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# CARTOGRAPHY AND DIACHRONIC STUDY OF THE NAAMA SABKHA (SOUTHWESTERN ALGERIA) THROUGH NDVI, NDWI INDICES, SALINITY, ELECTRICAL CONDUCTIVITY AND SOIL PH

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## Abstract

The present work focuses on the past (1985) and current (2018) status of the Naama's Sabkha, particularly its salinity, vegetation and water status. The acquired results will be useful for the preservation of Sabkha biodiversity. The representative sampling allowed us to make 136 soil samples over two depths (4 cm and 30 cm). The salinity analyses showed that the maximum values are of the order of 115.3 g/l at 4 cm and 80.3 g/l at of 30 cm depth. Regarding to the soil conductivity, the highest values recorded at 4 cm and 30 cm are respectively 198.4 mS.cm-1 and 141.89 mS.cm-1. At the same time, the results highlight that the Sabkha soil is weakly alkaline with strongly alkaline. The diachronic study based on the NDVI (Normalized Difference Vegetation Index) analysis of the Landsat_5, Landsat_8 and Sentinel_2 satellite images showed the installation of a varied vegetation during 33 years. The use of NDWI (Normalized Difference Water Index) for the period (1985 to 2018) highlights the importance of the water deficit in the region. The results of the images geostatistical treatments shed light on the changes that have occurred in particular the increase in the area of Sabkha, which was 431 Ha in 1985 to 514 Ha in 2018. This is an increase of 83 Ha for 33 years. In other words, an evolution of 19.25% compared to the area of 1985.

***Keywords:*** *Sabkha, Naama, Biodiversity, Salinity, NDVI, NDWI*

## 1. INTRODUCTION

Wetlands are rich environments they provide water and food for countless species of plants and animals (M.E.A., 2005). These environments, very different in nature and in operation; play a considerable role in the preservation of biodiversity and management of water resources. Since 1900, more than half of the world's wetlands, whose soil and water have been used for agriculture and other infrastructures have disappeared (Bonnet *et al*., 2005; Schuyt., 2005; Rappe *et al*., 1986).

Algeria is no exception; in recent decades, this country has suffered a significant erosion that has affected and marked different wetlands, (Nedkov et al, 2018; Samraoui., 2011; Bélair *et al*., 1994). Wanzie (2002) reports that the destruction of wetlands leads not only to the disappearance of the species that depend on them but also to the loss of the social and economic benefits of the local populations on which their lives depend. The conservation of wetlands involves cooperation between actors, institutions, and users (Samraoui *et al*., 2008; Bonnet *et al*., 2005).

The majority of the wetlands (Sabkha) is composed of huge saline lakes, they spread from the Algerian north coast to the Sahara crossing the Highlands. These areas are considered as inland wetlands (Mahowald *et al*., 2003; Bryant *et al*., 2002; Donaire., 2000). In 2009, Ramsar sites in Algeria numbered 42 and cover a total area of 2.959 million hectares. 45.23% of these protected sites are salt lakes covering approximately 2.07886 million hectares (Koopmanschap *et al*., 2011; Bellaoueur., 2008; Boumezbeur., 2005; Benchetrit., 1956).

The different plant species found in Sabkha are distributed in an orderly manner with respect to salt concentrations, an important development as long as the salinity is moderate and reduced when salinity is high (Castaneda *et al*., 2008; Larafa., 2004; Ramade., 2005).

In this respect, other halophile Sabkha species, which are of ecological interest such as *Malcolmia arenaria, Ononis antennata* have been reported as rare and endemic species in Algeria and Morocco (Si Bachir., 2008; Hammada *et al*., 2004; Ozenda., 1958). Indeed, Khaznadar *et al*. (2009), show the presence of six endemic species namely, *Astragalus armatus, Frankenia thymifolia, Helianthemum helianthemoides, Herniaria mauritanica, Hieracium amplexicaule* and *Melilotus indica* in El Beida Chott. The use of salt meadows for pasture is very common in the Mediterranean region.

Ornithological inventories have shown a diversity and a large number of waterbirds frequenting these Chotts either for wintering or for breeding (Bensizerara *et al*, 2013; Baaziz *et al*., 2011; Samraoui *et al*., 2011; Béchet *et al*., 2010; Bouzid *et al*., 2009; Houhamdi *et al*., 2008; Boulekhssaim *et al*., 2006; Samraoui *et al*., 2006; Isenmann *et al*., 2000; Tinarelli., 1987)

For Algeria, as for many developing countries, the weakness or absence of a wetland management system, strongly penalize both managers, decision-makers, professionals, and practitioners involved in the management of wetlands. On the other hand, stakeholders dealing with wetland ecosystems have not yet developed enough integrated natural resource management, monitoring and evaluation systems to address the major issues affecting them.

Through this paper, we attempt to take stock of the spatial and temporal evolution of the Naama Sabkha, thanks to the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) from processing a series of Landsat satellite images: Landsat_8 (April 2018), Landsat_5 (April 1985), and Sentinel_2 (February 2018). Thus, to make available to potential users (Environmental Department, Forest Services and others), reliable information (maps of salinity, conductivity, pH, the evolution of the NDVI and NDWI indices) for management and preservation of the Naama Sabkha.

## 2. METHODOLOGICAL APPROACH

### 2.1 The study area

The study area is part of the western steppe region of Algeria, which is north of the Naama city, it is the Naama Sabkha (Figure.1).

The Naama city has a border with the kingdom of Morocco. Our study region is part of the high plains of southern Oran which extends from 32 ° 08 'to 34 ° 22' latitude north and 0 ° 36 'is 0 ° 46 longitude west.

This wetland is home to floristic biodiversity (pastoral and medicinal plants) and some 400 species of migrating birds, including a rare species known as *Tadorna ferruginea*. Unfortunately, the Naama Sabkha is threatened with pollution due to the discharge of water from the treatment plant and solid waste with a significant sedentarization, which degrades this site that has a tourist and ecological character.

