université kasdi merbah ouargla

Faculty of Hydrocarbons, Earth and Cosmic Sciences

Department of Earth and Universe Sciences

Academic master thesis

Field : Earth and Universe Sciences

Sector : hydrogeologie

topic

Seasonal monitoring of the surface water in chott merouane by remote sensing

By :

Mehiri mohamed zakaria

supervised by :

Hacini messaoud

Hacini Med Elelmi

2023/2024

université kasdi merbah ouargla

Faculty of Hydrocarbons, Earth and Cosmic Sciences

Department of Earth and Universe Sciences

Academic master thesis

Field : Earth and Universe Sciences

Sector : hydrogeologie

topic

Seasonal monitoring of the surface water in chott merouane by remote sensing

By :

Mehiri mohamed zakaria

supervised by :

Hacini messaoud

Hacini Med Elelmi

2023/2024

Dedication

To my beloved parents

To my sisters and brothers,,

Thank you for your everlasting love and warm encouragement throughout my research.

I couldn’t overcome my difficulties and concentrate on my studies. Without you

ACKNOWLEDGMENTS

الحمد لله

I would like first and foremost to say that this dissertation would not have been possibly conducted without the guidance and mentoring of my supervisor Dr. Hacini messaoud

I also want to express my gratitude to some of my teachers throughout the years i also would like to thank Mr Med Elelmi hacini who help me choose the course of my studies and offered the most valuable lessons

Abstract

Surface water in watersheds is an essential element in the study and development of their roles in any hydrological system. However, rapid and accurate surface extraction is a major challenge because of the spatial diversity of the objects on the earth surface. Remote sensing through its spatial, temporal and synoptic capabilities becomes a very powerful tool in this type of problem.

The results of our study show that watershed of salt lake or (chott) merouane cover 130,6014km² in january 2022 and it goes down in august to 19.5618km² during the summer due to the effect of high temperature and thus an increase in evaporation and it goes high in december 2022 to 116.6084km²

Surface water of chott merouane do not dry completely due to the continuous drainage from canal oued righ , this canal contributes to supllying the chott with water maintaining a certain water level

Key words: surface water, remote sensing, salt lake,evaporation

الملخص

تعتبر المياه السطحية في مستجمعات المياه عنصرا أساسيا في دراسة وتطوير أدوارها في أي نظام هيدرولوجي. ومع ذلك، فإن الاستخراج السريع والدقيق للسطح يمثل تحديًا كبيرًا بسبب التنوع المكاني للأجسام الموجودة على سطح الأرض. إن الاستشعار عن بعد من خلال قدراته المكانية والزمانية والإجمالية يصبح أداة قوية جداً في هذا النوع من المشاكل

تشير نتائج دراستنا إلى أن مساحة مستجمع مياه البحيرات المالحة أو (شط) مروان تغطي 130.6014 كم² في جانفي 2022 وتنخفض في شهر اوت إلى 19.5618 كم² خلال فصل الصيف بسبب تأثير ارتفاع درجة الحرارة وبالتالي زيادة التبخر و يرتفع في ديسمبر 2022 إلى 116.6084 كم²

المياه السطحية لشط مروان لا تجف تماما بسبب التصريف المستمر من قناة الوادي، تساهم هذه القناة في إمداد الشط بالمياه مع الحفاظ على مستوى معين من المياه

الكلمات المفتاحية الاستشعار عن بعد. المياه السطحية. شط . التبخر

Table of contents

List of figures

List of tables

INTRODUCTION

INTRODUCTION GENERAL

Mapping the surface waters of a watershed constitutes a key element for studying and modeling their roles in any hydrological system. However, rapid and accurate extraction of its surfaces is a major challenge due to the spatial variety of objects in the earth surface.

Remote sensing through its spatial and temporal capabilities and sight synoptic that it offers becomes a very powerful tool in this type of problem

Remote sensing is usually defined as the science, technology or art of obtaining information about objects or phenomena at a distance. It encompasses all process of capturing and recording energy from electromagnetic radiation emitted or reflected, to process and analyze the information, to then apply this information

It is the technique which, through the acquisition of images, makes it possible to obtain information on the surface of the Earth without direct contact with it. This acquisition is carried out by the remote use of any type of instrument allowing the acquisitioninformation about the environment (e.g., from an airplane, spacecraft, satelliteor even a boat). Instruments such as devices are often used photographs, lasers, radars, sonars, seismographs or gravimeters

Remote sensing is a modern and effective tool in studying and analyzing water resources, especially in large and remote areas. Chott Marwan represents one of the important areas in surface water analysis due to its environmental and economic importance. Remote sensing techniques can be used to periodically and accurately monitor the surface water level in the chott Merouane, which helps in understanding the effects of various climatic factors such as evaporation and precipitation.

The Normalized Difference Water Index (NDWI) is one of the most important indicators used in analyzing surface water by remote sensing. This indicator helps distinguish between water and other terrestrial components such as soil and plants, facilitating the process of monitoring and evaluating water resources. Climatic factors such as evaporation and precipitation play a major role in determining the water level in the Chott Merouane, and understanding the impact of these factors is essential for managing water resources sustainably.

Chott Merouane faces multiple challenges related to changing water levels as a result of high evaporation and fluctuating rainfall rates. Therefore, studying these factors and their impact on surface water provides a scientific basis that can be relied upon in making decisions related to water management and protection. Using remote sensing techniques and NDWI analysis, accurate and comprehensive data can be obtained that contribute to understanding the dynamic changes of the water level in the Shat.

This memorandum aims to study the impact of evaporation and precipitation on the water level in Chott Marwan using remote sensing data and the NDWI index. The study will analyze temporal and spatial data to determine changes in water level and evaluate seasonal and annual patterns. Through this study, new insights will be provided that contribute to improving the management of water resources in the region and enhancing the use of modern technologies in environmental monitoring. This involves analyzing data collected from satellites and comparing it with available climate data to provide recommendations based on scientific evidence.

Chaptre I

Study area presentation

I. Introduction

Water resources are among the most crucial environmental factors playing a vital role in human life and the development of communities. With increasing human and climatic pressures on these resources, water management and conservation have become significant challenges for many countries. In this context, the importance of chotts as vital water sources emerges, requiring special attention and continuous monitoring to ensure optimal exploitation in line with sustainable development guidelines.

Remote sensing technology is an effective modern tool that provides significant capabilities for efficiently and accurately monitoring and analyzing water resources. This technology allows for large-scale data collection at a lower cost compared to traditional methods and contributes to providing comprehensive and continuous information about the state of water, its quality, and seasonal changes.

This thesis aims to study and monitor the seasonal waters of the chotts using remote sensing techniques, focusing on analyzing the changes that occur in these waters throughout different seasons. This will be accomplished through a review of the literature on the subject, the application of data analysis methodologies derived from satellite images, and providing recommendations necessary for improving the management of these resources.

Through this research, we aim to highlight the importance of using modern technology in preserving water resources and ensuring their sustainability, in line with efforts to achieve sustainable development, address current environmental challenges, and support the local and national economy.

I.1. Geographic location :

Chott Merouane is a salt lake, part of the Melghir basin, located in the North East of the northern Sahara, it belongs, (Wilaya of El m'ghair, Algeria) in the village of ourir , it extends over an area of 333,700ha (**hacini 2006**), it is grouped with all the Tunisian chotts in the form of lagoon areas following two directions

- A SW-NE direction, corresponding to the Atlas direction along which are grouped together the Chotts Chergui, El-Gherbi and El-Hodna
- A WNW-ESE direction, bringing together the chotts El-Hodna, Melghir, El Ghersa and the chott El Jerid

With it altitude which is 31 m below sea level, it represents the lowest region of North Africa, located approximately 9 km northeast of the Daïra de Meghaier, geographical coordinates

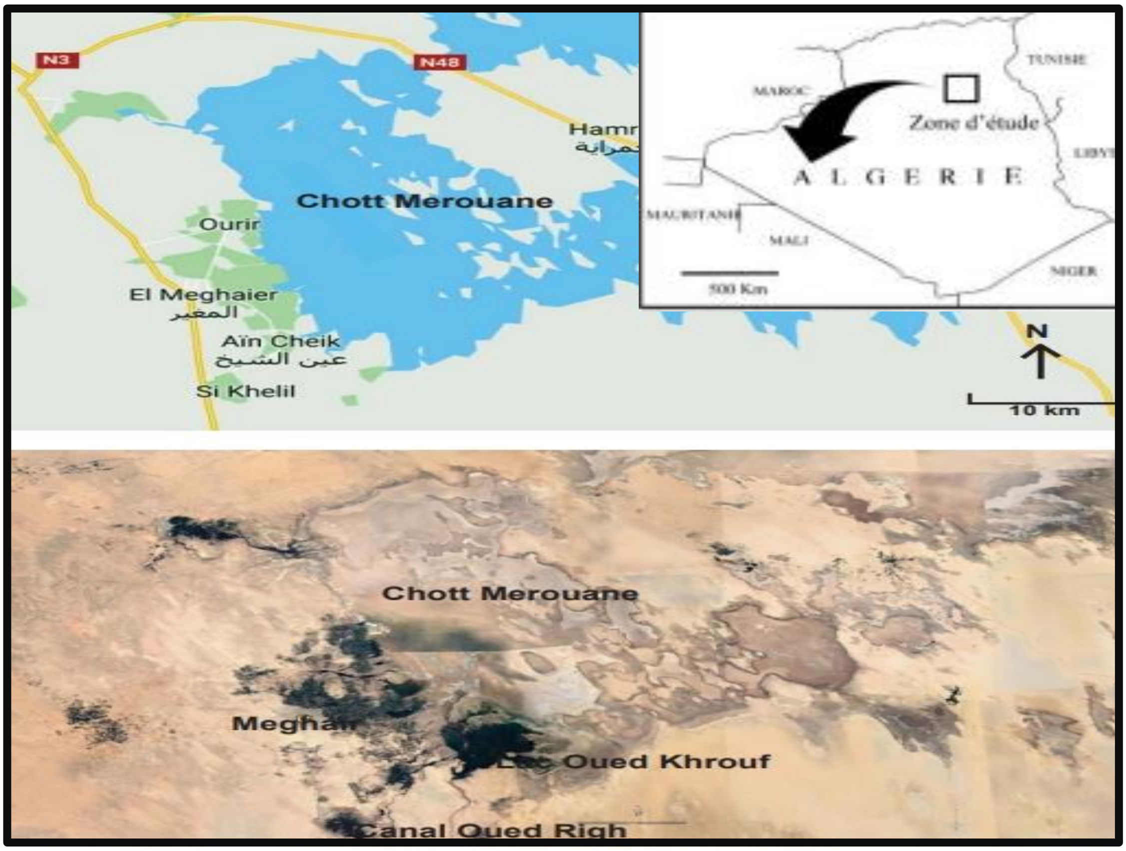

Figure I. 1: location of chott merouane

I.2. Situation Géologique

The Chott Merouane region is located in the northern Sahara of Algeria ina structured longitudinal saddlement trend in the Paleozoic (figure 2), on which it is limited to the north by the Aurès and Nememcha mountains, to the south by the hamadas of Tadmait and Tinghert, to the east by the Tunisian Dahar plateaus and to the west by the Mzab ridge

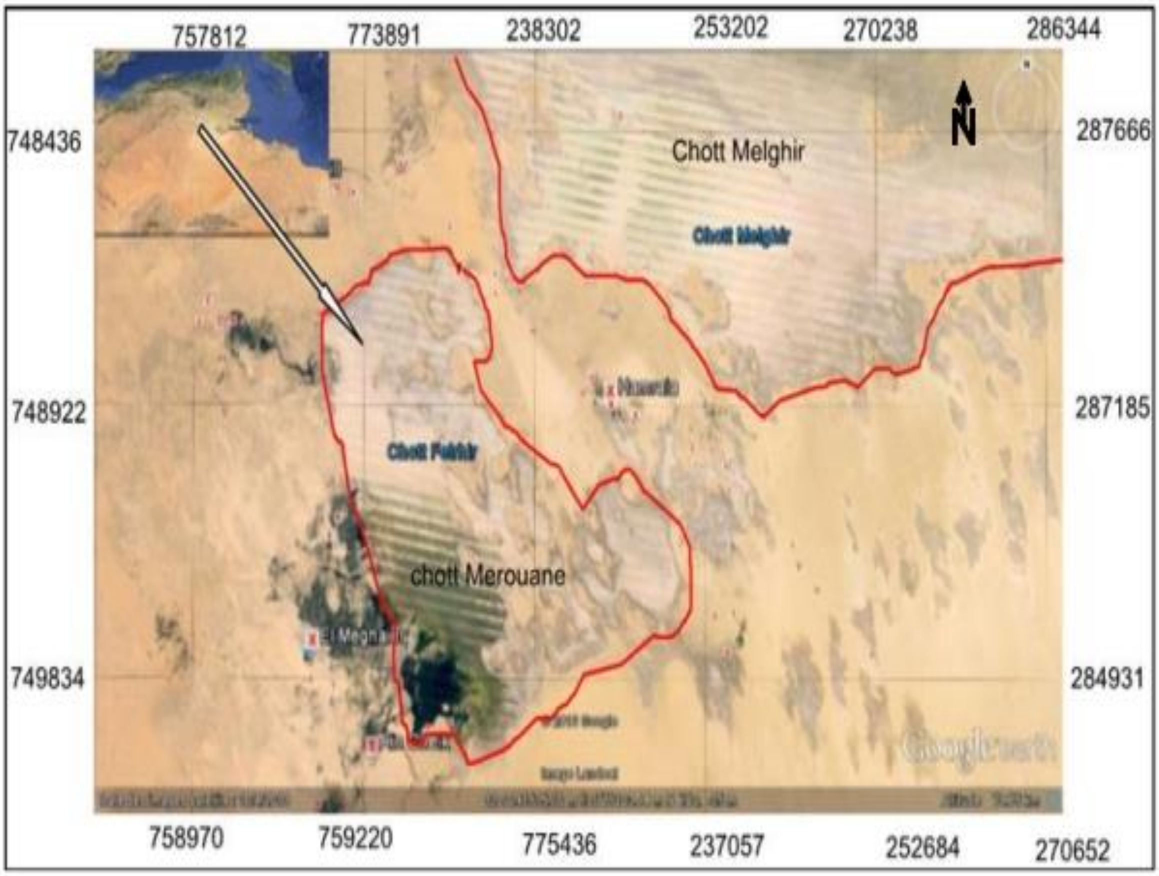

Figure I. 2: Geographical location of chotts meroune(google earth2016)

I.3. Geology

I.3.1 Regional geology

in the Chott Merouane region the geological formations are largely of Quaternary age and result from continental erosion of Mio-Pliocene deposits. She is characterized, on the surface, by consolidated dunes of silt to very fine sand (approximately 10 m thickness) (Khadraoui, 2007), at the depth of the gypsums, the thickness of the sands is very important where vegetation favors the stabilization of desert winds, underlying these fine sands, or finds approximately 70m of clays which in turn rest on approximately 35m of sandstone and sand, forming part of the most important aquifer, the terminal complex known as CT (Cornet, 1964 in Hacini, 2006). During the summer period, the Chott is covered by halite, with a thickness that varies between 0-20 cm. Minerals have been highlighted by x-rays and sometimes the naked eye, such as gypsum, calcite and clay minerals. There sub-surface geology has been reported by several geologists: Gouskov (1952), Cornet (1964) and Castany (1982). The halite overcomes a thick layer of clay 70m thick, and the aquifer of the terminal complex is located under this layer of clay (Hacini, 2006).

