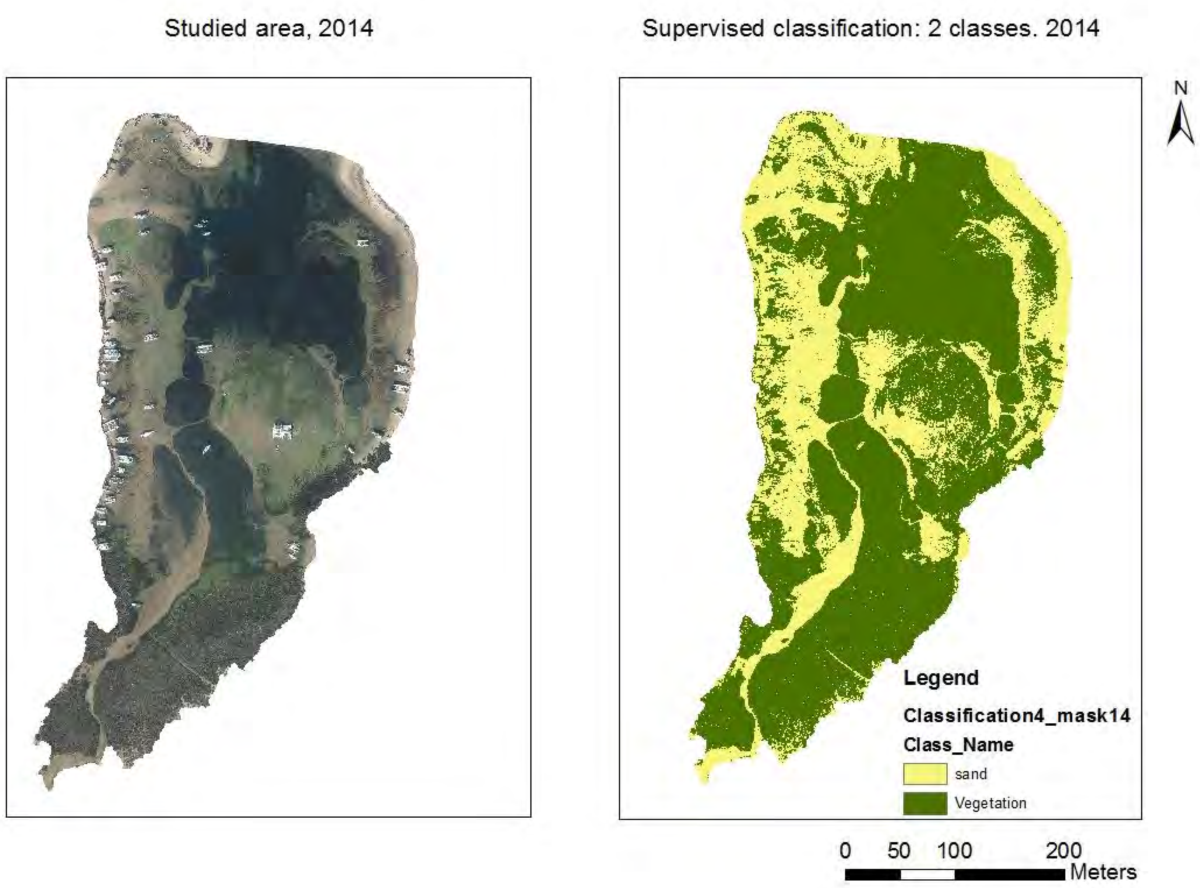



*Figure 20: Supervised classification: 2 classes, 2014*

We can clearly see that, as well as for the unsupervised classification, the upper part of the image is not well classified. Looking at the NDVI version, we can easily see that the upper part of the image is not vegetated as much as this.

But, if you compare the two types of classification (unsupervised and supervised) using the same number of classes (here two):

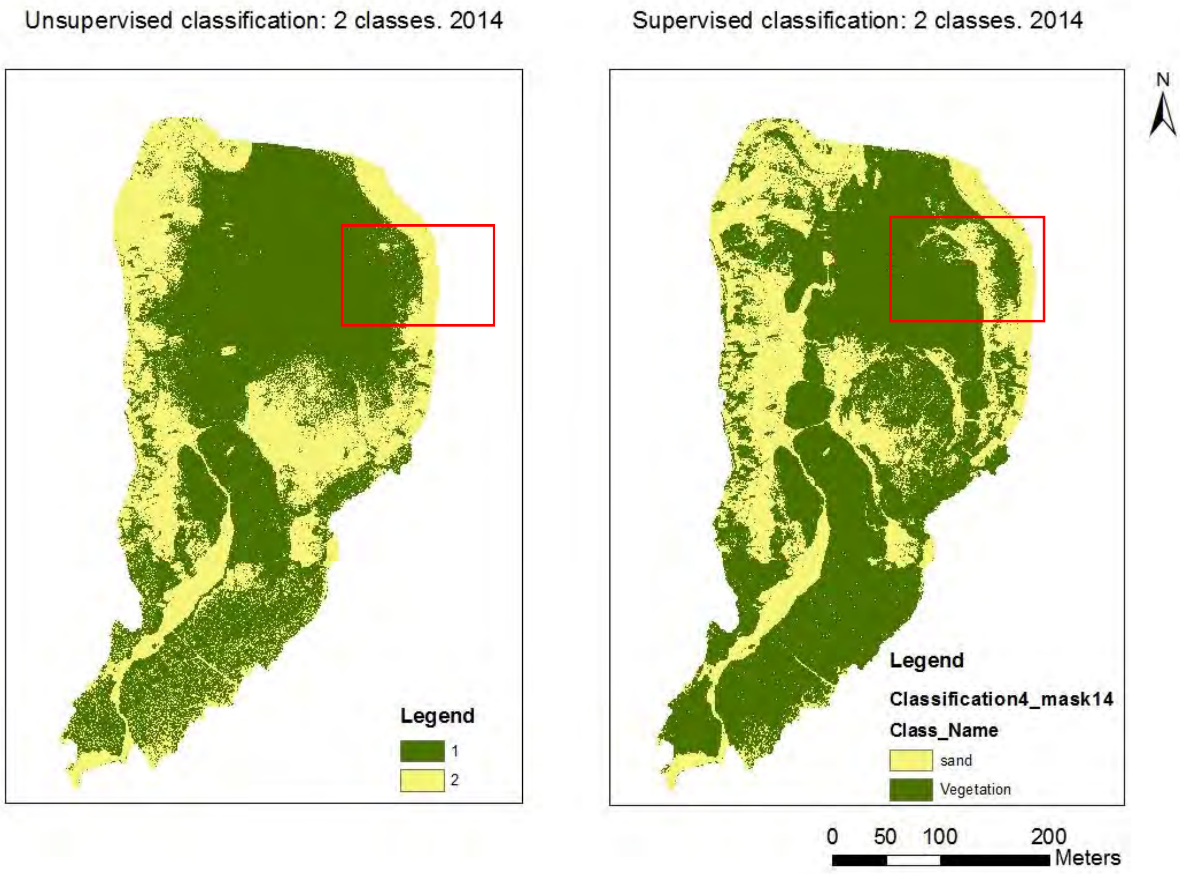



*Figure 21: Unsupervised classification compared to supervised classification, 2014*

We can admit that *The Interactive Supervised Classification* tool is doing a more accurate classification of the image than the *Iso cluster unsupervised Classification* tool.

The idea in this first step was to try to identify the vegetation using the image classification of ArcGIS on the orthophotos. The results are not satisfying so we will use another way: we will create a polygon of the vegetation by using the NDVI version of the embayment

- **Extract the exact shape of the vegetation using the NDVI function**

We are now going to use the *Reclassify* tool of ArcGIS. This geoprocessing tool reclassifies (or changes) the values in a raster.

In this case, the classification method is “manual”, with a number of two classes. The break value is **128**.