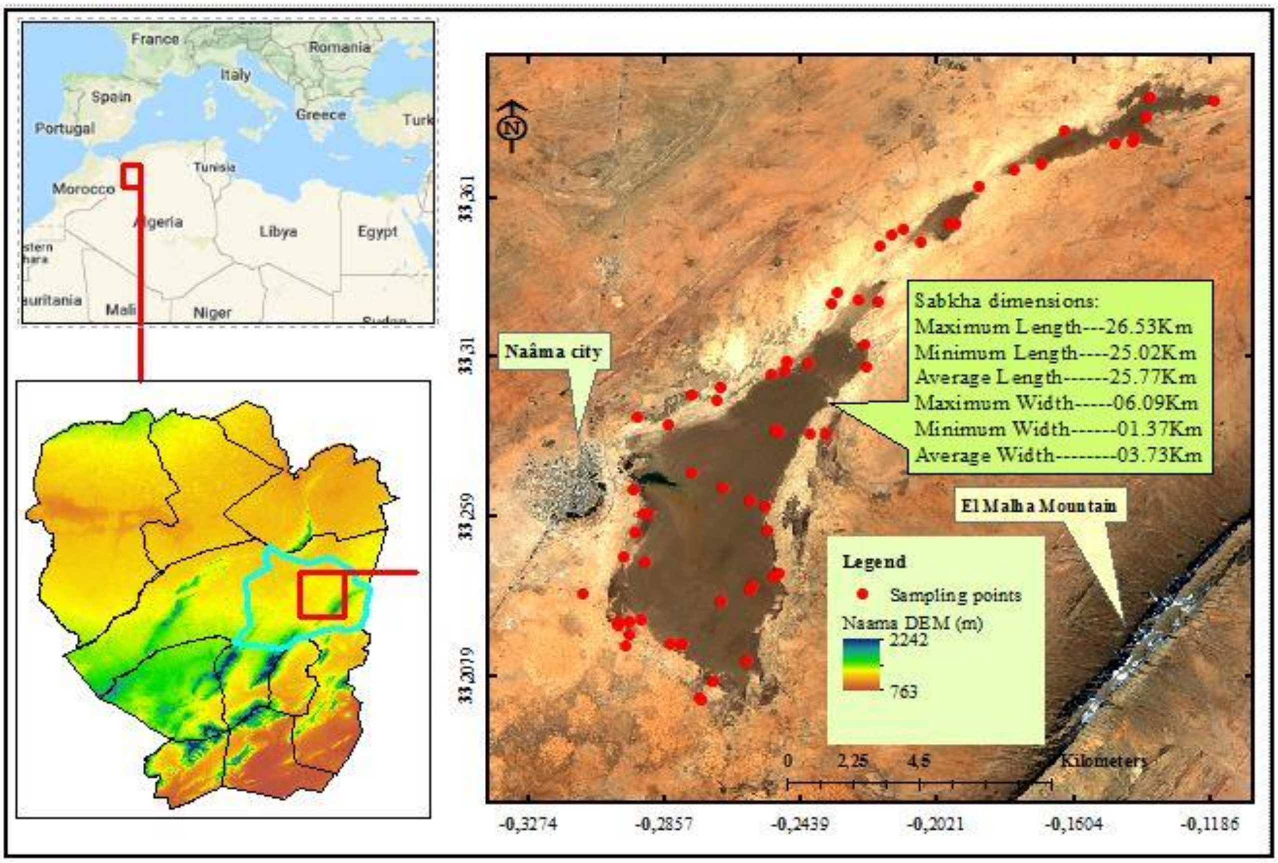


**Figure. 1:** Location Map of the Naama Sabkha.

The climate in this study area is semi-arid, characterized by a dry summer season with increasing aridity from north to south (Halimi., 1996; Seltzer., 1946). The annual average of precipitation in the Naama region is 238.49 mm. The rainfall regime characterized by a long period of drought that extends from April to October.

Following the field exploration and reconnaissance phase, we identified sampling points while taking into account certain criteria such as vegetation and geomorphology.

In the end, 68 representative sampling points were selected and geo-localized for the purposes of our study. The Flowchart below (Figure. 2) represents the approach adopted for the conduct of our study. We sampled soil at two depths (4 cm and 30 cm).

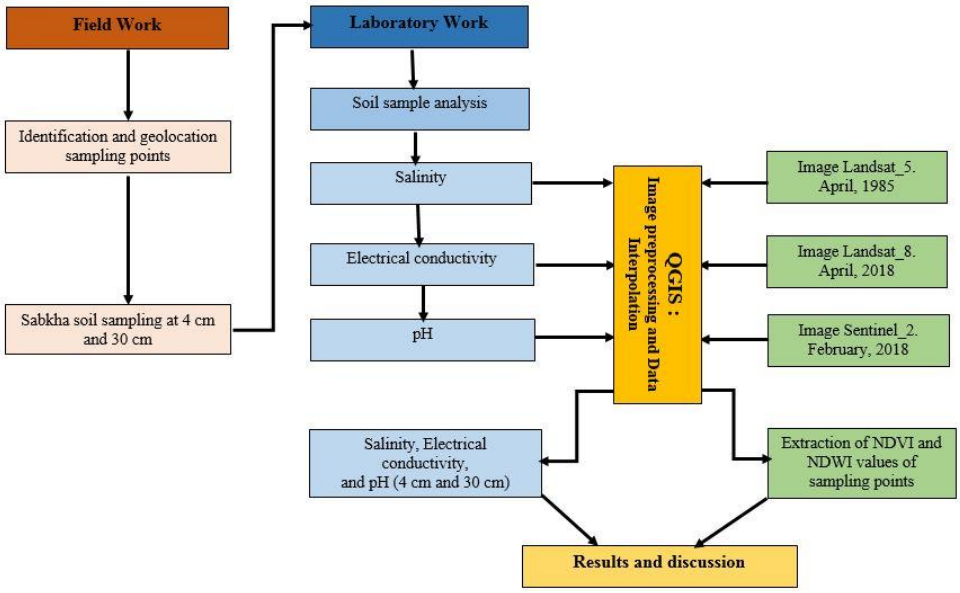


**Figure. 2:** Flowchart illustrating the approach followed for the study.

## 2.2 Normalized Difference Vegetation Index (NDVI)

To identify the past and current changes in Naama Sabkha, we undertook a diachronic study (1985 to 2018). We looked at changes in vegetation cover and soil moisture content while relying on the processing of a series of satellite images. These are from Landsat_5 TM (April 1985) Landsat_8 OLI (April 2018) and Sentinel_2 (February 2018).

