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TOPIC

Use of modeling for integrated management of water resources in the Ouargla region.

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ملخص:

تأدي العوامل المختلفة "طبيعة المنطقة، النمو الديموغرافي والمناخ" الى حالة غير مستقرة للموارد المائية في حوض ورقلة، هنا يأتي دور إدارة الموارد المائية في وضع منهجية لتوفير كمية المياه وتحديد النوعية المناسبة لمختلف القطاعات (الاستعمال المنزلي الزراعة والصناعة). ومن اجل ذلك سنقوم بدراسة العرض والطلب من أجل تسهيل إدارة الموارد المائية المتاحة للحد من الاستهلاك المفرط للمياه، مع الأخذ في الاعتبار طبيعة المنطقة والمشاكل التي تواجهها، وتوزيعها بشكل منهجي على القطاعات التي تحتاج إلى كميات كبيرة من المياه، وخاصة القطاع الزراعي تطور وتوزيع المساحات الزراعية والمسطحات المائية خلال السنوات سنقوم بتتبع ثم بعد ذالك باستعانة برموز برمجية الماضية وتحديد ما إذا كانت في ازدياد أم في انخفاض ومقارنتها باستهلاك المياه في الجزء الأول من درستنا.

كلمات مفتاحية: إدارة الموارد المائية، العرض والطلب، تتبع تطور، رموز برمجية،قوقل ارث انجن

Summary:

Various factors (the nature of the region, demographic growth and climate) lead to an unstable state of water resources in the Ouargla Basin. Here comes the role of the Water Resources Department in developing a methodology for providing the quantity of water and determining the appropriate quality for the various sectors (domestic use, agriculture and industry).

For this reason, we will study supply and demand in order to facilitate the management of available water resources to reduce excessive water consumption, taking into account the nature of the region and the problems it faces, and distribute it systematically to sectors that need large quantities of water, especially the agricultural sector.

Then, using software codes, we will track the development and distribution of agricultural areas and water bodies over the past years and determine whether they are increasing or decreasing and compare them to water consumption in the first part of our study.

Keywords: water resources management, supply and demand, tracking development, software codes

Résumé :

Divers facteurs (nature de la région, croissance démographique et climat) conduisent à un état instable des ressources en eau dans le bassin de Ouargla. D'où le rôle du Département des Ressources en Eau dans l'élaboration d'une méthodologie pour fournir la quantité d'eau et déterminer la quantité appropriée. qualité pour les différents secteurs (usage domestique, agriculture et industrie).

Pour cette raison, nous étudierons l'offre et la demande afin de faciliter la gestion des ressources en eau disponibles pour réduire la consommation excessive d'eau, en tenant compte de la nature de la région et des problèmes auxquels elle est confrontée, et la distribuer systématiquement aux secteurs qui en ont besoin en grande quantité. de l'eau, notamment dans le secteur agricole.

Ensuite, à l’aide de codes logiciels, nous suivrons l’évolution et la répartition des zones agricoles et des plans d’eau au cours des dernières années, déterminerons si elles augmentent ou diminuent et les comparerons à la consommation d’eau dans la première partie de notre étude.

Mots clés : gestion des ressources en eau, offre et demande, suivi du développement, codes logiciels

Dedication:

In the name of God, the Most Gracious, the Most Merciful. As for what follows: This dream could not have come true thanks to God's success, satisfaction, prayers, support, and assistance from my mother and father, and the prayers and support of my brothers {Yassin and his wife Majda, Wafa, Abd el Hakim, Wala} and of course we do not forget to mention my beloved little ones { Awab and Maryam} and the support of my good friends

Thanks:

Praise and thanks be to God always and forever for giving us the courage, will, and patience throughout our project.

We would first like to thank{Mr. Zduri Aziz}, the supervisor of the memorandum, for his patience in supervising us and his tireless efforts in providing such suggestions and guidance that helped us in completing this memorandum.

We also thank the jury members who agreed to read

And to evaluate our memorandum, which will contribute to giving it new momentum through their advice and critical comments.

We would also like to express our sincere thanks to everyone and those who contributed directly or indirectly to the development of these humble memoirs.

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Code List:

code In English / French	***meaning***
IWRM / GIRE	***Integrated Water Resources Management.***
SHBA /ABHS	***Sebou Hydraulic Basin Agency.***
NAHR /ANRH	***National Agency for Hydraulic Resources.***
T.C / C. T	***Terminal Complex.***
C.I	***Continental Interlayer.***
NBM / ONM	***National Bureau of Meteorology.***
NOC / ONA	***National Office for Cleansing***
GEE	***Google Earth Engine***
NDVI	***Normalized Difference Vegetation Index***
NDWI	***Normalized Difference Water Index***
NIR	***Reflectance value in the near-infrared spectrum.***
Red	***Visible red light reflected by the vegetation.***
SWIR	***Reflectance value in the short-wave infrared spectrum.***
Green	***Reflectance value in the green spectrum.***

General introduction

INTRODUCTION GENERALE

Water resources are a major concern in dry or semi-dry countries. They are crucial to the development of human, economic and social activities and as population and urbanization increases.

and the increases in industrial units and farm land have resulted in the degradation of groundwater and surface water quality and quantity, combined with a very significant decline in the groundwater resources, the only water reserves for the supply of populations.

For this reason, several methods have been followed in order to preserve this resource and One of the most important of these methods is:

- Integrated Water Resources Management (IWRM)
  Integrated Water Resources Management (IWRM) is an approach aimed at coordinating and harmonizing the use, protection, and conservation of water resources. This approach acknowledges that water is a finite and vulnerable resource, and that it is interconnected with various social, economic, and environmental aspects.

Here are some key elements of Integrated Water Resources Management:

1. **Holistic Approach**: IWRM considers the entire water cycle, from its extraction from sources to its reuse or return to the environment. It also examines the interactions between different water uses and economic, social, and environmental sectors.
2. **Stakeholder Participation**: IWRM encourages active participation of stakeholders, including governments, local communities, farmers, businesses, and environmental groups, in decision-making regarding water resources management.
3. **Adaptive and Flexible Approach**: Given natural variability and climate change, IWRM promotes an adaptive and flexible approach that can be adjusted based on changing conditions and new information.

4. **Basin-based Management**: Water resources management is often organized at the basin level because basins represent natural units of management and take into account interactions between different water uses in a given geographical area.
5. **Multiple Objectives**: IWRM recognizes that water has multiple uses, such as providing drinking water, agricultural irrigation, hydroelectric power production, navigation, environmental protection, etc. It seeks to balance these different needs equitably and sustainably.
6. **Data-driven Decision-making**: IWRM relies on scientific data to inform decision-making. This may include hydrological monitoring, analysis of climate trends, environmental impact assessments, etc.

In this context, this study that we will conduct consists of creating a digital model that will help in better and better management of the water resources of the state of Ouargla and proposing solutions to the problems of water management.

The Ouargla basin is located in the Algerian Sahara. It occupies the most central fringe of the lower Sahara, included in the great depression of the Oued M'ya fossil valley, it extends over an area of 990 km². The study area is part of the Northern Sahara aquifer system, which contains a significant reserve of groundwater, stored in two large aquifer layers superimposed those of the Terminal Complex (T.C) and the Continental Interlayer (C.I)

The main goal of this project is to create a model that enables us to better manage water resources, provide solutions to the problems raised (water scarcity and quality problems), and propose better scenarios for future projects within the framework of water management.

In order to respond to these concerns and achieve our resource management objectives in the study area, the work is spread over four chapters, preceded by an introduction and followed by a general conclusion.

Chapter 1: deals with generalities on water management.

Chapter 2: presents the main aspects and characteristics of the Ouargla region useful for understanding the ecosystem, namely: the geographical location of the study area, the population, the geology, the exploitation of aquifers.

Chapter 3: This chapter demonstrates the methodology followed.

Chapter 4: Study supply and demand and create maps using NDVI and NDWI code.

CHAPTER I:

GENERAL INFORMATION ON WATER RESOURCES MANAGEMENT

I. Introduction:

Effective and sustainable water management is a complex operation, which requires a new approach to improve the water situation of countries and thereby achieve sustainable development which takes into account the policies and conventions adopted at the international level. Any approach cannot succeed without taking into consideration the interests of all stakeholders and the needs of a state in terms of effective management of water resources.

The increase in demand for water while resources are limited, and sometimes non-renewable, and the emergence of new lifestyles and new industries have resulted in excessive water consumption. Likewise, the problem becomes more complex when it comes to countries sharing the same resource or the same watercourse. Competition for water is increasingly fierce between the city and the countryside, between the agricultural, industrial and also tourist sectors.

In addition, galloping population growth, increased urbanization and industrialization have resulted in increased demand for water. Furthermore, desertification, environmental pollution, the negative impact of climate change (drought, flooding) is beginning to ravage large areas of the world; knowing that water resources have undergone profound modifications on the quantitative and qualitative level, and have hampered watercourses and storage places (dams; lakes; underground aquifers) which has had a negative impact on the security of the water supply.

Optimal management of water resources is the appropriate choice to address this very important problem. Indeed, without optimal use of water we cannot meet the water needs of all sectors.[1]

II. The importance of legislation in the management of water resources:

Optimal management of water resources is based on fundamental, modern regulations and practical measures, knowing that the main problems that hinder this management lie in the multiplicity of stakeholders in the water field, the lack of coordination and the shortcomings recorded at the level of certain laws in force, notably those relating to the protection of water resources and the fight against pollution.

III. Integrated water resources management:

Faced with the growing increase in needs in relation to the relatively limited available resources, and the incessant pollution of these surface and underground resources, the need for a global water policy arises from conflicts of use within countries and between border countries.

We must therefore opt for integrated and sustainable management of water resources, taking into account the facts that water is a “heritage asset” and a “heritage asset”.

source of life ". In this sense, the management of water resources, in addition to technical aspects, must integrate political, economic and social dimensions.

Water, in addition to its essential role for life, carries and transports domestic, agricultural and industrial waste which are the main elements of pollution. This pollution reduces downstream water use and threatens public health and aquatic ecosystems. These problems are compounded by the absence of effective management systems. On the one hand, sectoral approaches present fragmented and uncoordinated water resources management; on the other hand, water management is generally done according to a top-down pattern, that is to say from the top to the base. This is why the main problems arise from such inefficient management and not from the existence of a limited resource.

Integrated water resources management calls for coordinated management of all natural resources within the same territory. It is a fundamental element of sustainable development which requires involving actors from different sectors at the local and global levels. Consequently, integrated water resources management is a process promoting the coordinated development and management of water, land and resources.

related resources, with a view to maximizing, in an equitable manner, the resulting economic and social well-being, without compromising the sustainability of vital ecosystems.

Note that water resources planning based solely on the hydrological cycle and its modification presents a very uncertain basis for water resources planning. Consequently, the concept of integrated water resources management is safe and solid but difficult to apply. This concept is the subject of extensive consultation, forcing regional and national institutions to develop their own management practices.

integrated based on the participatory framework that is developing at the regional and global level.

IV. Objectives of integrated water resources management (IWRM):

The objectives of integrated water resources management (IWRM) are multiple the main ones of which are as follows (Burton, 2001).

- ✓ Empower women, men and communities to decide on their level of access to drinking water and hygienic living conditions, to choose the type of economic activities lending to the use of water that suits them and to organize to achieve it;
- ✓ Produce more food, design sustainable livelihoods per unit of water used (increased agricultural yield) and ensure that all people can obtain the food they need to live healthy and productive lives;
- ✓ Manage water use in order to conserve the number and quality of ecosystems.

V. National water plan:

It is a vast project initiated in 1992, financed by Europe and entrusted to a group of design offices, aimed to draw up an inventory of data, as complete as possible, on surface and groundwater and on the water demands. It was to define the main areas of investment in urban, industrial and agricultural water for the next two decades [2].

Established on the databases established in 1995, this plan requires permanent updating which has been entrusted to the river basin agencies. Since their creation, the basin agencies have been very interested in the use of modern means such as computerized cartography and the databases.

CHAPTER II:

PRESENTATION OF THE STUDY AREA

I. Introduction:

The Ouargla basin is an oasis in the middle of the Algerian desert. It occupies an important and strategic geographical location due to the diversity of its underground and surface riches.

