Contents available at ISC and SID
Journal homepage: www.rangeland.ir

Research and Full Length Article:

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

Lakhdar Guerine[A*], Mustapha Belgourari[B], Hanane Guerinik[C]
[A] Professor, University Center of Naama, Naama 45000. Algeria, *(Corresponding author),
Email: lguerine.dz@gmail.com
[B] M.Sc., Forest Service, Forests District of El Bayadh, El Bayadh 32000, Algeria
[C] M.Sc., National Institute of Training and Education of Naama. Naama 45000, Algeria

Received on: 31/07/2018
Accepted on: 07/11/2019

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 $NDVI_{2018}$ ($p<0.01$, $R^2=0.77$) 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 ($p<0.01$, $R^2=0.72$). 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 Hammee, 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; Bellaouer, 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).

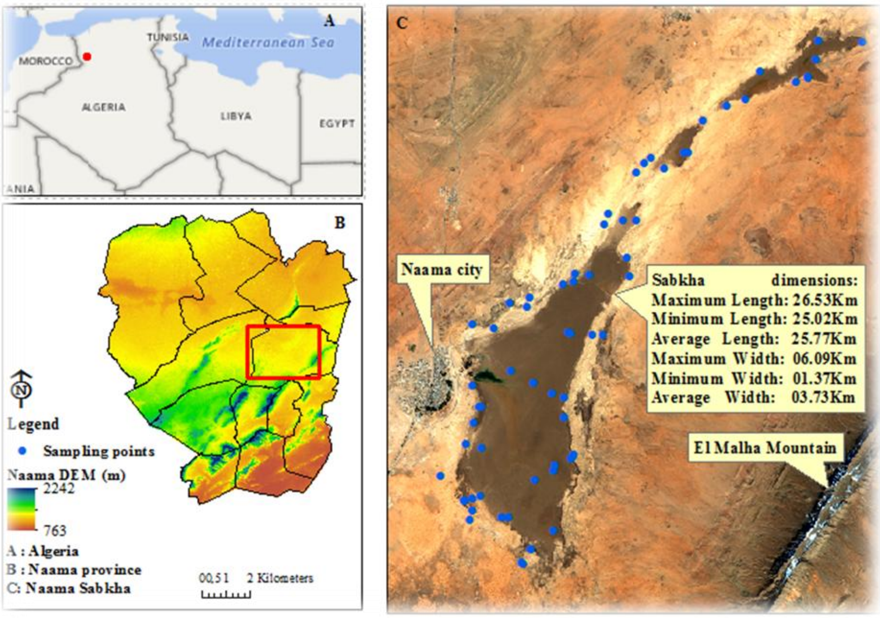

Fig. 1. Location map of the Naama Sabkha.

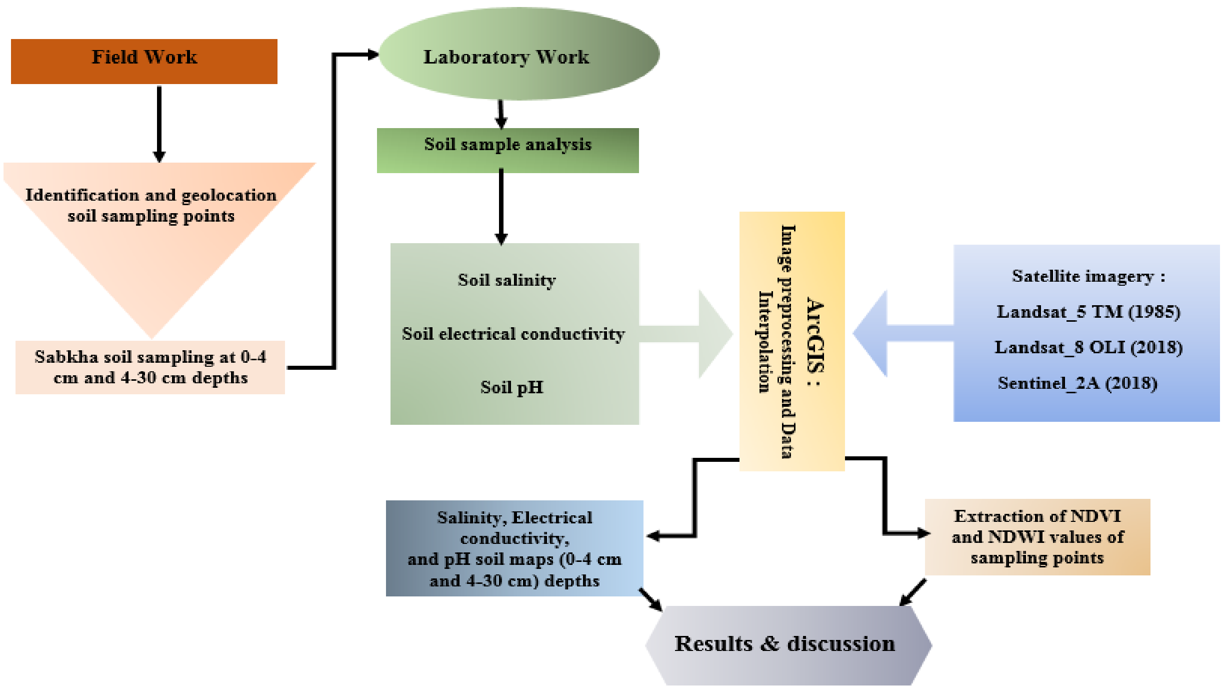

Fig. 2. Flow chart illustrating the approach followed for the study

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):