The vegetation index is a tool used in the environmental domains and for agriculture in particular, because it provides information on the state of the vegetation. The following formula is used to calculate the NDVI (1):

$$NDVI = (NIR - RED) / (NIR + RED)\ldots..\ (1)$$

NIR**:** Near Infra-Red

As a reminder, the NDVI uses the RED and NIR bands. With values between -1 and 1, the index reflects the quantity and quality of vegetation (Abdalla *et al*., 2015; Ke et *al*., 2015; Frampton *et al*., 2013; Aguilara *et al*., 2012; Farrar *et al*., 1994; Nicholson *et al*., 1994; Huete *et al*., 1987).

## 2.3 Normalized Difference Water Index (NDWI)

Following the same principle as the NDVI, the Normalized Difference Water Index uses the near infrared band and a **S**hort **W**ave **I**nfra-**R**ed band (SWIR) (Hassen., 2014; Gu *et al*., 2008; Gu *et al*., 2007; Gao., 1996). The NDWI index is calculated according to the following equation (2):

$$NDWI = (NIR - SWIR) / (NIR + SWIR)\ \ldots..\ (2)$$

This index makes it possible to check the effectiveness of irrigation systems because properly irrigated plants with high water content will reflect a value of NDWI close to 1.

# 3. RESULTS AND DISCUSSION

## 3.1 Naama Sabkha soil salinity map

The elaborate maps of soil salinity (Figure. 3 and 4) at 4 cm and 30 cm depth show a tangible and remarkable variation in salinity. Indeed, the soil salinity reaches a maximum value of about 115.3 g/l at a depth of 4 cm and 80.3 g/l at 30 cm depth. In addition, smaller values (classified as low) oscillate between 1.71g/l at 4 cm, and 3.84 g/l at 30 cm.

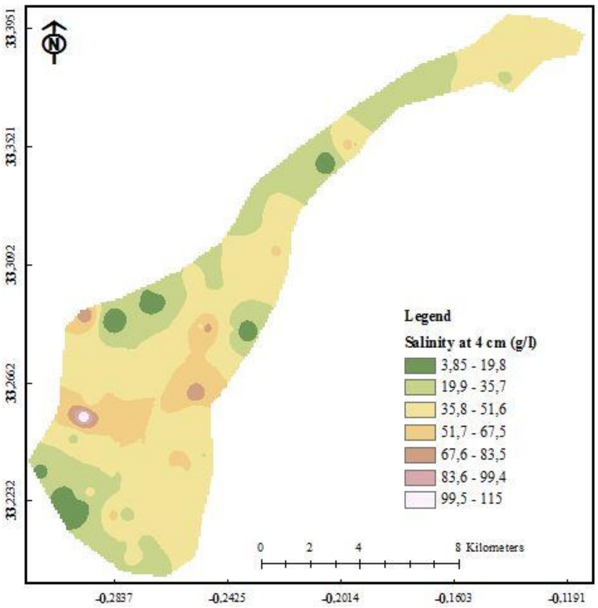


**Figure. 3:** Naama Sabkha soil salinity map (4 cm depth)

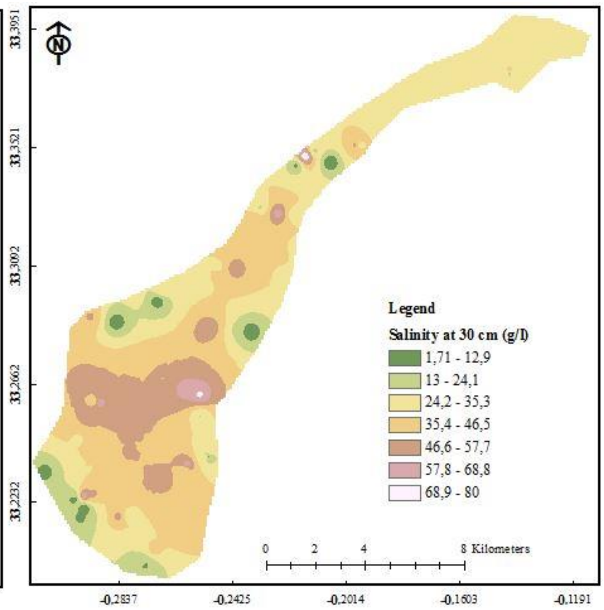


**Figure.** 4: Naama Sabkha soil salinity map (4 cm depth)

### *3.1.1 Salinity at 4 cm*

We find (Figure. 3) that the values vary from 3.84 to 115.31 g/l. To better understand the salinity of the Sabkha of Naama, we reclassified the classes of the map above into 3 classes:

Low class [3.84 – 35.96]: Located near the Sabkha. Among the observations made on the ground the installation of vegetation composed only of *Salicornia macrostachya* (Figure.5). The latter tolerate low class salinity.

**Figure. 5:** Salicornia macrostachya (The Naama Sabkha)

It turns out that the lowest values of salinity can be explained by the installation of a sandy accumulation (silting phenomenon) which tends to reduce the level of salt in the soil.

Middle class [35.96 – 67.54]: Located in the interior of Sabkha. The floor of this class is bare. This class represents the largest area of Sabkha.

High class [67.54 – 115.31]: has the highest values. The soil is bare. This class forms a small area.