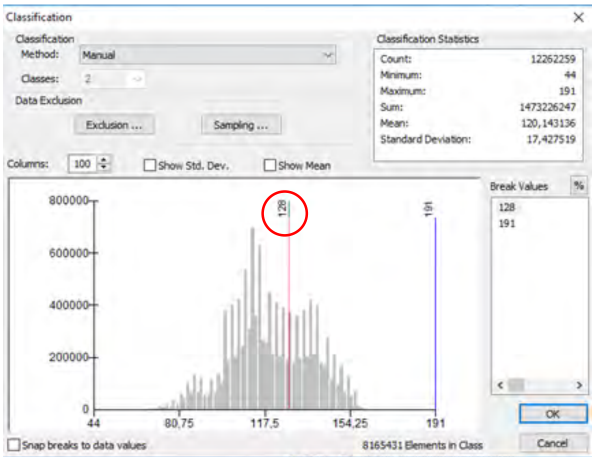



Figure 22: Reclassify tool

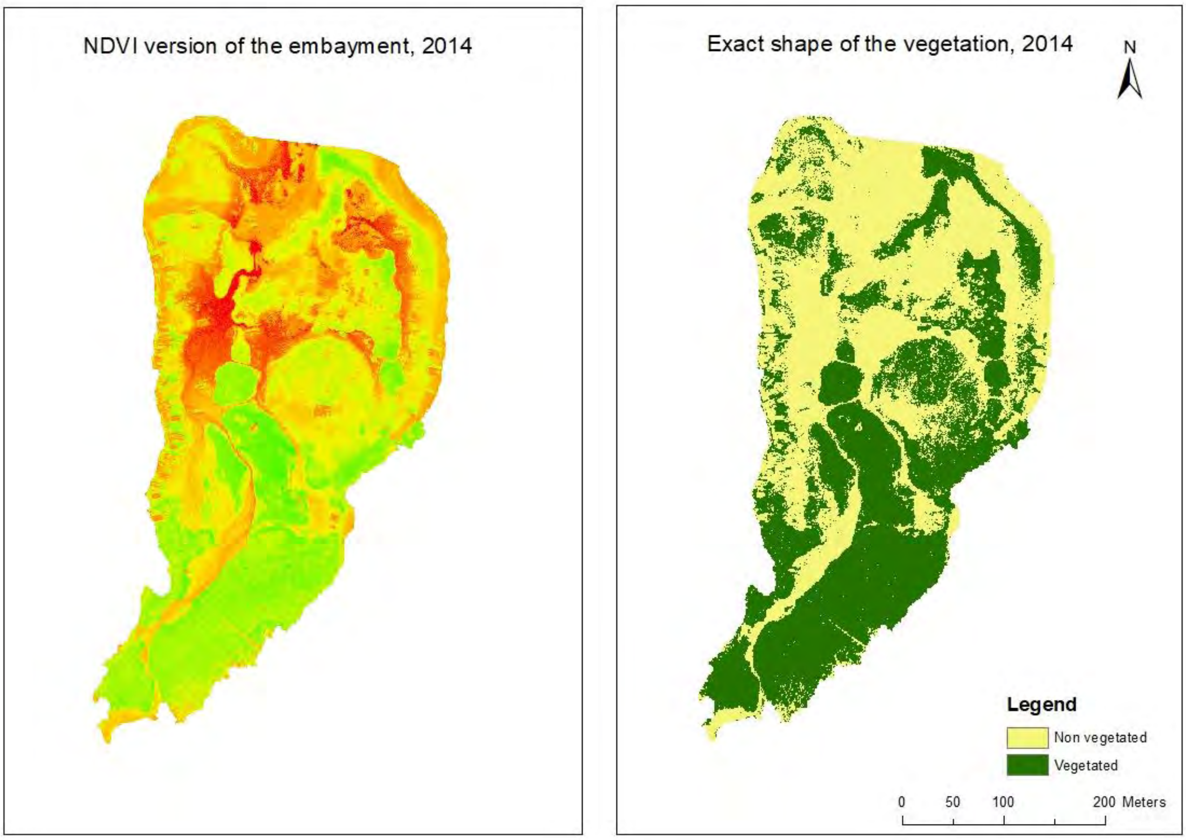



Figure 23: Exact shape of the vegetation using NDVI, 2014

This way of classifying the image is more satisfying and really close to the reality of the NDVI version.

### 2) Classify the vegetated part along with the different environment and species present

The main idea of this second part is now to try to classify the vegetated part for a result of four final classes:

- High marsh dominated by *Salicornia sp.*
- Low marsh dominated by *Spartina maritima*

- Tidal flat dominated by *Zostera noltei*
- Non vegetated area

- **Use the Iso Cluster Unsupervised Classification on the whole image**

In order to classify the image, we first tried with four classes and then five classes. The results with four classes were not satisfying, the upper part of the image was still remaining a problem. So we tried to add one class, but it didn't fix the problem.

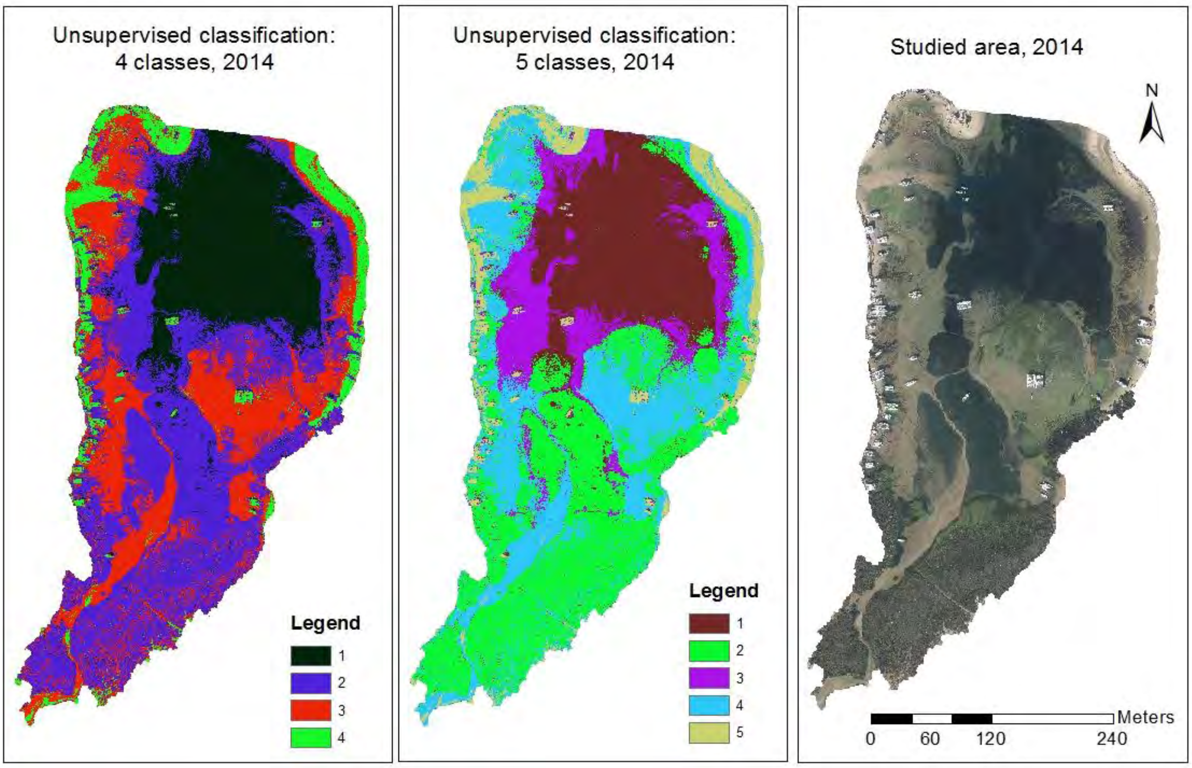



*Figure 24: Unsupervised classification, 4 and 5 classes, 2014*

- **Use the *Iso Cluster Unsupervised Classification* inside of the vegetated area created during first step**

We first ask the classification to make 3 classes in the idea of identifying the tidal flat, low marsh and high marsh.

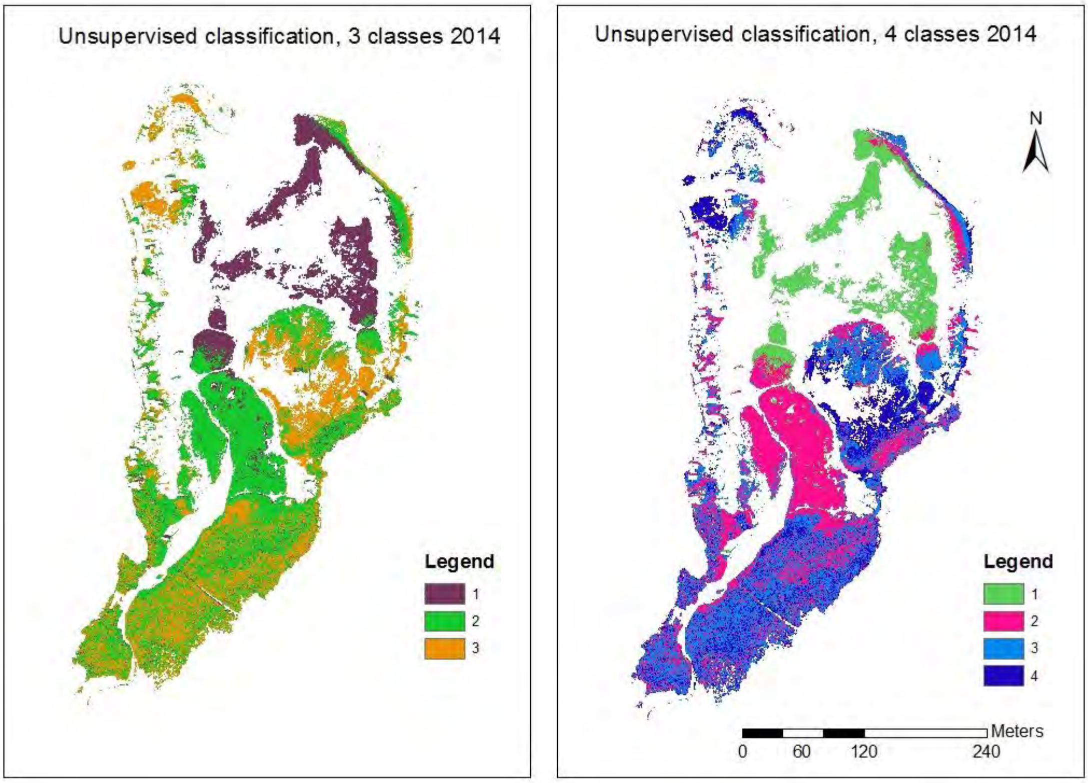



*Figure 25: Unsupervised classification on the vegetation shape, 3 and 4 classes. 2014*

The 3 classes classification is not satisfying: the purple class is not bad; it corresponds to some parts of the tidal flat but not whole of it. The green and orange part are mixed too much.
So we added 1 class: the results are better, but not quite satisfying. The green part represents some parts of the tidal flat area. The pink class is more or less satisfying: it covers quite well some other parts of the tidal flat but it also covers some parts of the low and high marsh, which is not good. Finally, the light and dark blue classes are not good, they cover the three different environments of the vegetated area.

- **Use the *Interactive Supervised Classification* tool inside the vegetated area created during the first part**

In a first place, we made 3 classes of samples:

- High marsh dominated by *Salicornia sp.*
- Low marsh dominated by *Spartina maritima*
- Tidal flat dominated by *Zostera noltei*

The results are satisfying, but, the low marsh got mixed with some parts that are not "low marsh dominated by *Spartina maritima"* but floating vegetation with *Ulva* (red rectangles).

