Cartography and Diachronic Study of the Naama Sabkha (Southwestern Algeria) Remotely Sensed Vegetation Index and Soil Properties

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Abstract. The present study 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: topsoil (0-4 cm) and down soil (4-30 cm) layers. The salinity analyses revealed that the maximum values are 115.3 g/l at 4 cm and 80.3 g/l at 30 cm depths. Regarding the soil conductivity, the highest values recorded at 4 cm and 30 cm are 198.4 mS.cm⁻¹ and 141.89 mS.cm⁻¹, respectively. At the same time, the results highlight that the Sabkha soil is weakly alkaline with strongly alkaline. The diachronic study based on the NDVI analysis of the Landsat_5, Landsat_8, and Sentinel_2 satellite imagery showed the installation of varied vegetation during 33 years. The outcomes of the statistical analysis of NDVI_{1985} and NDVI_{2018} (p<0.01, R²=0.77) show a significant development of vegetation. The use of NDWI for the period (1985 to 2018) highlights the importance of the water deficit in the region (p<0.01, R²=0.72). The results of the imagery geostatistical treatments reveal the changes which have occurred in particular the increase in the area of Sabkha, which was 431ha in 1985 to 514 ha in 2018. This is an increase of 83 ha for 33 years (2.5 ha per year). In other words, there was an evolution of 19.25% compared to the area in 1985.

Keywords: Naama Sabkha, Algeria, Salinity, Landsat, NDVI, NDWI
Introduction

Wetlands are among rich environments that provide water and food for countless species of plants and animals (MEA, 2005). These ecosystems are very different in nature and in operation and play a vital role in the provision of biodiversity and management of water resources. Since 1900, more than half of the world's wetlands of which soil and water have been used for agriculture and other infrastructures have disappeared (Rappe and Hamme, 1986; Bonnet et al., 2005; Schuyt, 2005). Algeria is no exception; in recent decades, this country has suffered significant erosion that has affected and marked different wetlands (Bélair and Samraoui, 1994; Samraoui et al., 2011). 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 (Wanzie, 2002; Russi et al., 2013). The conservation of wetlands involves cooperation between actors, institutions, and users (Bonnet et al., 2005; Samraoui and Samraoui, 2008). The majority of the wetlands (i.e., Sabkha wetland in Naama city, Algeria) are composed of huge saline lakes; they are spread from the Algerian north coast to the Sahara crossing the Highlands. These areas are considered as inland wetlands (Donaire, 2000; Bryant and Rainey, 2002; Mahowald et al., 2003). In 2009, Ramsar sites in Algeria numbered 42 and cover a total area of 2.95 m ha. 45% of these protected sites are salt lakes covering approximately 2.07 m ha (Benchetrit, 1956; Boumezbeur, 2004; Bellauuer, 2008; Koopmanschap et al., 2011).

The different plant species found in Sabkha wetland 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 (Larafa, 2004; Ramade, 2005; Castaneda and Herroro, 2008). 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 (Ozenda, 1958; Hammada et al., 2004; Si Bachir, 2008). Besides, the use of salt meadows for pasture is very common in the Mediterranean region.

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

The conservation and wise use of wetlands are essential for the livelihoods of people. Due to the very wide range of ecosystem services they provide, wetlands play a crucial role in sustainable development. However, policy makers often underestimate their values which offer to both humanity and nature. Therefore, a better knowledge of these values and the status of wetlands is fundamental to their conservation and wise use.

For Algeria, as for many developing countries, the weakness or absence of a wetland ecosystem management system, strongly penalize managers, decision-makers, professionals, and practitioners are involved in the management of wetlands ecosystem. 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.

The Naama Sabkha wetland is home to floristic biodiversity (pastoral and medicinal plants) and some 400 species of migrating birds including rare species such 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.