*3.1.2 Soil salinity at 30 cm*

Salinity values at 30 cm (Figure.4) are between 1.71 and 80.03 g/l. After reclassification, 3 salinity classes were established:

Low class [1.71 – 35.27]: Located on the outskirts of Sabkha. This class has a large area of Sabkha. Thanks to profiles made in the soil of Sabkha, we noticed a sandy accumulation

Middle class [35.27 – 46.46]: Located in the interior of Sabkha. This class represents an average area.

High class [46.46 – 80.03]: We emphasize that the values obtained are the highest. This class has a small area of Sabkha.

There is a large difference between the minimum and maximum values of salinity at 4 cm and 30 cm. This may be related to environmental conditions (climate, hydrology), water supply, control systems [drainage], soil texture and salt mobility. The soil texture rich in fine elements is positively correlated with salinity (Attia., 2013; Le Brusq *et al*., 1982). These factors affect the water balance and thus the accumulation of salts in the soil. This is the case of our study area.

### 3.2 Naama Sabkha soil electrical conductivity map

The results obtained from the analyses of the 136 samples showed that the minimum value of the electrical conductivity (EC) is 1.71 $mS.cm^{-1}$ while the maximum of the EC is 198.4 $mS.cm^{-1}$. To meet the objectives of our study, conductivity maps were developed (Figure. 6 and 7).

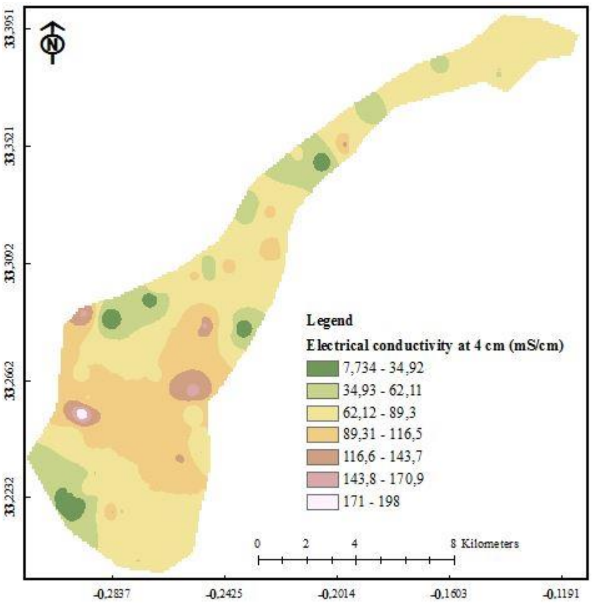


**Figure. 6:** Naama Sabkha soil electrical conductivity map (4 cm depth)

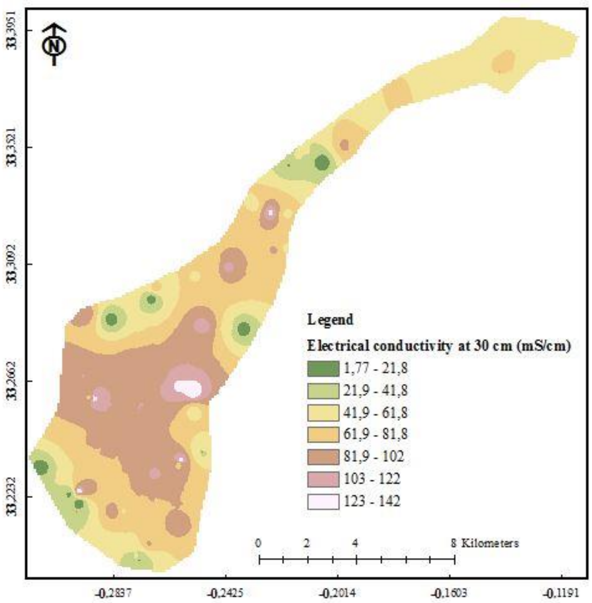


**Figure. 7:** Naama Sabkha soil electrical conductivity map (30 cm depth)

*3.2.1 Soil electrical conductivity at 4 cm*

Electrical conductivity values at 4 cm are between 7.73 to 198.04 $mS.cm^{-1}$. We find that at 4 cm the concentration of ionizable solutes present in the samples is very high.

Following the data processing of the conductivity analyses, we obtained 7 classes. These have been reclassified into 3 classes:

Low class [7.73 – 62.11]: Has the lowest values. She went back to the outskirts of Sabkha. This class has a small area of Sabkha.

Middle class [62.11 –116.48]: Located in the interior of Sabkha, characterized by bare ground. This class represented a large part of the Sabkha.

High class [116.48 – 198.04]: This class has the smallest area of Sabkha.

*3.2.2 Soil electrical conductivity at 30 cm*

It appears that the values of the conductivity (Figure.7) are between 1.77 to 141.89 $mS.cm^{-1}$. To make interpretations easy, we have reclassified the classes of conductivity to 30 cm in 3 classes:

Low class [1.77 – 61.82]: Located on the outskirts of Sabkha. The presence of broadband composed mainly of *Salicornia macrostachya* on a sandy accumulation (mound). The latter allowed the diffusion of the root system of Salicornia.

Middle class [61.82 – 81.84]: Located in the interior of Sabkha, characterized by bare ground. Presents a large area of Sabkha.

High class [81.84 – 141.89]: Characterized by bare soil .This class has an average area of Sabkha.

The ionic concentration of the soil solution "Electrical conductivity" will be all the more important as the quantity of water is important and that it is rich in salts.

Unsalted soils have conductivities ranging between 0 and 50 $mS.cm^{-1}$, salty soils between 100 and 200 $mS.cm^{-1}$. The nature of the soil constituents and their retention capacity affect the conductivity. Soil capacity varies in a wide range: from 30 to 60 $mS.cm^{-1}$ for clay soils, from 10 to 20 $mS.cm^{-1}$ for loamy soils, and below 10 $mS.cm^{-1}$ for sandy soils. Conductivity increases significantly as soil temperature increases (Dehni., 2018; Dehni *et al*., 2012; MADR., 2008; Loyer., 1991).