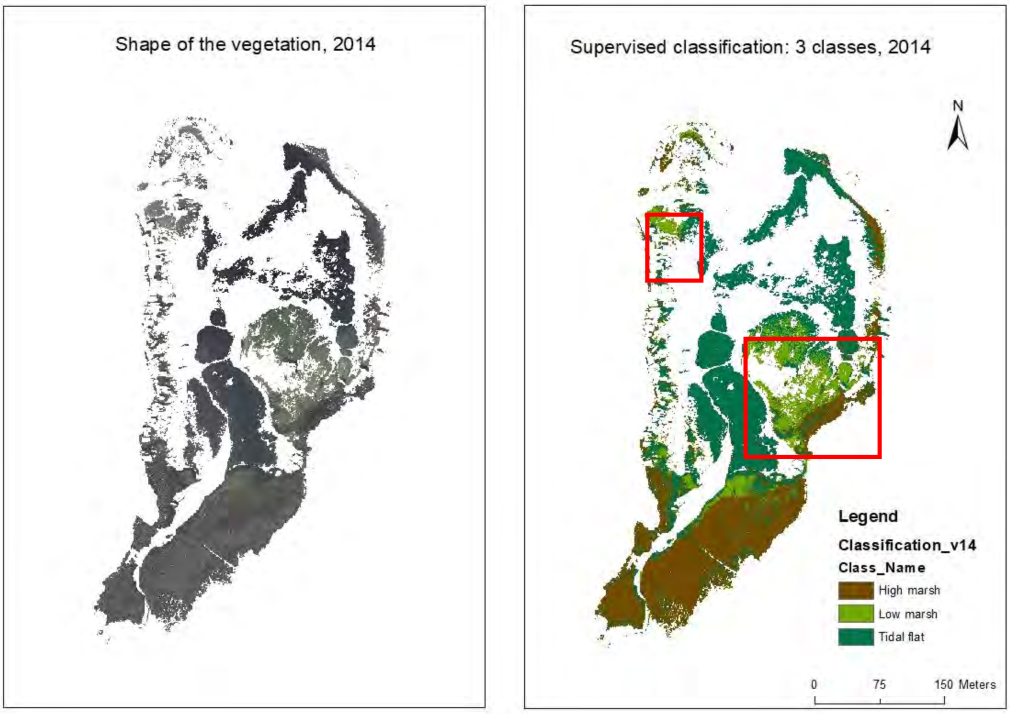



*Figure 26: Supervised classification on the vegetation shape, 3 classes. 2014*

The idea now is to see if it is possible to isolate the floating vegetation with a new class in order to exclude it from the vegetation shape.

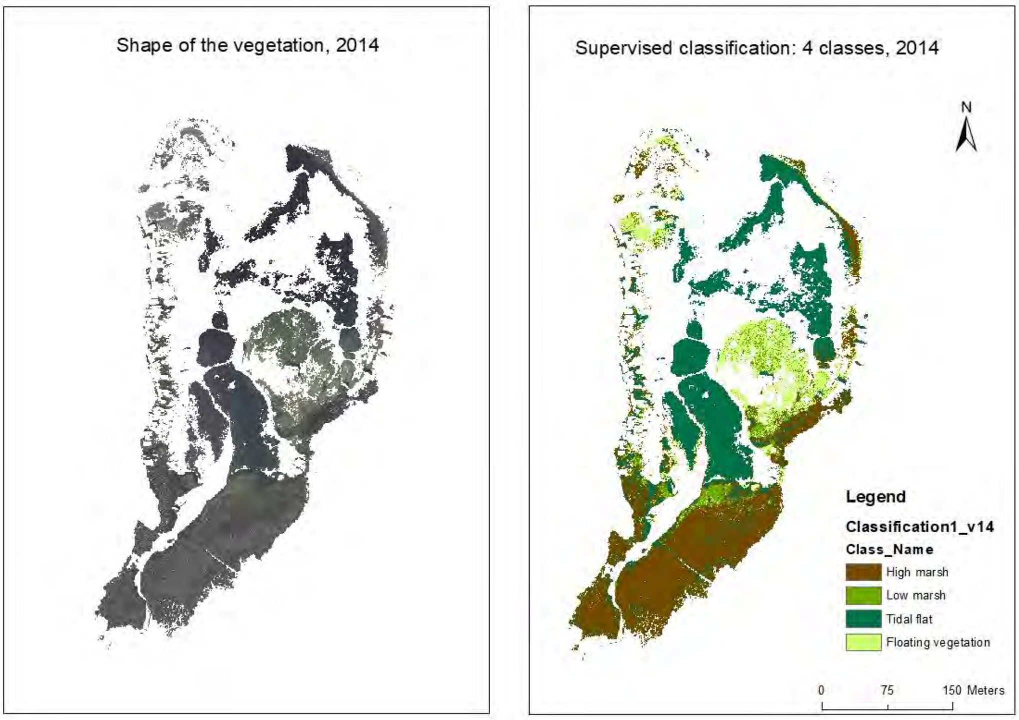



*Figure 27: Supervised classification on the vegetation shape, 4 classes. 2014*

The classification looks good: we can clearly identify the 3 environments and the floating vegetation but Some parts are not well defined. The tidal flat class mixes with the high marsh and low marsh part.

### B. Classification of 2008

The method used to classified the vegetation on the orthophotos of 2008 is the same than the method applied for the orthophotos of 2014:

**Classify the aerial photography in two final classes: Vegetated/Non vegetated**

- Using the *Iso Cluster Unsupervised Classification*
- Using the *Interactive Supervised Classification tool*
- Using the *Reclassify* tool on the NDVI version

**Classify the vegetated area along with the different environment and species present**

- Using the *Iso Cluster Unsupervised Classification* on the whole area
- Using the *Iso Cluster Unsupervised Classification* inside the vegetated area created during the first part
- Using *Interactive Supervised Classification tool* inside the vegetated area created during the first part

#### 1) Separate sand and vegetation

- **Use the Iso Cluster Unsupervised Classification**

Before any classification, the NDVI function is applied in order to have the correct vegetated area. This version of the studied area will be used as a model to see if the classification is right or wrong.
The idea here is to see if the classification is able to map two final classes:

- Vegetated area
- Non vegetated area

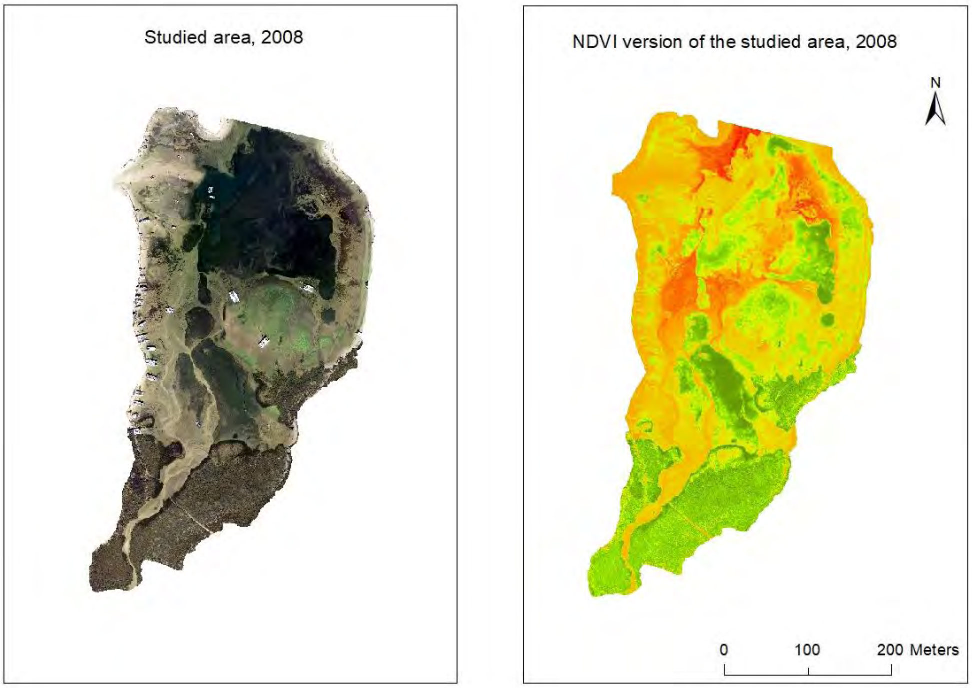



*Figure 28: RGB and NDVI versions of the studied area, 2008*

Firstly, the *Iso Cluster Unsupervised Classification* tool is used and asked to create **2 classes**:

- Vegetation
- Sand

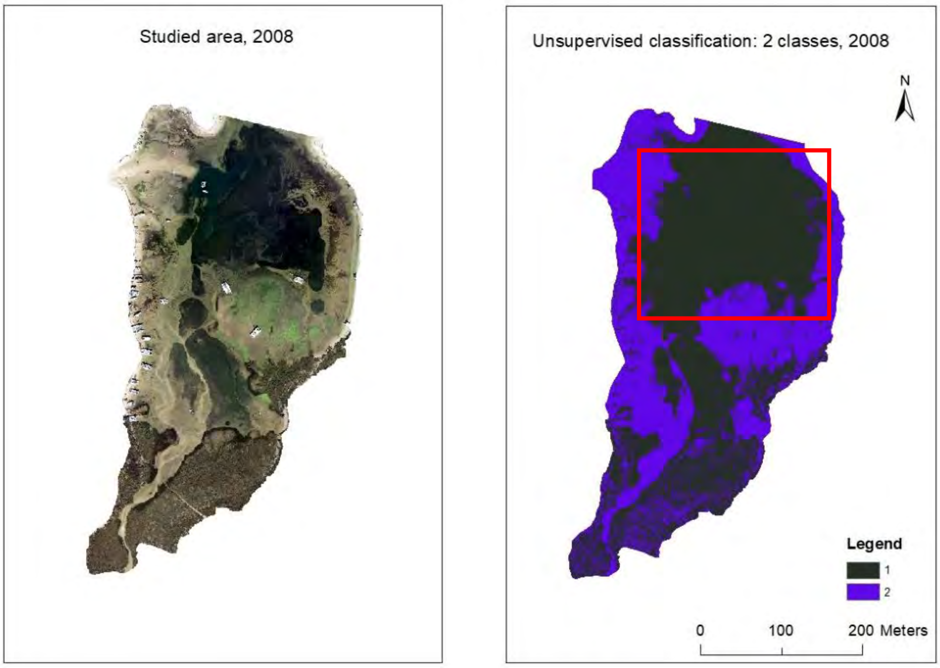



*Figure 29: Unsupervised classification, 2 classes. 2008*

Thanks to the NDVI version of the embayment, we can clearly see that the upper part of the image is not well classified.