It includes a precambrian base on which a powerful sediment coverage rests in discrepancy, structured in the paleozoic in several basins separated by zones high that tilts in a gentle slope towards the depressed parts which forms a trend of assemblies, materialized by the ssw-nne axis occupied by chotts and whose bottom is lower than sea level. (Kadri, 2012)

The study area is part of the Northern Sahara sedimentary basin. This pool better known as its Western counterpart. Thanks to oil research. The Eastern Sahara, limited to the west by the M'zab and to the south by the Tademaït and Tinrhert plateaus, extends eastwards to Tunisia and Libya

When we approach the Sahara from the North we are surprised by the speed with which we pass from the Atlas mountains and plateaus to the Saharan desert platform. This passage highlighted by almost vertical outcrops of white limestone of Albian age corresponds to the South Atlas access which, depending on the location, is a fold, a fold-fault, or a flexure.

At the base of the sedimentary edifice there are marine Paleozoic terrains containing salty aquifer levels and hydrocarbon deposits above, and in unconformity we encounter secondary and tertiary formations which can exceed 3000 meters in the center of the basin (region of Ouargla, Touggourt, El oued) as well as on the edge of the Aurés (Zibane). The Quaternary; represented essentially by dune sands, sometimes reaching some meters in thickness. (Lahcini, 2004)

I.3.2 Local geology

In the Chott Merouane region, geological formations are largely quaternary and result from the continental erosion of Mio-Pliocene deposits. It is characterized, on the surface, by consolidated dunes of very fine sand silt (about 10 m thick) (Khadraoui, 2007), in depth of the gypsies, the thickness of the sands is very important where the vegetation promotes the Stabilization of desert winds, underlying these fine sands, or finds about 70m of clays which in turn rest on approximately 35m of sandstone and sand, part of the most important aquifer tablecloth, the so-called CT terminal complex (Cornet, 1964 in Hacini, 2006). During the summer period, the chott is covered by the halite, with a thickness which varies between 0-20 cm. Minerals have been highlighted by X -rays and sometimes to the naked eye, such as gypsum, calcite and clay minerals. The geology of Sub-surface has been reported by several geologists: Gouskov (1952), Cornet (1964) and Castany (1982). Halitis surmounts a thick layer of clay of 70m thick, and the tablecloth of the terminal complex is located under this layer of clay (Hacini, 2006).

The geological formations that characterize the region of Chott Merouane on the surface are largely quaternary and result from the continental erosion of the Miopliocene deposits.

They are made up of an alluvial or wind material, consolidated dunes of very fine sand silt (about 10 m thick) which are cement in depth by gyps, the thickness of the sands is very important where the vegetation promotes The stabilization of desert winds, underlying these fine sands, there are around 70 m of clays which in turn rest on about 35 m of sandstone and sand, part of the most important aquifer tablecloth, the terminal complex (CT).

At the end of the Miocene, sedimentation continues and a continental mantle of detrital origin covers the Saharan plateau composed of clays, sands, gravels and marls, is covered by the Pliocene and generally does not outcrop, only in the level of the banks and terraces of Oued Tell.

In the Pliocene the Saharan crust It is overcome give birth to, Hamada located in the western part of the Melghir and merouane chotts formed by a gypsum calcare often encompassing in its mass of pudding, sands and gravel rests on the red clay sands of the red clay Tertiary which suddenly interrupted in its eastern part at the level of the Bordj of Stile under the effect of erosion (Cornet; 1951,1952; Gouskov, 1964)

On the northern borders of the eastern Sahara, the boreholes of the water wells which have the main objective of the Albian tablecloth have recognized a stratigraphic column consisting essentially of the mesozoic and cenozoic deposits, resting in major discrepancy on paleozoic age fields Quaternary age rests in discontinuity on the cenozoic

I.4 Lithostratigraphy

The Vraconian is the passage between the sandy Albian (top of the intercalated Continental) and the clay-carbonate Cenomanian (base of the Terminal Complex)

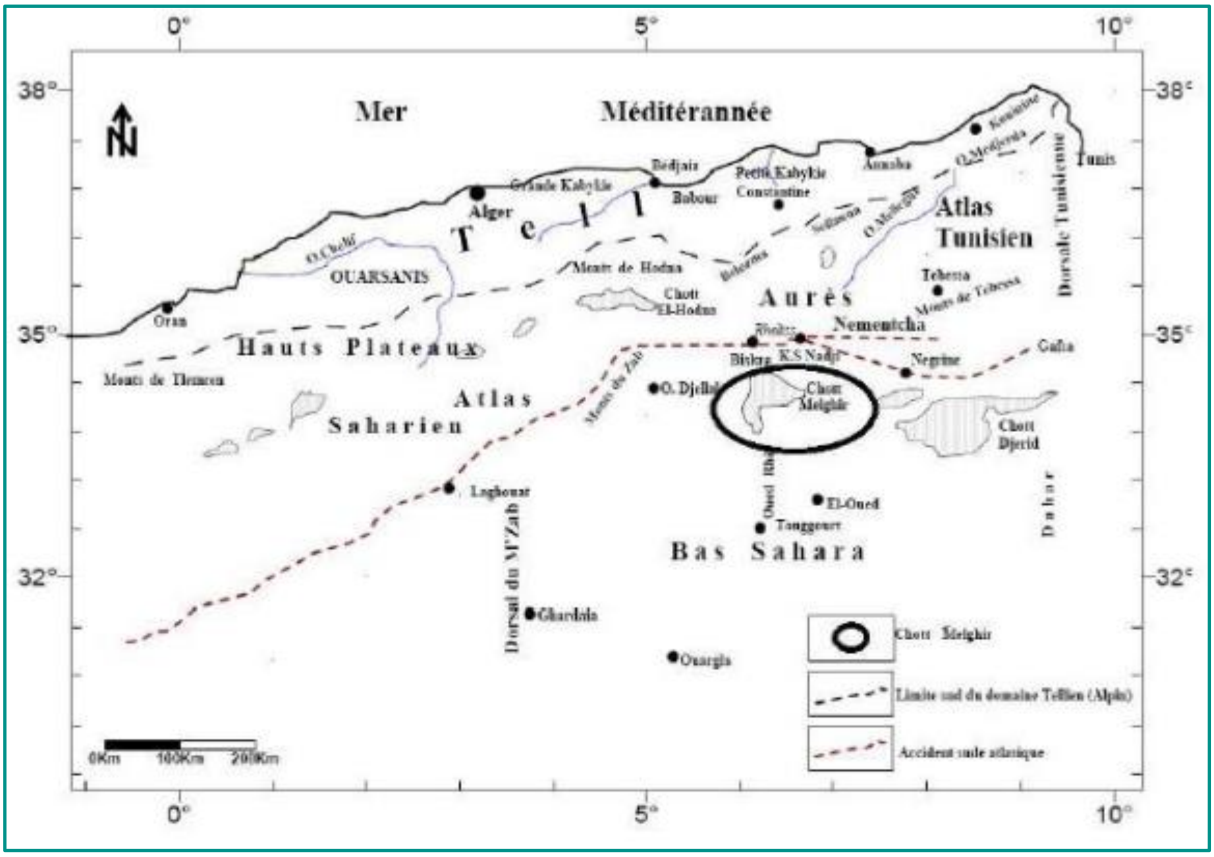

Figure I. 3: Geological situation of the Chott Merouane(Guiraud N., 1990)

The Vraconian is an alternation of dolomitic clay, sometimes sandy clays, with a fine transition from sandstone to carbonate cement

The Cenomanian He is represented by a lagoon series, of Marne, gypsum with anhydrites and carbonated benches throughout the Eastern basin of the Algerian Sahara.

The Turonian composed by a bench of fossiliferous limestone on a large part of the basin, the high electrical resistivity of carbonates with that of evaporites and clays facilitates the Duturonian identification of the Cenomanian by Diagraphie

The Senonian He is subdivided into three levels which are from bottom to top :

The Salifere Senonian This term only exists in the central part of the basin, it is essentially made up of the gemal salt which rests on a laterally anhydritic bench which extends towards the NE, have gone to the SW it becomes clay

the lagoonal Senonian Three very distinct intervals characterize the lagoonal Senonian: anhydritic at the base, carbonate in the middle part and anhydritic at the summit. These levels are not often well individualized, and the clay levels generally do not exceed 1 to 2 meters with the presence of traces of salt.

The carbonate senonian composed mainly by dolomitic levels has dolomitic limestone, with marly-argile intercalations, with rare anhydrite. The limit between Lagunaire and Senonian carbonate Senonian is not always clear, although the limit

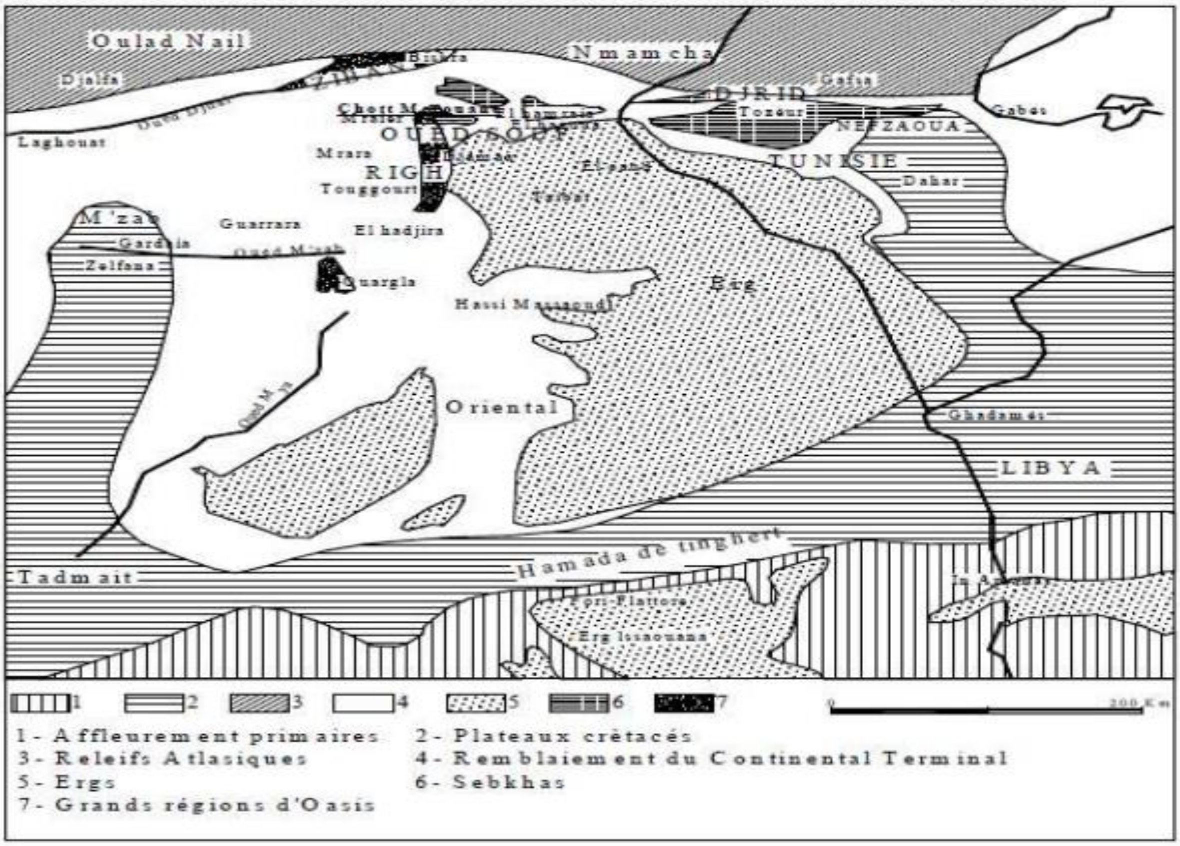

Figure I. 4: Large geological units in the Sahara (Hacini M., 2006)

upper part of the carbonate Senonian is even more vague. Indeed, there is practically continuity from a lithological point of view between the Senonian and the carbonate Eocene, the two levels being formed by limestones of the same nature. Only the presence of nummulites makes it possible to identify the Eocene.

In the Eocene, there are two lithological formations, as in the Senonian, and it is the carbonate eocene at the base and the evaporitic eocene at the top

the Eocene carbonate It is an alternation of calcareous dolomite, passing to dolomitic limestones towards the base, a nummulite series completed by a sequence of lagoon facies (evaporitic), presence of limestones.

Evaporitic eocene An alternation of limestone clays, anhydrite marls, associated with a microfauna, of Eocene age, made up of nummulitis, military and globigerins.

I.5 Tectonics

After the deposition of marine formations in the Primary period, the Sahara underwent Hercynian tectonic movements both vertically and horizontally, followed by further post-Triassic movements. The substantial thickness of sediment layers led to significant subsidence movements along the northern edges of the African basement. During the Atlas orogeny, a major tectonic event occurred, where uplift caused by the sedimentary rocks forming the Atlas chain led to abrupt folding at the end of the African basement, resulting in a longitudinal fault.

The Atlas orogeny is responsible for the emergence of large-scale deformations, where the M'Zab limestones have been transformed into a ridge, those of Tadmait into a basin, and further south, the Amguid-el-Biod axis collapses to give way to a meridian synclinal axis that extends to the Aurès. Additionally, in the Plio-Quaternary phase, movements are intertwined with the previous Alpine phase, leading to the appearance of east-west fractures that accentuate the uplift of the Aurès massif and the subsidence of the southern part known as the "Southern Aurès Trench." These fractures directly influence the flow of underground and surface waters, giving rise to the formation of Chotts such as Chott Melghir and Chott Merouane.

I.6 Geomorphology

The constitution of salt depressions is linked to the geological history of the Algerian high plains. It is marked by a sedimentary substratum inherited from secondary and tertiary marine transgressions, and would have experienced towards the end of the Oligocene a phase of extremely active orogenesis, coinciding with the Alpine folding which led to the uplift of the Saharan Atlas (Dresch J. 1954). However, at the end of the Tertiary, a phase of erosion resulted in the shaping of Jura forms and the filling of depressions with continental deposits, both in the Atlas and the long Saharan foothills and also towards the north in the high plains. During the Villafranchian (Tertiary/Quaternary boundary) a homogeneous whole results with the appearance of a vast plain, which will constitute the framework for the morphological processes of the Quaternary. The latter sees the rearrangement of geological units in place, through the combined action of tectonic movements (uplift, subsidence, folding) and climate (erosion, deposition).