This chapter is devoted to the presentation of our study area, while giving an idea of the geographical location, demography, identification of pedological and geomorphological characteristics of the soils, as well as geology; the hydrogeology and climatology of the region.[1]

II. Geographical setting:

The Ouargla basin is located in a depression in southeast Algeria, it occupies an area of 95,000 hectares, measuring 30 km long and 12 to 18 km wide. Its height is between 103 and 150 meters above sea level, it is bordered to the West by a plateau of 200 to 230 m altitude and to the East by a plateau less than 160 m above sea level. altitude, linked to the sands of the great oriental erg.

It is limited by the following States: (Boukhalifa,N and Hammya,H; 2016)

- ✓ To the North by the States of El Djelfa and El-Oued,
- ✓ To the East by the Tunisian Republic,
- ✓ To the West by the States of Ghardaïa,
- ✓ To the South by the States of Illizi and Tamanrasset.

Its natural boundary is marked by:

- ✓ Sebkhat Safioune in the North.
- ✓ the Touil and Arifdji to the east.
- ✓ the eastern slope of the Mzab ridge to the west.
- ✓ the dunes of Sedrata in the South. **(fig 1)**

It currently has 21 municipalities grouped into 10 daïras. It includes the towns of Ouargla, N'Goussa, Rouissat, Ain El Beida and Sidi Khoulied.

And extends between the coordinates (BG; 2004)

X= [710000 -730000] East

Y= [3530000 -360000] North

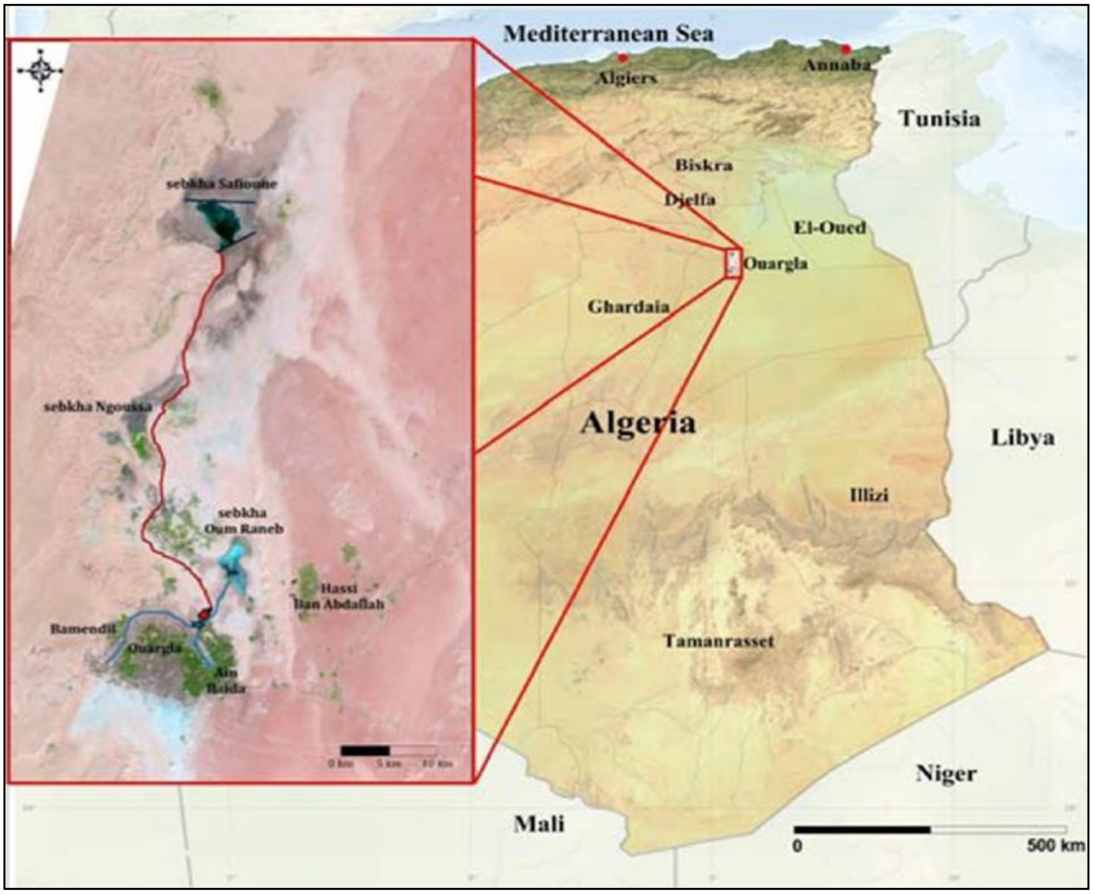


Fig. II.1: Location map of the study area [2]**.**

III. ***Population:***

The table below represents the trend population in the Ouargla region.

Table.II.1: Population of the Ouargla basin [3]**.**

Municipality	Ouargla	Ain Beida	N'Goussa	Rouissat	Sidi Khouiled	Total
Pop2020	169 870	27 562	22 460	100 973	21 561	342426
Pop2021	172 799	28 340	22 962	105 406	23 170	352677
Pop2022	175 674	29 122	23 463	109 960	24 885	363104
Pop2023	178 510	29 911	23 963	114 647	26 709	373740
Pop2024	181 284	30 704	24 461	119 455	28 649	384553
Estimates for the next five years						
Pop2025	184 012	31 500	24 956	124 391	30 713	395572
Pop2026	186 448	32 263	25 416	129 310	32 867	406304
Pop2027	188 843	33 029	25 874	134 346	35 152	417244
Pop2028	191 175	33 798	26 328	139 512	37 575	428388
Pop2029	193 439	34 569	26 778	144 793	40 142	439721
Pop2030	195 634	35 340	27 223	150 202	42 860	451259
rate of growth	1,42	2,52	1,94	4,05	7,11	3.4

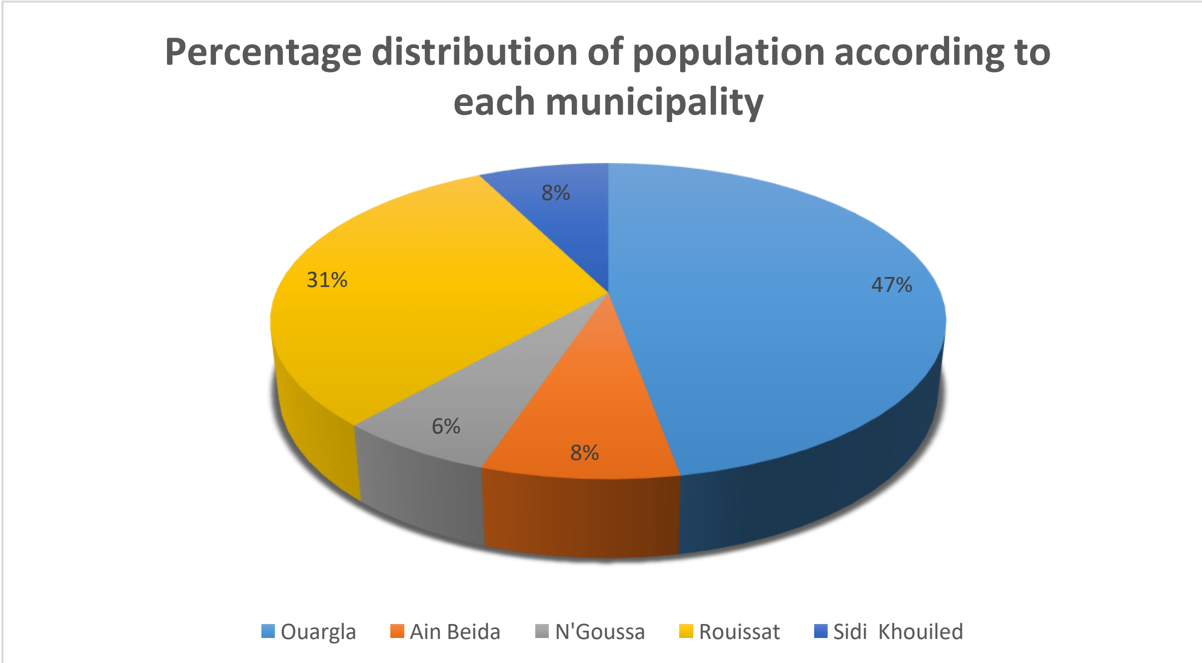


Fig. II.2: Percentage distribution of population according to each municipality.[4]

The population of the Ouargla basin increased from 373,740 inhabitants in 2023 to 384,553 inhabitants in 2024 with an increase rate of 3.4 %. The majority of the population is concentrated in the commune of Ouargla and Rouissant.

IV. Topography:

The study area is part of the Lower Sahara basin, it offers a low topography as its name indicates and constitutes a vast sedimentary basin.

We note the presence of three levels of main slopes:

- ✓ The slopes of 2‰ are located from the feet of DjabelAbbad to the bank of the Sebkha d'Ouargla.
- ✓ The slopes of 1.8‰ are located north of the Sebkha d'Ouargla, up to the N'goussa palm grove.
- ✓ The topography becomes practically flat from N'goussa to the banks of Sebkha Safioune, at a slope of 0.6‰ [5].

V. Geomorphology:

The region studied belongs to the Saharan sub-basin, we distinguish:

- ✓ Hamada Miopliocene: it is a detrital continental formation, which forms plateaus whose altitude varies from 180 m to 200 m.
- ✓ Sand formations: corresponding to dunes and erg cords.
- ✓ The three large Oueds which cross the Ouargla region are: Oued M'ya, Oued Rhir, and Oued Igherghert. **(fig.3.)**

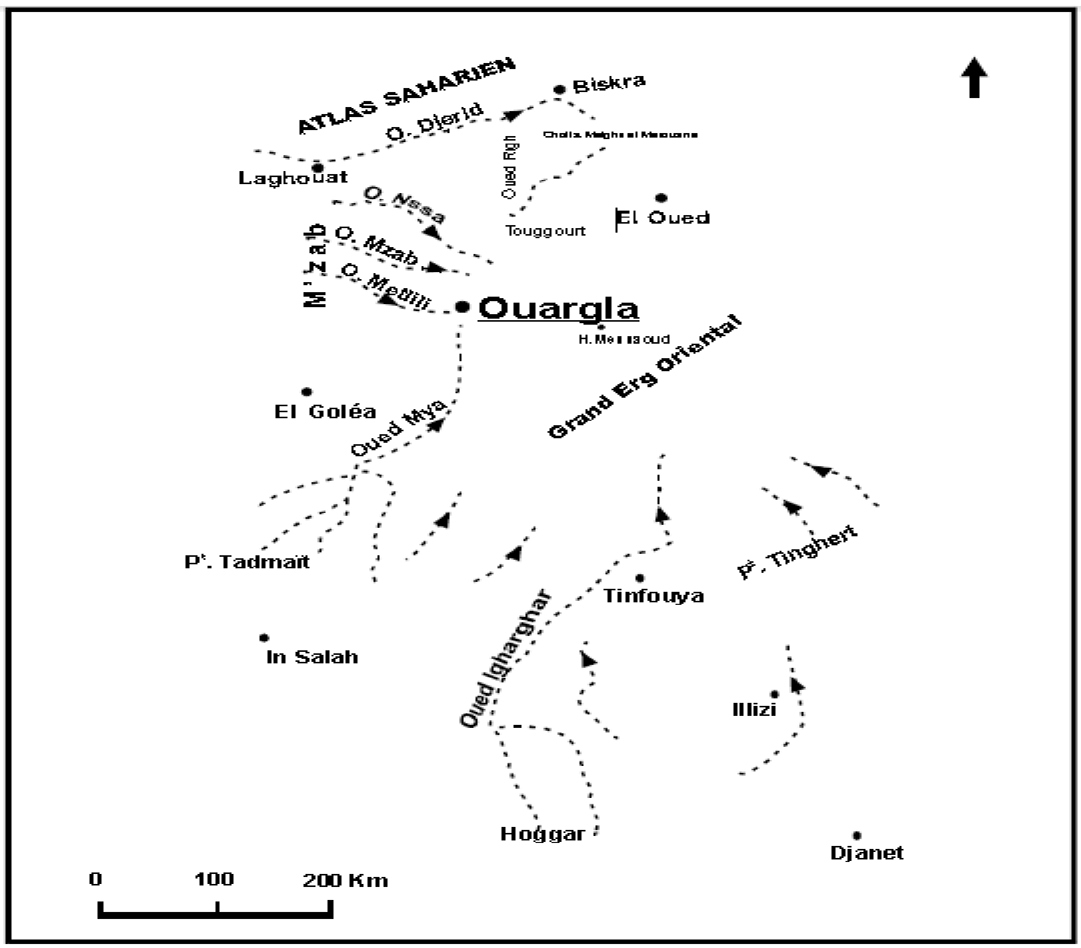


Fig. II.3: Hydrographic network of the Northern Sahara (Dubief, 1963).