Through this paper, we attempt to take stock of the spatial and temporal evolution of the Naama Sabkha wetland using the remotely sensed vegetation indices such as Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI) from processing a series of Landsat satellite imagery: Landsat_5 (1985), Landsat_8 (2018), and Sentinel_2 (2018). Remote sensing is an indispensable tool for the management and monitoring changes in ecosystems. Several authors have used the processing of satellite imagery series to monitor vegetation cover (Bhandari et al., 2012; Lemenkova, 2015).

Thus, to make available to potential users (Environmental Department, Forest Services and others), reliable information (maps of salinity, EC, pH, the evolution of the NDVI and NDWI indices) could provide roadmap for management and preservation of the Naama Sabkha wetland.

**Materials and Methods**

**The study area**

The study area is a part of the western steppe region of Algeria, extended from southwestern to northwestern of Naama city (Fig. 1). The Naama city has a border with the kingdom of Morocco. Our study region is a part of the high plains of southern Oran which extends from 32°08' to 34°22' northern latitude and 0°36' is 0°46 western longitude. The Naama Sabkha is characterized by altitudes ranging between 1140 m and 1273 m above sea level, with a slope that is between complete flat to 7%. According to Bensaid (2006) the soils of the Naama region are sandy; however, the halomorphic soils are localized in the Sabkhas.

The climate in this study area is semi-arid, characterized by a dry summer season with increasing aridity from north to south (Seltzer, 1946; Halimi, 1980; Mansour, 2011). The annual 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 (Mseguem, 2017). Following the field exploration and reconnaissance phase, we identified sampling points while taking into account certain criteria such as vegetation and geomorphology. Taken together, 68 representative points were selected and geo-localized for the purposes of our study. The flowchart (Fig. 2) represents the approach adopted for the conduct of our study. We sampled soil at two depths (0-4 cm and 4-30 cm). Soil sampling was carried out on 25/04/2018 by adopting soil sampling design developed by CEAEQ (2010). For mapping of the salinity, EC and pH point data, we have opted for the Inverse Distance Weighting (IDW) interpolation method in ArcGIS environment. This method has several advantages such as the simplicity of use and the reliability of the obtained results (Setianto and Triandin, 2013).
Fig. 1. Location map of the Naama Sabkha.
Normalized Difference Vegetation Index (NDVI)

To identify the past and current changes in Naama Sabkha wetland, 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 imagery (Table 1). These are from Landsat_5 TM, Landsat_8 OLI and Sentinel_2A. The used images are previously processed with the Fast Line-of-sight Atmospheric Analysis of Hypercubes (FLAASH) model under ENVI software (ver.5.3) for atmospheric corrections. The use of Sentinel_2A images seeks more precision to validate the obtained results from the satellite Landsat_8.

The remotely sensed vegetation index is a common tool used in the environmental researches and for agriculture in particular because it provides information on the state of the vegetation. The following formula is used to calculate the NDVI (Equation 1, Rouse et al., 1974):

\[
NDVI = \frac{(NIR - RED)}{(NIR + RED)}
\]

Where:
NIR: Near Infra-Red band;
RED: Red band.

The NDVI values vary between -1 to 1. This vegetation index reflects the quantity and quality of vegetation used as the common vegetation index (Huete et al., 1987; Farrar et al., 1994; Nicholson and Farrar, 1994; Frampton et al., 2013; Aguilar et al., 2012; Abdalla et al., 2015; Ke et al., 2015).