Secondly, the _Iso Cluster Unsupervised Classification_ tool is used and asked to create **3 classes**:

- Vegetation
- Sand
- Boats

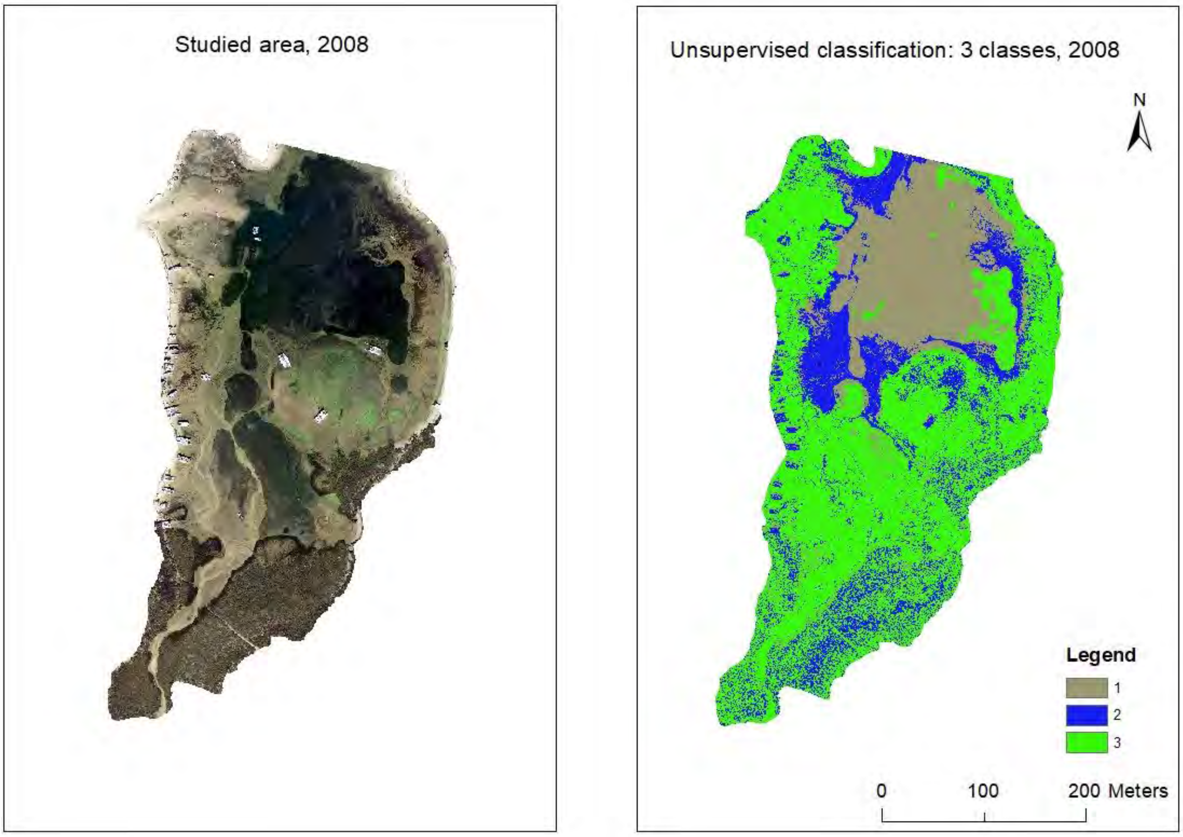



*Figure 30: Unsupervised classification, 3 classes. 2008*

In this case, the image is not well classified. Looking at the RGB version of the embayment, we can see that the vegetated part is mixed with the sand, and the upper part of the image is still not well classified.
Thanks to the VDVI and RGB versions, we can clearly affirm that the _Iso cluster unsupervised Classification_ tool is not working on the studied area.

- **Use the Interactive Supervised Classification tool**

The idea here is still the same: Is it possible to create a map with two final classes ? :

- Vegetated area
- Non vegetated area

Because the _Iso cluster unsupervised Classification_ tool was not satifying on the orthophotos, we will now try to use the _Interactive Supervised Classification tool_.
To use this tool, you have to create your own samples of pixels with polygons and create some classes with them. Here, two classes of samples where made:

- Vegetation
- Sand

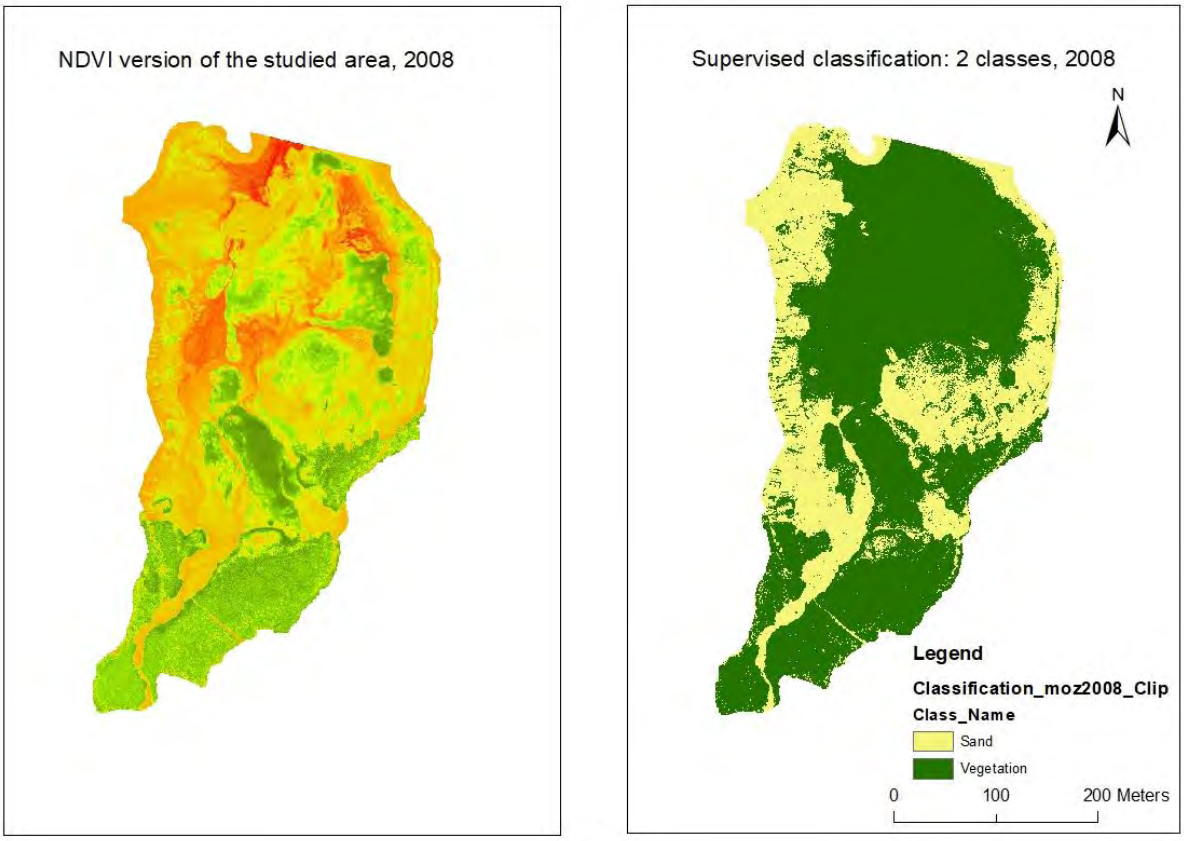


*Figure 31: Supervised classification, 2 classes compared to NDVI version. 2008*

We can clearly see that, as well as for the unsupervised classification, the upper part of the image is not well classified. Looking at the NDVI version, we can easily see that the upper part of the image is not vegetated as much as this.

The idea in this first step was to try to identify the vegetation using the image classification of ArcGIS on the orthophotos. The results are not satisfying so we will use another way: we will create a polygon of the vegetation by using the NDVI version of the embayment

- **Extract the exact shape of the vegetation using the NDVI function**

We are now going to use the *Reclassify* tool of ArcGIS.