VI. Pedology:

Soils in arid regions are classified according to the level of salts (HALITIM, 1988). In the chott, the surface deposit becomes abundant and a crust is then formed, sometimes made up of limestone, sometimes of gypsum and chlorides [6]

Saline and gypso-saline soils occupy most of the Aïn El-Beïda chott. The internal areas of the sabkha, like all the others, have the highest rate of saltiness.

VII. Geological setting:

In the Ouargla region, the Mio-Pliocene lands outcrop, they are covered by a small thickness of Quaternary deposit (ergs, dunes). The basin is dug into the continental formations of the Mio-Pliocene. These are red sands and soft sandstones with cross-stratification, with limestone nodules, interspersed with limestone or gypsum levels that can be seen outcropping on its eastern and western edges.

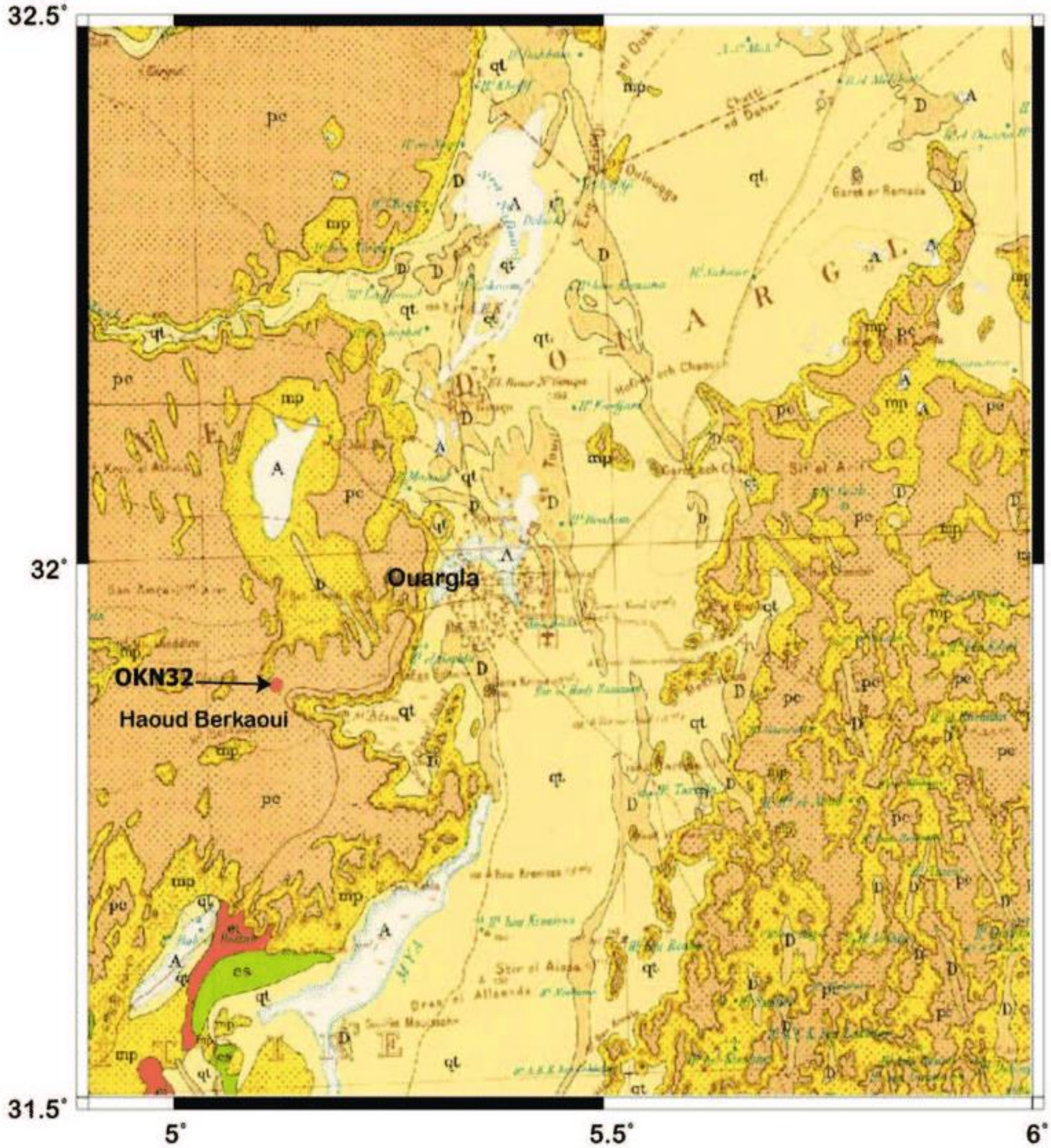


Fig. II.4: Geological map of the Ouargla basin.[7]

VIII. Stratigraphy:

- ✓ The stratigraphic series of the Ouargla basin is represented from bottom to top by the following formation:
- ✓ The sandstones and sandy clays of the Albian aquifer of the Continental Interlayer, with a thickness of approximately 600 m, located at a depth of 1000 m.
- ✓ Limestones, with the Senon-Eocene carbonate layer, 300 m thick, located at a depth of 200 m.
- ✓ The detrital ensemble (sands, clays, and evaporites) of the continental formations, with the Mio-Pliocene water table, located between 20 and 100 m deep and approximately 100 m thick.
- ✓ Quaternary sands with the surface layer, located at a depth of 2 m on average.

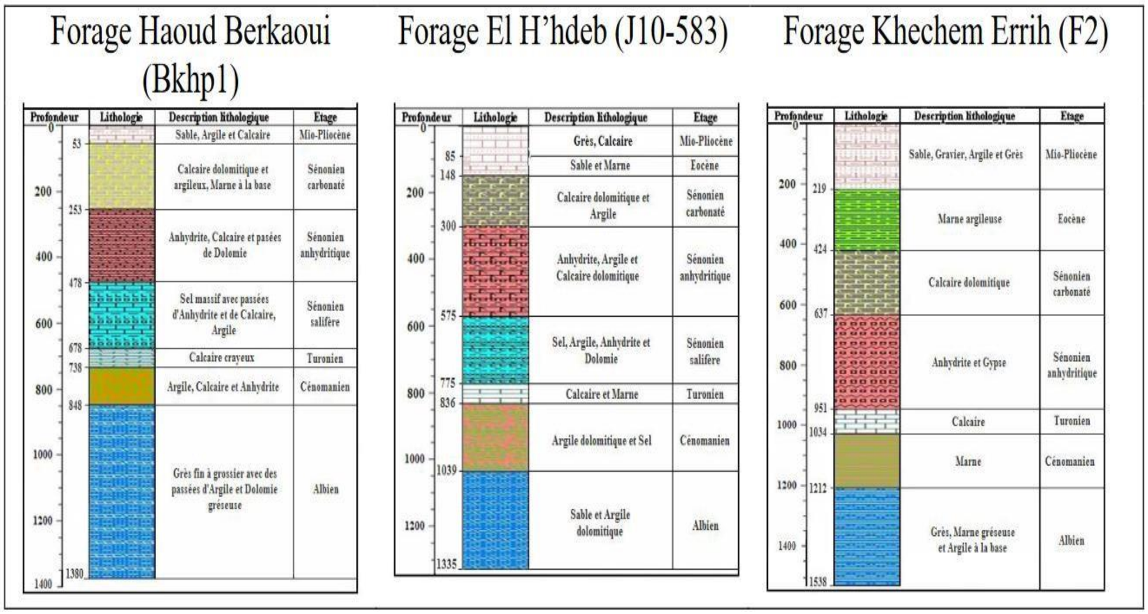


Fig. II.5: Stratigraphic litho logs of drillings across the Ouargla basin. [8]

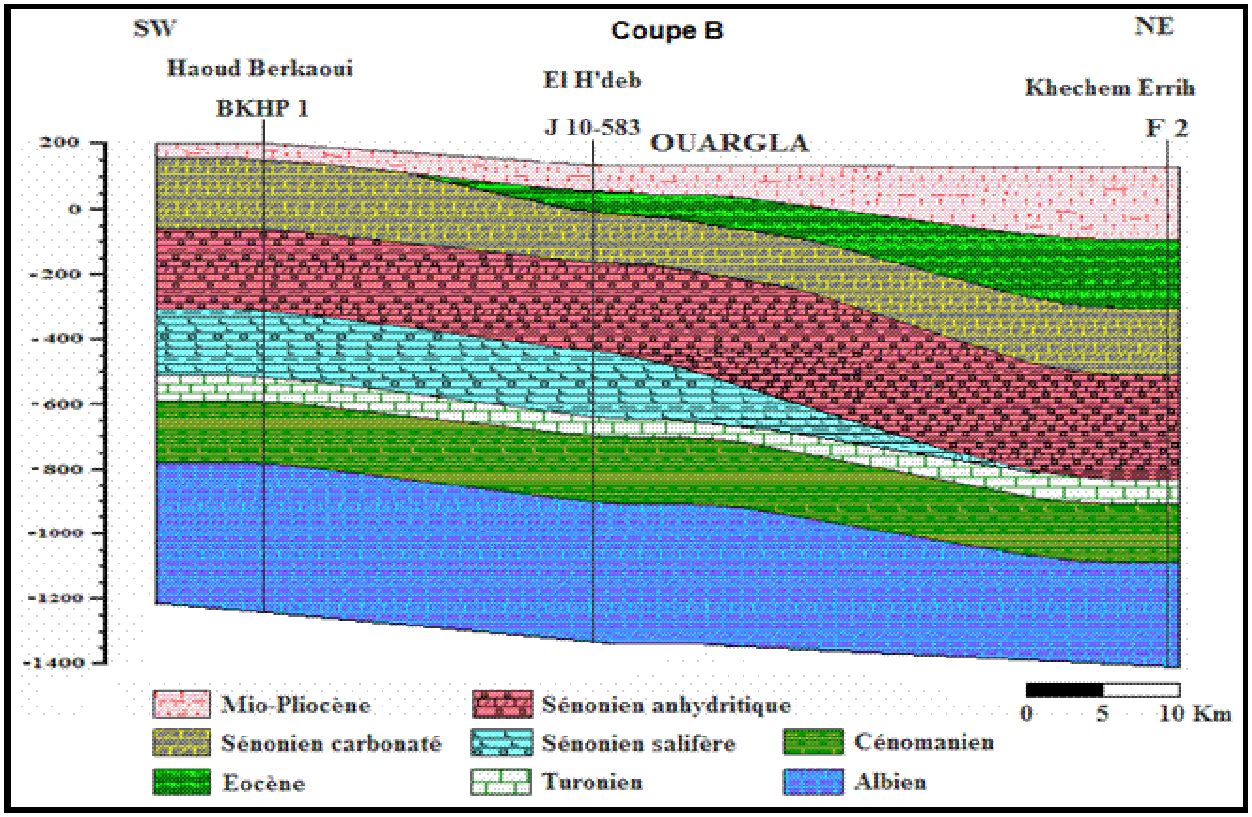


Fig. II.6: Geological section of the Ouargla basin established according to stratigraphic logs [9]**.**

A quasi-horizontal stratification. Regarding the lithology of each floor, it is noted as follows:

- ✓ The Albian is characterized by a great thickness (>400 m) in almost all the boreholes, it is marked mainly by detrital formations: sandstone, sand, sometimes clay and marl and very rarely limestone.
- ✓ The Cenomanian is characterized mainly by dolomitic clay formations, we sometimes find limestone, anhydrite and rarely salts, its thickness varies around 200 m.
- ✓ The Turonian appears in the form of limestone banks with a thickness not exceeding 100 m in most cases, sometimes chalky with marl.
- ✓ The Senonian is subdivided into three sub-stages, from bottom to top: the salt-bearing Senonian, the anhydritic Senonian and the carbonate Senonian (mostly dolomitic limestone), with a thickness of 200 m.