$$\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})} \quad (1)$$

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

Platform	Acquisition date	Path	Row	Tile number	Cloud cover	Used Bands	Spatial resolution (m)
Landsat_5 TM	19/04/1985	197	37		< 10	B2	30
						B3	30
						B4	30
Landsat_8 OLI	30/04/2018	197	37		< 10	B3	30
						B4	30
						B5	30
Sentinel_2A	12/02/2018			T30SYB	< 10	B3	10
						B4	10
						B8	10

Normalized Difference Water Index (NDWI)

Following the same principle as the NDVI, the NDWI uses the near infrared band and a **S**hort 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):

$$\mathrm{NDWI} = \frac{(\mathrm{NIR} - \mathrm{SWIR})}{(\mathrm{NIR} + \mathrm{SWIR})} \quad (2)$$

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 1.71g/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:

<u>Low class</u> [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.

<u>Middle class</u> [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.

<u>High class</u> [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:

<u>Low class</u> [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.

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

<u>High class</u> [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.

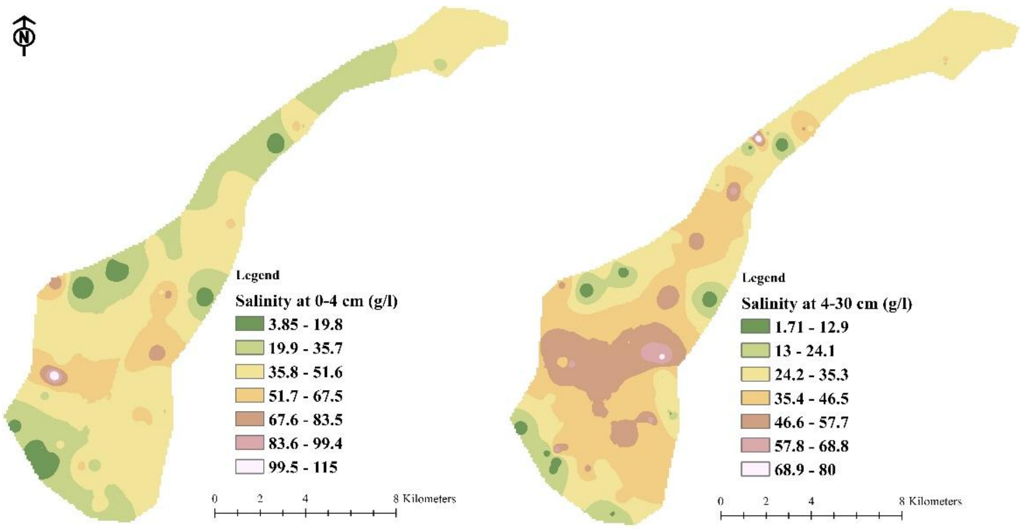

Fig. 3. Naama Sabkha soil salinity maps (0-4 cm and 4-30 cm depths)

Fig. 4. *Salicornia macrostachya* (Naama Sabkha)

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.

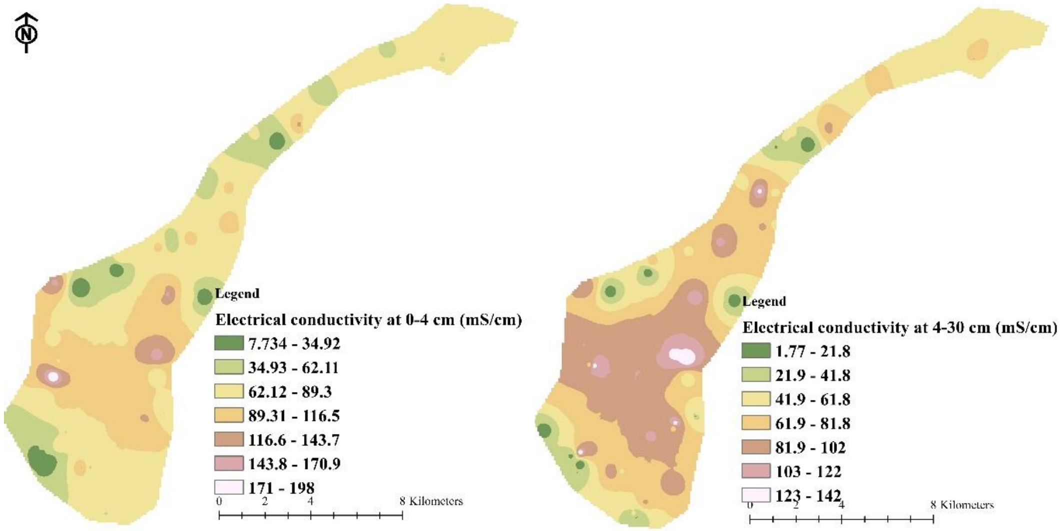

Fig. 5. Naama Sabkha soil electrical conductivity maps (0-4 cm and 4-30 cm depths)

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.