Table 1. Characteristics of used satellite imagery

<table>
<thead>
<tr>
<th>Platform</th>
<th>Acquisition date</th>
<th>Path</th>
<th>Row</th>
<th>Tile number</th>
<th>Cloud cover</th>
<th>Used Bands</th>
<th>Spatial resolution (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat_5 TM</td>
<td>19/04/1985</td>
<td>197</td>
<td>37</td>
<td>&lt; 10</td>
<td>B2, B3, B4</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Landsat_8 OLI</td>
<td>30/04/2018</td>
<td>197</td>
<td>37</td>
<td>&lt; 10</td>
<td>B3, B4, B5</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Sentinel_2A</td>
<td>12/02/2018</td>
<td>T30SYB</td>
<td>&lt; 10</td>
<td></td>
<td>B3, B4, B8</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
Normalized Difference Water Index (NDWI)

Following the same principle as the NDVI, the NDWI uses the near infrared band and a Short Wave Infra-Red band (SWIR) (Gu et al., 2007; Gu et al., 2008; Hassan, 2014). The NDWI index is calculated according to the following equation (Equation 2: Gao., 1996):

\[ \text{NDWI} = \frac{(\text{NIR} - \text{SWIR})}{(\text{NIR} + \text{SWIR})} \]  

Where:
NIR: Near Infra-Red band;
SWIR: Short Wave Infra-Red band.

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.

Results

1. Naama Sabkha soil salinity map

Taking into account the maximum and minimum values obtained, the elaborate maps of soil salinity at 0-4 cm and 4-30 cm depths showed 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 0-4 cm and 80.3 g/l at 4-30 cm depth. In addition, smaller values (classified as low) oscillate between 1.71 g/l at 0-4 cm, and 3.84 g/l at 4-30 cm.

1.1. Salinity at top soil layer

We found (Fig. 3) that the values vary between 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 g/l]: it is located near the Sabkha. Among the observations made on the ground, the installation of vegetation was composed of Salicornia macrostachya (Fig. 4). The latter tolerates low class salinity.

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 g/l]: Located in the interior of Sabkha. The floor of this class is bare. This class represents 23.74% of Sabkha wetland area.

High class [67.54 – 115.31 g/l]: it has the highest values. The soil is bare. This class forms a small area (0.47%).

1.2. Soil salinity at 30 cm

Salinity values at down soil (Fig. 3) vary between 1.71 and 80.03 g/l. After reclassification, three salinity classes were established:

Low class [1.71 – 35.27 g/l]: Located on the outskirts of Sabkha. This class has a large area (69.23%) of Sabkha. Using the profiles made in the soil of Sabkha, we noticed a sandy accumulation.

Middle class [35.27 – 46.46 g/l]: Located in the interior of Sabkha. This class represents 29.03% of the Sabkha wetland average area.

High class [46.46 – 80.03 g/l]: 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 0-4 cm and 4-30 cm soil depths.
The results obtained from the analyses of the 136 samples showed that the minimum value of the 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 using IDW interpolation method (Fig. 5).

2. Naama Sabkha soil EC map

The results obtained from the analyses of the 136 samples showed that the minimum value of the 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 using IDW interpolation method (Fig. 5).

2.1. Soil EC at 4 cm

EC values at 0-4 cm were between 7.73 to 198.04 mS.cm\(^{-1}\). We found 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 mS.cm\(^{-1}\)]: This class has the lowest values and is located in the outskirts of Sabkha. In addition, this class formed a small area (19.11%) of Sabkha.
- **Middle class** [62.11 – 116.48 mS.cm\(^{-1}\)]: Located in the interior of Sabkha, characterized by bare ground. This class represented large part of the Sabkha area (80.28%).
- **High class** [116.48 – 198.04 mS.cm\(^{-1}\)]: This class represents 0.61% of Sabkha wetland area.

2.2. Soil EC at 30 cm

It appears that the values of the soil EC (Fig. 5) were between 1.77 to 141.89 mS.cm\(^{-1}\). To make interpretations easy, we
have reclassified the classes of soil EC to 4-30 cm in 3 classes:
Low class [1.77 – 61.82 mS.cm⁻¹]: 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 mS.cm⁻¹]: Located in the interior of Sabkha, characterized by bare ground and presents a large area of Sabkha (89.32%).
High class [81.84 – 141.89 mS.cm⁻¹]: Characterized by bare soil. This class forms 3.39% of the total area of Sabkha wetland.