- ✓ The anhydritic Senonian, sometimes with limestones, clays, dolomites, its average thickness is around 240 m. The Saliferous Senonian is known for its massive salt, we sometimes find clays, limestones and anhydrite, the thickness of this formation is of the order of 200 m on average.
- ✓ The boundary between the Albian and the Senonian is remarkably thick because it is formed by the Cenomanian (≈180 m) which is an impermeable formation (clays and marls), so we can confirm the absence of any contact between the waters of the two aquifers.
- ✓ The Eocene, absent in the South (Berkaoui), is characterized by marls, anhydrite and sometimes sand at the top, called evaporitic Eocene (Lutetian), and limestones and dolomites at the top.
- ✓ base, called carbonate Eocene (Ypresian), at a relatively thin thickness in the center (50 m) and thick to the north of Ouargla (≈200 m).
- ✓ The Mio-Pliocene of the Ouargla region is formed by sands and sandstones and sometimes limestones and clays, the thickness of this formation is of the order of 75 m on average in the South (Berkaoui) and reaches the 250 m to the North (KhechemErrih). There may be contact between the two overlying layers: Mio-Pliocene and Senonian/Sénono-Eocene due to the absence of a clear impermeable boundary, water changes and chemical elements can be put in place.

*IX. **Hydrogeology:***

In the Algerian Sahara, the detrital and carbonate formations of the Meso-Cenozoic constitute the aquifers exploited for the various domestic, agricultural and industrial water needs. There is an aquifer system made up of three layers.

- ✓ A water table of more modest importance is added to the two previous sets.
- ✓ The Terminal Complex (T.C) aquifer: bringing together the Mio-Pliocene, Eocene and carbonate Senonian aquifers.
- ✓ The Continental Interlayer (C.I) aquifer: presents itself as a multi-layer aquifer of the Albian, Barremian and Neocomian.

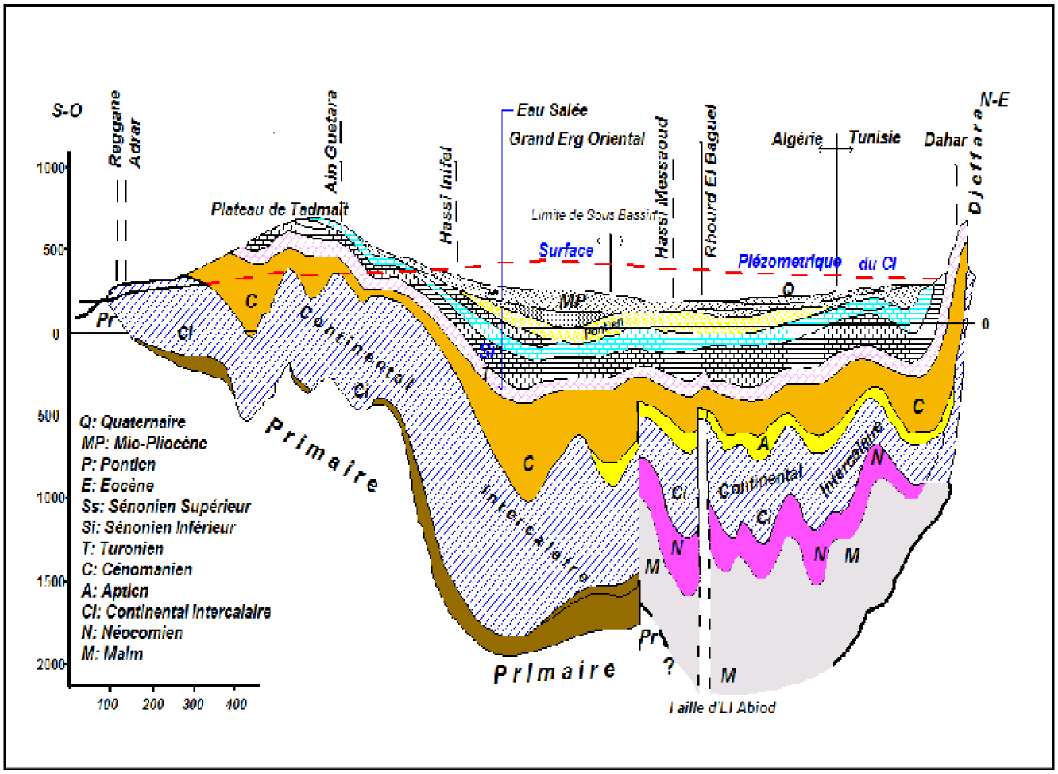


Fig. II.7: Hydrogeological section of the CI and CT aquifer system of the northern Sahara[10]

1. ***Quaternary water table:***

It is located in Quaternary alluvial accumulations. It is better known from the palm groves, sebkhas and wadis, its depth varies from 0 to 8m; its reservoir of heterogeneous composition is made up of detrital materials (blocks, pebbles, gravel and sand).

It is relatively deep in the high topographic zones (sandstone columns and Ergs), and shallower in the zones near the irrigated sebkhas and palm groves.

Its bedrock is made up of a thick clay formation, sometimes it appears in the form of sand lenses in discordance with the clay layers. It is, above all, fed by precipitation water, infiltration from wadis and irrigation water. The category of water in this aquifer is salty or very salty (up to 50g/L), it is classified among alkaline chlorides and calc-magnesium sulfates.

Their supply comes essentially from wastewater discharges of domestic origin, excess water linked to irrational irrigation of the palm groves and runoff water coming from the upper parts and the contributions of the floods of the three Oueds in the basin (N' sa, M'Zab, M'ya).

2. The Terminal Complex (T.C) aquifer:

In the Ouargla basin the aquifer of the terminal complex is made up of two aquifer horizons, namely the Mio-Pliocene aquifer and the Senon Eocene aquifer. The Miopliocene water table containing several aquifer levels of heterogeneous composition; detrital materials, gravels and sands in a clayey matrix. The Sénon Eocene tablecloth is made up of Senonian and Eocene carbonate formations forming a single litho-stratigraphic unit, formed of limestone, whose thickness varies from 50 to 250 meters. This aquifer has low permeability on the scale of the eastern Sahara basin. Locally, as in Biskra and Ouargla and in other points of the Sahara, secondary cracking gives this ensemble interesting hydrogeological properties.

The Turonian is a limestone-dolomitic formation and is considered as an extensive sheet to the north of the Eastern Sahara, but it becomes impermeable in the extreme where it is very marly. Its low potential and its strong mineralization do not give it any interest in the study area.

Features:

- ✓ Artesianism in the center.
- ✓ Shallow depth 100 to 400m.
- ✓ Supply is low, around 583 M m^3/year. It is carried out by infiltration of runoff from the Saharan Atlas and by direct infiltration of rains in the Grand Erg Oriental which rests directly on the permeable grounds of the Terminal Complex.

3. ***The Continental Interlayer (C.I) aquifer:***

According to Kilian (1931), the “Continental Interlayer” designates a continental episode located between two marine sedimentary cycles at the base, the Paleozoic cycle which completes the Hercynian orogeny, while at the summit, the Upper Cretaceous cycle, resulting from the Cenomanian transgression (Busson, 1970). It occupies the sandy and clayey sandstone formations of the Barremian and Albian (Cornet, 1964). The aquifer is continuous from North to South, from the Saharan Atlas to the Tassili du Hoggar, and from West to East, from the Guir and Saoura valley to the Libyan desert. It is one of the most extensive aquifers on the planet.

It extends over more than 600,000 km², one of the particularities of which is to constitute a fossil groundwater resource, since it is very poorly supplied with current climatic conditions (UNESCO, 1972). The supply flow of the Continental Interlayer coming from the foothills of the Saharan Atlas is 7.7 m3/s, (Ould Baba Sy, 2005).

Features:

- ✓ The aquifer becomes deeper and deeper towards the North-East, where the roof of the water table is at 1500 to 2000m. Towards the periphery, the water table is ascending, shallow and at average temperature.
- ✓ The aquifer crops out in the regions of Adrar and Aïn Salah. The waters are warm in the northeast of the basin (the average temperature is 60° C). The supply is low, around 268 Mm³/year, thanks to the spreading of the wadis descending from the Saharan Atlas and the infiltration of rains in the large western erg. In addition to the foggaras and boreholes which are the artificial outlets of the Albian aquifer, the water flows mainly towards the South and West of the aquifer where the evaporative zones of Touat du Gourara and Tidikelt are located. Another direction of flow is towards the North-East, Tunisian coastal zone, through the faults of El Hamma and Medenine.

Table.II.2: General data on the C.I aquifer. [11]

Extent	**600,000km²**
Total thickness (m)	50 to 1,000
Depth (m)	60 to 2,400
Depth to roof (m)	20 to 2,000
Thickness of the useful productive layer (m)	150 to 200
Flow rate (l/s)	50 to 400
Static level relative to the ground (m)	artesian (25 bars)
Reduction relative to the N.S (m)	Artesian
Transmissivity (10^{-3} m^2/s)	10 to 30
Storage coefficient (10^{-4})	6 to 1,200
Average supply (Hm^3/year)	270
Calculated theoretical reserve (m^3)	50,000 x 10^9
Temperature (°C)	25 to 70
Water salinity	0.5 to 6 g/l*

X. Climatology:

The climatic study is necessary to know the climatic characteristics of the study region, it must be based on the following main parameters: Precipitation, temperatures, wind and humidity. This provides an overview of the distribution of climatic parameters in time and space.

These parameters are of great importance for any hydrogeological study because they have an influence on the hydraulic behavior and especially the water balance of the aquifers.

1. Presentation of the climatic station:

These are climatic data from the Ouargla station, the characteristics of which are in the table below:

Table.II.3: Coordinates of the Ouargla meteorological station (ONM).

Ouargla station	indicatory	altitude	Longitude	Latitude	Start of archives	Station type
	60580	**141m**	**31.92° N**	**5.40° E**	**30January 1949**	**METAR /SYNOP**

2. Precipitation study:

Precipitation is one of the most variable hydrological processes. On the one hand, they are characterized by great variability in space, whatever the spatial scale taken into account (regional, local, etc.). On the other hand, they are characterized by great variability over time, both on an annual scale and that of a rainy event.

To identify and classify the region of our study, we studied variations in average monthly, precipitation. Cumulative over 1 month and Max precipitation over 24 hours from 1991 to 2020. **(fig.8.)**

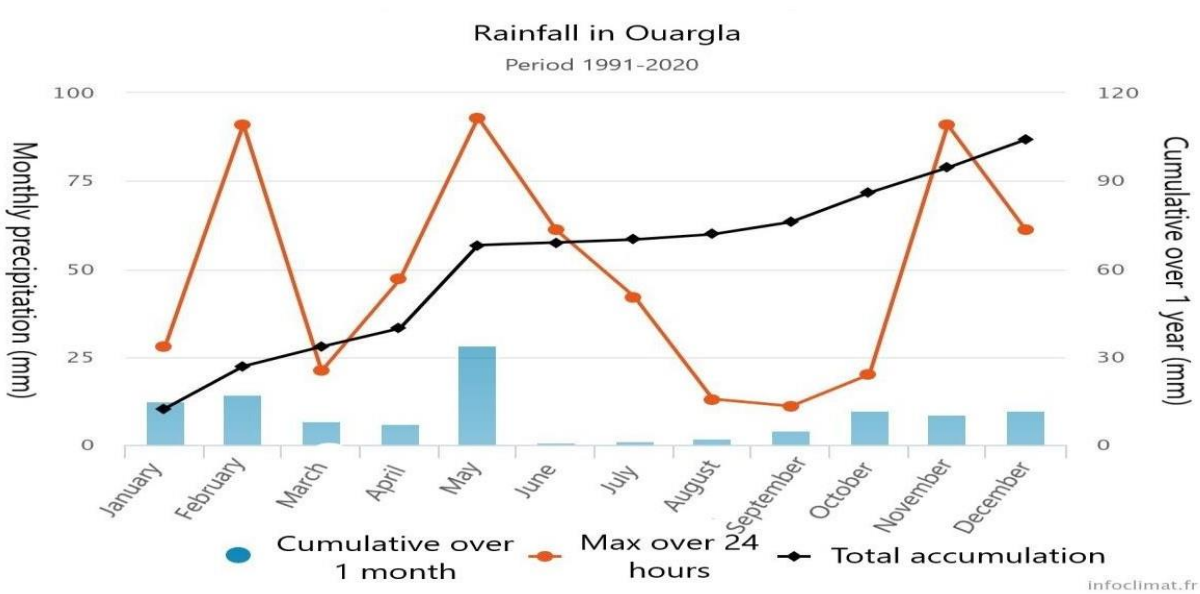


Fig. II.8: Precipitation in Ouargla Period 1991-2020[12]

The picture shows a graph of rainfall in the Algerian city of Ouargla from 1991 to 2020.

The graph shows that the rainfall rate during this period ranges between 0 mm and 120 mm.

The peak rainfall in the graph shows that the highest amount of rainfall typically occurs during the winter months.

The graph shows that rainfall varies greatly from month to month.