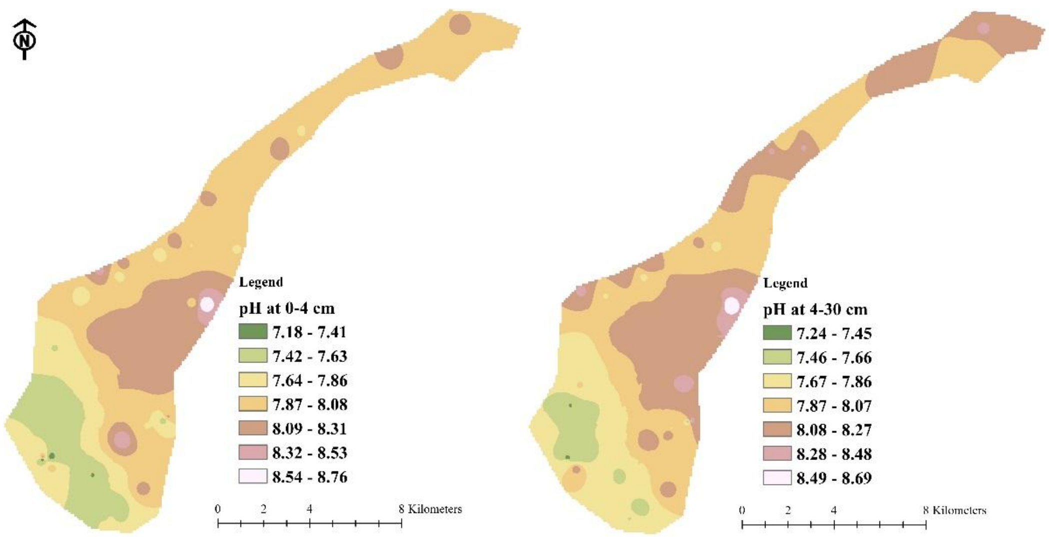

Fig. 6. Naama Sabkha soil pH maps (0-4 cm and 4-30 cm depths)

4. The Naama Sabkha vegetation change evolution (1985 – 2018)

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.

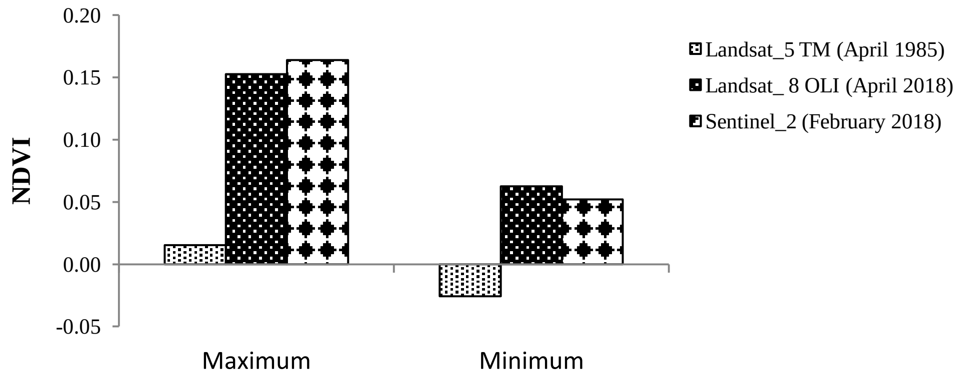

Fig. 7. NDVI evolution of the vegetation cover indices between 1985 and 2018

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 retam*.

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.

Table 2. The Naama Sabkha area distribution by class

Classes	Area %			
	NDVI_L8 (2018)	NDVI_L5 (1985)	NDWI_L8 (2018)	NDWI_L5 (1985)
1	0.75	0.24	2.19	17.00
2	0.21	42.20	33.30	13.00
3	46.07	30.70	60.21	25.28
4	48.00	26.00	1.42	17.02
5	4.97	0.86	2.88	27.70