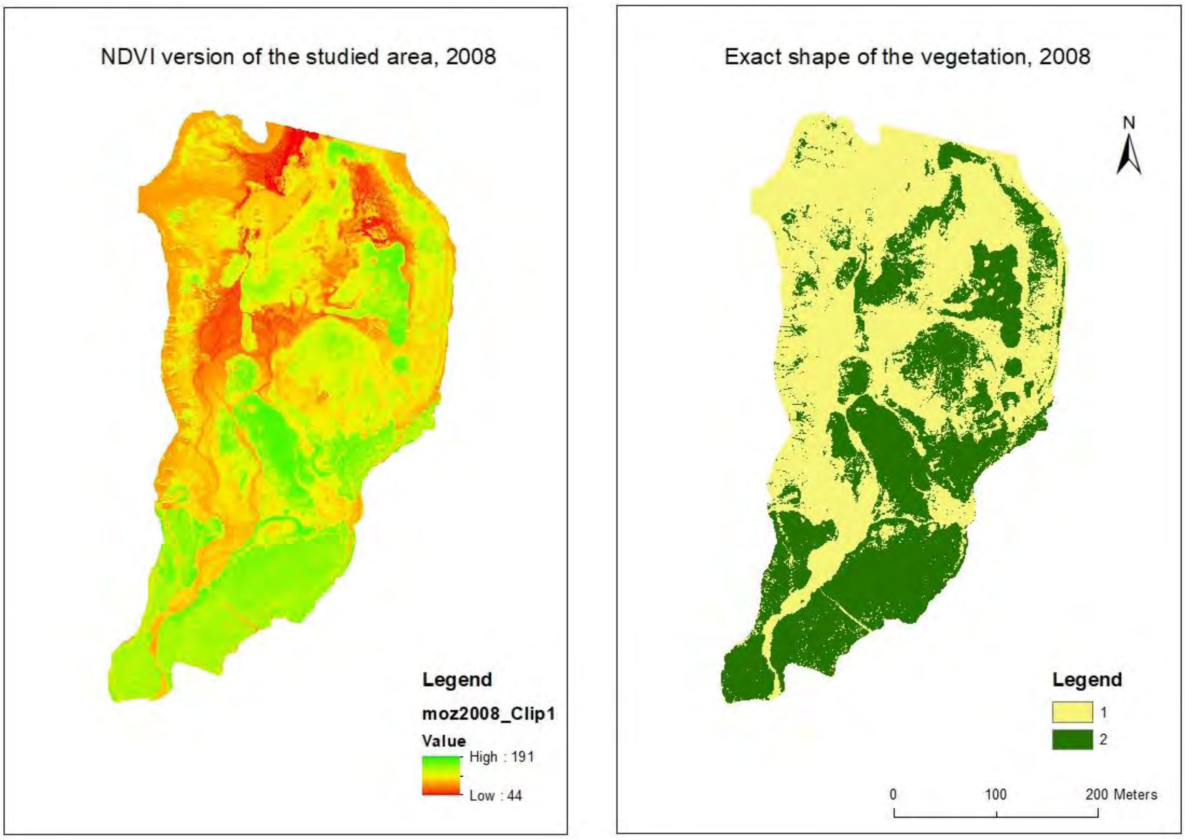



*Figure 32: Exact shape of the vegetation using NDVI version. 2008*

This way of classifying the image is more satisfying and really close to the reality of the NDVI version.

### 2) Classify the vegetated part along with the different environment and species present

The main idea of this second part is now to try to classify the vegetated part for a result of four final classes:

- High marsh dominated by *Salicornia sp.*
- Low marsh dominated by *Spartina maritima*
- Tidal flat dominated by *Zostera noltei*
- Non vegetated area

#### ▪ Use the Iso Cluster Unsupervised Classification on the whole image

In order to classify the image, we first tried with four classes and then five classes. The results with four classes were not satisfying, the upper part of the image was still remaining a problem. So we tried to add one class, but it didn't fix the problem.

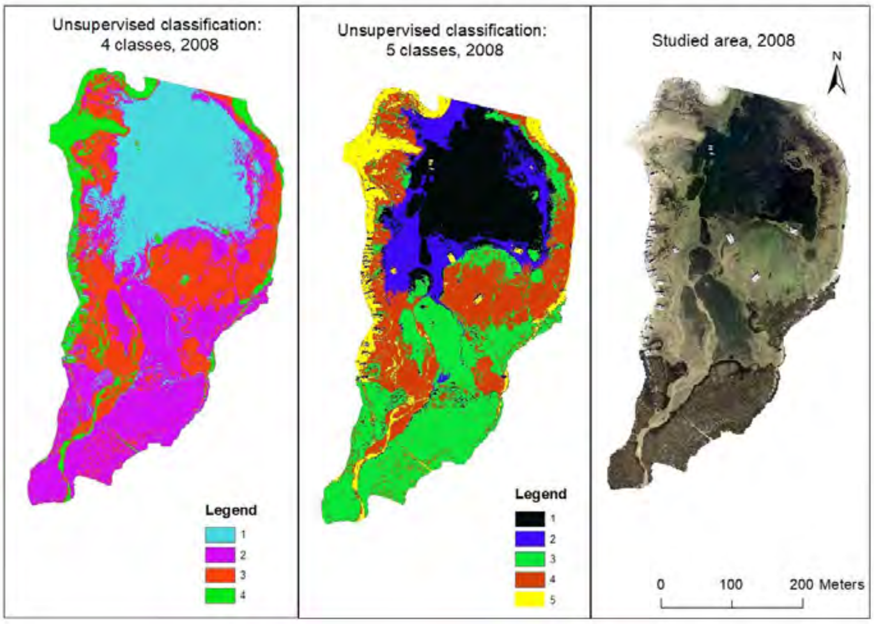



*Figure 33: Unsupervised classification, 4 et 5 classes. 2008*

- Use the ***Iso Cluster Unsupervised Classification*** **inside of the vegetated area created during first step**

We first ask the classification to make 3 classes in the idea of identifying the tidal flat, low marsh and high marsh.

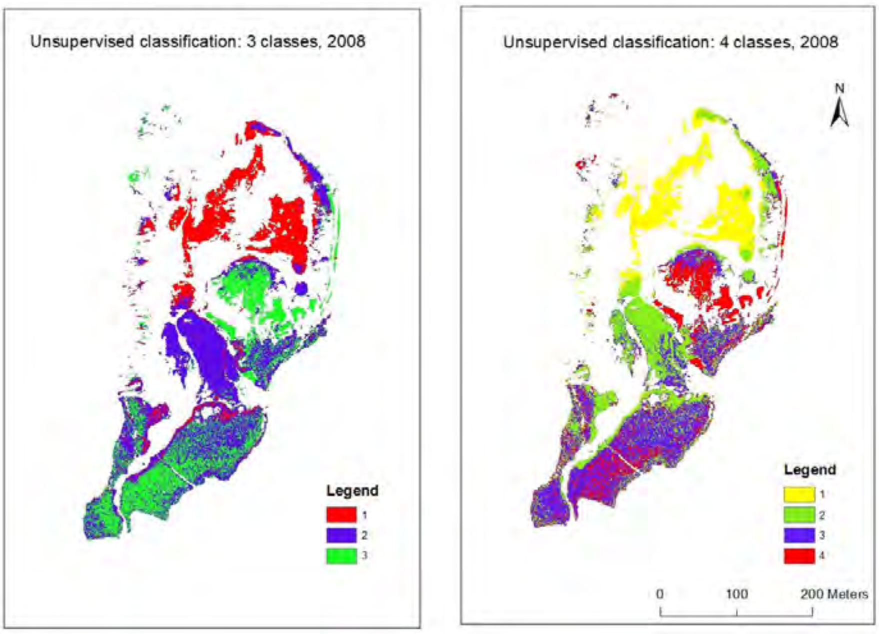


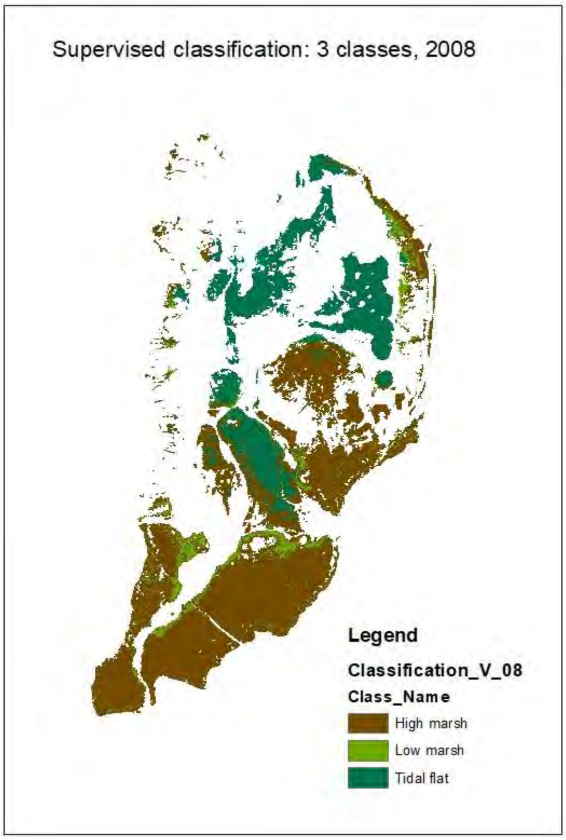

*Figure 34: unsupervised classification: 3 and 4 classes. 2008*

The 3 classes classification is not satisfying, the red class is both in tidal flat part and low marsh part, as well as the purple and the green classes: they are both in the high marsh and tidal flat class.
So we added one class to the classification and the results aren't satisfying neither.