We observe a variability of the conductivity of the samples for the two depths. The highest values recorded at 4 and 30 cm are respectively 198.4 $mS.cm^{-1}$ and 141.89 $mS.cm^{-1}$. In addition, we recorded a minimum value of 7.73 $mS.cm^{-1}$ at 4 cm and 1.71 $mS.cm^{-1}$ at a depth of 30 cm. This variation in conductivity values is proportional to the ionized dissolved mineral concentration (Benmoussa., 2017; Soulama., 2011)

## 3.3 Naama Sabkha soil pH map

The two pH maps (Figure.8 and 9) developed from the results of the analyses highlight the small difference between the values. These last oscillate between 7.18 and 8.75; we deduce that the ground of the Sabkha is clearly alkaline.

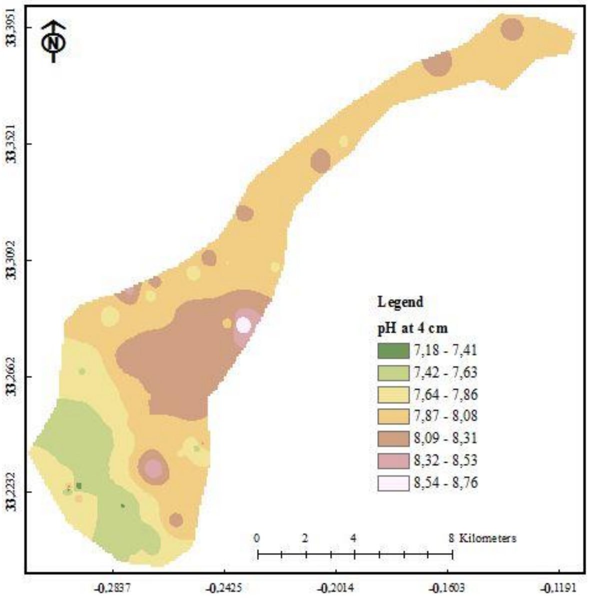


**Figure. 8:** Naama Sabkha soil pH map (4 cm depth)

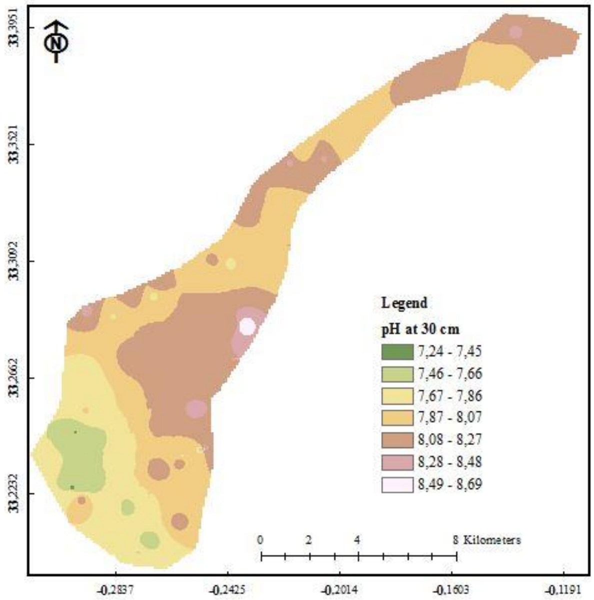


**Figure. 9:** Naama Sabkha soil pH map (30 cm depth)

*3.3.1 Soil pH at 4 cm*

pH values at 4 cm (Figure. 8) range from 7.18 to 8.75. After reclassification, 3 pH classes were established:

Low class [7.18 – 7.63]: Represented by a small area of Sabkha with moderately alkaline soil.

Middle class [7.63 – 8.08]: Occupies most of the Sabkha with bare soil. The latter is between moderately alkaline and strongly alkaline.

High class [8.0 – 8.75]: Characterized by bare soil with a small area. The soil is strongly alkaline (Le Tacon., 1978; Ferrière., 1933).

*3.3.2 Soil pH at 30 cm*

The 7 classes shown on the map (Figure. 9) have been reclassified to 3 classes:

Low class [7.24 –7.65]: The soil is weakly alkaline. This class represents a small area of the Sabkha of Naama.

Middle class [7.65 – 8.06]: The soil is moderately alkaline. This class occupies a large area of Sabkha.

High class [8.06 – 8.68]: Usually located on the outskirts of Sabkha. This class characterizes a strongly alkaline soil.

The pH values (Figure. 9) obtained from the laboratory analyses show that the Naama Sabkha soil pH varies between "weakly alkaline soil with strongly alkaline soil".

The phenomenon of alkalization is characterized by an increase in pH which can then be a brake on the availability and assimilability of certain elements (Zn, P, N). Alkalization results in an increase of the exchangeable Na content on the soil-absorbing complex (Hachicha., 2007)

The rapid precipitation of Ca and Mg carbonates allows the Na ions to bind to the absorbing complex. The content of $Na^{+2}$ and $K^{+}$ ions in the soil from alkaline salts (carbonates and sulfates) leading to pH values higher than 8. The pH varies according to the nature of the soil. The pH should be [6.8 – 8.06] for heavy soils; [6.2 – 6.8] for light soils and [5.0 – 5.6] for organic soils (Doucet., 2006).

We concluded that the soil of Naama Sabkha is characterized high salinity, strongly alkaline pH, and high conductivity.

### 3.4 The Naama Sabkha NDVI evolution (1985 – 2018)

NDVI and NDWI Data from QGIS satellite image processing allowed us to establish relative histograms of vegetation cover and moisture content during the 1985 and 2018.

We notice that the Landsat_8 NDVI values are positive and between [0.0625 – 0.1526] (Figure. 10). This involves the installation and development of vegetation. However, the Landsat_5 NDVI have negative values (absence or little vegetation cover) between [-0.0259 – 0.0152]. These conclusive results highlight the development of an important cover for 33 years.

The accumulation of sand (silting) has allowed the installation of a large vegetation cover mainly composed of Salicornia, which tolerates high levels of salinity.