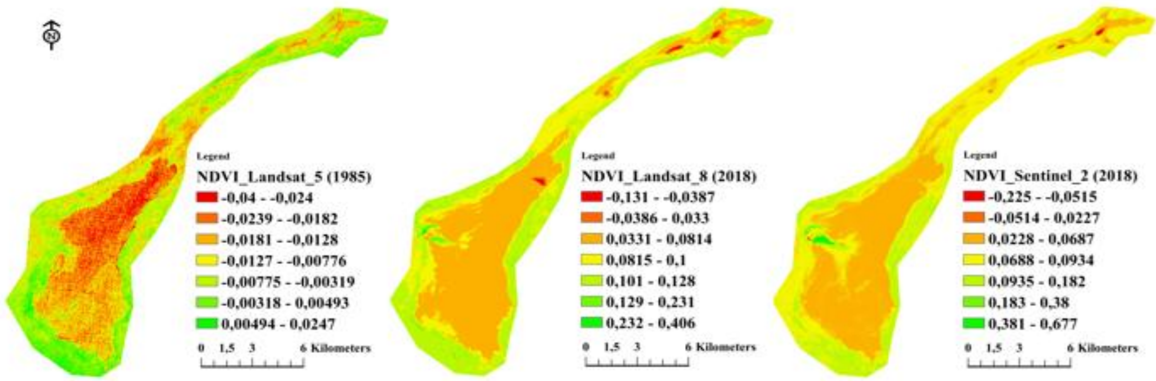

Fig. 8. NDVI evolution of the vegetation cover of Naama Sabkha between 1985 and 2018

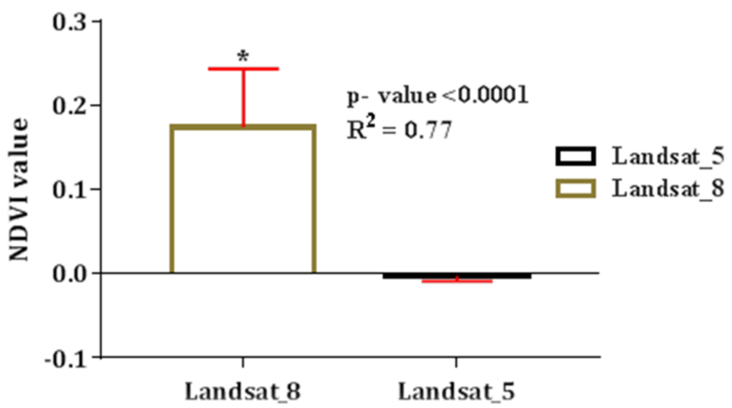

Fig. 9. NDVI Student t-test

5. The Naama Sabkha NDWI change evolution (1985–2018)

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).

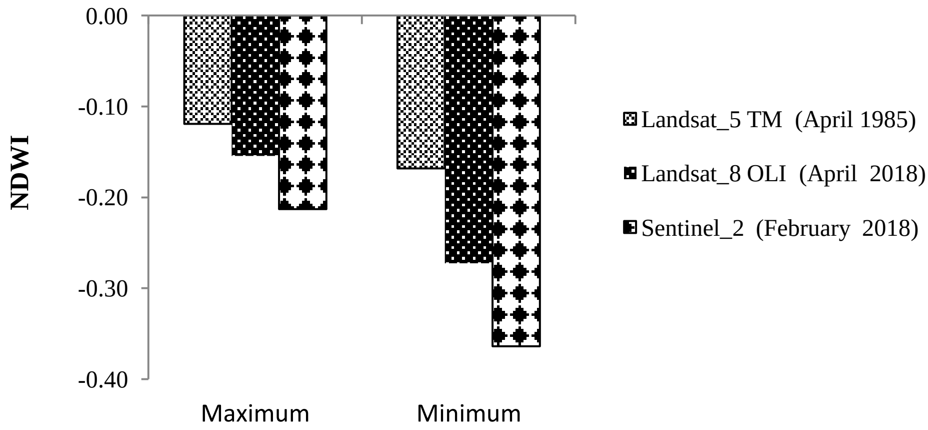

Fig. 10. Evolution of water levels during 33 years (1985 and 2018) represented by NDWI

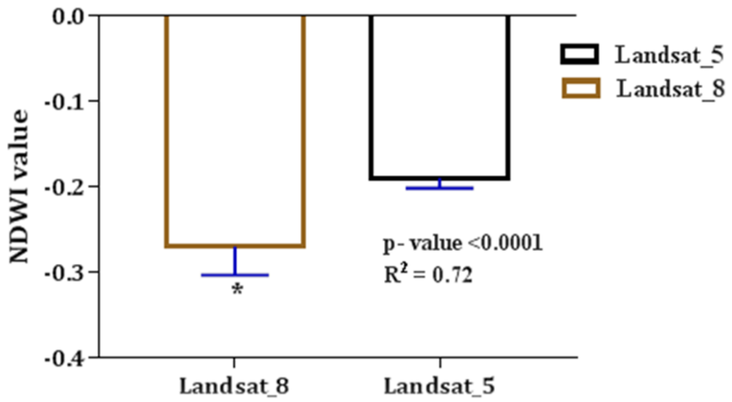

Fig. 11. NDWI Student t-test

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.