At the end of the Villafranchian is preceded by the formation of a vast limestone crust resistant to erosion, thus fossilizing the Villafranchian surface. This encrusted surface corresponds to the upper Moulouyan or upper Villafranchian surface. The uplift of the entire Saharan Atlas, in the post-Villafranchian period, places it in a dorsal position in relation to the Saharan compartment, which remained stable, and to the plains, which remained wedged between the two Atlases. Considerable pressures will subject the upper Moulouyan surface to folding and dislocation phenomena which will result in breaks which will promote the formation of subsidence pits (Pouget M. 1980)

I.7 Hydrology

The Chotts, Melghir and Merouane belong to the Chott Melghir drainage area. This area covers an area of 68,750 km2 (Khadraoui, 2010). It is bordered to the north by the great flexure, going from Agadir in Morocco to the Gulf of Gabès in Tunisia (Rabia and Zargouni, 1990). The new classification adopted in 1990 by the National Water Resources Agency (ANARH) , classifies these Chotts in the hydrographic area of the Sahara (Benkhaled et al., 2008).

The hydrology of the region is mainly and generally characterized by two water sources, the Oued Rhir canal for Chott Merouane and the watershed of the Saharan Atlas for Chott Melghir.

Le Chott est alimenté par trois principales sources d'eau à savoir le canal de Oued Righ qui draine aussi les eaux urbaines locales, des eaux souterraines provenant de l'aquifère du complexe terminal et des précipitations (Hacini et al., 2009)

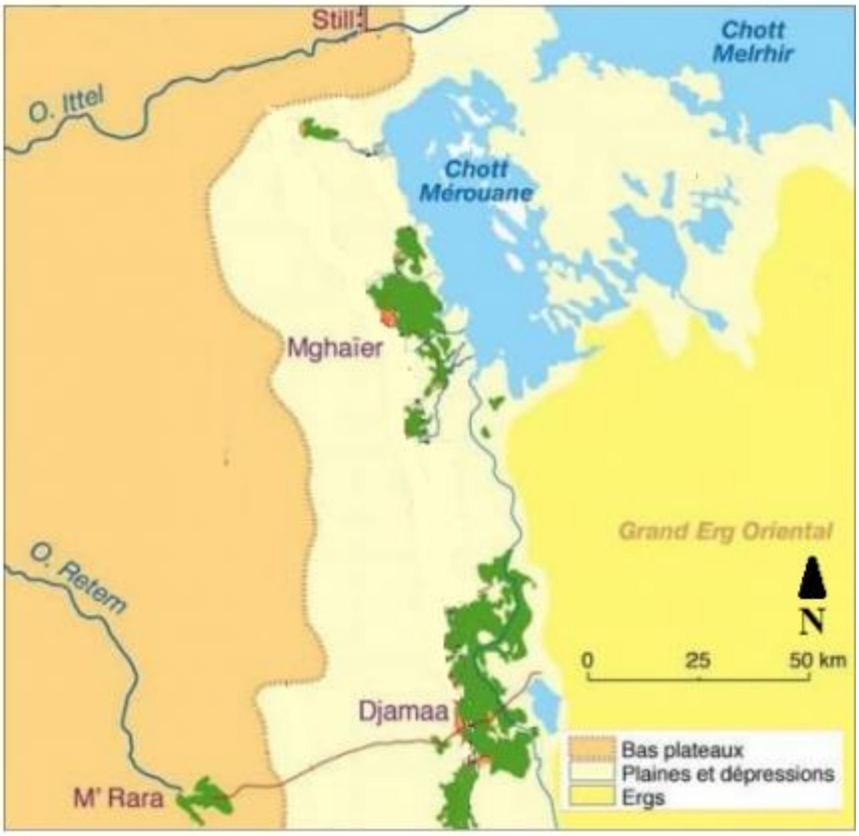

Figure I. 5: water supply of chott merouane (Ballais, 2010)

The 150 km long canal drains the water to Chott Merouane. The total quantity of water drained by the Oued Righ canal was estimated at 131.5 x 106 m3 during the year 1994 (Hacini et al., 2009). It is fed according to Ballais (2010) by water from urban collectors and oases. The annual share of groundwater which supplies the Chott Merouane was estimated at 62 x 106m3 (U.N.E.S.C.O., 1972). While the contribution of precipitation, according to (Hacini et al. (2009)),

I.8 Pedology

The hydromorphic and low humus soil is distinguished by four (4) types

• Gypsum soil with a crust with a minimum depth of 0.30 m and a maximum of 1.20 m. Salty, its texture is silty-sandy.

• Deep gley soil with the presence of gypsum and a sandy loam texture.

• Aeolian, saline soil, with a depth of 0.70 m to 1.20 m, with a sandy-silty texture.

• Pseudo-gley saline soil with the presence of gypsum with a depth of 0.70 m to 1.20 m with a sandy silty texture. (ramsar)

Chaptre II

Hydrogeologie and climatology

II.1. Hydrogeology

When approaching the Sahara from the north, one is struck by how quickly the transition occurs from the mountains and plateaus of the Atlas to the desert platform of the Sahara. This transition, marked by outcrops of nearly vertical white limestone, corresponds to the southern Atlas fault, which in some places is a fold, a faulted fold, or a flexure. South of this fault, stretching from Agadir to the Gulf of Gabes, lies the African shield that has withstood folding and on which the sea has at times encroached but never reaching significant depths. It is on this shield made up of igneous and metamorphic rocks that several thousand meters of sedimentary layers from the Cambrian to the Quaternary have been deposited, with some horizons serving as reservoirs for the aquifers we study.

Groundwater resources in the sedimentary basin of the northern Sahara or the Chott Merouane region are contained within two major aquifers, extending beyond the Algerian borders (Tunisia and Libya): the Continental Intercalaire (CI) and the Terminal Complex (CT).

II.1.1. The Continental Intercalaire Aquifer

The Continental Intercalaire, often referred to as the "Albian bed," occupies part of the extensive sedimentary series of the Algerian Sahara. The term Continental Intercalaire has a geological origin, referring to the continental formations deposited between the marine Paleozoic cycle, terminated by the Hercynian orogeny that pushed the sea away from the Saharan platform, and the major marine transgression of the Cenomanian. Therefore, the Continental Intercalaire covers a wide period ranging from the Triassic to the Albian. The term is not entirely appropriate as it also includes some lagoonal and marine formations deposited during small marine incursions from the Gulf of Gabes.

At the outcrop, in the Adrar and Ain Salah regions, the Continental Intercalaire appears as a series of sandy benches, fine sands, and clay levels; permeable levels are predominantly abundant. The sandstones are unconsolidated, friable, often poorly cemented, ranging in color from pink to brown or green, always sandy, and form intercalations a few centimeters thick.

This reservoir has a substantial volume due to both its vast extension across the entire northern Sahara (600,000 km²) and its significant thickness, which can reach 250 meters in most of the basin and has a depth exceeding 2000 meters in Ouargla, El-Oued, and Oued Righ. However, on the outskirts of the basin, the depth of the water table does not exceed a few tens of meters (El-Goléa, Timimoune...).

The Continental Intercalaire aquifer is a good quality freshwater reservoir across the entire basin, especially in the western limits of the basin (El Goléa). Most of this resource's water was replenished during the Quaternary rainy periods.

This groundwater is artesian in most of the basin; however, it is being exploited by pumping in the basin's edges. It is worth noting that previously, the tablecloth was artesian even in the edges; this decrease in pressure is due to overexploitation of this aquifer.

The groundwater flow of this aquifer starts from western Algeria towards western Tunisia, and from southern Algeria towards western Tunisia. The natural outlet of this aquifer is Chott Djérid in Tunisia.

II.1.2 The Terminal Complex aquifer

The Terminal Complex (C.T) is a multilayer aquifer characterized by the intercalation of impermeable to semi-permeable formations with permeable formations. It spans from the Senonian to the Quaternary period, with the Turonian locally included in the overall "Terminal Complex."

Covering an area of 350,000 km² and reaching a depth ranging from 100 to 500 meters, it encompasses two distinct aquifers based on lithological nature. From top to bottom, the aquifers are classified as :

- The Mio-Pliocene sandy-clay aquifer

Composed mostly of sand with the presence of limestone and clays, recognized to have an average thickness of 300 meters.

- The carbonated Senon-Eocene aquifer

Represented by carbonate and evaporitic formations intercalated by marls sometimes clays, recognized over a thickness of around 400

- The Turonian aquifer

It is the base of the terminal complex, recognized over a thickness of about 46 m, represented by limestones separated from the two underlying aquifers by the lagoon Senonian formations, which constitute an impermeable screen.

This hydrogeological peculiarity and their lithological heterogeneity have led them to be grouped under the term Complex

The aquifer was fed mainly during the rainy periods of the Quaternary, currently the aquifer receives significant quantities at the level of the edges which are relatively watered and by infiltration through the sands of the Grand Erg Oriental, which rests in places directly on the permeable formations of the Mio-Pliocene, or by drainage through the faults of Amguid l'Abiod which masters in contact the terminal complex with the Continental aquifer Interlayer.

The natural outlet for this aquifer in Algeria is the Merouane and Melghir chott in Tunisia, El Jerid and El Ghersa chott. The recharge rate of this aquifer is estimated at 18.5 m3/s, the salinity is good on the edges is relatively high in the centre of the basin (exceeds 3 g/l in the region of Touggourt and Ouargla), the direction of flow of this aquifer is South-North and North-South.

The ERESS study. (1969) shows that the water table of the terminal complex feeds the Chott by drainage with an estimated volume of water of 62.34 x 106 m 3 /year

II.1.3. Groundwater table

Represented by fine sands of medium quaternary age with traces of gypsum crystals, very permeable, free, characterized by waters with high salinities is located at depths varying from 1 m to 50 cm, with excess irrigation and pumping through the confined aquifers (CI and CT), The water table of the valley of the Wadi Righ has experienced a rise in its piezometric level as a result of which many sectors are flooded in winter, poor agricultural yields. For this reason, an artificial drainage network has been built in the depression of the Wadi Righ in order to reduce the danger of the situation.

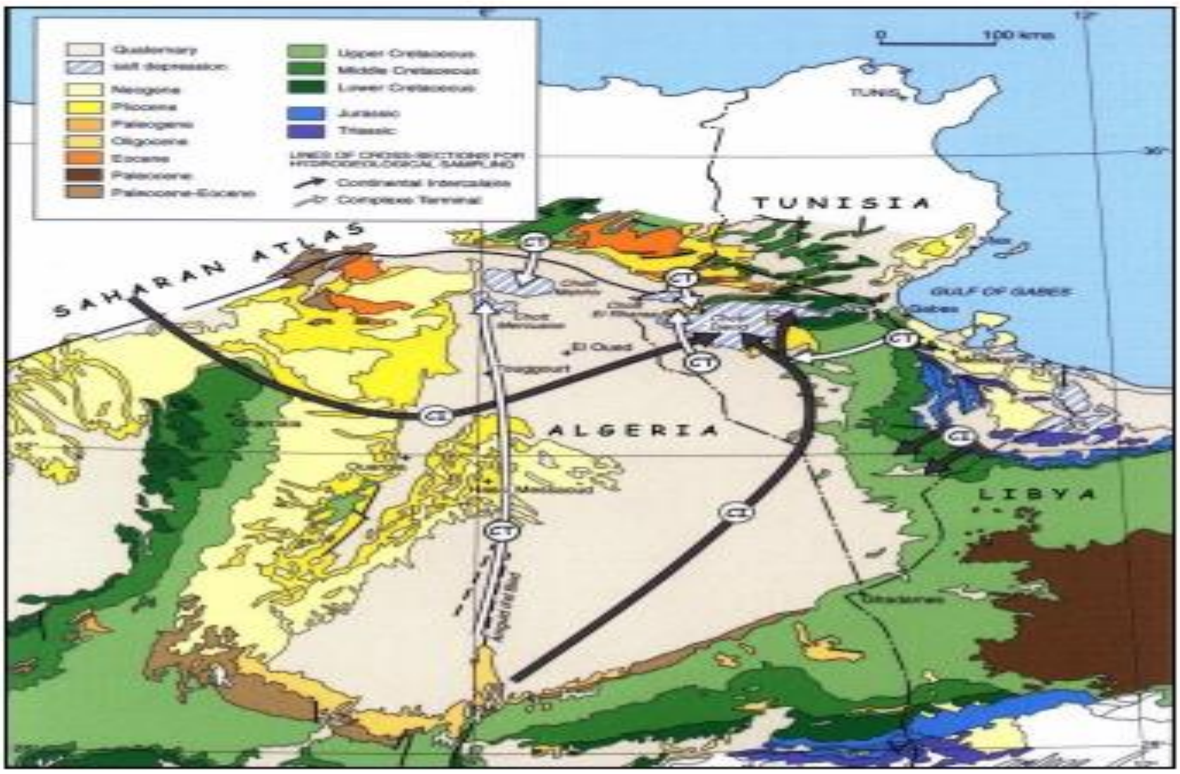

Figure II. 1: Hydrogeological map of the two aquifers of the northern Sahara with the direction of flow of the two aquifers (ERESS study modified by Gundouz et al, 2003).

II.2. Climatology

The determining factor is rainfall. The Saharan regions are experiencing significant rainfall deficits. Rainfall is low everywhere and shows very high yearly, seasonal and regional variability. Temperatures are high. The climate is arid to hyperarid with significant temperature variations. (MATE, 2000).

The Chott Merouane region is part of the great hydrological basin of the Sahara known as the Melghir basin, characterized by a Saharan type climate, marked by very low and random rainfall, the maximum temperature can reach 60°C in summer, while the absolute minimum is 5°C in winter and relatively low humidity

II.2.1 Temperature

Temperature is a fundamental factor in the characterization of the climate of a region, it is linked to solar radiation, its variation influences the transformation of water into steam whether on the surface or in the subsoil, consequently it acts on the salinity of the water

The analysis of the curve of variation of monthly average temperatures over a period of 2022 shows that June is the warmest month with 34.46 °C and January is the coldest with an average temperature of 10.18 °C. The effect of temperature on water levels is felt during the summer period, When evaporation of water is observed

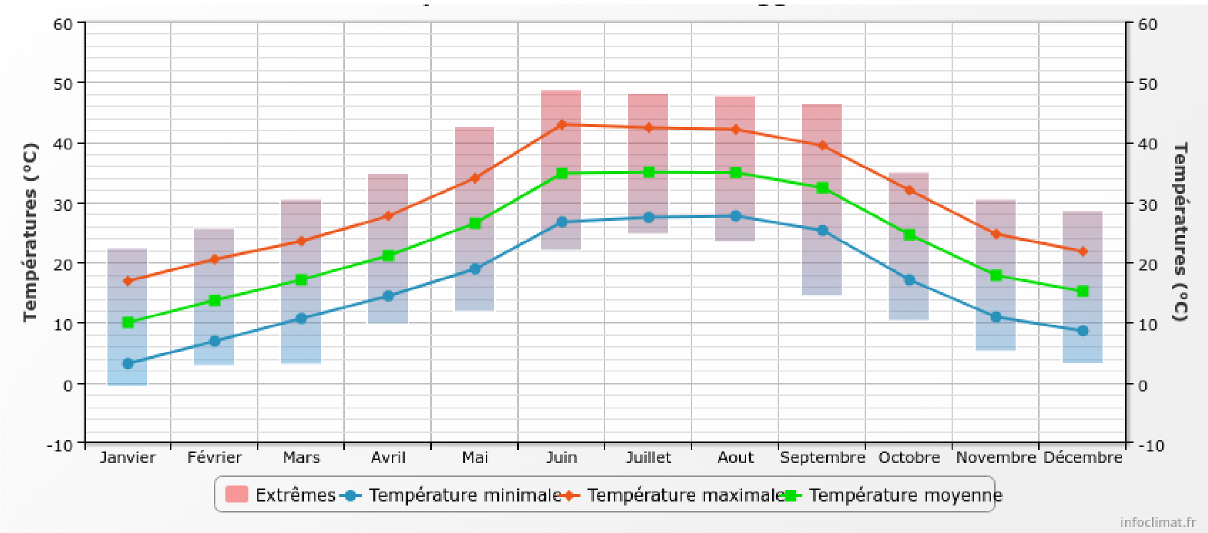

Figure II. 2: temperatures during the observation period 2022 (infoclimat.fr)

II.2.2. Humidity

During the observation period (2022), the humidity of the air in the region marked by two distinct periods.