3. *Temperature study:*

On the earth's surface, the importance of temperature no longer needs to be demonstrated: it conditions physical and physiological evaporation (evapotranspiration), and plays an essential role in the evaluation of the flow deficit which occurs in the estimation of the hydrological balance.

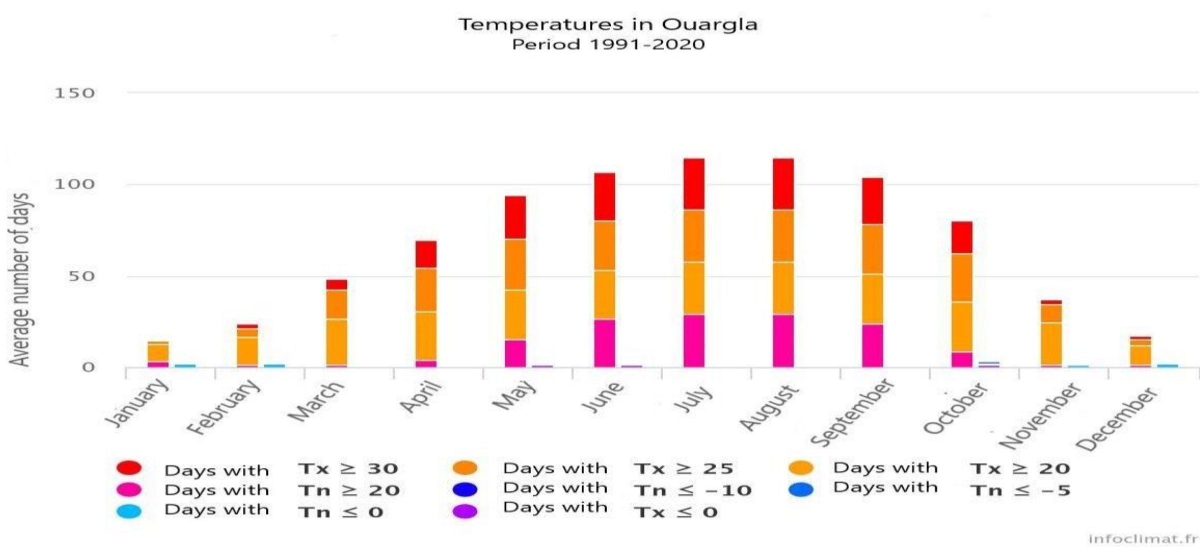


Fig.II.9: Average number of days with different temperatures in Ouargla period (1991-2020)[13]

This graph shows the average number of days with different temperatures in Ouargla, where we notice that the number of days with high temperatures increases significantly from May to September, where the temperature exceeds 30 degrees, and the number of days with low temperatures increases significantly from December to January. From here we notice that The number of hot days is greater than the number of cold days, which explains the hot nature of the region.

XI. Conclusion:

- ✓ The study region is located in the South-East of Algeria forming a syncline depression.The Moi-Pliocene lands outcrop.These are red sands and soft sandstones with cross-stratification, with limestone nodules.
- ✓ There is an aquifer system made up of three layers: the continental interlayer (C.I), the terminal complex (T.C) and the superficial layer. It is characterized by the Moi-pliocene formation, sandy formations, chotts and sebkhas.
- ✓ Saline and gypso-saline soils occupy most of the Ouargla basin.
- ✓ The majority of the population is concentrated in the commune of Ouargla and Rouissat with a growth rate equal to 3.4%.
- ✓ The climate is hyper-arid. High temperatures are recorded in months: June, July, August and September and precipitation is almost zero. They do not exceed 10 mm, recorded in January.

Analysis of the studied factors shows that rainwater has almost no role in feeding crops and providing water to various sectors. These different indicators are what lead to excessive demand for water in various sectors and an imbalance in water distribution.

CHAPTER III:

MATERIALS AND METHODS

I. Introduction:

Integrated water resources management: a major political issue. It includes all measures aimed at increasing technical, social, economic, institutional and environmental efficiency in various uses of water.

For about ten years, Algerian water management policy has focused more on mobilizing new resources than on seeking better use of already available resources.

In this context of increasing shortages and in the face of uncertainties associated with climate change, we seek to adapt water management policies, in order to better manage different uses and use resources more economically and optimally, to meet the needs of residents and local communities. Development of today and tomorrow.

In this Materials and Methods chapter, we present all the data considered, software and methods used for water management in the region.

From Ouargla. For IWRM, in our study, we relied on the web-based cloud computing platform created by Google to process and analyze large-scale geospatial data “Google Earth Engine” and the power BI program created by Microsoft, which makes it easy. Creating a model that facilitates the organization of water resources by creating maps that show the distribution of water sources and the percentage of water consumption in each area (agricultural, industrial, residential) with the aim of reducing irrational consumption of this resource, and then determining the amount of supply and demand in order to develop a future plan to determine the amount of water needed. . To meet the needs of each sector or region in order to provide better suggestions and scenarios for better and better management of this resource.

In our study, we will follow two approaches to water management:

First: We will study supply and demand in order to facilitate the management of available water resources to reduce excessive water consumption, taking into account the nature of the region and the problems it faces, and distribute it systematically to sectors that need large quantities of water, especially the agricultural sector, using the Power BI Desktop program.

Second: Creating two software codes in GEE under the name NDVI and NDWI in order to track the development and distribution of agricultural areas and water bodies over the past years and determine whether they are increasing or declining and compare it with water consumption in the first part of the study.

II. Introduction to the programs and code used:

II.1. Power BI Desktop:

Power BI Desktop is a powerful data visualization and business intelligence tool developed by Microsoft. It enables users to connect to a wide range of data sources, transform and model the data, and create interactive reports and dashboards. Here are some key features and components of Power BI Desktop:

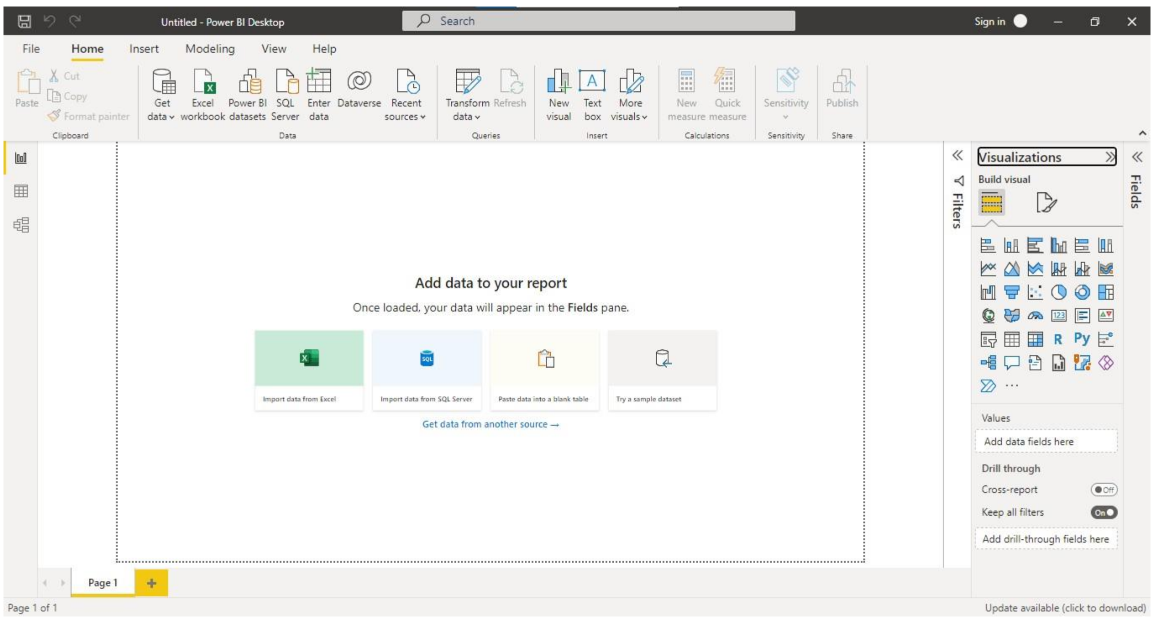


Fig.III.1. The program interfaces[1]

II.1.1. Key Features:

1. **Data Connectivity**

   ✓ Power BI Desktop can connect to a wide array of data sources, including databases (SQL Server, Oracle, MySQL), cloud services (Azure, Google Analytics, Salesforce), files (Excel, CSV), and many others.

2. **Data Transformation**

   - ✓ The tool includes Power Query Editor, which allows users to clean, transform, and prepare their data. This includes functionalities like merging tables, filtering rows, changing data types, and more.

3. **Data Modeling**

   - ✓ Users can create relationships between different data tables, define calculated columns, measures, and use DAX (Data Analysis Expressions) for advanced data manipulation.

4. **Visualizations**

   - ✓ Power BI Desktop offers a variety of visualization types, such as bar charts, line charts, pie charts, maps, scatter plots, and more. Users can customize these visualizations extensively.

5. **Interactivity**

   - ✓ Reports and dashboards created in Power BI are highly interactive, allowing users to drill down into data, filter results on the fly, and explore the data from different angles.

6. **Publishing and Sharing**

   - ✓ Once reports are created, they can be published to the Power BI Service, where they can be shared with others within the organization, embedded into apps or websites, and scheduled for regular updates.

7. **Custom Visuals**

   - ✓ In addition to built-in visuals, Power BI supports custom visuals, which can be created using the Power BI Visuals SDK or downloaded from the Power BI Marketplace.

II.1.2. Components of Power BI Desktop:

1. **Ribbon**

   - ✓ The ribbon at the top of Power BI Desktop provides access to various features and functionalities, such as importing data, transforming data, creating visuals, and publishing reports.

2. **Report View**

   - ✓ This is the main canvas where you create and arrange your visualizations. It allows you to design multiple report pages and add various elements like charts, slicers, and text boxes.

3. **Data View**

   - ✓ The Data View displays your data in tabular form, allowing you to inspect and manage your datasets, columns, and data types.

4. **Model View**

   - ✓ The Model View enables you to create and manage relationships between different tables in your data model. You can also define hierarchies, calculated columns, and measures here.

5. **Fields Pane**

   - ✓ The Fields Pane lists all the data tables and fields available for your report. You can drag and drop these fields onto your report canvas to create visualizations.

6. **Visualizations Pane**

   - ✓ The Visualizations Pane provides a collection of visual types that you can use in your reports. It also includes options to format and configure each visualization.

7. **Filters Pane**

   - ✓ The Filters Pane allows you to apply filters to your entire report, individual pages, or specific visualizations. You can use basic filters, advanced filters, or slicers for more dynamic filtering.

Our work with this program consists of creating a distribution map for used water wells in several areas and identifying suitable locations for agricultural, residential or industrial expansions(**fig.2**).

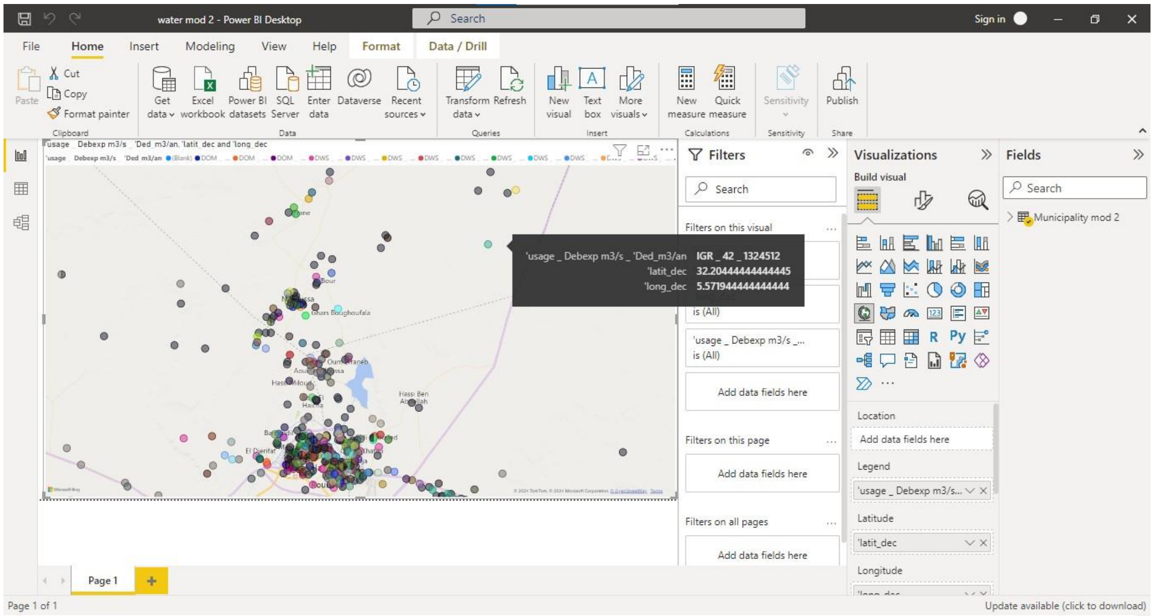


Fig.III.2. Example of a projected map[2]

II.2. NDVI:

Where NDVI represents: Normalized Difference Vegetation Index (NDVI) is a widely used remote sensing index that measures and monitors plant growth, vegetation cover, and biomass production. NDVI is calculated using the visible and near-infrared (NIR) light reflected by vegetation. Healthy vegetation absorbs most of the visible light and reflects a large portion of the NIR light, while unhealthy or sparse vegetation reflects more visible light and less NIR light.[3]

The NDVI formula is:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

where:

- ✓ **NIR** is the near-infrared light reflected by the vegetation,
- ✓ **Red** is the visible red light reflected by the vegetation.