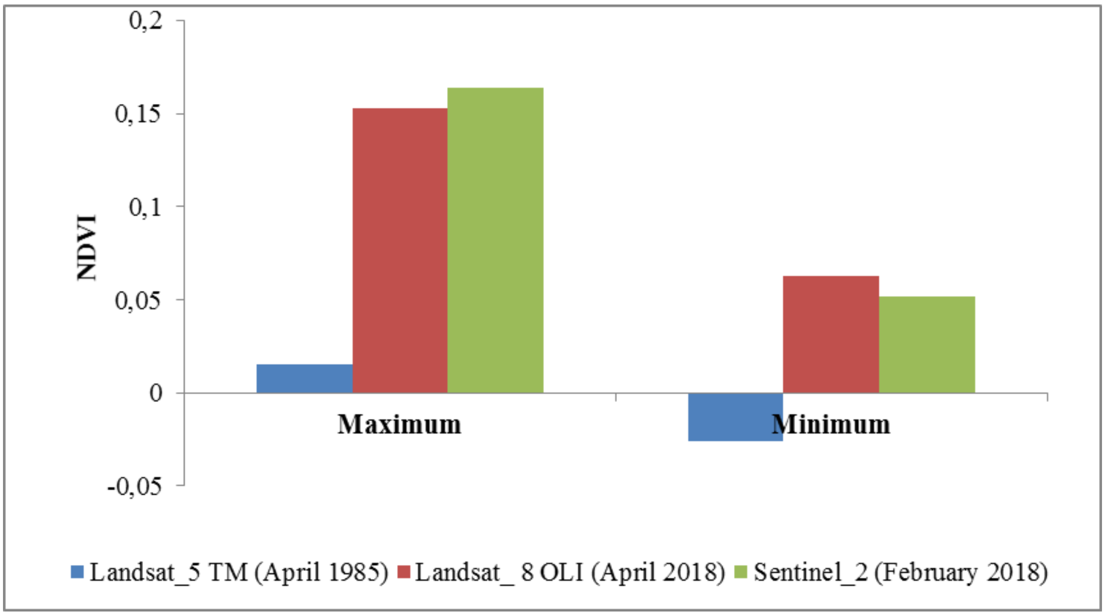


**Figure. 10:** Landsat_5, Landsat_8 and Sentinel_2 NDVI evolution between 1985 and 2018

#### *3.4.1 Landsat_8 OLI and Sentinel_2 NDVI*

The maximum and minimum values of NDVI obtained following the processing of Landsat_8 and Sentinel _2 images for the period February and April of 2018 are practically closed.

The Sentinel_2 NDVI values are slightly higher than those of Landsat_8. The very small difference can be explained by the quality of the Sentinel_2 satellite image with a resolution of 10*10m. On the other hand, Landsat 8 satellite images have a resolution of 30*30m. This difference in resolution affects the results of the different indices.

According to El Halimi (2015) healthy vegetation absorbs much of the visible light in the red through chlorophyll pigments and strongly reflected in the NIR; the strong contrast between the reluctance in the red and the near infrared is also exploited to build the NDVI.

#### *3.4.2 Landsat_5 TM, Landsat_ 8 OLI and Sentinel_2 NDVI comparison*

We carried out a comparison between NDVI (Figure. 11, 12 and 13) from 1985 and 2018 to illustrate the evolution of the vegetation cover of Naama Sabkha.