- **Use the *<u>Interactive Supervised Classification</u>* tool inside the vegetated area created during the first part**

In a first time, we made 3 classes of samples:

- High marsh dominated by *Salicornia sp.*
- Low marsh dominated by *Spartina maritima*
- Tidal flat dominated by *Zostera noltei*



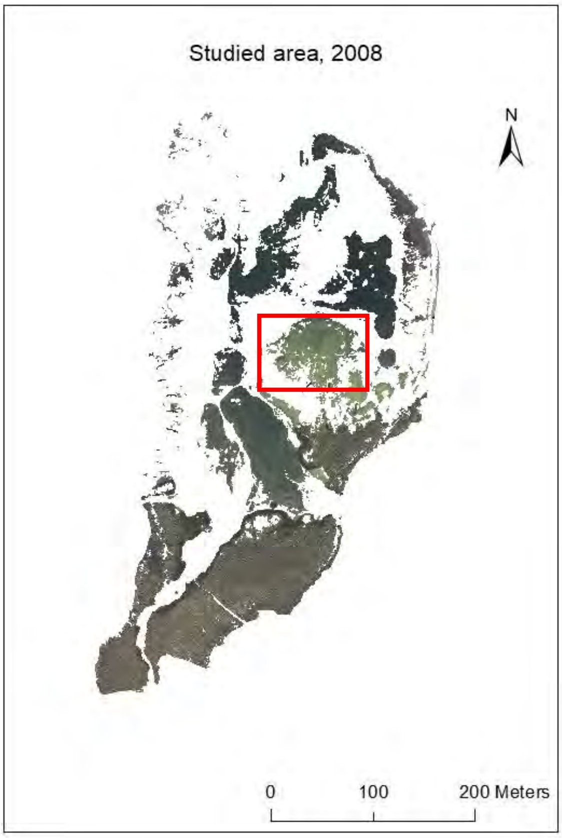




*Figure 35: Supervised classification on the vegetation shape, 3 classes. 2008*

This classification is not satisfying; the high marsh class is mixed with the tidal flat part. As well as for the 2014 classification, we can see some floating vegetation (red rectangle). We will try to add one final class to the classification in order to isolate the floating vegetation.

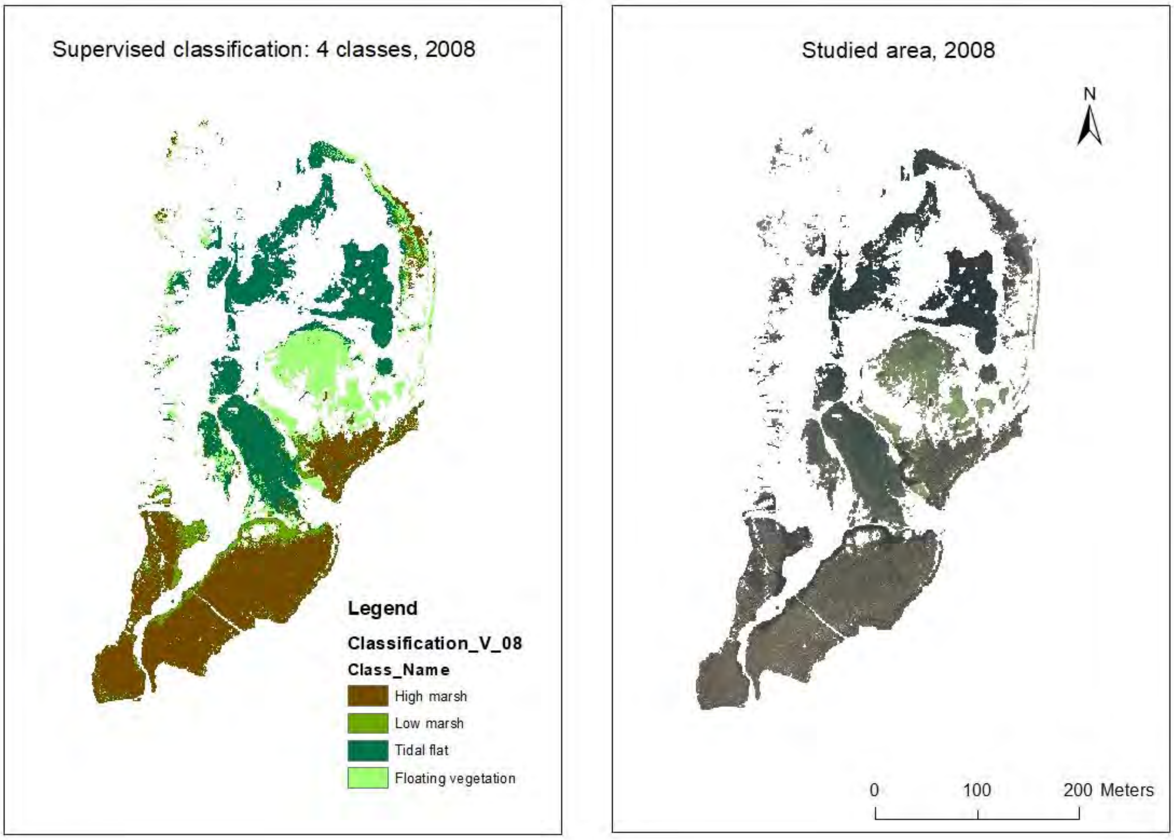



*Figure 36: Supervised classification on the vegetation shape, 4 classes. 2008*

The classification looks good: we can clearly identify the 3 environments and the floating vegetation but the low marsh class mixes with the high marsh class.

### C. Mapping

Now that the image classification is finished, some processes are applying on the classification in order to "clean it". This task involves three steps:

- Filtering the classified output
- Smoothing class boundaries
- Generalizing classified output

#### ▪ Filtering the classified output

This steps consists of removing pixels or "noise" from the classified output. The *Majority Filter* tool is used. In this case.

The **Number of neighbours** to use is: **EIGHT**. The kernel of the filter will be the eight nearest neighbours (a 3-by-3 window) to the present cell.

The **Replacement threshold** is: **MAJORITY**. A majority of cells must have the same value and be contiguous. Three out of four or five out of eight connected cells must have the same value.

For this classification, we decided to run this tool five times.

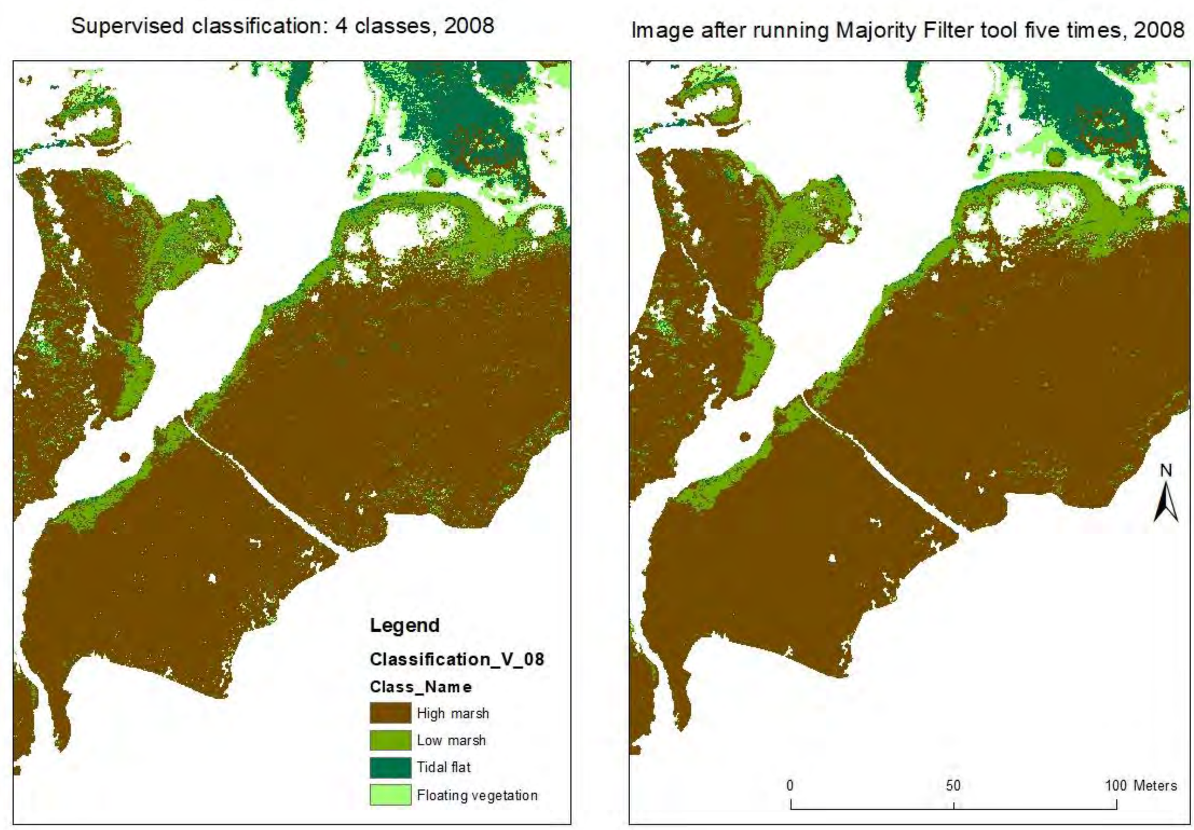



*Figure 37: Majority filter tool*

- Smoothing class boundaries and clumping classified output

For this step, the *Boundary Clean* tool is used. It smooths the rages class boundaries and clumps the classes. We decided for the **Sorting technique** to apply the function: Sorts zones in descending order by size. Zones with larger total areas have a higher priority to expand into zones with smaller total areas.