3. Naama Sabkha soil pH map
The two pH maps (Fig. 6) developed from the results of the analyses highlight the small difference between the values. These oscillate between 7.18 and 8.75; we deduce that the ground of the Sabkha is clearly alkaline.

3.1. Soil pH at 4 cm
pH values at 0-4 cm range from 7.18 to 8.75. After reclassification, 3 pH classes were established:
The neutral class [7.18–7.63]: it represented 9.97% of Sabkha with moderately alkaline soil.
Middle class [7.63–8.08]: it occupies 89.62% of the Sabkha with bare soil. The latter is between moderately alkaline and strongly alkaline.
High class [8.0–8.75]: it is characterized by bare soil with 0.41% of Sabkha area. The soil is strongly alkaline (De Ferrière, 1933; Le Tacon, 1978).

3.2. Soil pH at 30 cm
The 7 classes were shown on the map of soil pH as 4-30 cm depth (Fig. 6), which has been reclassified to 3 classes:
The neutral class [7.24–7.65]: The soil is weakly alkaline. This class represents 13.25% of the Naama Sabkha area.
Middle class [7.65–8.06]: The soil is moderately alkaline. This class occupies 86.51% of Sabkha wetland area.
High class [8.06–8.68]: It is usually located on the outskirts of Sabkha. This class characterizes a strongly alkaline soil with 0.23% of Sabkha area.

NDVI and NDWI data prepared using ArcGIS (ver.10.2) and satellite imagery allowed us to establish relative histograms of vegetation and moisture indices during 1985 and 2018.

We notice that the Landsat_8 NDVI (Fig. 7) values are positive and between [0.0625–0.1526].

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 imagery for the periods 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 imagery has a resolution of 30×30m. This difference in resolution affects the results of the different indices.

4.2. Comparison of the vegetation cover evolution

We carried out a comparison between NDVI maps extracted using Landsat_5, Landsat_8, and Sentinel_2 (Fig. 8) from 1985 and 2018 to illustrate the evolution of the vegetation cover of Naama Sabkha.

To estimate vegetation cover evolution, the NDVI results were reclassified into 5 vegetation classes from 1 to 5 (Table 2). It turns out that the percentage of areas with classes (4 and 5) of dense vegetation is significantly higher in 2018 with a total of...
52.97%. In addition, a total of 26.86% was recorded in 1985 for the same classes.

We observe that NDVI values calculated from Landsat_8 and Sentinel_2 were significantly higher than Landsat_5. The results of the Student’s t-test (p<0.01, \( R^2 = 0.77 \), Fig. 9) of the data extracted from the NDVI maps of 1985 and 2018 have highlighted the evolution of the vegetal cover composed by xerophilic species such as *Tamarix articulata* and *Retama retama*.

The highest values of NDVI obtained by Landsat_8 and Sentinel_2 imagery were 0.1526 and 0.164, respectively. However, the maximum value Landsat_5 NDVI equal to 0.0152.

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<td>2.19</td>
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<td>13.00</td>
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<td>3</td>
<td>46.07</td>
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<td>5</td>
<td>4.97</td>
<td>0.86</td>
<td>2.88</td>
<td>27.70</td>
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</table>

Fig. 8. NDVI evolution of the vegetation cover of Naama Sabkha between 1985 and 2018

Fig. 9. NDVI Student t-test


The maximum and minimum NDWI values (Fig. 10) were extracted from the maps developed for 1985 and 2018 satellite imagery. The comparison of Landsat_5 and Landsat_8 NDWI values will allow us to assess the spatiotemporal evolution of water levels during 33 years. Over 33 years, NDWI values are
decreasing. The changes were obtained from NDWI based on the Landsat_5.