The NDVI values range from -1 to +1:

- ✓ **Values close to +1** indicate healthy, dense vegetation.
- ✓ **Values close to 0** suggest barren areas of rock, sand, or snow.
- ✓ **Values less than 0** usually correspond to water bodies, clouds, and snow.

II.2.1. Applications of NDVI:

1. **Agriculture:** Monitoring crop health, predicting yields, and managing agricultural practices.
2. **Forestry:** Assessing forest health, biomass, and changes due to logging or disease.
3. **Environmental Management:** Monitoring droughts, desertification, and land degradation.
4. **Climate Studies:** Analyzing vegetation changes over time and their relationship to climate change.
5. **Urban Planning:** Assessing green space distribution and planning for sustainable urban development.

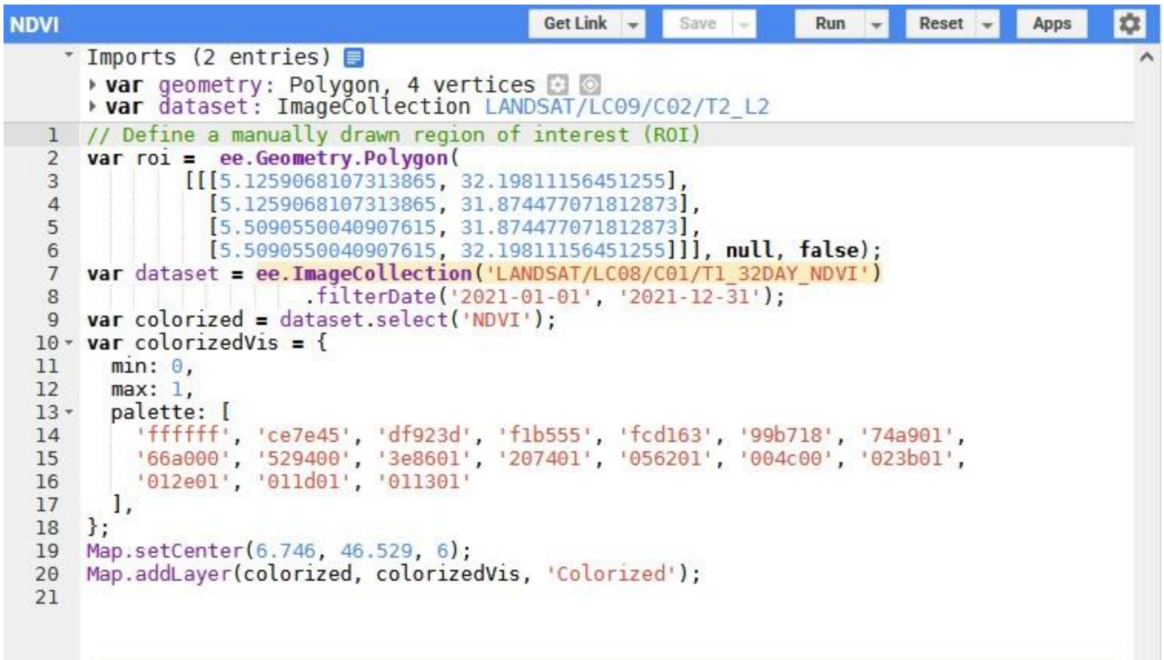
II.2.2. How NDVI is Measured

NDVI is commonly measured using satellite imagery, with data provided by various space agencies such as NASA (Landsat, MODIS) and the European Space Agency (Sentinel-2). Drones and other remote sensing platforms can also capture NDVI data for more localized studies.

II.2.3. Interpreting NDVI Data

Interpreting NDVI data requires understanding the context of the specific area being studied, including the type of vegetation, soil characteristics, and weather conditions. Combining NDVI data with other indices and ground-truthing (on-the-ground validation) can provide more accurate insights.

In summary, NDVI is a critical tool in remote sensing for understanding and managing vegetation and ecosystems, providing valuable insights across various fields from agriculture to climate science.




```
Imports (2 entries)
  var geometry: Polygon, 4 vertices
  var dataset: ImageCollection LANDSAT/LC09/C02/T2_L2
// Define a manually drawn region of interest (ROI)
var roi =  ee.Geometry.Polygon(
        [[[5.1259068107313865, 32.19811156451255],
          [5.1259068107313865, 31.874477071812873],
          [5.5090550040907615, 31.874477071812873],
          [5.5090550040907615, 32.19811156451255]]], null, false);
var dataset = ee.ImageCollection('LANDSAT/LC08/C01/T1_32DAY_NDVI')
                  .filterDate('2021-01-01', '2021-12-31');
var colorized = dataset.select('NDVI');
var colorizedVis = {
  min: 0,
  max: 1,
  palette: [
    'ffffff', 'ce7e45', 'df923d', 'f1b555', 'fcd163', '99b718', '74a901',
    '66a000', '529400', '3e8601', '207401', '056201', '004c00', '023b01',
    '012e01', '011d01', '011301'
  ],
};
Map.setCenter(6.746, 46.529, 6);
Map.addLayer(colorized, colorizedVis, 'Colorized');
```

Fig.III.3. Google Earth Engine Script NDVI[4]

II.3. NDWI

The NDWI expresses: Normalized Difference Water Index. It is an index used to monitor changes in water content of leaves and to map water bodies. The NDWI uses near-infrared (NIR) and short-wave infrared (SWIR) reflectance values, calculated using satellite or aerial imagery.[5]

The NDWI is calculated using the following formula:

$$NDWI = \frac{NIR - SWIR}{NIR + SWIR}$$

Where:

- ✓ **NIR (Near-Infrared)**: Reflectance value in the near-infrared spectrum.

- ✓ **SWIR (Short-Wave Infrared)**: Reflectance value in the short-wave infrared spectrum.

II.3.1. Uses of NDWI:

1. **Water Bodies Detection**: Identifying and monitoring lakes, rivers, reservoirs, and wetlands.
2. **Vegetation Water Content**: Assessing the moisture content in vegetation, which can be useful in drought monitoring and agriculture.
3. **Flood Monitoring**: Tracking changes in water bodies during flood events.
4. **Environmental Management**: Assisting in the management of water resources and land-use planning.

II.3.2. NDWI vs NDWI (Normalized Difference Water Index - McFeeters):

It's important to note that there are variations of the NDWI:

- ✓ **NDWI (Gao, 1996)**: Uses NIR and SWIR bands.
- ✓ **NDWI (McFeeters, 1996)**: Uses green and near-infrared (NIR) bands, primarily designed to enhance open water features and minimize the presence of vegetation and soil noise.[6]

NDWI (McFeeters) Formula:

$$NDWI_{\text{McFeeters}} = \frac{Green - NIR}{Green + NIR}$$

Where:

- ✓ **Green**: Reflectance value in the green spectrum.

II.3.3. Practical Application:

For example, using NDWI in satellite imagery from sources like Landsat, Sentinel-2, or MODIS, researchers can generate maps highlighting water bodies. These maps are useful for hydrological studies, climate change impact assessments, and disaster management.

II.3.4. Software Tools:

Several software tools and platforms can be used to compute and analyze NDWI, including:

- ✓ **Google Earth Engine**: An online platform for large-scale data analysis.
- ✓ **QGIS**: An open-source geographic information system that supports NDWI calculation through plugins.
- ✓ **ArcGIS**: A comprehensive GIS platform with NDWI computation capabilities.

In summary, NDWI is a vital index for water and vegetation monitoring, aiding in environmental research and resource management. Its simplicity and effectiveness make it a popular choice in remote sensing applications.

```
NDWI
Imports (1 entry)
▸ var geometry: Polygon, 4 vertices
// Define a region of interest (ROI)
var roi = ee.Geometry.Polygon(
        [[[4.8903014041797555, 32.443575601294555],
          [4.8903014041797555, 31.80390820733427],
          [5.6373717166797555, 31.80390820733427],
          [5.6373717166797555, 32.443575601294555]]], null, false);

// Load Landsat imagery
var landsat = ee.ImageCollection('LANDSAT/LE07/C02/T1_L2')
  .filterBounds(roi)
  .filterDate('2020-01-01', '2021-01-01')
  .map(function(image) {
    return image.clip(roi);
  });

// Compute NDWI function
var addNDWI = function(image) {
  var ndwi = image.normalizedDifference(['SR_B3', 'SR_B5']).rename('NDWI');
  return image.addBands(ndwi);
};

// Apply NDWI to the image collection
var landsatNDWI = landsat.map(addNDWI);

// Select NDWI band from the first image
var firstImage = landsatNDWI.first();
var ndwiBand = firstImage.select('NDWI');

// Display NDWI
Map.centerObject(roi, 10);
Map.addLayer(ndwiBand, {min: -1, max: 1, palette: ['blue', 'white', 'green']}, 'NDWI');
```

Fig.III.4. Google Earth Engine Script NDWI[7]

To carry out the process of building these maps, we decided to carry out real predictive work: our role was to provide methodological assistance. Our aim here is to provide a brief description of this experience, so as to provide on the one hand a concrete and practical vision of what a forward-looking approach could be, and on the other hand to explain our view on what such an exercise has been able to provide in arid conditions such as the Ouargla region.

The approach to take begins by first describing the initial context (see Chapter 1) and the problem to be addressed through future analysis. Then the scenario building phase is presented. Finally, find an explanation for the results.

III. Description of the Google Earth Engine:

Google Earth Engine is a web-based Cloud Computing platform created by Google for large-scale geospatial data processing and analysis.It allows users to apply image processing and geospatial analysis algorithms using Python and Java Script.

III.1. Earth Engine Code Editor:

The Earth Engine (EE) Code Editor at code.earthengine.google.com is a web-based IDE for the Earth Engine JavaScript API. Code Editor features are designed to make developing complex geospatial workflows fast and easy. The Code Editor has the following elements (illustrated in Figure 1):

- ✓ JavaScript code editor
- ✓ Map display for visualizing geospatial datasets
- ✓ API reference documentation (Docs tab)
- ✓ Git-based Script Manager (Scripts tab)
- ✓ Console output (Console tab)
- ✓ Task Manager (Tasks tab) to handle long-running queries
- ✓ Interactive map query (Inspector tab)
- ✓ Search of the data archive or saved scripts
- ✓ Geometry drawing tools

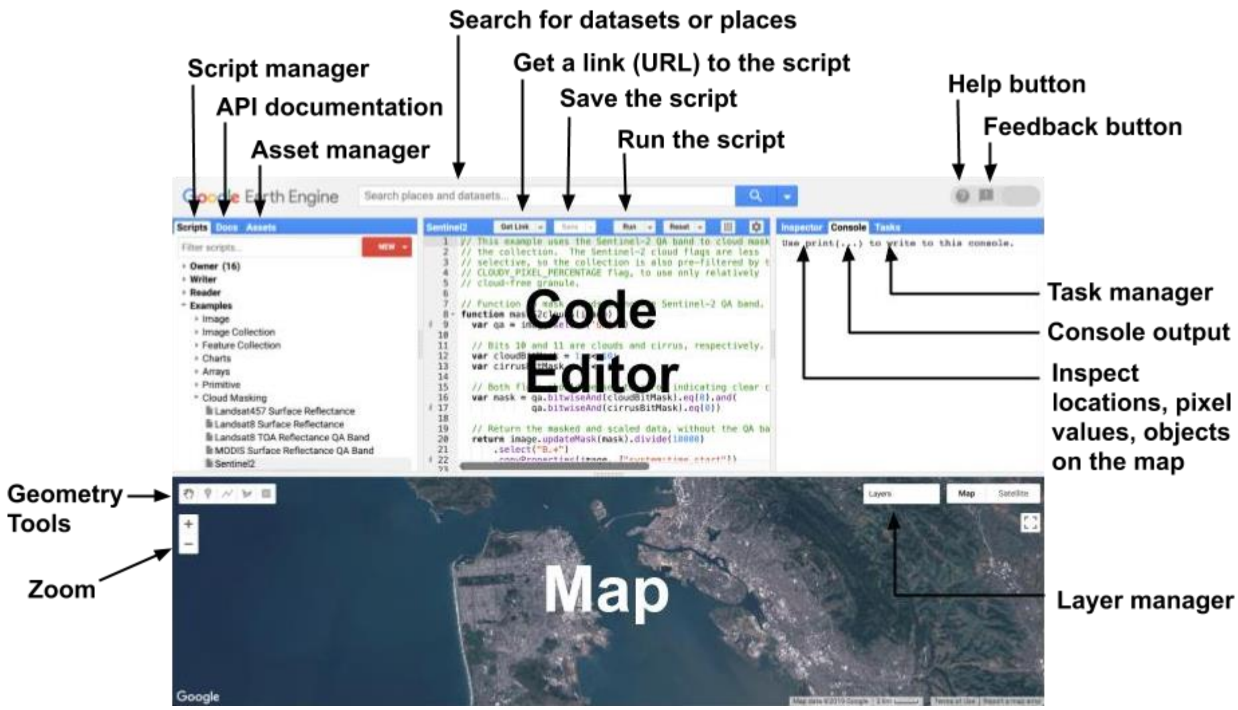


Fig.III.5. Diagram of components of the Earth Engine Code Editor at code.earthengine.google.com.