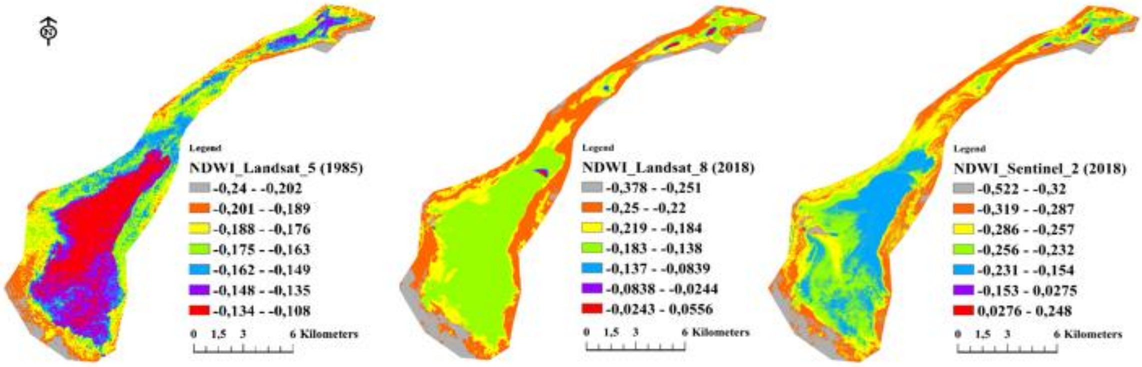

Fig. 12. Values of the water content index represented by NDWI between 1985 and 2018

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 (Eklundh, 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%.

References

Abdalla, N. I., Abdelaziz K. G., Kätsch, C., Sulieman, M., Mariod, A. 2015. Using MODIS-Derived NDVI and SAVI to distinguish Between different rangeland sites according to soil types in semi-arid areas of Sudan (North Kordofan State). International Journal of Life Science and Engineering. 1 (4):150-164.

Aguilar, C., Zinnert, J. C., Polo, M. J., Young, D. R. 2012. NDVI as an indicator for changes in water availability to woody vegetation. Ecological Indicators 23:290–300.

Attia, O. E. A. 2013. Sedimentological characteristics and geochemical evolution of Nabq sabkha, Gulf of Aqaba, Sinai Egypt.Arab J Geosci. 6: 2045–2059

Aubert, G. 1978. Méthodes d’analyses des sols. 2ème Edition, Centre régional de Documentation Pédagogique, CRDP Marseille, 191 p.

Baaziz, N., Mayache, B., Saheb, M., Bensaci, E., Ounissi, M., Metallaoui, S., Algérie. 2011. Centre de recherche de la Tour du Valat, Arles, France. 28 p.

Bélair, G. De., Samraoui, B. 1994. Death of lake: Lac Noir in Northern Algeria. Environmental Houhamdi, M. 2011. Statut phénologique et reproduction des peuplements d‟oiseaux d‟eau dans l’écocomplexe de zones humides de Sétif (Hauts plateaux, Est de l’Algérie). Bulletin de l’Institut Scientifique de Rabat 32 (2): 77-87

Béchet, A., Samraoui, B. 2010. Plan d’action pour le Flamant rose Phoenicopterus roseus en Conservation 21: 169-172.

Bellaouer, A. 2008. Etude hydrogéologique des eaux souterraines de la région de Ouargla soumise à la remontée des eaux de la nappe phréatique et perspectives de solutions palliatives (Sahara Nord-est Septentrional - Algérie). Mémoire de Magister Université d’Annaba. 146 p.

Benamara, N., Mimouni, H. 2017. Approche phytosociologique et contribution à l’étude de la régénération de Stipa tenacissima L. dans deux zones steppiques de la wilaya de Naâma (Cas des communes de Sfissifa et El Biodh). Mémoire Master 2. Centre Universitaire de Naâma (Algérie) 98 p

Benchetrit, M. 1956. Les sols d'Algérie. In: Revue de géographie alpine.

Benmoussa, H. 2017. Cours en Génie des procédés de l’environnement. Université des Sciences et de la Technologie d’Oran Mohamed Boudiaf. 124 p.

Bensaid, A. 2006. SIG et télédétection pour l’étude de l’ensablement dans une zone aride : le cas de la wilaya de Naâma (Algérie). Thèse de Doctorat, Univ. de Grenoble 1, France, 318 p

Bensizerara, D., Chenchouni H., Si Bachir, A., Houhamdi, M. 2013. Ecological status interactions for assessing bird diversity in relation to a heterogeneous landscape structure. Avian Biology Research 6: 67 -77.

Bhandari, S., Phinn, S., Gill, T. 2012. Preparing Landsat Image Time Series (LITS) for Monitoring Changes in Vegetation Phenology in Queensland, Australia. Remote Sensing. 4, 1856-1886

Bonnet, B., Aulong, S., Goyet, S., Lutz, M., Mathevet, R. 2005. Gestion intégrée des zones humides méditerranéennes: Conservation des zones humides. Tours du Valat, Arles, 160 p.

Boulekhssaim, M., Houhamdi, M., Samraoui, B. 2006. Status and diurnal behaviour of the Shelduck Tadorna tadorna in the Hauts plateaux, northeast Algeria. Wildfowl, 56: 65-78.