From November to March: this is a relatively wet period as percentages above 40% were recorded with a growth of 42.69% to a maximum of 50.55% in January

From April to October: this is a dry period, when the humidity level decreases to a minimum of 19.18% in June

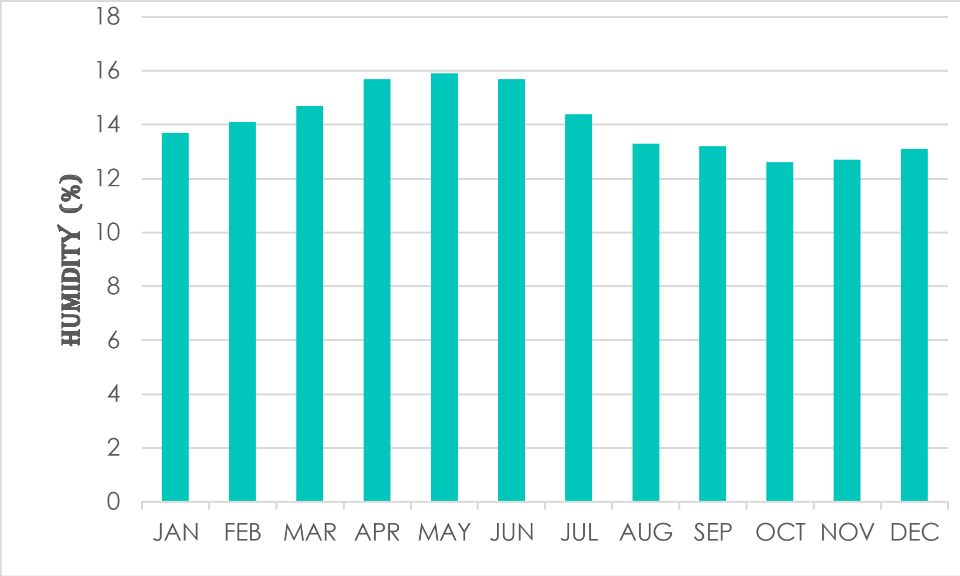

Figure II. 3: The average humidity monthly during the observation period.2022 (power.larc.nasa)

II.2.3 The winds

The observation of the curve of variation of wind speed as a function of time during the period (2022), shows that the wind speed is stable of about 14km/h, except for the period (March, July) when an increase in wind speed ranging from 15 to 16km/h was recorded

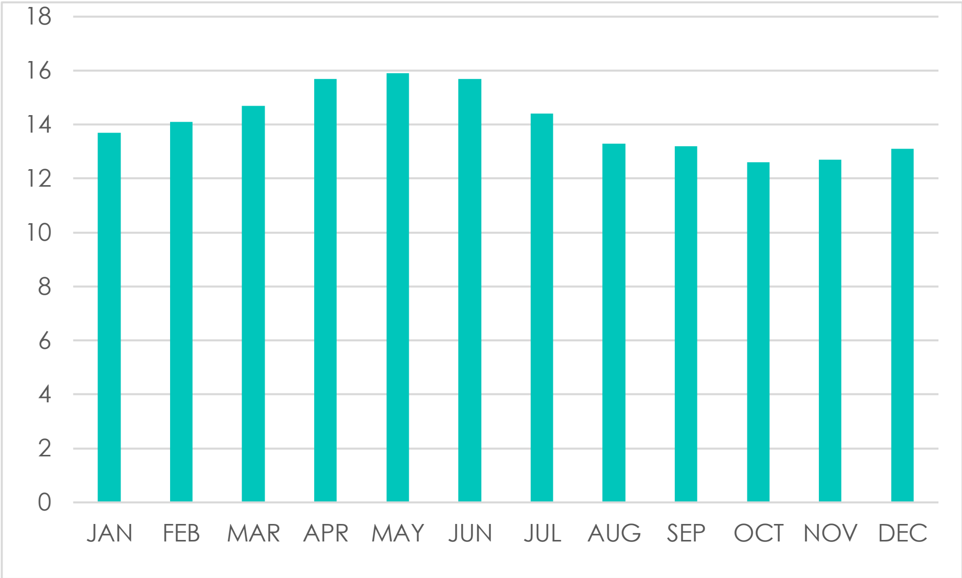

Figure II. 4: wind speeds during the observation period 2022 (power.larc.nasa)

II.2.4 The precipitation

The observation of the curve of variation of the average monthly precipitation of the waters, over a period that extends from (2022) shows that the month of December is the wettest with 10mm and the month of July is the driest with 0 mm.

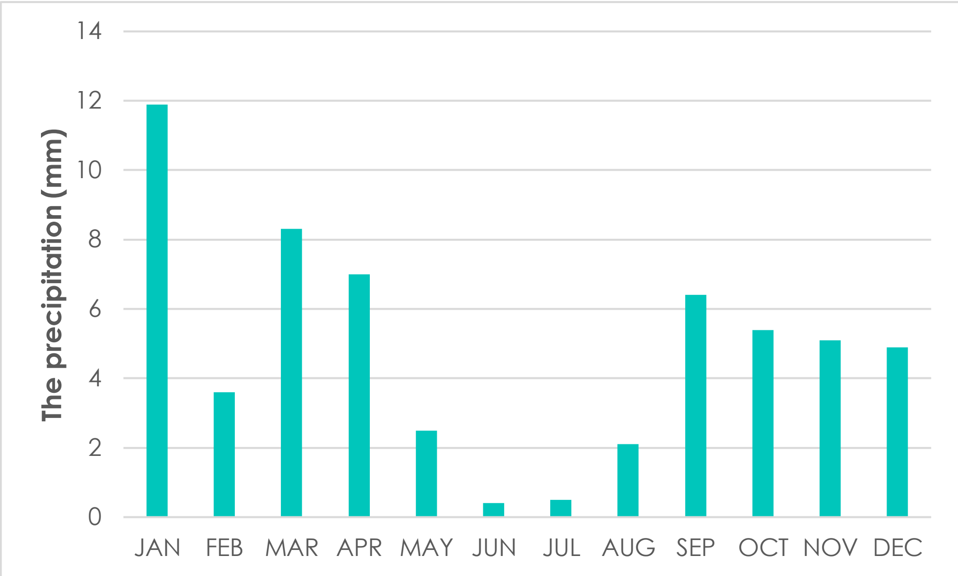

Figure II. 5: precipitation during the observation period 2022 (climatengine)

II.2.5. Evaporation

It is the amount of water that has been transformed from a liquid to a gaseous state under the effect of temperature, which causes an increase in the concentration of the amount of untransformed water, it is low in humid regions and it is high in arid regions where wind speed is high.

In the case of Chott Merouane, evaporation is influenced by salinity, with a high salinity the quantity of dissolved solids is important which decreases the pressure of water evaporation

With a series of observations (2022) the curve of variation of the monthly mean evaporation shows such a simple appearance, with a tendency that decreases towards the months of the winter season followed by a growth once a year goes towards the months of the summer season, this fluctuation of evaporation is governed by the temperature.

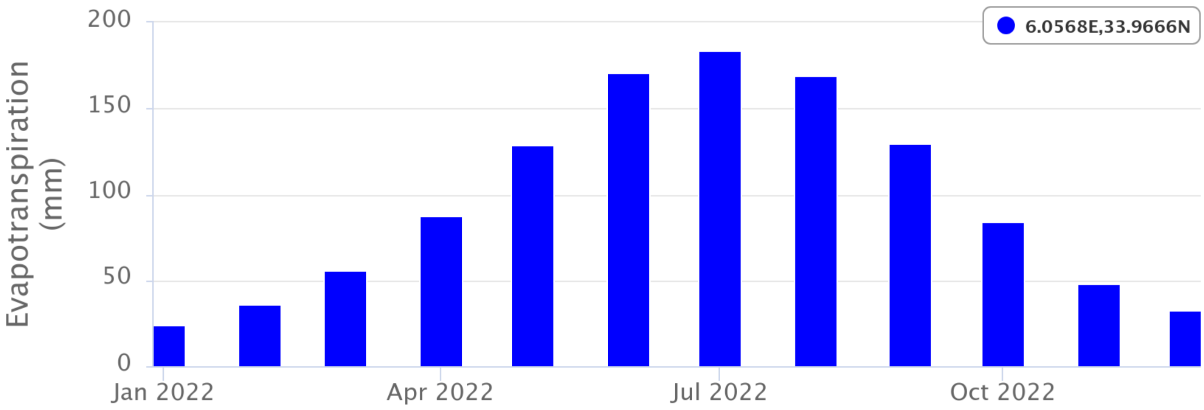

Figure II. 6: evaporation during the observation period 2022 (climatengine)

II.2.6. Sunshine

The duration of sunshine, or the duration of effective insolation, is a climate indicator that measures the time during which a place or place is subject to effective insolation, i.e. subject to solar radiation that is intense and powerful enough to produce distinct shadows. In our study area, it receives strong periods of sunshine reaching their maximum in July

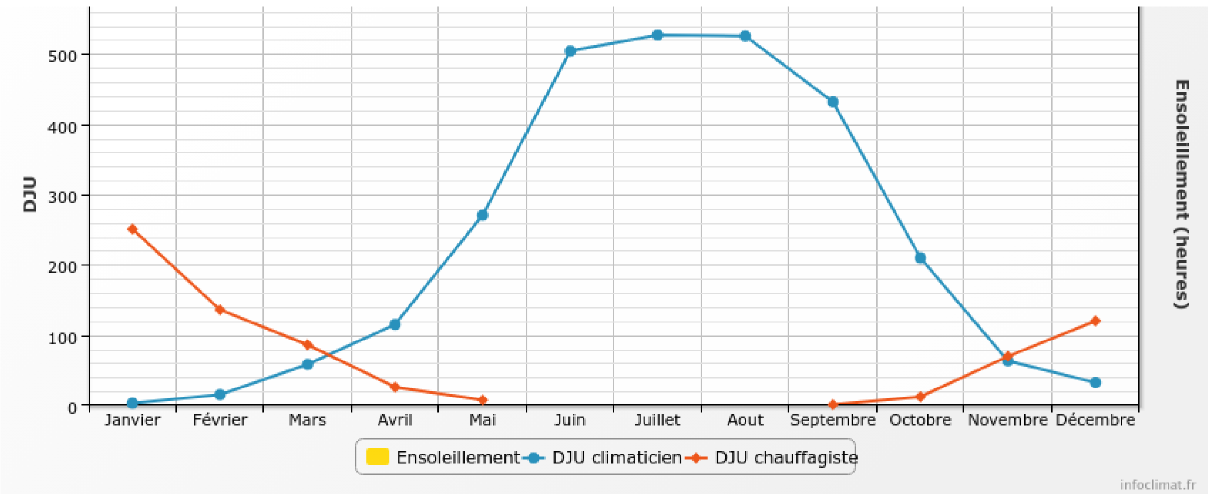

Figure II. 7: Distribution of insolation durations, interannual average (h)

II.3. WATER BALANCE

II.3.1. Estimation of potential and actual evapotranspiration :

In hydrogeological studies, the two main elements of the balance, evaporation and In hydrogeological studies, the two main elements of the balance, evaporation and transpiration are combined into one In hydrogeological studies, the two main elements of the balance, evaporation and transpiration are combined into one: evapotranspiration.

Evapotranspiration or total evaporation (ET) is the set of evaporation (physical process) and transpiration (biological phenomenon) phenomena. Evapotranspiration or total evaporation (ET) is the set of phenomena of evaporation (physical process) and transpiration (biological phenomenon). Evapotranspiration or total evaporation (ET) is the set of phenomena evaporation (physical process) and transpiration (biological phenomenon). We distinguish:

- Potential evapotranspiration (ETP)

- L'évapotranspirationréelle(E.T.R)

a) Potential evapotranspiration (ETP)

We call potential evapotranspiration (ETP), expressed in height of blade or slice ofevaporated water, the sum of the quantities of water that can evaporate and transpire on a given surface and during a well-defined period, considering inputs of water. sufficient water.

For the estimation of potential evapotranspiration we used the Thornthwaite formula which established a correction between the monthly average temperature and the monthly evapotranspiration, this author first defines a monthly thermal index (i), where:

$$i = \left[\frac{T}{5} \right]^{1.5} \qquad I = \sum_{1}^{12} i \qquad a = \frac{1.6}{100} I + 0.5$$

$$ETP = 16 \left(\frac{10\ T}{I} \right)^{a} k$$

ETP : Potential evapotranspiration

T : Average Monthly Temperature

i : Monthly thermal index.

I : Annual Thermal Index.

- interpretation of thornthwaite's balance

MONTH	J	F	M	A	M	J	J	A	S	O	N	D
T(moy)	10.18	14.03	17.2	21.6	27.01	34.46	34.1	34.03	32.1	25.2	18.1	15.9
P(mm)	11.9	2.8	8.15	7.01	2.3	0.53	0.63	2	6.01	4.9	5	4.8
i	2.9	4.7	6.38	8.97	12.55	18.09	17.8	17.71	16.26	11.32	6.88	5.67
I	129.23											
a	2.56768											
ETP	12.1	20.1	35.6	61.3	104.21	177.46	198.86	197.88	137.1	76.82	31.41	14.69
ETR	4.2	2.08	5.31	2.11	2.23	0.57	0.09	0.21	2.24	4.8	4.59	3.01
RFU	0	0	0	0	0	0	0	0	0	0	0	0
DA	11.56	17.25	36.7	67.31	125.2	202.3	244.1	227.15	143.1	68.42	27.64	11.48
EX	0	0	0	0	0	0	0	0	0	0	0	0

Table II. 1: WATER BALANCE of chott meroune 2022 (climateengine)

Chaptre III

Remote sensing

Introduction

In the first chapter, we provided an overview of Chott Merouane. The second chapter discusses climatology and hydrogeology. In this chapter titled "remote sensing," we describe our approach to creating a geovisualization of Chott Merouane using satellite images acquired over the study area since the launch of the LANDSAT 8 satellite.

USGS has deployed a prototype viewer enabling easy access to over 3 million scenes in the Landsat archive. LandsatLook is used for global search and full-resolution download of LandsatLook imagery, as well as access to Level 1 data products. This graphical interface encompasses over a decade of Landsat data, serving as a valuable resource for anyone interested in the evolution of Earth's surface, whether natural or human-induced (Lakdawalla, 2013).

III.1. Remote senseng :

Remote sensing is both a scientific field and a craft that involves retrieving information about an object, area, or event by analyzing data obtained by a device not physically touching the target under examination.