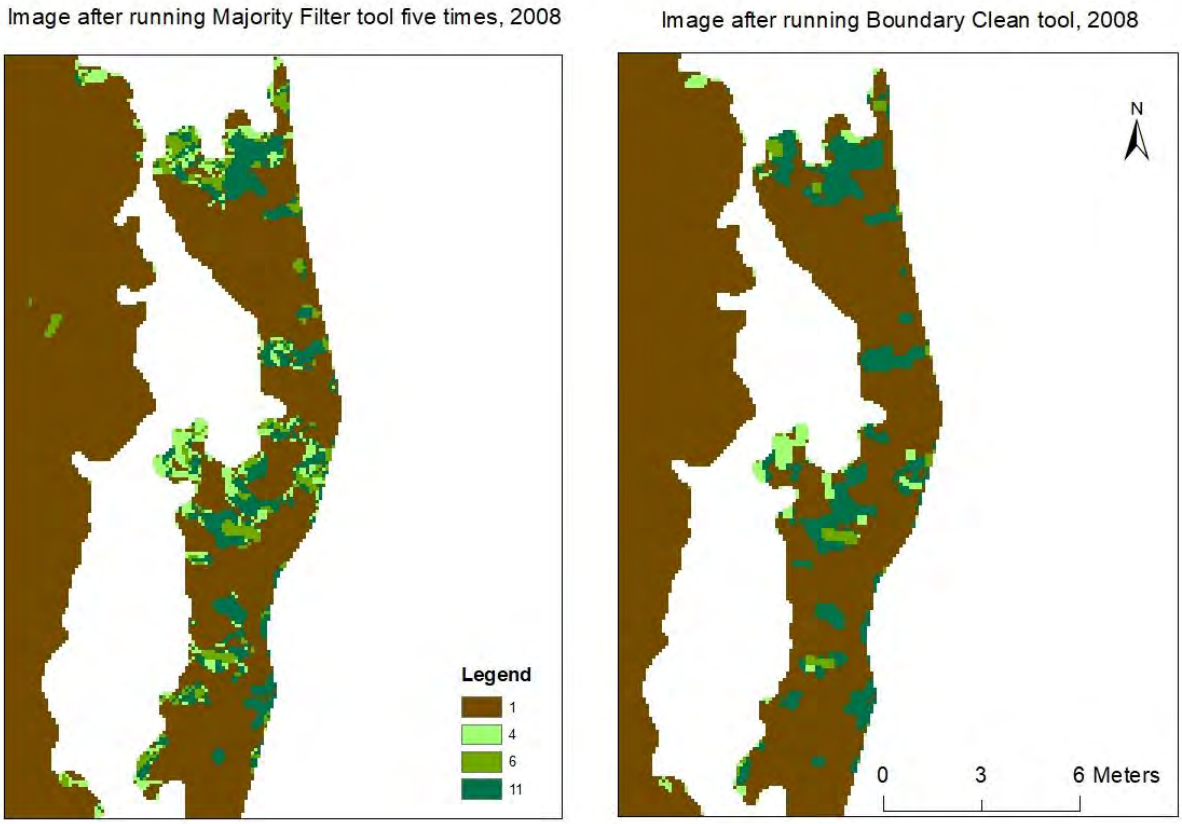


*Figure 38: Boundary Clean tool*

- **Generalizing classified output by removing small isolated regions.**

This step reclassifies small isolated regions of pixels to the nearest classes. The *Region Group*, *Set Null* and *Nibble* tools are used.

For the *Region Group* tool, the **number of neighbours** to use is: EIGHT - Defines connectivity between cells of the same value if they are within the immediate eight-cell neighbourhood (eight nearest neighbours) of each other. This includes to the right, left, above, or diagonal to each other.

The **zone grouping method** is: **WITHIN** - Tests connectivity between input values that are the same within the same zone. The only cells that can be grouped are cells from the same zone (value) that meet the spatial requirements of connectivity specified by the FOUR and EIGHT keywords.