The Code Editor has a variety of features to help you take advantage of the Earth Engine API. View example scripts or save your own scripts on the **Scripts** tab. Query objects placed on the map with the **Inspector** tab. Display and chart numeric results using the Google Visualization API. Share a unique URL to your script with collaborators and friends with the **Get Link** button. Scripts you develop in the Code Editor are sent to Google for processing and the generated map tiles and/or messages are sent back for display in the **Map** and/or **Console** tab. All you need to run the Code Editor is a web browser (use Google Chrome for best results) and an internet connection.[8]

III.2. EXCEL software:

Microsoft Excel is a spreadsheet that you can use to manage, analyze, and chart data.

This program, which is a spreadsheet, was primarily used to enter and manage data files.

Data on wells dug in the Ouargla Basin (location, use, quantity of water exploited per day and year...).

Here we present some cases using Google Earth Engine and ArcMap in the field of water resources management:

IV. Cases 1: Using Google Earth Engine

In these cases, we discuss the use of the Automated Water Extraction Index (AWEI) as a valuable tool for identifying water bodies in satellite imagery. The AWEI helps in water resources management by utilizing specific spectral bands to detect water presence accurately.[9]

IV.1. Spectral Bands Used in AWEI Calculation:

- ✓ **BLUE (B2) **
- ✓ **GREEN (B3) **
- ✓ **NIR (B8) ** (Near-Infrared)
- ✓ **SWIR1 (B11) ** (Shortwave Infrared 1)
- ✓ **SWIR2 (B12) ** (Shortwave Infrared 2)

IV.2. Key Points:

IV.2.1. Reflectance Differences:

- ✓ The AWEI takes advantage of the differences in reflectance between these bands to identify water bodies.
- ✓ Water has a higher reflectance in the blue band compared to the green band. Therefore, AWEI values greater than 0 indicate the presence of water.

IV.2.2. AWEI in Binary Mode:

- ✓ AWEI can be used in binary mode to calculate a value of 0 or 1, indicating the absence or presence of water, respectively.
- ✓ The blue and green bands are crucial because they are sensitive to the light reflected by water in a characteristic way.

IV.2.3. Role of NIR, SWIR1, and SWIR2:

- ✓ **NIR (Near-Infrared):** Useful for identifying various features like vegetation, soil, snow, and water.
- ✓ **SWIR1 and SWIR2 (Shortwave Infrared):** These bands help in distinguishing water bodies from other land features.

IV.2.4. AWEI Formula:

AWEI=4*(GREEN–SWIR2)–(0.25*NIR+2.75*SWIR1)

The formula for calculating the AWEI takes into account the reflectance values from the specified bands. it typically involves a combination of these band reflectances to enhance water detection accuracy.

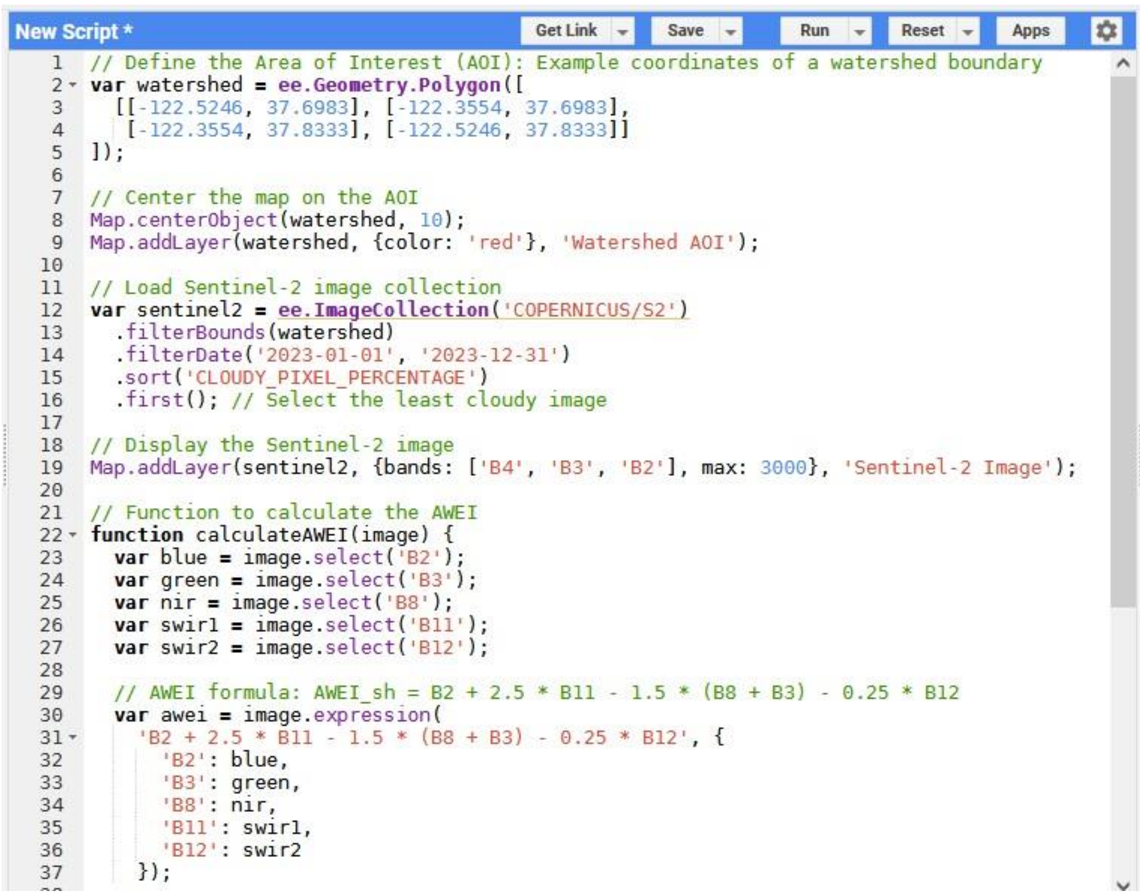
By using AWEI, water bodies can be efficiently and accurately identified in satellite imagery, aiding in effective water resources management.

In the first phase, an asset was created in the code editor in Google Earth Engine (GEE). In GEE, an "asset" is a geospatial data resource or dataset that can be uploaded, stored, managed, and used for geospatial analysis and processing. Assets can include a variety of data types such as satellite imagery, vector data, shapefiles, terrain data, and more. (fig.2)

1. Load a vector dataset containing the geometry and names of the hydrographic basins. Store this in the variable "bh".
2. Filter the table by the pool name "Bahlui" using. filter () and store the result in "selected".
3. Extract the geometry of the Bahlui basin from the "selected" object using. geometry () and store it in the "geometry" variable.
4. Load a collection of Sentinel-2 images, stored in "sentinel".
5. Filter the image collection by the Bahlui Basin using. filter () with geometry boundaries. It is also filtered by clouds and date. The result is in "filtered".
6. Create a median image from the filtered collection using. median () and clip it to the geometry with. clip (). The result is in "image".

7. Calculate the AWEI value on the filtered image, using the formulas given in the comments. The result of the AWEI value is stored in "awei".
8. Define three color palettes for visualization: rgbVis, ndviVis, ndwiVis.
9. Center the map on the basin geometry with Map.centerObject().
10. Add the AWEI visual layer to the map with Map.addLayer(), using the ndwiVis palette.

Thus, a collection of images was filtered by a certain watershed, the AWEI value was calculated on the filtered image, and the result was displayed on the map.




```
// Define the Area of Interest (AOI): Example coordinates of a watershed boundary
var watershed = ee.Geometry.Polygon([
  [[-122.5246, 37.6983], [-122.3554, 37.6983],
   [-122.3554, 37.8333], [-122.5246, 37.8333]]
]);

// Center the map on the AOI
Map.centerObject(watershed, 10);
Map.addLayer(watershed, {color: 'red'}, 'Watershed AOI');

// Load Sentinel-2 image collection
var sentinel2 = ee.ImageCollection('COPERNICUS/S2')
  .filterBounds(watershed)
  .filterDate('2023-01-01', '2023-12-31')
  .sort('CLOUDY_PIXEL_PERCENTAGE')
  .first(); // Select the least cloudy image

// Display the Sentinel-2 image
Map.addLayer(sentinel2, {bands: ['B4', 'B3', 'B2'], max: 3000}, 'Sentinel-2 Image');

// Function to calculate the AWEI
function calculateAWEI(image) {
  var blue = image.select('B2');
  var green = image.select('B3');
  var nir = image.select('B8');
  var swir1 = image.select('B11');
  var swir2 = image.select('B12');

  // AWEI formula: AWEI_sh = B2 + 2.5 * B11 - 1.5 * (B8 + B3) - 0.25 * B12
  var awei = image.expression(
    'B2 + 2.5 * B11 - 1.5 * (B8 + B3) - 0.25 * B12', {
      'B2': blue,
      'B3': green,
      'B8': nir,
      'B11': swir1,
      'B12': swir2
    });
```

Fig.III.6. Google Earth Engine Script: Automated Water Extraction Index (AWEI)

V. Cases 2: Using ArcMap (GIS) In Conjunction With WEAP:

V.1. ArcMap (GIS):

ArcMap is one of the main components of Esri's ArcGIS suite of geospatial processing programs. It is primarily used for creating, analyzing, and managing geographic information systems (GIS) data and associated attributes. Below are some key features and functionalities of ArcMap:[10]

V.2. Key Features:

V.2.1. Data Visualization:

- ✓ **Map Creation:** Allows users to create detailed maps with multiple layers of data, such as satellite imagery, vector data, and more.
- ✓ **Symbology:** Users can customize the appearance of map features using various symbols, colors, and styles to represent different types of data.

V.2.2. Data Management:

- ✓ **Geodatabases:** Supports storing and managing spatial data in file-based, personal, and enterprise geodatabases.
- ✓ **Shapefiles and Other Formats:** Works with a variety of data formats including shapefiles, coverages, and other spatial data types.

V.2.3. Spatial Analysis:

- ✓ **Geoprocessing Tools:** Offers a wide range of tools for performing spatial analysis, such as buffering, overlay, and spatial statistics.
- ✓ **ModelBuilder:** Allows users to create, edit, and manage geoprocessing models for automating workflows.

V.2.4. Editing and Data Creation:

- ✓ **Feature Editing:** Users can create, modify, and delete spatial features directly within the map interface.
- ✓ **Topology Rules:** Ensures the spatial relationships between features are maintained during editing.

V.2.5. Cartography:

- ✓ **Layout View:** Provides tools for designing map layouts, including elements like titles, legends, scale bars, and north arrows.
- ✓ **Labeling and Annotation:** Advanced labeling and annotation tools help in creating clear and informative maps.