Our results indicated higher values [Min: -0.1681 and Max: -0.1190] than those found in Landsat_8 NDWI [Min: -0.2726 and Max: -0.1544]. The processing of the data extracted from the 1985 and 2018 NDWI maps by the Student’s t-test shows a significant decrease in the water content of the Naama Sabkha (p<0.01, $R^2 = 0.72$, Fig. 11).

5.1. Landsat_5, Landsat_8 and Sentinel_2 NDWI comparison

It appears that the values of the water content index represented by NDWI (Fig. 12) have declined significantly since 1985. Table (2) perfectly illustrates the evolution of the water status and percentage of surfaces for each NDWI classes since 1985. It appears that NDWI$_{1985}$ has high values compared to NDWI$_{2018}$. Classes 4 and 5 of the NDWI$_{1985}$ occupy 44.72% of the Sabkha wetland area. However, the same classes for NDWI$_{2018}$ represent only 4.3% of the total area, and highlight the substantial decline in the water status.

The water déficit has led to the exacerbation of some phenomena such as evapotranspiration and silting. The processing of Landsat_5 and Landsat_8 satellite imagery allowed us to estimate the change occurred in the Naama Sabkha. 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, it is an evolution of 19.25% compared to the area in 1985.
Discussion

Salinity

The difference in salinity between 0-4 cm and 4-30 cm depths is likely to be related to environmental conditions (climate, hydrology), water supply, control systems [drainage], soil texture and the mobility of salt. It should be noted that in halophytic plants such as Suaeda, too much salt-containing tissues darken, fall and eventually increase the level of salt in the soil (Halitim, 1988). The soil texture rich in fine elements is positively correlated with salinity (Le Brusq and Loyer, 1982; Attia, 2013). These factors affect the water balance and thus the accumulation of salts in the soil. This is the case of our study area.

Soil EC

We observe a variability of soil EC among the samples collected in the two depths of the soil. The highest values recorded at 0-4 cm and 4-30 cm were 198.4 mS.cm\(^{-1}\) and 141.89 mS.cm\(^{-1}\), respectively. In addition, we recorded a minimum value of 7.73 mS.cm\(^{-1}\) at 0-4 cm and 1.71 mS.cm\(^{-1}\) at 4-30 cm depths. These variations in soil EC values are proportional to the concentration of ionized dissolved minerals (Soulama, 2011; Benmoussa, 2017). The ionic concentration of the EC soil solution will be all the more important as the quantity of water is rich in salts. Unsalted soils mainly have an EC range of between 0 and 50 mS.cm\(^{-1}\) while EC of salty soils varied between 100 and 200 mS.cm\(^{-1}\) (Aubert, 1978). The nature of the soil constituents and their retention capacity affect the soil EC. In general, the soil EC capacity can vary over 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. Also, soil EC is likely to increase significantly with increasing soil temperature (Loyer, 1991; MADR, 2008; Dehni and Lounis, 2012; Dehni, 2018).

Soil pH

The pH values obtained from laboratory analyses showed that the Naama Sabkha soil pH varied between "weakly alkaline soil and strongly alkaline soil". The phenomenon of alkalization is characterized by an increase in pH which can then slow down the availability and assimilability of certain elements (Zn, P, N). Alkalinization resulted in an increase in the exchangeable Na content on the soil-absorbing complex (Hachicha, 2007). Rapid precipitation of Ca and Mg carbonates allows Na\(^{+2}\) ions to bind to the absorbing complex. The soil's Na\(^{+2}\) and K\(^{+}\) ion content is derived from alkaline salts (carbonates and sulphates) leading to pH values above 8. In general, the pH varies depending on 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 Naama Sabkha soil is
characterized by high salinity, strongly alkaline pH and high conductivity.