For the *Set Null* tool, the **expression** used is: **"COUNT" <200**

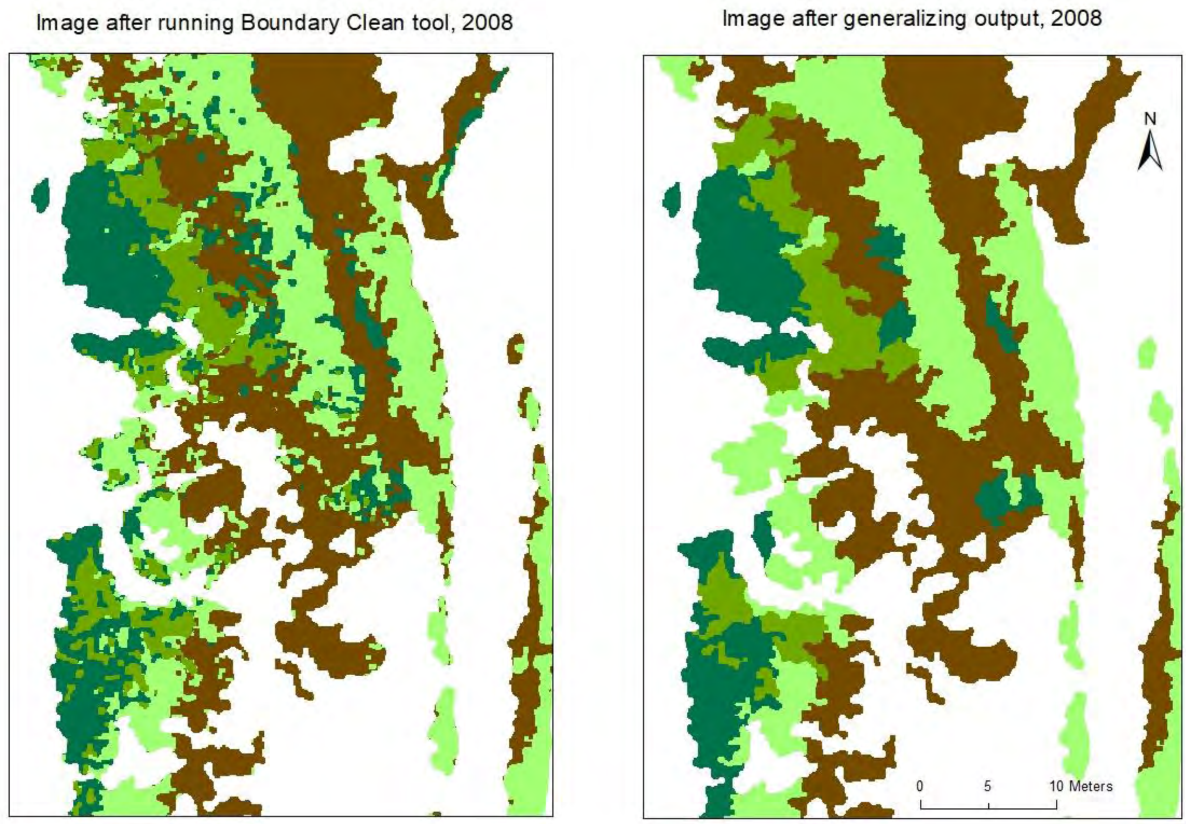



*Figure 39: Image after using Region Group tool, Set Null tool and Nibble tool*

- Final maps

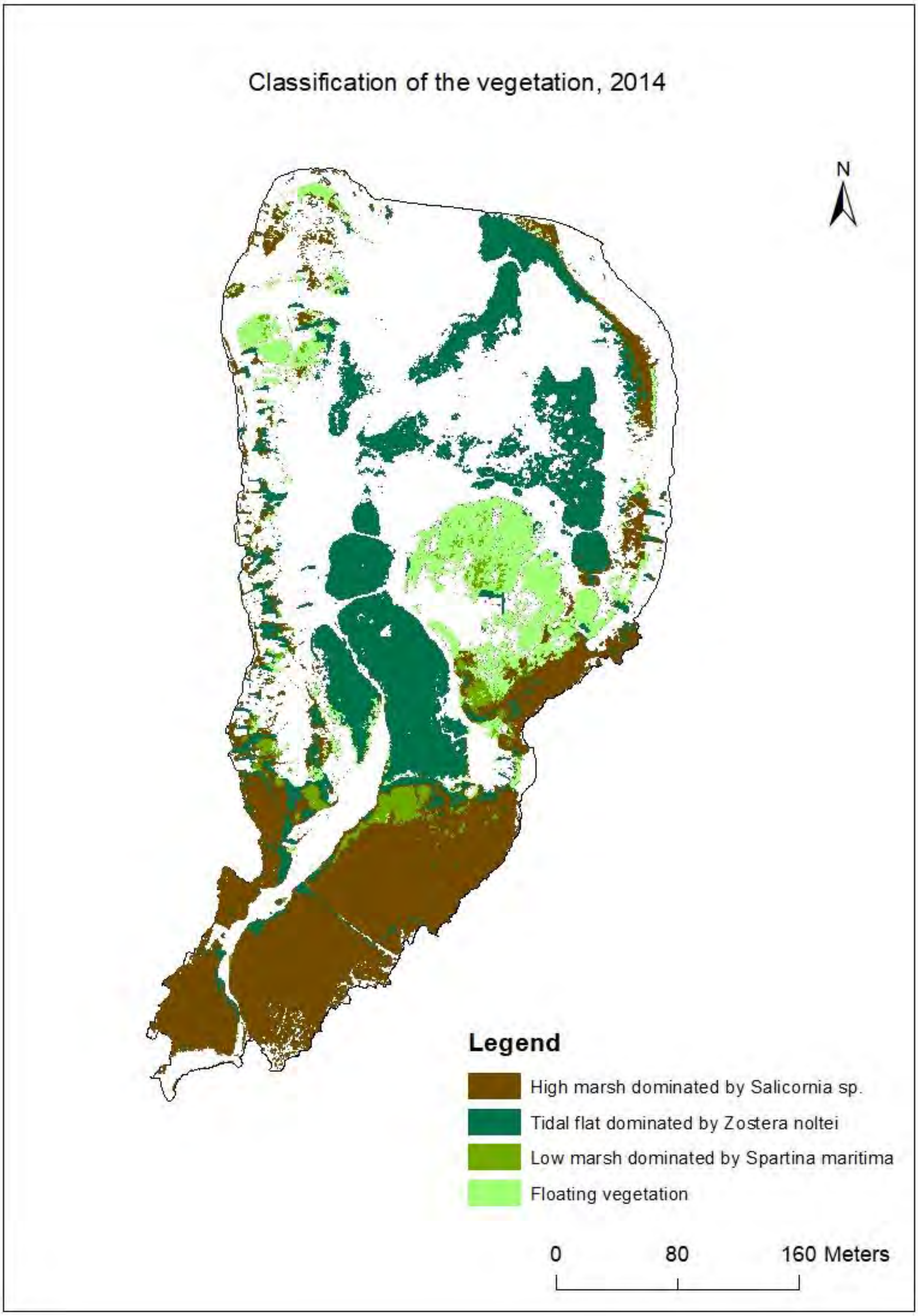



*Figure 40: Final map of the vegetation, 2014*

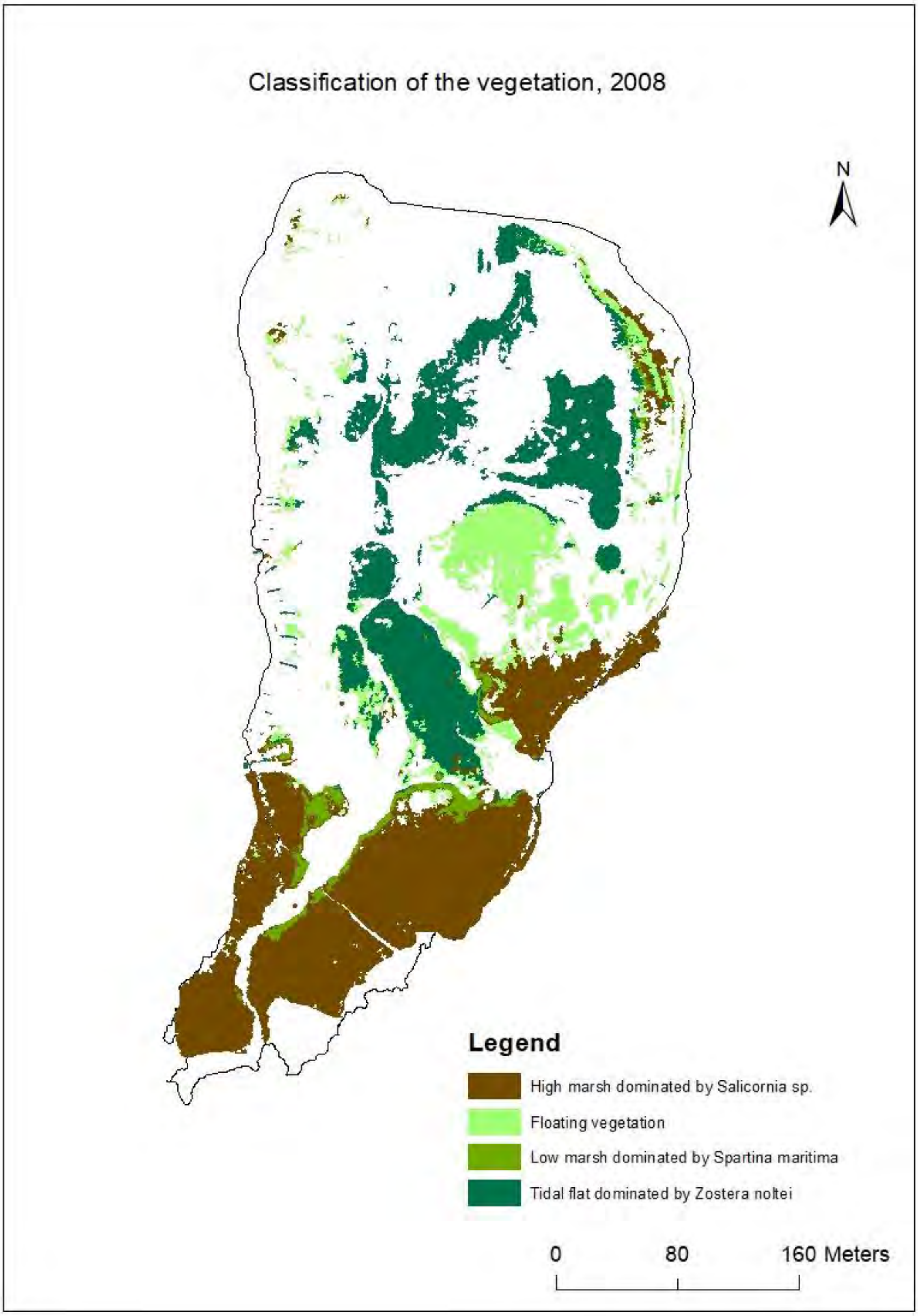



*Figure 41: Final map of the vegetation, 2008*

## 5) DISCUSSION

The use of aerial photographs to execute image classifications can be difficult. The problem is that from one year to another, the pictures weren't taken at the same time of the year: the climate or the meteorology is not the same. Also, the tide is not the same at the moment when the pictures where taken, and this fact sensibly change the colour of the vegetation because of the presence of the water column.

The right classification of the vegetation was able to be done thanks to field work and the NDVI function that could be applied on the orthophotos.

The best way to classify the images was to use the *Interactive Supervised Classification* tool. The problem of this technique is its subjectivity: the samples created to make the final classes are the result of the personal analysis of one person.

This technique can be a good way to analyse the evolution of the salt marsh on a short term period like this one: 2014 – 2008. But, because this technic cannot be applied on old aerial pictures, the methods can't be applied to evaluate long term evolution.

## ANNEX 1

CIACOMAR
Centro de Investigação dos
Ambientes Costeiros e Marinhos

**Análise Granulométrica – Fracção > 0,063**

**Referência da amostra:**____________________ **Data:**________

| Abertura dos peneiros (mm) | Limites em unidades ϕ | | Peso retido (g) | % | % Cumulativa |
|---|---|---|---|---|---|
| > 31,5 | >-5,0 | | | | |
| 22,40 | -5,0 | -4,5 | | | |
| 16,00 | -4,5 | -4,0 | | | |
| 11,20 | -4,0 | -3,5 | | | |
| 8,00 | -3,5 | -3,0 | | | |
| 5,60 | -3,0 | -2,5 | | | |
| 4,00 | -2,50 | -2,00 | | | |
| 2,80 | -2,00 | -1,50 | | | |
| 2,00 | -1,50 | -1,00 | | | |
| 1,40 | -1,00 | -0,50 | | | |
| 1,00 | -0,50 | 0,00 | | | |
| 0,710 | 0,00 | 0,50 | | | |
| 0,500 | 0,50 | 1,00 | | | |
| 0,355 | 1,00 | 1,50 | | | |
| 0,250 | 1,50 | 2,00 | | | |
| 0,180 | 2,00 | 2,50 | | | |
| 0,125 | 2,50 | 3,00 | | | |
| 0,090 | 3,00 | 3,50 | | | |
| 0,063 | 3,50 | 4,00 | | | |
| <0,063 | >4,00 | | | | |
| Totais | | | | | |

Peso inicial:____________
Peso final:____________
Erro:____________

Rubrica:____________

Avenidas das Forças Armadas. 8700-311 Olhão. Tel: 289 707087

## ANNEX 2

# CIACOMAR

Centro de Investigação dos Ambientes Costeiros e Marinhos
da Universidade do Algarve

### GRANULOMETRIA — PIPETAGEM

| DIÂMETRO Ø / μ | < 4 / < 62 | < 5 / < 32 | < 6 / < 16 | < 7 / < 8 | < 8 / < 4 | < 9 / < 2 | < 10 / < 1 |
|---|---|---|---|---|---|---|---|
| TEMPO DE COLHEITA 20 ml (24°C) h m s | 0 00 00 | 0 01 45 | 0 07 00 | 0 28 00 | 1 50 00 | 7 28 00 | 22 , 32 |
| Cápsula n° | | | | | | | |
| Cápsula + amostra + + dispersante | | | | | | | |
| Cápsula + dispersante | | | | | | | |
| Amostra | | | | | | | |
| Amostra x factor correctivo do volume ( ______ ) | | | | | | | |
| Peso de cada fracção Ø | | | | | | | |
| Peso Cumulativo | | | | | | | |
| % Cumulativa | | | | | | | |
| % Individual | | | | | | | |

*Dispersante (nome, concentração e quantidade)* ______

______

______

______

*Peso do dispersante (por 20 ml)* ______

*Fracção > 32 mm* ______ g ______ %

*Fracção de 2 a 32 mm* ______ g ______ %

*Areia (62 μ - 2 mm)* ______ g ______ %

*Silte (8Ø - 4Ø)* ______ g ______ %

*Argila (< 8Ø)* ______ g ______ %

*Total da amostra* ______ g

*Comentários:* ______

______

______

*Amostra n°* ______

*Data* ______

*Local* ______

*Analista* ______

*Data* ______

Avenida das Forças Armadas, 8700 OLHÃO  Tel. (089) 707087

## *BIBLIOGRAPHY*

Carrasco, A. R., Ferreira, Ó., Davidson, M., Matias, A., & Dias, J. A. (2008). An evolutionary categorisation model for backbarrier environments. Marine Geology, 251(3), 156-166.

Garcia, T., Ferreira, Ó., Matias, A., & Dias, J. A. (2002). Recent Evolution of Culatra Island (Algarve – Portugal),1-6.

POOC (Plano de Ordenamento da Orla Costeira entre Vilamoura e Vila Real de Santo António) 1997. Estudos de base - Caracterização da zona de intervenção. Instituto de Conservação da Natureza.

ICN (1999). Estudo Ambiental do Projecto de "Requalificação do Sistema Lagunar da Ria Formosa. Relatório da Situação de Referência. ICN, Parque Natural da Ria Formosa. Kennedy, R. H., James, W. F., Montgomery, R. H. & J. Nix, 1984. The influence of sediments on the nutrient status of DeGray Lake, Arkansas. Sediment and water interactions. Peter G. Sly Springer-Verlag. Proceedings of the third international symposium on interaction between sediments and water, 517 pp.

J. Blott, S., & Pye, K. (2001) Gradistat: A grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surf. Process. Landforms 26, 1237–1248 (2001)

DITTY project (2003). Development of an Information Technology Tool for the Management of European Southern Lagoons under the influence of river-basin runoff EVK3-CT-20022-00084 (DITTY Project) SYNTHESIS REPORT (September 2003) RIA FORMOSA