Boumezbeur, A. 2004. Atlas [IV] des zones humides algériennes d'importance internationale. Ministère de l'Agriculture et du Développement rural. Direction générale des Forêts Alger. 107 p.

Bouzid, A., Yousfi, J., Boulkhssaim, M., Samraoui, B. 2009. Première nidification réussie du flamant rose (Phoenicopterus roseus) dans le Sahara algérien. Alauda 77: 139-143

Bryant, RG., Rainey MP. 2002. Investigation of flood inundation on playas within the zone of Chotts, using a time-series of AVHRR. Remote Sensing of Environment 82: 360–375.

Castaneda, C., Herrero, J. 2008. Assessing the degradation of saline wetlands in an arid agricultural region in Spain. Catena 72: 205-213.

CEAEQ (Centre d’expertise en analyse environnementale du Québec). 2010. Cahier 5 échantillonnage des sols. 66p

Chapungu, L., Nhamo, L. 2016. An assessment of the impact of climate change on plant species richness through an analysis of the normalised difference water index (NDWI) in Mutirikwi sub-catchment, Zimbabwe. South African Journal of Geomatics 5 (2): 244 - 268

De Ferrière, M. F. 1933. Les zones de pH des sols. Bulletin de l'Association de Géographes Français 69: 74-78

Dehni, A. 2018. Télédétection de la salinité des sols à l'aide des techniques de traitement d'images satellitaires - Application à la région d'Oran. Thèse de Doctorat, Université d'Oran. 220 p.

Dehni, A., Lounis, M. 2012. Remote Sensing Techniques for Salt Affected Soil Mapping: Application to the Oran Region of Algeria / Procedia Engineering, 33, 188-198.

Donaire, J, S. 2000. Descriptive and functional wetland typology and classification. Observatorio Medioambiental 3: 311-339

Doucet, G. 2006. Étude du potentiel odonatologique des étangs du bassin de GOUZON (Creuse, 23) – S.L.O: Limoges.52 p

Eklundh, L. 1998. Estimating relations between AVHRR NDVI and rainfall in East Africa at 10-day and monthly time scales, International Journal of Remote Sensing 19 (03):563-570.

El Halimi, M. 2015. Apport de la télédétection pour l'évaluation de la variation des surfaces d'eau et du couvert végétal dans la plaine du Haouz depuis 1984 jusqu'à, 133p

Farrar, T.J., Nicholson, S.E., Lare, A.R. 1994. The influence of soil type on the relationships between NDVI, rainfall, and soil moisture in semi-arid Botswana. II. NDVI response to soil Moisture, Remote Sens. Environ. 50 (2):121-133.

Frampton, W, J., Dash, J., Watmough, G., Milton, E, J. 2013. Evaluating the capabilities of Sentinel-2 for quantitative estimation of biophysical variables in vegetation. ISPRS Journal of Photogrammetry and Remote Sensing 82: 83–92

Gao, B. 1996. NDWI - A normalized difference water index for remote sensing of vegetation liquid water from space, Remote Sensing of Environment 58: 257– 266

Girard, M.C., Girard C.M. 1999. Traitement des données de télédétection, 530 p

Gu, Y., Hunt, E., Wardlow, B., Jeffrey, B., Basara, J., Brown, F., Verdin, J, P. 2008. Evaluation of MODIS NDVI and NDWI for vegetation drought monitoring using Oklahoma Mesonet soil moisture data. Geophysical research letters. 35 (22):

Gu, Y., Brown, J. F., Verdin, J. P., Wardlow, B. 2007. A five-year analysis of MODIS NDVI and NDWI for grassland drought assessment over the central Great Plains of the United States, Geophys. Res. Lett., 34, L06407.

Hachicha, M. 2007. Les sols salés et leur mise en valeur en Tunisie. 18: 45-50.

Halimi, A. 1980. L'Atlas Blidéen : climat et étages végétaux. Alger: O.P.U. 484 p.

Halitim, A. 1988. Sols des régions arides d'Algérie. O.P.U

Hammada, S., Dakki, M., Ibn Tattou M., Ouyahya A., Fennane M. 2004. Analyse de la biodiversité floristique des zones humides du Maroc. Flore rare, menacée et halophile. Acta Botanica Malacitana 29: 43-66.

Hassan, E.T. 2014. Using (NDVI), (NDBI) and (NDWI) Indices for Change Detection in Land Cover for Selected Area from the Province of Najaf for the Period from (2001-2006) by Using Remote Sensing Data. Journal of Kufa – Physics (2):12-18.

Houhamdi, M., Bensaci T., Nouidjem, N., Bouzegag, A., Saheb, M., Samraoui, B. 2008. Écoéthologie du Flamant rose (Phoenicopterus roseus) hivernant dans les oasis de la Vallée de l'Oued Righ (Sahara algérien). Aves 45: 15-27.