**NDVI**
The analysis of satellite imagery reveals a clear difference between the values of NDVI 1985 and 2018. This involves the installation and development of vegetation. However, the Landsat_5 NDVI has 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. Our results are consistent with those of many authors who have studied the spatio-temporal evolution of vegetation, specially using remotely sensed vegetation indices (Toby and Ripley, 1997; Paruelo and Lauenroth, 1998; Lukasová et al., 2014). The accumulation of sand (silting) has allowed the installation of a large vegetation cover mainly composed of Salicornia and *Tamarix gallica* which tolerates high levels of salinity. 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 reflectance in the red and the near infrared bands is also exploited to build the NDVI.

These values reflect an increase in the vegetation ratio in the Naama Sabkha along 33 years. The choice of the date of the series of imagery was not fortuitous; on the contrary, it turns out that the treatment of imagery 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 (Eklandh, 1998; Girard and Girard, 1999)

**NDWI**
The NDWI values have decreased considerably, mainly due to the drought stress 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).

The analysis of Sentinel_2 NDWI shows a sharp decrease compared to Landsat_5 NDWI. This decline is obvious, caused by climate change that negatively affected the region since 1985 (Benamara and Mimouni, 2017; Mseguem, 2017). We are witnessing a reduction of precipitation regime for 33 years. Different studies have focused on the importance and influence of climate change on declining NDWI values (Møller and Merila, 2004; Gu et al., 2007; Gu et al., 2008; Chapungu and Nhamo, 2016). In the end of these analyses, we can conclude that the comparisons made with NDVI and NDWI developed through ArcGIS environment highlight 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. Moreover, 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.

**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 important plant diversity such as *Retama retam, Tamarix gallica, Aristida pungens, Salicornia macrostachya, Atriplex halimus*. Based on the results obtained, the Naama Sabkha soil salinity at 0-4 cm and 4-30 cm depths indicates a substantial variation in soil salinity. Indeed, the soil salinity reaches a maximum value of 115.3 g/l at a depth of 0-4 cm and 80.3 g/l at a depth of 4-30 cm. At the same time, the values of the soil EC showed variability for the two depths. 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 ranges between weakly alkaline to strongly alkaline soil, respectively.

The diachronic study of Landsat_5, 8 and Sentinel_2 images highlight tangible changes over 33 years. Using Landsat_5 (1985) and Landsat_8 (2018) satellite imagery, we have detected changes occurred since 1985 resulting in the perimeter extension of the Naama Sabkha wetland with 19%.

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نقشه برداری و مطالعه تشريحي شاخص گياهی و خصوصيات خاک نعما سبخا(الجزایر جنوب غربي) از راه دور

چکیده. پژوهش حاضر به وضعیت گذشته (1985) و فعلی (2018) منطقه نعما سبخا، به وژه شوری، پوشش گياهی و وضعیت آب آن می پردازد. نتایج بهدست آمده برای حفظ تنوع زیستی سبخا مفید خواهد بود. اجازه برداشت 501 لامونه خاک در دو عمق 0-4 سانتیمتر و خاک پایین (0-4 سانتیمتر) توسط نماینده نمونبرداری داده شد. تجزیه و تحلیل نتایج شوری نشان داد که حداکثر و حداقل مقدار به میزان 115/3 گرم در لیتر در 4 سانتیمتر و 80 گرم در لیتر در عمق 30 سانتیمتر است. از نظر هیدات خاک، بیشترین مقادیر ثابت شده در 4 و 3 سانتیمتر به ترتیب 198/4 و 198/3 mS.cm-1 و 1/16 و 1/17 بود. در عین حال، نتایج حاصل از آن است که خاک سبخا از نظر قلیاپی ضعیف است. مطالعه تصاویر ماهواره‌ای لندست، لندست 9 و سنتینل سال نشان داد که افزایش پوشش گیاهی در منطقه سبخا به میزان 50 هکتار در سال 1985 به میزان 50 هکتار در سال 2018 رسد. این افزایش 82 هکتاری مربوط به سال 1985 به میزان 19/25 درصد پوشش گیاهی افزایش داشته است.

کلمات کلیدی: نعما سبخا، الجزایر، شوری، لندست، NDWI، NDVI