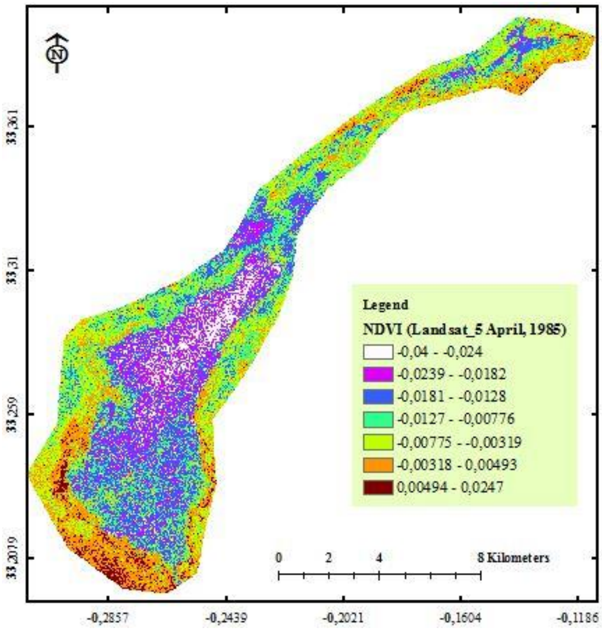


**Figure. 11:** Landsat_5 (April 1985) NDVI map

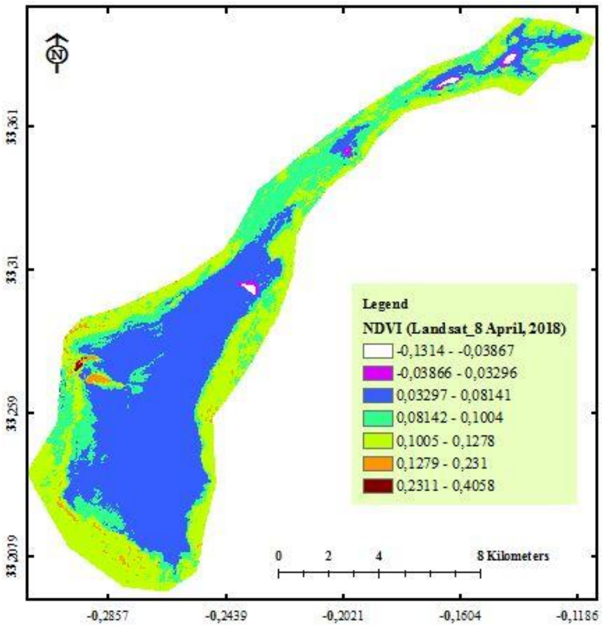


**Figure. 12:** Landsat_8 (April 2018) NDVI map

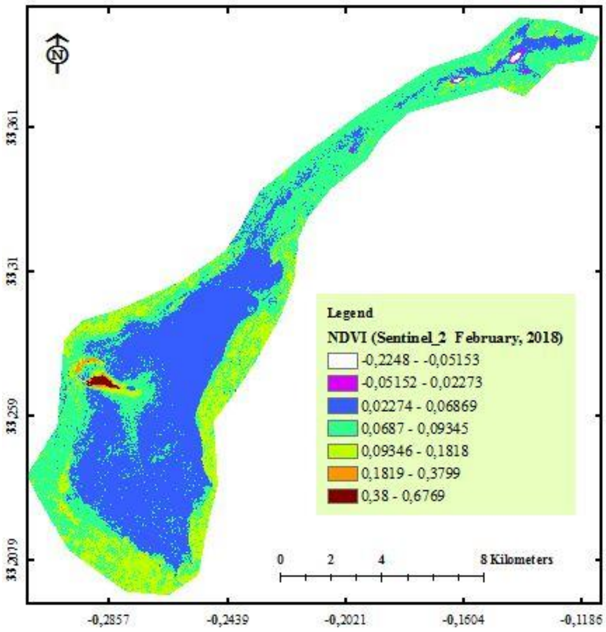


**Figure. 13:** Sentinel_2 (February 2018) NDVI map

We observe that NDVI values calculated from Landsat_8 and Sentinel_2 are significantly higher than Landsat_5. Peak values Landsat_8 and Sentinel_2 NDVI were recorded at 0.1526 and 0.164 respectively.

However, the maximum value Landsat_5 NDVI is equal to 0.0152. These values reflect significant changes in the Naama Sabkha. The choice of the date of the series of images was not fortuitous, on the contrary, it turns out that the treatment of images taken during the month of April offers multiple advantages for the detection of chlorophyll (photosynthetic activity).

When a vegetation index is high, this usually indicates an increase in vegetation area (Yarlequé *et al*., 2009; Girard., 1999; Eklundh., 1998).

### 3.5 The Naama Sabkha NDWI evolution (1985 – 2018)

The maximum and minimum NDWI values (Figure.14) were extracted from the maps developed from the 1985 and 2018 satellite images. The comparison of Landsat_5 and Landsat_8 NDWI values will allow us to assess the spatiotemporal evolution of this indi during 33 years (1985 - 2018).

Over 33 years, NDWI values are decreasing. The values obtained from the computation of the Landsat_5 NDWI show higher values [Min: -0.1681 and Max: -0.1190] than those of Landsat_8 NDWI [Min: -0.2726 and Max: -0.1544]. The NDWI values have decreased considerably; this is due to the droughts that hit the region with their corollary palpable water deficit. The NDWI takes negative values when the reflectance in the mid infra-red is greater than that of the NIR (El Halimi., 2015).

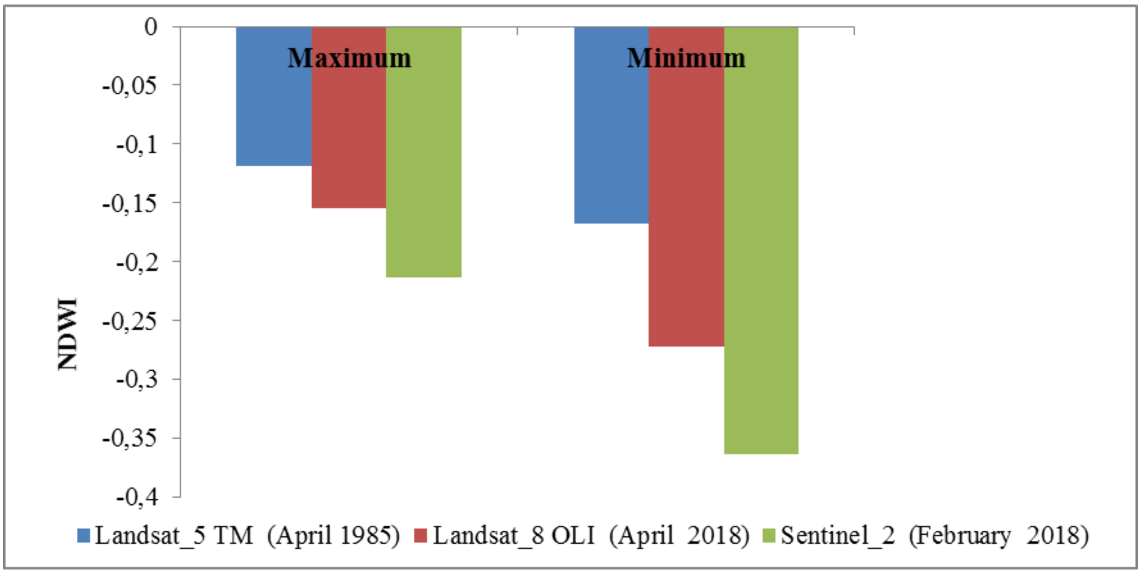


**Figure. 14:** Landsat_5, Landsat_8 and Sentinel_2 NDWI evolution between 1985 and 2018

#### *3.5.1 Landsat_5 TM and Sentinel_2 NDWI*

The analysis of Sentinel_2 NDWI shows a sharp decrease compared to Landsat_5 NDWI. This decline is obvious, caused by climate change that has affected the region since 1985. We are witnessing a reduction of the rainy regime for 33 years.

In the end of these analyses, we can conclude that the comparisons made with NDVI and NDWI developed through QGIS treatments have highlighted the tangible changes that have taken place over 33 years. We are witnessing the installation of a variety of vegetation that best adapts to the current conditions of the region. In addition, the calculated NDWI values highlight the importance of the water deficit in the region. It would have been wise to compare the results of the Landsat_5 and Landsat_8 NDWI with climate data. Unfortunately, these are difficult to acquire.

### *3.5.2 Landsat_5, Landsat_8 and Sentinel_2 NDWI comparison*

It appears that the values of the water content index by Normalized difference (Figure. 15, 16 and 17) has declined significantly since 1985. This has led to the exacerbation of some phenomena such as evapotranspiration and silting.