In many respects, remote sensing can be seen as a reading process. We use various sensors to remotely collect data, which can then be analyzed to obtain information about the objects, areas, or phenomena being studied (LILLESAND & KEIFER, 2015).

However, the human eye is limited to a small part of the total electromagnetic spectrum, approximately 400 to 700 nm. In remote sensing, various types of tools and devices are used to make electromagnetic radiation outside this range visible to the human eye, especially near-infrared, mid-infrared, thermal infrared, and microwaves. Remote sensing now plays an important role in a wide range of environmental disciplines such as geography, geology, zoology, agriculture, forestry, and botany.meteorology, oceanography and civil engineering (JONG & VAN DER MEER, 2004).

III.2. image collection

The Landsat 8 satellite collects approximately 400 scenes per day, each covering an area of 160 km^2. These scenes (images) can be downloaded for free from the USGS website at the following address: http://earthexplorer.usgs.gov/. These images are available free of charge or for a fee on online portals such as EarthExplorer. In addition to images, topographic data, weather data, and field data are also available. Satellite images can be used to track the evolution of chott surfaces over time. Topographic data can determine the elevations of different areas within the sebkha or chott. Meteorological data can provide information on precipitation, evapotranspiration, and local climatic conditions. Field data can be collected using drones or measurement equipment to provide additional information about topography, soil salinity, vegetation, and other factors influencing the evolution of the chott.

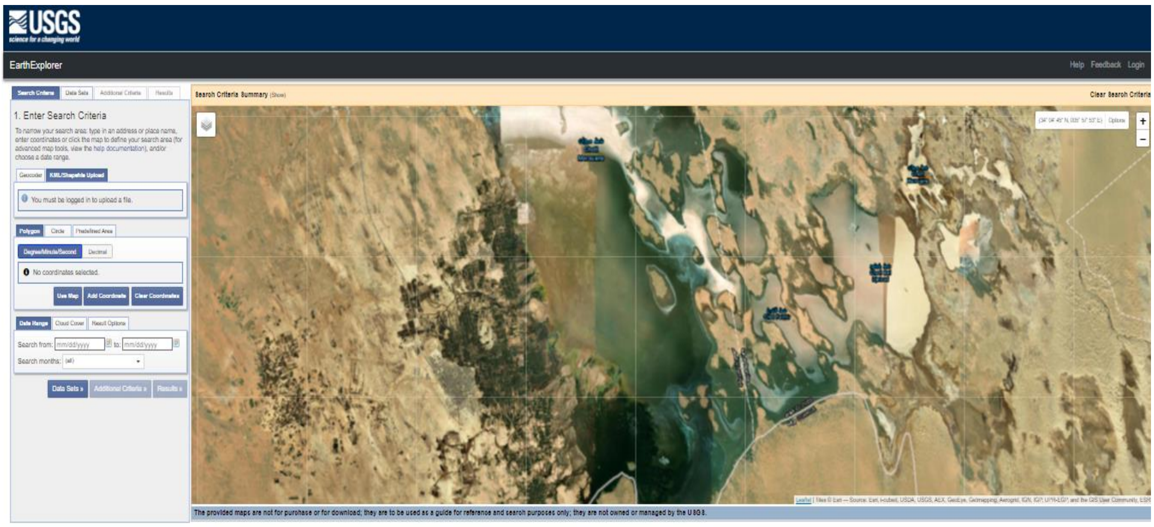

Figure III. 1: Delineation of the study area (USGS.2024)

III.2.1 Software used :

III.2.3.1. ENVI 5.0 :

ENVI software is a robust commercial program specifically built for processing remote sensing imagery, including optical and radar data. It includes a variety of image processing functions like geometric and radiometric corrections, radiometric unmixing, classification, and map creation. The team behind ENVI consists of scientists currently focusing on remote sensing research.

which makes it a product in continuous development enriched with multiple functions addressing various issues and themes. The strength of ENVI lies in its image processing approach that combines file-based and band-based techniques with interactive functions.

When an image file is opened, each band is stored in a list and can be manipulated using all system functions. If multiple files are opened simultaneously, you can select the bands to be processed.

III.3. Image preprocessing

Image preprocessing is a crucial stage in remote sensing, focusing on achieving accurate values of energy reflected or emitted from any location on Earth's surface. Typical procedures include:

III.3.1. Layer stacking

Layer Stacking is used to build a new multi-band and/or multi-date image from geo-referenced images of various sizes.

III.3.2 Resize data

Processing starts with extracting the area of interest and geometrically correcting the LANDSAT image in the UTM/WGS 84 reference system, 32 N zone. We conducted spectral stacking and subsequently resized the image spatially to include only the area of interest while ensuring all channels were cropped to the same dimensions

III.3.3 Enhance

Ces des techniques d'augmentation de la qualité visuelle de l'image et d'amélioration de contraste

III.4. Segmentation

The ENVI software workflow, briefly outlined above, was applied in the classification of satellite imagery. The sequence of modules used aimed to categorize pixels and group them into clusters based on their unique characteristics. This process enabled the differentiation of spectral properties of land cover objects using signature files and generated classification maps depicting the assigned land cover classes. Land cover categories are identified based on the contrast in the digital numbers (DNs) of pixels, which are then linked to specific land cover classes and visualized using color schemes. These solutions incorporate advanced features and a high degree of automation, allowing for the efficient processing of a time series consisting of twelve images.

After the classification process using ENVI software, distinct land cover classes were assigned to interpret the diverse landscapes in northeastern Algeria. These classes represent the primary features observed in the images, each displaying unique vegetation patterns and specific characteristics. Adapted from the FAO and customized for the study area, the land cover classes include: (1) Desert sands; (2) Salt hardpans; (3) Water bodies (Chotts Melrhir and Merouane); (4) Non-consolidated soils; (5) Consolidated soils; (6) Sparse grassland; (7) Sparse shrubland; (8) Sparse trees; (9) Sparse vegetation; (10) Grassland; (11) Broadleaved shrubland. These designated classes served as representative regions on the classified maps, enabling the examination and distinction of changes in landscape characteristics over a one-year timeframe. Additionally, they facilitated the evaluation of variations such as reductions in lake size, expansion of salt areas, and the distribution of patches within the visualized landscapes.

.III.5. Image classification

The process of image classification and analysis involves digitally identifying and categorizing pixels within an image. Various methods exist to achieve numerical classification. Here, we will briefly outline two commonly employed approaches: supervised classification and unsupervised classification.

III.5.1 classification no supervised

It analyzes pixels and groups based on prevalent spectral characteristics, without pre-existing knowledge of object attributes for classification. Special algorithms are utilized to automatically identify and classify signatures (Bonn and Rochon, 1992).

Once pixels have been allocated to specific classes within the image, assessing the importance of each class is essential. This evaluation necessitates human intervention to establish meaningful connections and categorize these groups into coherent classes using field data and additional information sources.

.**Steps :**

We employed the following steps to classify the false-color satellite image using the features available in ArcGIS 10.8:

1. Developed multiple false-color composites based on the targets' sensitivity to the electromagnetic spectrum, using a linear contrast with 2.5% saturation.

2. We applied the Isodata algorithm, adjusting the number of classes (ranging from 5 to 15), setting a maximum of 15 iterations, and using a default threshold or stopping criterion of 5%.

3. Enhanced the visual quality of the classified image by implementing a low-pass filter.

III.5.2 classification supervised

Supervised classification is the method of categorizing data into distinct groups with shared attributes, separate from other classes. This categorization is achieved by employing predetermined reference elements before initiating the classification procedure.

This type of classification, as its name suggests, is user-controlled, as it is the operator's responsibility to define the various classes into which the image pixels will be grouped.

It serves as a crucial complement to unsupervised classification, heavily relying on visual interpretation of the satellite image. Therefore, applying this classification method requires the operator to have solid prior knowledge of the landscape. The operator identifies various objects within the image (training zones) to extract their spectral signatures. Subsequently, the supervised classification algorithm utilizes these spectral signatures to categorize the entire image by assigning each pixel to one of the predefined land use classes based on the training zones.

We employed the maximum likelihood method for the satellite image classification. This method has demonstrated robust performance and is widely recommended in numerous research studies, establishing it as a highly effective classification technique (Bensaid, 2006).

Steps :

To conduct this classification, we followed these steps:

1. Initially, we delineated all land use categories based on the study's objectives, utilizing existing land information plans.

2. We conducted thorough and precise sampling for each category by digitally capturing polygons throughout the entire image. This process demands careful attention and is labor-intensive, as the accuracy of the land use map is directly linked to the quality of the initial sampling. Subsequently, these samples were divided into two groups: the first was used to establish spectral signatures (training zones), while the second was allocated for verification tests (test zones).

3. Commands were then employed to evaluate the homogeneity of pixels representing each training site based on the spectral signatures.

III.6. Normalized Difference Water Index, NDWI

The NDWI index is most suitable for mapping water bodies. The water body has a high absorption capacity and a low radiation in the visible to infrared wavelength range. The index uses the green and near-infrared bands of remote sensing images based on this phenomenon. The NDWI can effectively improve water information in most cases. It is sensitive to built-up land and often results in overestimated water bodies

NDWI provides an effective way to monitor surface moisture and detect areas of water, contributing to better understanding and management of natural resources.

NDWI = (Band 2 – Band 4)/(Band 2 + Band 4)

III.7. Results and discussions

Producing maps of water surfaces in a watershed is vital for examining and modeling their roles in hydrological systems. However, accurately and efficiently extracting these surfaces presents a significant challenge due to the spatial diversity of Earth's features. Remote sensing, with its spatial and temporal capabilities and its comprehensive perspective, emerges as a powerful tool for addressing these challenges.

The subsequent maps depict the variations in surface water across different dates.

month	j	f	m	a	m	j	j	o	s	o	n	d
water surface (km²)	130.6014	120.5754	229.7246	187.9249	39.97654	28.75589	25.6749	19.56183	29.9296	62.85215	96.79231	116.6084
eva (mm)	24	35	55.7	88.18	130.16	172	182.2	168.3	130	84.1	47.6	32.6
tem (C°)	10.6	13.6	17.2	21.1	26.6	34.4	34.8	34.5	32.3	24.9	17.9	15.2
pre (mm)	11.9	3.6	8.3	7	2.2	0.4	0.3	2.1	6.4	5.4	5.1	4.9

Table III. 1: surface water and climatic factors of chott meroune

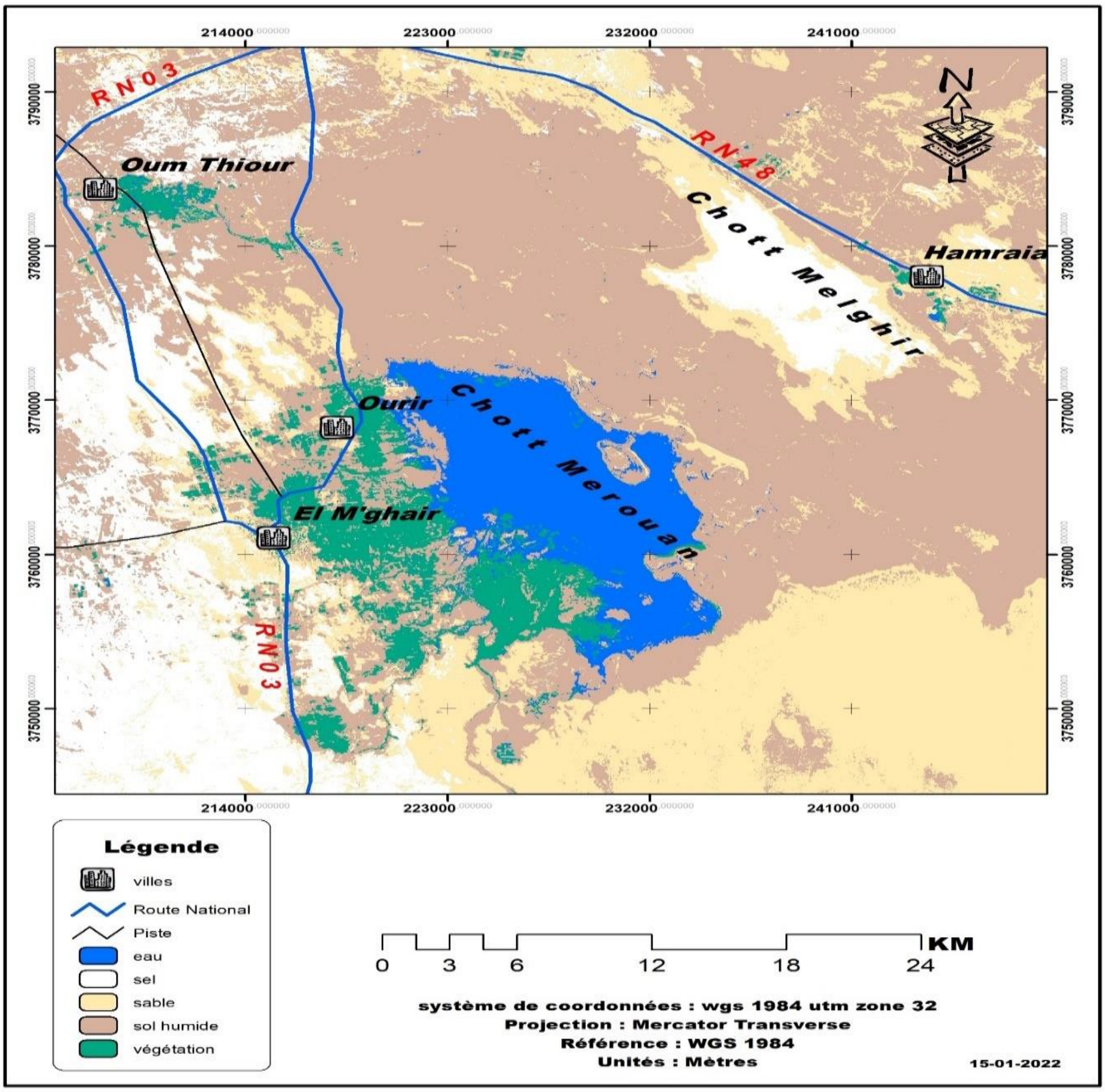

Figure III. 2: land cover in chott merouane January 2022.

Surface water levels are observed to be elevated, attributed to last year's rainfall, drainage from the Oued Righ canal, groundwater discharge, and reduced temperatures and evaporation. Moderate precipitation has significantly contributed to the increased surface water formation.