Huete, A. R., Jackson, R. D. 1987. Suitability of spectral indices for evaluating vegetation characteristics on arid rangelands, Remote Sensing of Environment. 25: 89-105.

Isenmann, P., Moali, A. 2000. Oiseaux d'Algérie. Birds of Algeria. Paris: SEOF édition.

Ke, Y., Im, J., Lee, J., Gong, H., Ryu, Y. 2015. Characteristics of Landsat 8 OLI-derived NDVI by comparison with multiple satellite sensors and in situ observations. Remote Sensing of Environment 164: 298–313.

Koopmanschap, E., Hammami, M., Klok, C. 2011. Lac Ayata dans la Vallée d'Oued Righ. Quick-scan of options and preliminary recommendations for the Management of Lake Ayata in the Valley of Oued Righ. Wageningen: Centre for Development Innovation Wageningen UR edition.

Larafa, M. 2004. Dynamique de la végétation halophile en milieu aride et semi-aride au niveau des chotts (Melghir, Merouane et Bendjelloul) et Oued Djeddi en fonction des conditions du milieu. Thèse. Doct. Sci. Nat. Opt. Biol. Vég. Univ. Annaba: 149 p

Le Brusq, J.Y., Loyer J.Y. 1982. Relations entre les mesures de conductivités sur des extraits de sols de rapports sol/solution variables, dans la vallée du fleuve Sénégal. Cah. O.R.S.T.O.M., sér. Pédol., 19 (3): 293-301.

Le Tacon, F. 1978. La présence de calcaire dans le sol. Influence sur le comportement de l'Epicéa commun (Picea excelsa Link.) et du Pin noir d'Autriche (Pinus Nigra nigricans Host.). Annales des sciences forestières, INRA/EDP Sciences 35 (2): 165-174.

Lemenkova, P. 2015. Analysis of Landsat NDVI time series for detecting degradation of vegetation. Proceedings of 3rd International conference of young scientists. Belgorod State University. 11–13.

Loyer J.Y. 1991. Classification des sols salés: les sols Salic. Cah. ORSTOM, sér. Pédol., vol. XXVI, n "1: SI-61

Lukasová, V., Lang, M. and Đkvarenina, J. 2014. Seasonal changes in NDVI in relation to phenological phases, LAI and PAI of Beech Forests. Baltic Forestry 20 (2): 248-262

Ozenda, P. 1958. Flore du Sahara Septentrional et Central. Paris: C.N.R.S. édition ,480p

Mahowald, N.M., Bryant, R.G., Coral, J.D., Steinberger, L. 2003. Ephemeral lakes and desert dust sources. Geophysical Research Letters 30: 1-4

Mansour, C. 2011.Contribution à l'étude de la répartition du Pistachier de l'Atlas (*Pistacia atlantica* Desf) dans la wilaya de Naâma – Cas de Gaaloul. Mémoire d'Ingéniorat foresterie. Université de Tlemcen. 115 p.

MEA (Millennium Ecosystem Assessment). 2005. Ecosystems and human well-being: Wetlands and water Synthesis. 80 p.

Ministère de l'Agriculture et du Développement Rural (MADR). 2008. Les sols salins en Algérie. 8 p.

Nicholson, S.E., Farrar, T.J. 1994. The influence of soil type on the relationships between NDVI, rainfall, and soil moisture in semi-arid Botswana. I. NDVI response to Rainfall. Remote Sensing of Environment 50 (2):107-120.

Møller, A.P., Merila, J. 2004. Analysis and interpretation of longterm studies investigating responses to climate change. Advances in Ecological Research. 35: 111–130

Mseguem, A. 2017. Study of the germination, regeneration and geo-localization by remote sensing of the Atlantic Pistachio settlements in Ain Ben Khelil region - (Naama province). Master thesis. Naama University Center. 104 p.

Paruelo, J.M., Lauenroth, W.K. 1998. Interannual variability of NDVI and its relationship to climate for North American shrublands and grasslands. Journal of Biogeography. 25: 721–733

Ramade, F. 2005. Eléments d'écologie. Ecologie appliquée. Paris: Dunod édition. 93 p.

Rappe, AML., Hammee, V. 1986. Environment–agriculture–pollutants. Aves; 22: 13–14

Rouse, J.W, Haas, R.H., Scheel, J.A., Deering, D.W. 1974. Monitoring Vegetation Systems in the Great Plains with ERTS. Proceedings, 3rd Earth Resource Technology Satellite (ERTS) Symposium. 1: 48-62

Russi, D., Brink, P., Farmer A., Badura, T., Coates, D., Förster, J., Kumar, R., Davidson, N. 2013. The Economics of Ecosystems and Biodiversity for Water and Wetlands. IEEP, London and Brussels. Ramsar Secretariat, Gland. 84p

Samraoui, B., Samraoui, F. 2008. An ornithological survey of Algerian wetlands: Important Bird Areas, Ramsar sites and threatened species. Wildfowl. 58: 71-96.