The processing of Landsat_5 (1985) and Landsat_8 (2018) satellite imagery allowed us to estimate the area of Sabkha of Naama. In 1985, the area was of the order of 431 Ha, while in 2018 we recorded 514 Ha, it is an increase of 83 Ha for 33 years. In other words, an evolution of 19,25% compared to the area in 1985.

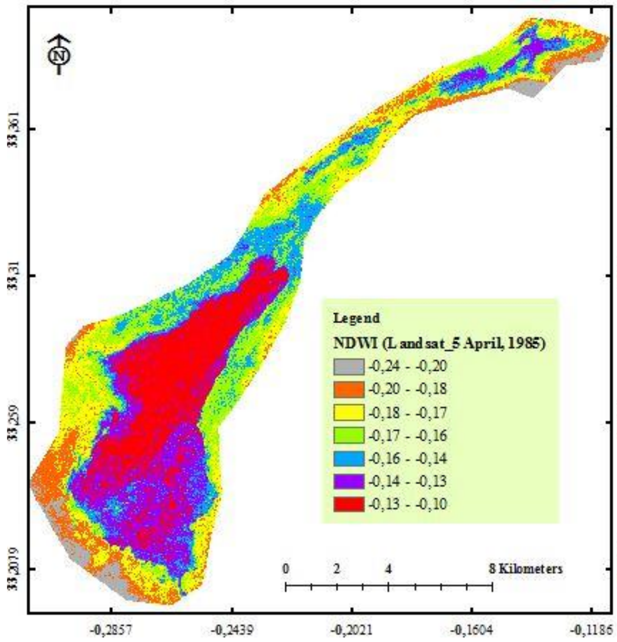


**Figure. 15:** Landsat_5 (April 1985) NDWI map

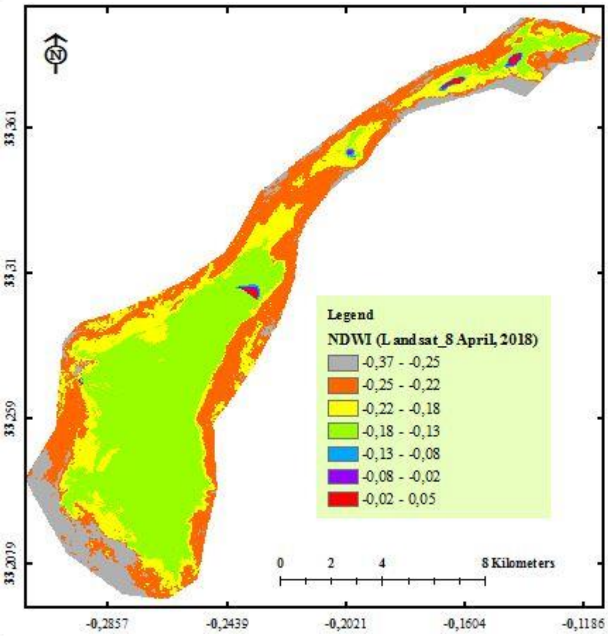


**Figure. 16:** Landsat_8 (April 2018) NDWI map

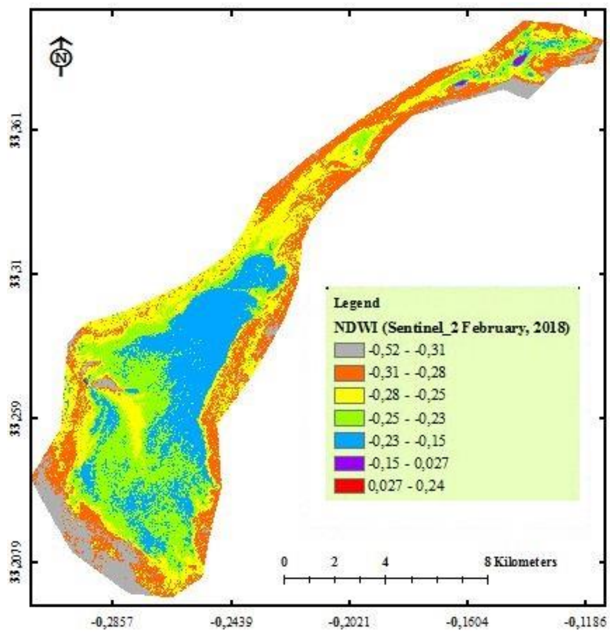


**Figure. 17:** Sentinel_2 (February 2018) NDWI map

## 4. CONCLUSION

The Naama Sabkha is a suitable wintering place for many birds such as Tadorna ferruginea, Anas platyrhynchos and Phoenicopterus roseus. It is also characterized by an important plant diversity such as *Retama retam, Tamrix gallica, Aristida pungens, Salicornia macrostachya, Atriplex halimus.*

In the end of the results obtained, the Naama Sabkha soil salinity at 4 cm and 30 cm depth, show a remarkable variation of salinity. Indeed, the soil salinity reaches a maximum value of 115.3 g/l at a depth of 4 cm and 80.3 g/l at a depth of 30 cm. At the same time, the values of the conductivity show a variability for the two depths. The highest values recorded at 4 cm and 30 cm are respectively 198.4 mS.cm-1 and 141.89 mS.cm-1. Regarding, pH results, the analyses highlight the small difference between the values. These last oscillate between 7.18 and 8.75, we deduce that the Sabkha soil is weakly alkaline with strongly alkaline soil.

The diachronic study of Landsat_5, 8 and Sentinel_2 images highlight tangible changes over 33 years. We are witnessing the installation of a variety of vegetation that best adapts to the current conditions of the region. In addition, the calculated NDWI values highlight the importance of the water deficit in the region.

Thanks to the processing of Landsat_5 (1985) and Landsat_8 (2018) satellite imagery, we have detected the changes that have occurred in the area of Sabkha de Naama. In 1985, the area was of the order of 431 Ha, while in 2018 514 Ha were registered. This is an increase of 83 Ha for 33 years. In other words, an evolution of 19.25% compared to the area of 1985.

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