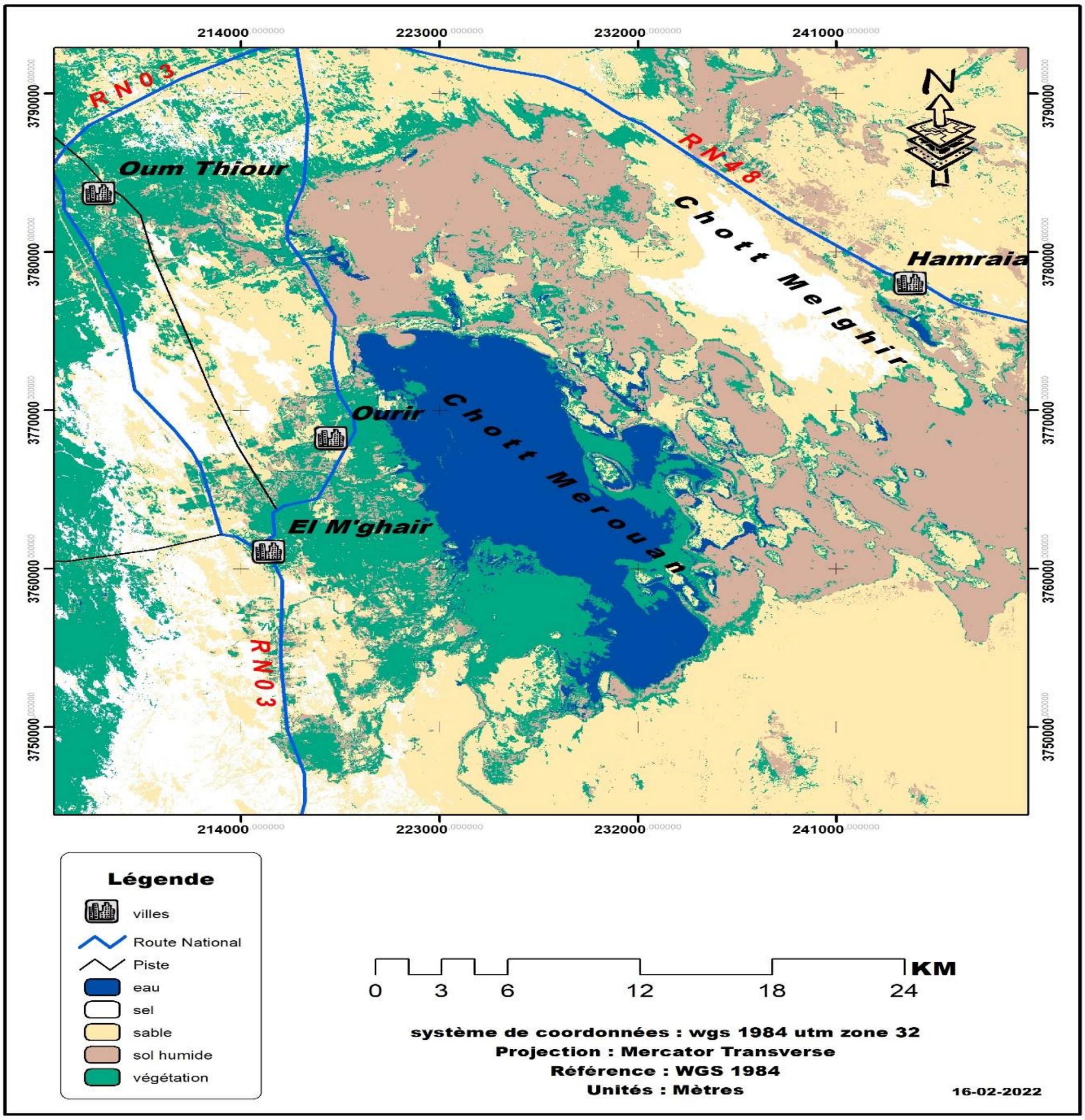

Figure III. 3: land cover in chott merouane february 2022

Surface water has decreased by 11%, primarily due to rising temperatures and increased evaporation, coupled with reduced precipitation.

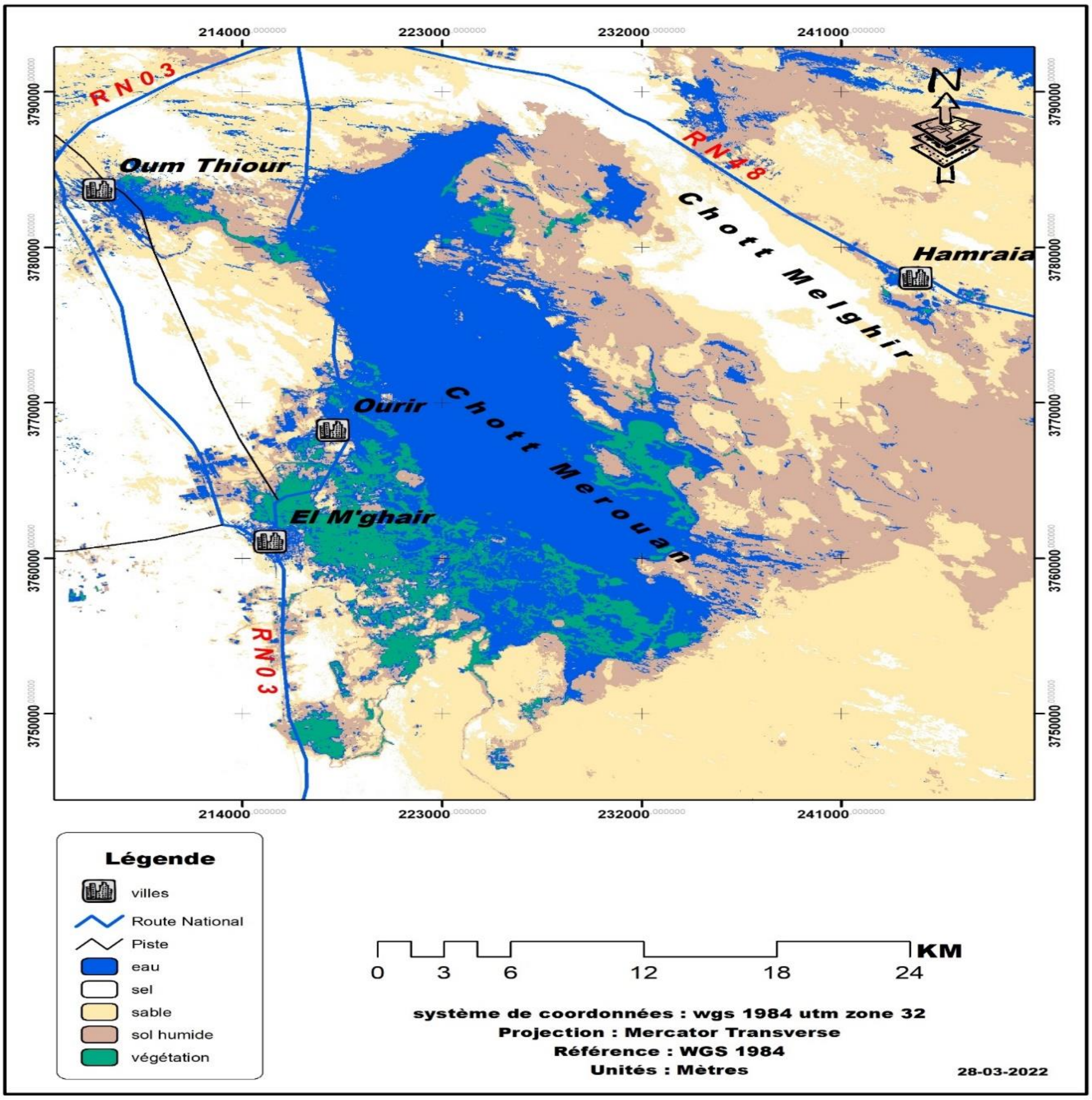

Figure III. 4: land cover in chott merouane march 2022

Surface water has seen a 51% increase, attributed to higher precipitation levels and substantial drainage from agricultural activities, coupled with moderate temperatures.

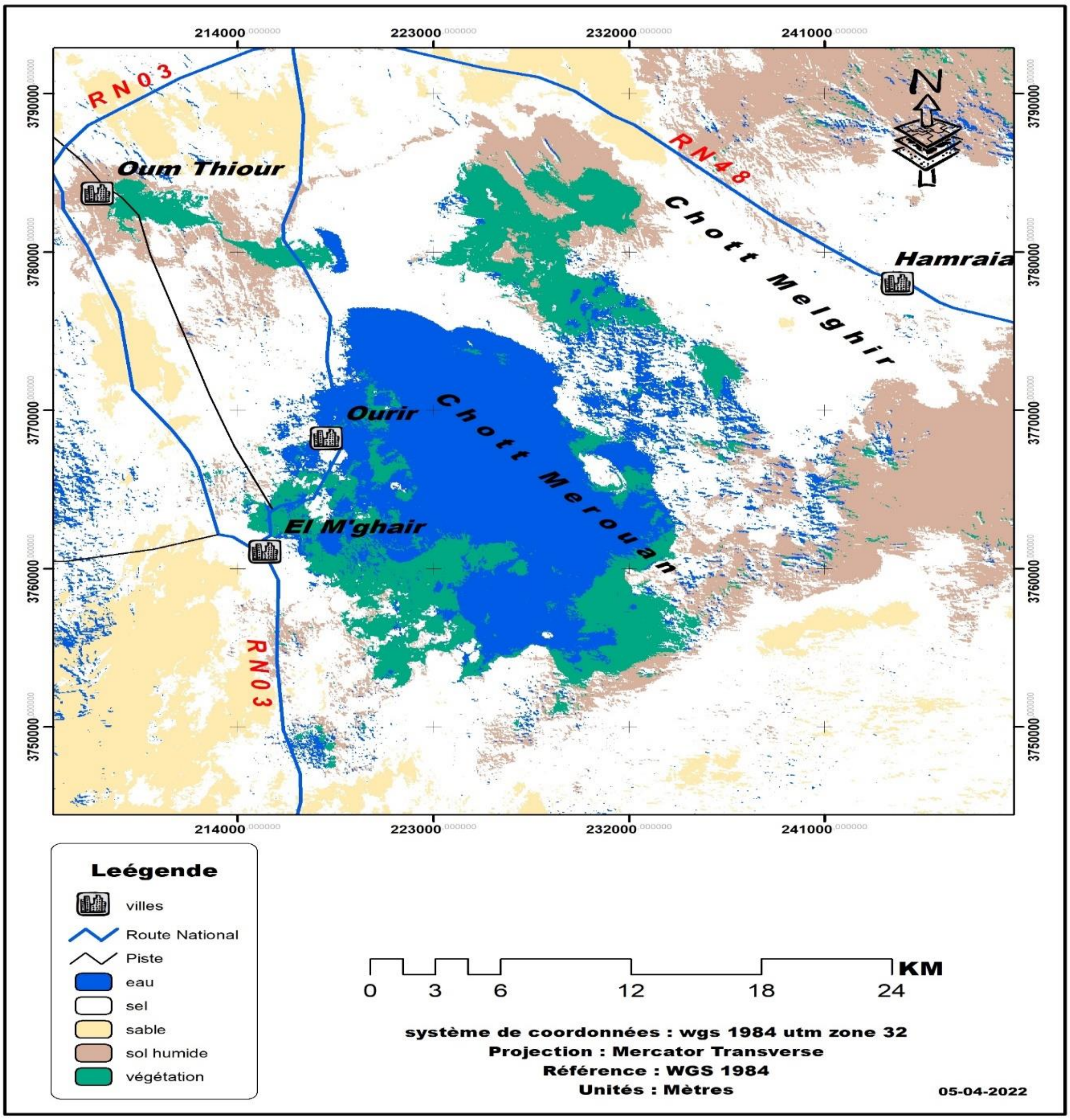

Figure III. 5: land cover in chott merouane april 2022

Surface water has decreased by 12% due to reduced precipitation, higher temperatures, and increased evaporation.

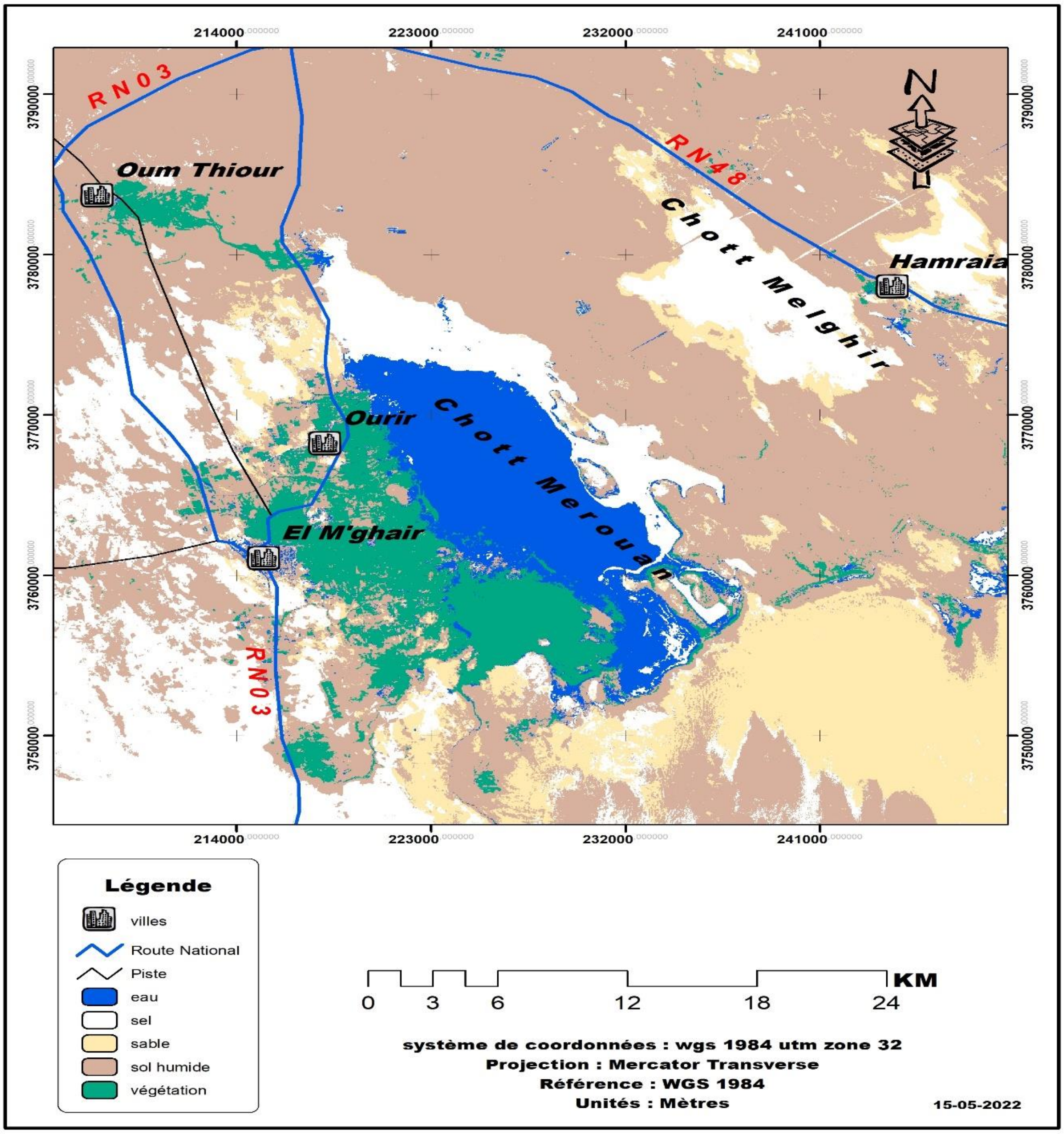

Figure III. 6: land cover in chott merouane may 2022

A 47% decrease in surface water is attributed to reduced precipitation and a significant rise in temperature associated with the onset of the summer season