Samraoui, F., Alfarhan, A.H., Al-Rasheid K.A.S., Samraoui, B. 2011. An appraisal of the status and distribution of waterbirds of Algeria: Indicators of global changes? Ardeola 58:137–163.

Schuyt, D.K. 2005. Economic consequences of wetland degradation for local population in Africa. Ecological Economics 53: 177–190.

Seltzer, P. 1946. Le climat de l'Algérie. Carbonel, Alger, 219 p.

Setianto, A., Triandin, T. 2013. Comparison of kriging and inverse distance weighted (IDW) interpolation methods in lineament extraction and analysis. Journal of Southeast Asian Applied Geology. 5(1): 21–29

Si Bachir, A. 2008. Connaissances et mises en valeur des ressources biologiques des zones humides du sud-constantinois (Algérie). Séminaire international sur la biodiversité et la conservation des zones humides nord africaines. 2-4 décembre 2008, Université de Guelma, Algérie.

Soulama, K. 2011. Influence du pH sur la chloration de l'eau à la station ONEA de Nasso. Mémoire de Licence en Génie biologique. Université polytechnique Bobo Dioulasso Burkina Faso. 57 p

Tinarelli, R. 1987. Wintering biology of the Black-Winged Stilt in the Maghreb region. Wader Study Group Bulletin 50: 30-34.

Toby, N. C., Ripley, D. A. 1997. On the Relation between NDVI, fractional vegetation cover, and leaf area index. Remote Sensing of Environment 62: 241-252.

Wanzie, S.C. 2002. Wetland conservation and development in the Sahel of Cameroon. Garoua: Actes du colloque 6 p.

نقشه برداری و مطالعه تشریحی شاخص گیاهی و خصوصیات خاک نعما سبخا(الجزایر جنوب غربی) از راه دور

لکدر گرین[الف*]، مصطفی بلگوراری[ب]، هانان گرینیک[ج]
[الف] استاد، مرکز دانشگاه نعما، نعما ۴۵۰۰۰، الجزایر ، [*](نگارنده مسئول)، پست الکترونیک: lguerine.dz@gmail.com
[ب] کارشناسی ارشد، خدمات جنگلی. منطقه جنگلی البیاد. البیاد ۳۲۰۰۰. الجزایر
[ج] کارشناسی ارشد، مؤسسه ملی آموزش و آموزش نعما، نعما۴۵۰۰۰. الجزایر

چکیده. پژوهش حاضر به وضعیت گذشته(۱۹۸۵) و فعلی(۲۰۱۸) منطقه نعما سبخا، به‌ویژه شوری، پوشش گیاهی و وضعیت آب آن می‌پردازد. نتایج به‌دست آمده برای حفظ تنوع زیستی سبخا مفید خواهد بود. اجازه برداشت ۱۳۶ نمونه خاک در دو عمق لایه‌های خاک سطحی(۴-۰ سانتی‌متر) و خاک پایین(۳۰-۴ سانتی-متر) توسط نماینده نمونه‌برداری داده شد. تجزیه و تحلیل نتایج شوری نشان داد که حداکثر و حداقل مقدار آن به میزان ۱۱۵/۳ گرم در لیتر در ۴ سانتی‌متر و ۸۰/۳ گرم در لیتر در عمق ۳۰ سانتی‌متر است. از نظر هدایت خاک، بیشترین مقادیر ثبت شده در ۴ و ۳۰ سانتی‌متر به ترتیب ۱۹۸/۴ mS.cm-1 و mS.cm-1 ۱۴۱/۸۹ است. در عین حال، نتایج حاکی از آن است که خاک سبخا از نظر قلیایی ضعیف است. مطالعه تشریحی براساس تجزیه و تحلیل NDVI تصاویر ماهواره‌ای لندست ۵، لندست ۸ و سنتینل ۲ رویش پوشش گیاهی متنوعی را طی ۳۳ سال نشان داد. نتایج تجزیه و تحلیل آماری NDVI1985 و NDVI2018، ($p<0.01$, $R2=0.77$) نشان دهنده توسعه قابل توجهی از پوشش گیاهی است. استفاده از NDWI برای دوره(۱۹۸۵ تا ۲۰۱۸) اهمیت کمبود آب در منطقه را برجسته می‌کند($p<0.01$, $R2=0.72$). نتایج حاصل از تیمارهای زمین آماری تصاویر، تغییراتی را نشان داده است که به ویژه افزایش پوشش گیاهی در منطقه سبخا بوده است که ۴۳۱ هکتار در سال ۱۹۸۵ به ۵۱۴ هکتار در سال ۲۰۱۸ رسید. این افزایش ۸۳ هکتاری مربوط به ۳۳ سال (۲/۵ هکتار در سال) گذشته است. به عبارت دیگر، در این منطقه در سال ۲۰۱۸ در مقایسه با سال ۱۹۸۵ به میزان ۱۹/۲۵ درصد پوشش گیاهی افزایش داشته است.

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