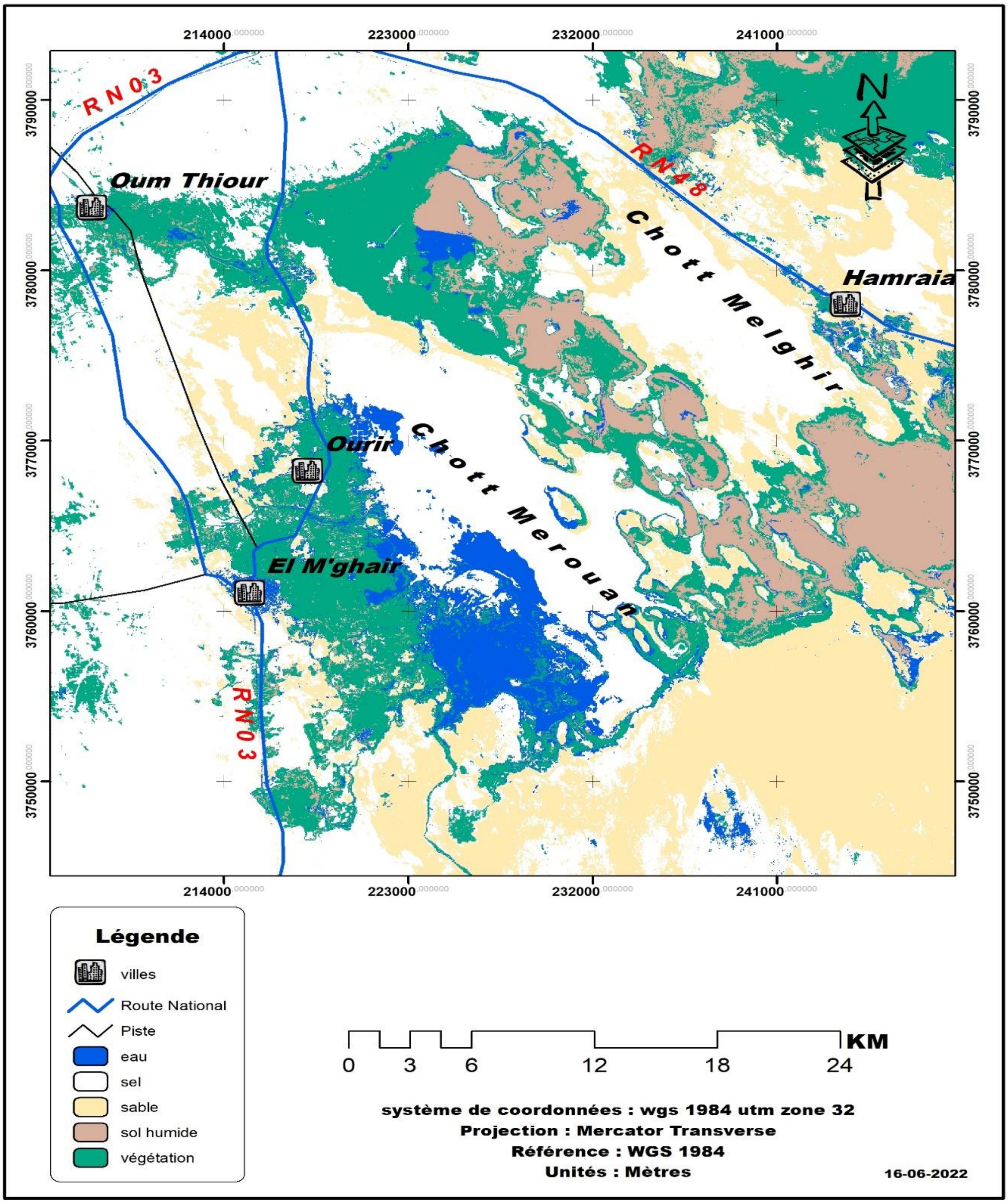

Figure III. 7: land cover in chott merouane june 2022

Surface water decreased by 12% due to higher temperatures causing increased evaporation compared to May, coupled with reduced precipitation, resulting in a decrease in surface water levels.

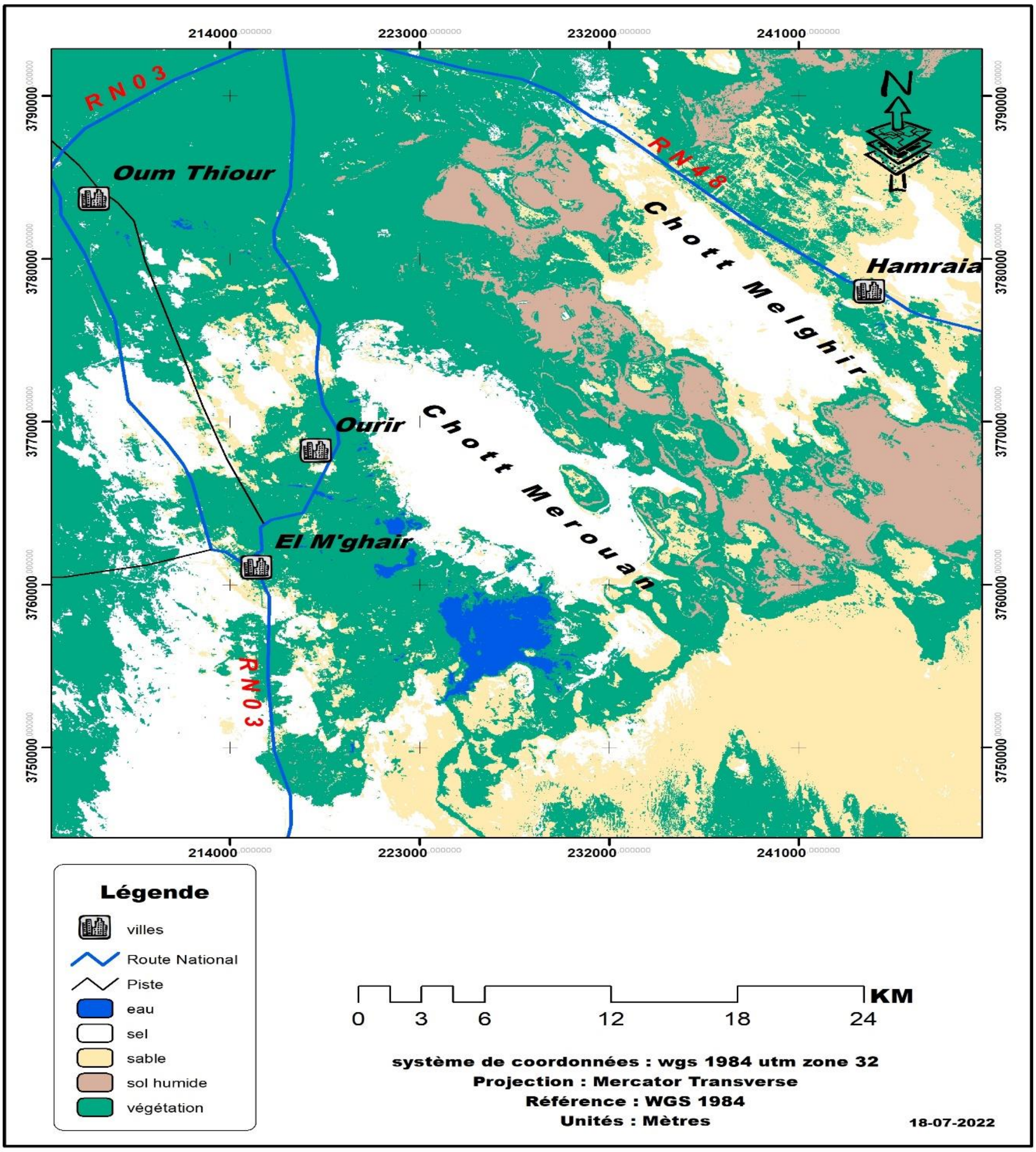

Figure III. 8: land cover in chott merouane july 2022

The surface water area decreased by approximately 10.7%. This decline is attributed to the increased heat causing higher evaporation rates, resulting in water loss. Moreover, insufficient precipitation failed to compensate for the water lost through evaporation.

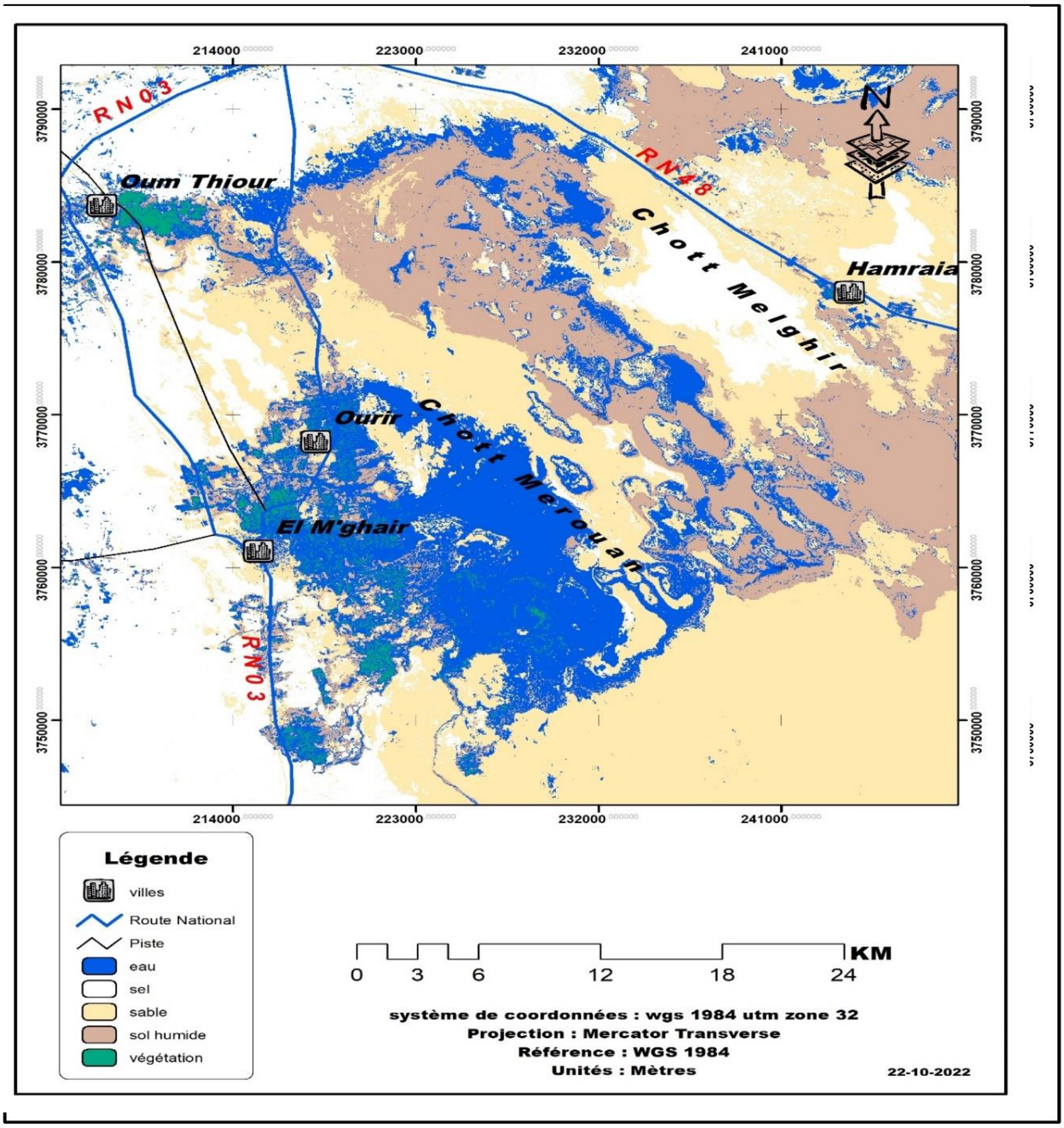

Figure III. 9: land cover in chott merouane august 2022

Surface water decreased by 11% due to high temperatures causing increased evaporation, coupled with low precipitation. Despite this decrease, surface water persists due to continuous drainage, groundwater, and occasional rainfall.

Figure III. 10: land cover in chott merouane september 2022

Surface water increased by 6% due to precipitation in September and a slight decrease in temperature, leading to reduced evaporation.

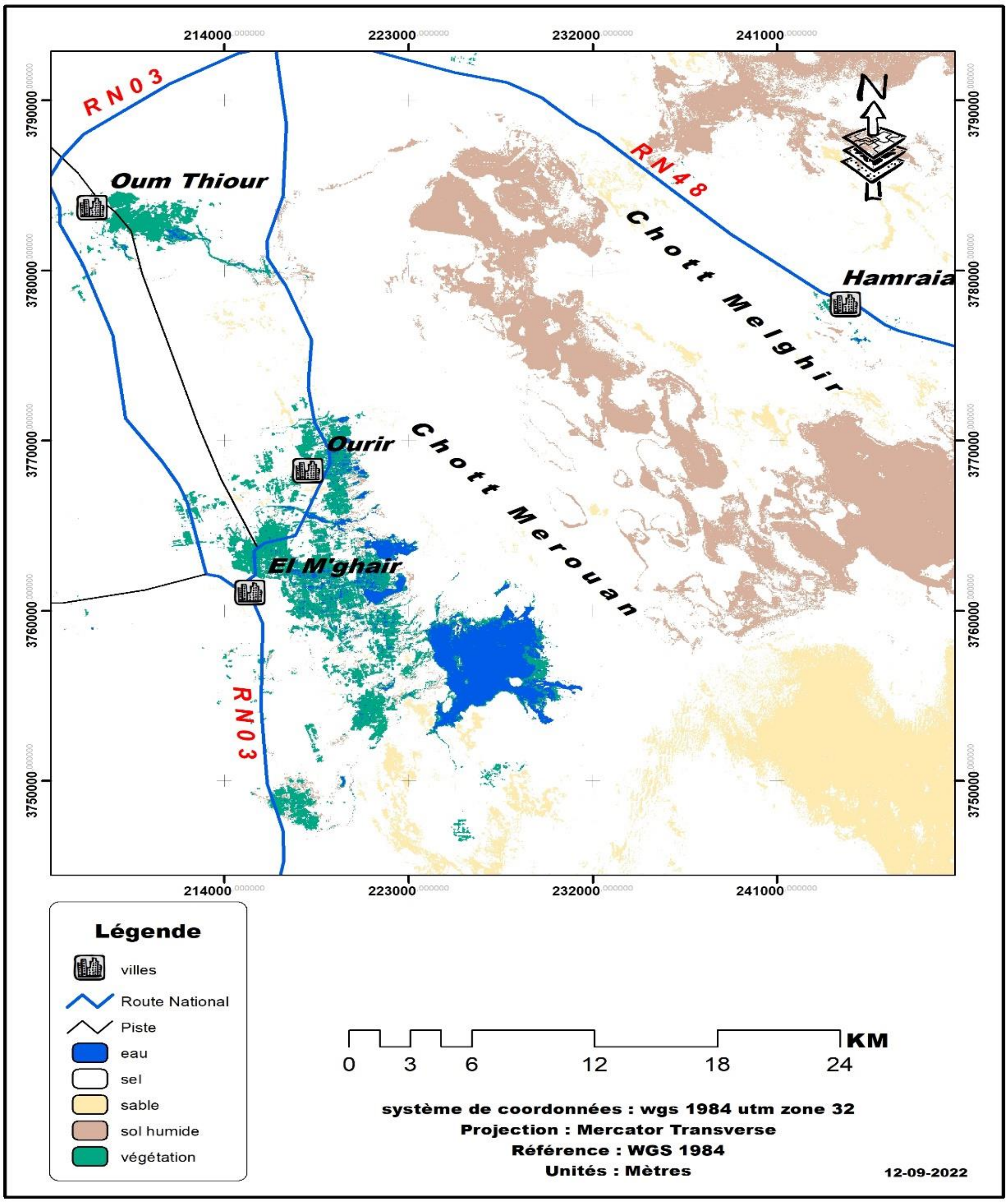

Figure III. 11: land cover of chott merouane october 2022

Surface water in Chott Merouane increased by 40% due to lower temperatures, which resulted in reduced evaporation.

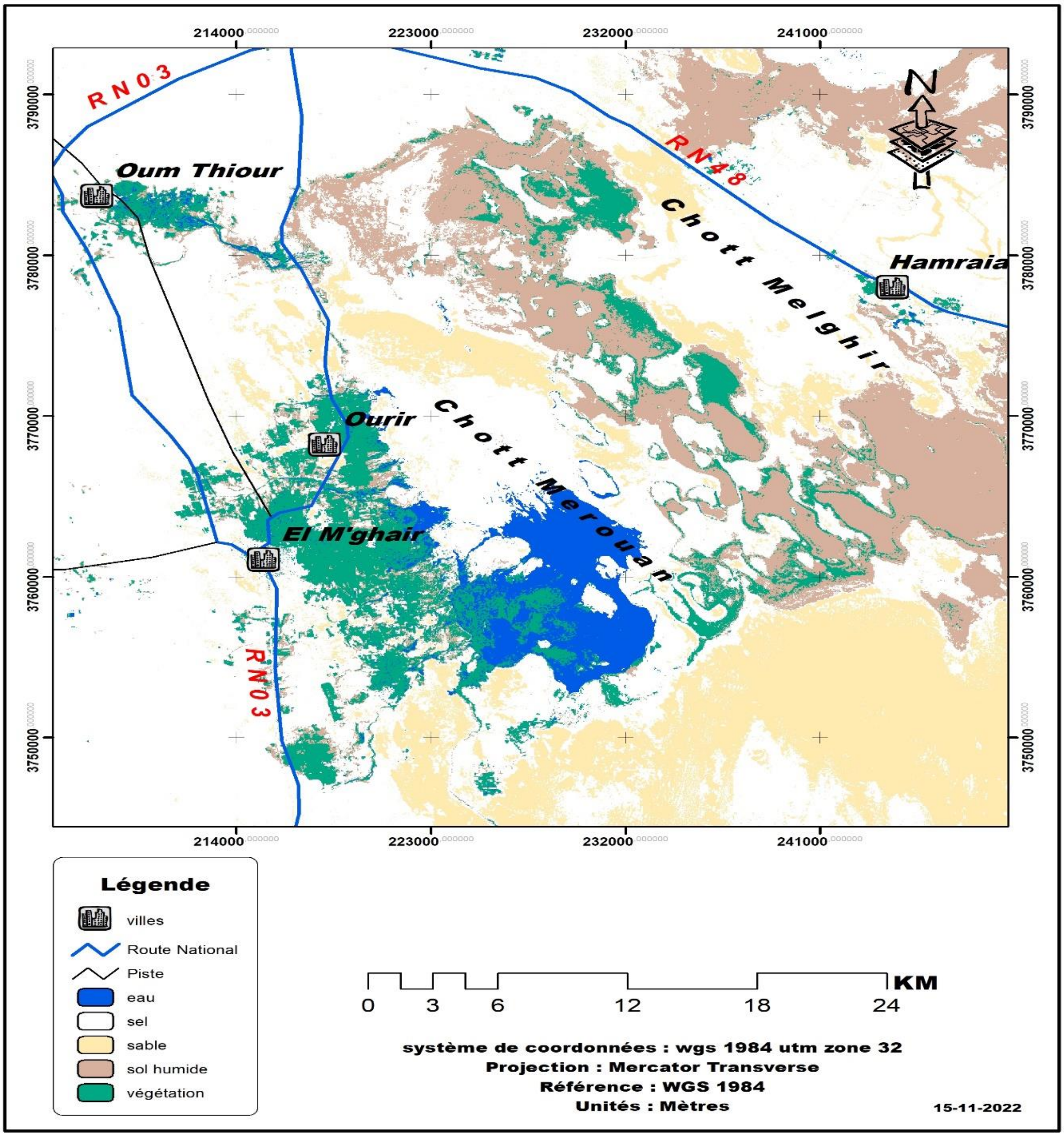

Figure III. 12: land cover of chott merouane november 2022

Surface water in Chott Merouane has increased by 57%, primarily because of lower temperatures resulting in reduced evaporation, along with a slight uptick in precipitation.

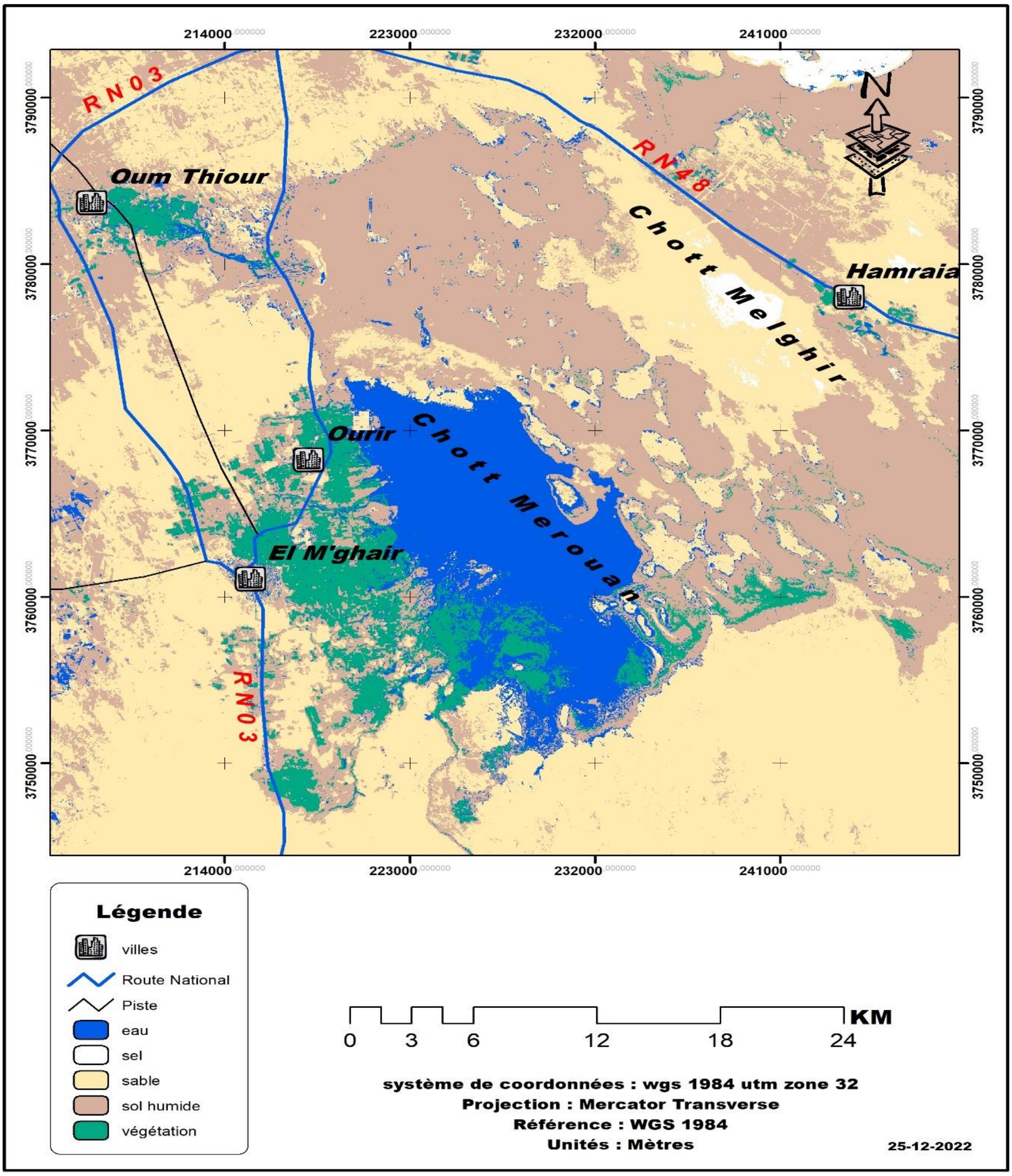

Figure III. 13: land cover of chott merouane december 2022

Surface water has increased by 20.4% due to lower temperatures, resulting in reduced evaporation, coupled with a slight increase in precipitation.

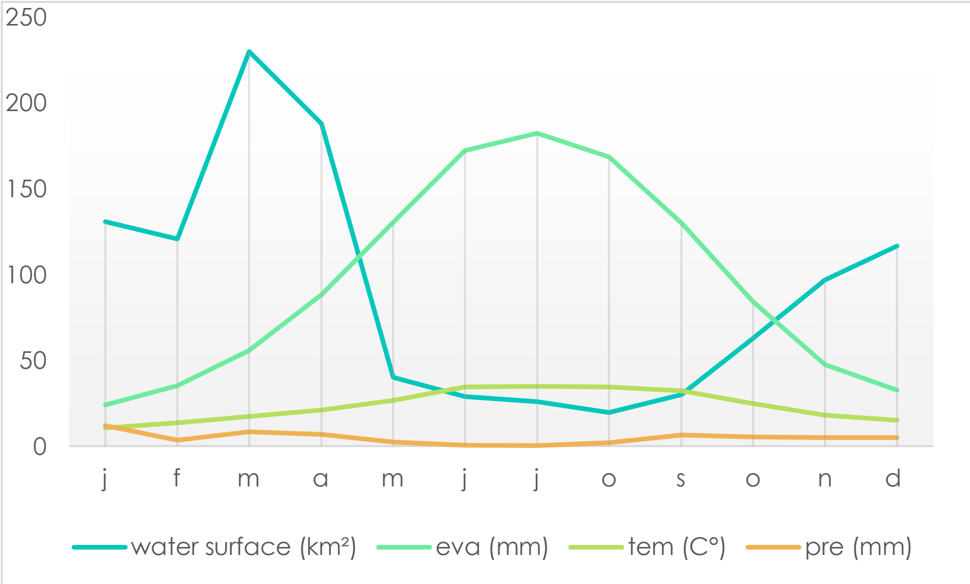

Figure III. 14: curve of water level and climatology of chott merouane

the graph demonstrates how temperature, evapotranspiration, and precipitation influence water surface levels. Higher temperatures lead to increased evapotranspiration, resulting in lower water surface levels. Precipitation can partially offset these effects, but overall, the water surface level is most sensitive to changes in temperature and evapotranspiration.

CONCLUSIONS

Conclusions GENERAL

Remote sensing is a technique for acquiring information about objects by analyzing data collected by instruments not in direct contact with those objects. In this context, our focus is on extracting high-resolution satellite images from Landsat 8 .

Our approach involves using high spatial resolution multispectral satellite images, specifically Landsat 8 OLI multispectral images, which are available for free download from the U.S. Geological Survey (USGS) website. Our first step was selecting the data acquisition period to avoid atmospheric disturbances, choosing the period from January to December for downloading the images. These images underwent preprocessing using ENVI software.

Subsequently, land cover classification was performed into five categories: vegetation in a broad sense, water surfaces, urban fabric, bare soils, and agriculture that is partially or completely bare. However, these categories do not fully reflect the high rates of soil erosion due to water, possibly because this cover is widely dispersed and does not provide effective protection. Extraction of water surfaces is possible with a multispectral satellite image. Surface areas are estimated on maps that appear in reality. The margin of error does not exceed 2%.

We finally conclude that satellite imagery can effectively contribute to extracting surface water features. The repetitive nature of spatial images allows for temporal studies of surface water bodies (such as sedimentation, degradation, etc.). This technique provides us with significant time and effort savings.

Appendices (Photos taken in the study area)

References

Reference

- **Hacini,M (2006)** Géochimie des sels et des saumures du chott Merouane et calcule des vitesses de précipitation de quelques minéraux évaporitiques,Thèse de doctorat
- **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 Doctorat, Université Joseph Fourier-Grenoble 1, France
- **BOUANANI WARDA .; BENYAHIA FATIMA ZAHRA.** SIMULATION SPATIO-TEMPORELLE PAR IMAGERIE LANDSAT8 : CAS DE LA GRANDE SEBKHA D'ORAN 2015
- **Amri, K.; Rabai, G.; Benbakhti, I.M.; Khennouche, M.N.** Mapping geology in Djelfa District (Saharan Atlas, Algeria), using Landsat 7 ETM+ data: An alternative method to discern lithology and structural elements. Arab. J. Geosci. Vol. 2017
- **Zatout, M., Hacini, M., Hamzaoui, A.H., M'nif, A., 2017.** Sequence crystallization during isotherm evaporation of southern Algeria Chott Baghdad natural brine. J. Fundam. Appl. Sci.,.
- **Djamil D., Mohamed K., 2013**. Extraction des différents indices de végétation à partir des images satellitaires,
- **Kadri M., M.** Étude géochimique comparative des deux cycles géochimique dans les zones désertiques (Cas du chott Merouane) (2012)., Thèse de Magister, département de sciences de la terre et de l'univers, université d'Ouargla,
- **GUETTAIA Sabrine. ;** Etude de la relation Chott Merouane /Nappe du Mio-Plio-Quaternaire et son impact sur la qualité des eaux souterraines 2017
- **CHEKCHEK Amira ;FENNOUH Zeyneb.** Détection Et Extraction Des Surfaces D'eau A Partir Des Données Spatiales Cas Du Bassin Versant Côtier Constantinois Ouest
- **Ben hamida. R., & Talbi. E., 2003-2004**. Bilan Hydrique de la vallée d'Oued Righ. Mémoire d'ingénieur, spécialité: hydraulique saharienne. Univ. Ouargla, 97p.

References

- **Bettahar, 2013.** Aspects qualitatifs des eaux de la region de Touggourt (nappes du complexe terminal et Continental intercalaire) Sud-est de l'Algérie, Mémoire de Master en géologie, Université Kasdi Merbah Ouargla
- **Hacini M., Kherici N., Oelkers E.H., 2010**. Le lithium dans les lacs salés des régions désertique ; cas du chott Merouane sud-est de l'Algérie ; comportement, origine, potentialités et perspectives. Bulletin du Service Géologique National,
- **Demnati F., 2012**. Biodiversité et Enjeux Socioéconomiques des lacs salés (Chotts et Sebkhas) d'Algérie. Cas du Chott Merouane et Melghir, Thèse de doctorat en Sciences Agronomiques,
- **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 Doctorat, Université Joseph Fourier-Grenoble 1, France,
- **Demnati F., Allache F., Ernoul L., Samraoui B., 2012**. Socio-Economic stakes and perceptions of wetland management in an arid region: a case study from ChottMerouane,

Sites used ; - http://earthexplorer.usgs.gov

- https://rsis.ramsar.org/