V.2.6. Georeferencing:

- ✓ Allows users to align spatial data to a known coordinate system, which is crucial for integrating different data sources.

V.2.7. Spatial Data Query:

- ✓ **Attribute Queries:** Users can select and analyze data based on attribute values using SQL-like queries.
- ✓ **Spatial Queries:** Perform selections based on spatial relationships between features (e.g., within a distance, intersecting).

V.3. Common Uses:

1. **Urban Planning:** ArcMap helps planners visualize zoning areas, infrastructure, and demographic data to make informed decisions.
2. **Environmental Management:** Analyzing spatial data related to natural resources, wildlife habitats, and environmental impacts.

3. **Transportation:** Designing and managing transportation networks, analyzing traffic patterns, and planning routes.
4. **Utilities:** Managing and mapping utility networks such as water, gas, and electricity.
5. **Public Health:** Mapping disease outbreaks, healthcare facility locations, and analyzing public health data.

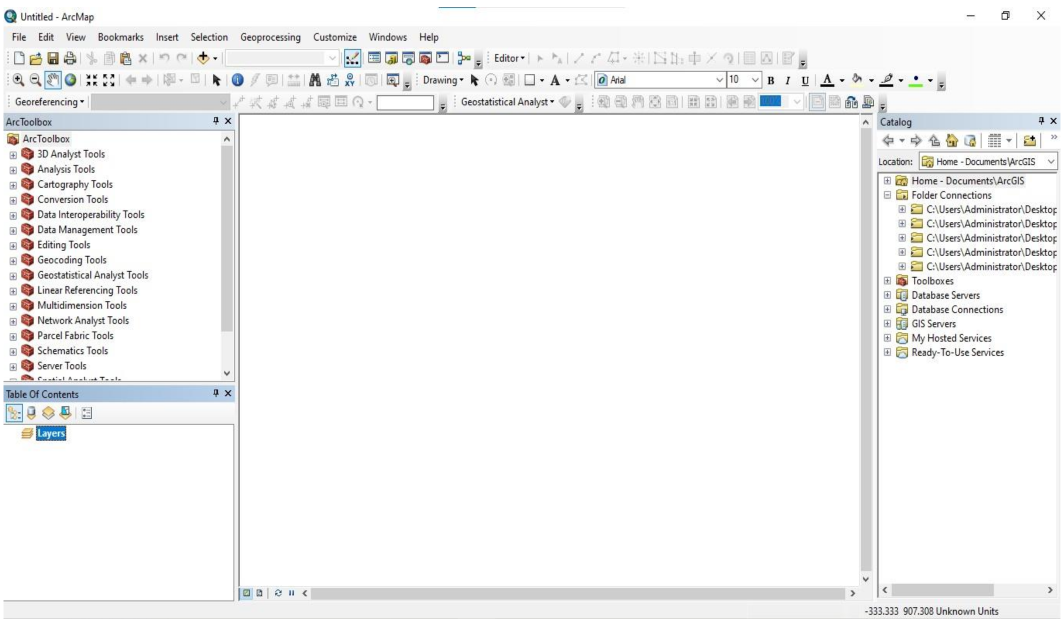


Fig.III.7. ArcMap Program interface[11]

Using ArcMap in conjunction with WEAP (Water Evaluation And Planning system) can enhance water resource management by leveraging geographic information system (GIS) capabilities. ArcMap, a component of the Esri ArcGIS suite, provides powerful tools for spatial data analysis, visualization, and mapping. Here's how to integrate and use ArcMap with WEAP for effective water resource management:

V.4. Steps for Integrating ArcMap with WEAP

V.4.1. Data Preparation in ArcMap:

- ✓ **Collect Spatial Data**: Gather spatial datasets relevant to water resources, such as hydrological networks, watershed boundaries, land use, soil types, and climate data.
- ✓ **Data Cleaning and Preparation**: Use ArcMap to clean and preprocess the data. This may involve clipping datasets to the study area, reprojecting data to a common coordinate system, and ensuring data accuracy.

V.4.2. Exporting Spatial Data from ArcMap:

- ✓ **Convert to Appropriate Formats**: Export the spatial data from ArcMap in formats compatible with WEAP, such as shapefiles or raster datasets.
- ✓ **Attribute Data Export**: Ensure that relevant attribute data (e.g., land use classifications, soil properties) are included in the exported files, as these will be crucial for WEAP's modeling processes.

V.4.3. Importing Data into WEAP:

- ✓ **Create a New WEAP Project**: Start a new project in WEAP and define the study area and time horizon.
- ✓ **Import Shapefiles**: Use WEAP's GIS interface to import the shapefiles created in ArcMap. These shapefiles can represent various elements like rivers, catchments, and infrastructure.
- ✓ **Link Attribute Data**: Ensure that the attribute data from the shapefiles are correctly linked within WEAP. This may involve mapping fields from the shapefiles to WEAP's data structure.

V.4.4. Scenario Development and Analysis in WEAP:

- ✓ **Define Scenarios**: Develop different water management scenarios in WEAP. These scenarios can include variations in water demand, supply conditions, policy interventions, and climate change impacts.
- ✓ **Run Simulations**: Use WEAP to run simulations for each scenario, analyzing the outcomes in terms of water availability, demand satisfaction, and sustainability.

V.4.5. Visualizing and Analyzing Results in ArcMap:

- ✓ **Export WEAP Results**: Export the results of WEAP simulations as spatial datasets.
- ✓ **Import into ArcMap**: Bring these datasets back into ArcMap for advanced spatial analysis and visualization.
- ✓ **Create Maps and Visualizations**: Use ArcMap's powerful cartographic tools to create detailed maps and visualizations of the simulation results. This can include maps showing water shortages, areas at risk, and the impacts of different management strategies.

V.5. Practical Applications:

V.5.1. Watershed Management:

- ✓ Use ArcMap to delineate watersheds and identify critical areas for intervention. Import these into WEAP to assess the impacts of various management practices on water availability and quality.

V.5.2. Urban Water Supply Planning:

- ✓ Utilize ArcMap to map current and projected urban growth. Integrate these maps into WEAP to plan for future water supply needs and infrastructure development.

V.5.3. Climate Change Impact Assessment:

- ✓ Analyze climate data in ArcMap to identify trends and anomalies. Import this data into WEAP to model the potential impacts of climate change on water resources.

V.5.4. Environmental Conservation:

- ✓ Use ArcMap to map ecologically sensitive areas and habitats. Incorporate these maps into WEAP to develop conservation strategies that ensure sustainable water use and ecosystem protection.

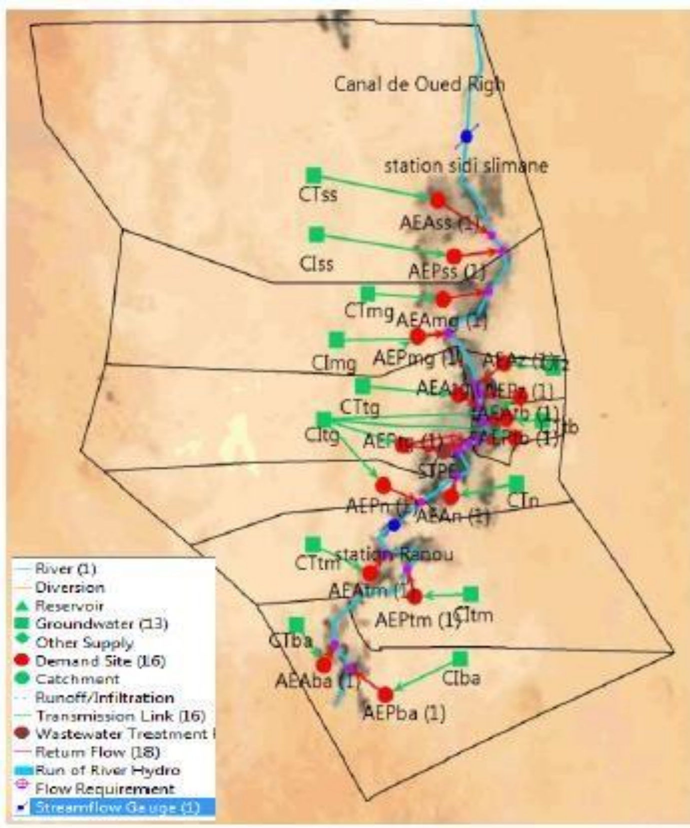


Fig.III.8. Example of Final diagram of the WEAP model[12]

CHAPTER IV:

Study supply and demand and create maps using NDVI and NDWI code.

I. Study supply and demand:

Tab.IV.1. Evolution of the number of drillings in the Ouargla basin.[1]

Municipality	DWS drilling		Agricultural water drilling		IND drilling	
	Number	Volume (m3/d)	Number	Volume (m3/d)	Number	Volume (m3/d)
Ouargla	40	46179.072	285	136559.52	16	3464.64
Rouissat	8	3963.168	150	152875.528	33	24710.4
Sidi Khouiled	8	4037.472	101	26123.04	6	950.4
Ain Beida	7	3888	188	177139.872	16	0
N'Goussa	8	7501.248	88	63922.176	2	0
TOTAL	71	65568.96	812	556620.136	73	29125.44

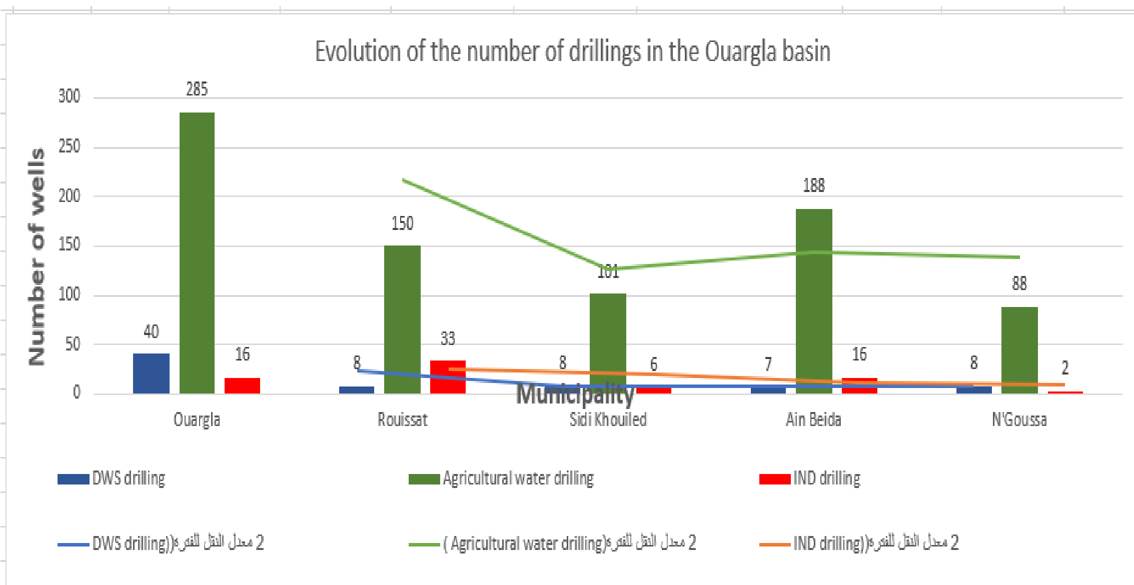


Fig.IV.1. A bar chart representing Evolution of the number of drillings in the Ouargla basin.[2]

https://drive.google.com/file/d/1ljanw1mzz59ID_bC36BQvd-CRxa8AznR/view?usp=drive_link

Fig.IV.2. This is a map showing the distribution of wells across the Ouargla Basin, which was created using a program power BI to view, please visit the link.[3]

The chart titled "Evolution of the number of drillings in the Ouargla basin" depicts the number of wells drilled across five municipalities: Ouargla, Rouissat, Sidi Khouiled, Ain Beida, and N'Goussa. The wells are categorized into three types:

1. **DWS (Drinking Water Supply) drilling**: Represented by blue bars.
2. **Agricultural water drilling**: Represented by green bars.
3. **IND (Industrial) drilling**: Represented by red bars.

Additionally, there are trend lines for each category:

- ✓ A blue trend line representing the trend of DWS drilling.
- ✓ A green trend line representing the trend of agricultural water drilling.
- ✓ An orange trend line representing the trend of IND drilling.

From the chart, it is evident that agricultural water drilling is the most prevalent type of well across all municipalities, with the highest numbers in Ouargla (285) and Ain Beida (188). DWS and IND drillings are significantly lower in comparison. The trend lines indicate the overall trend in the number of wells for each category.

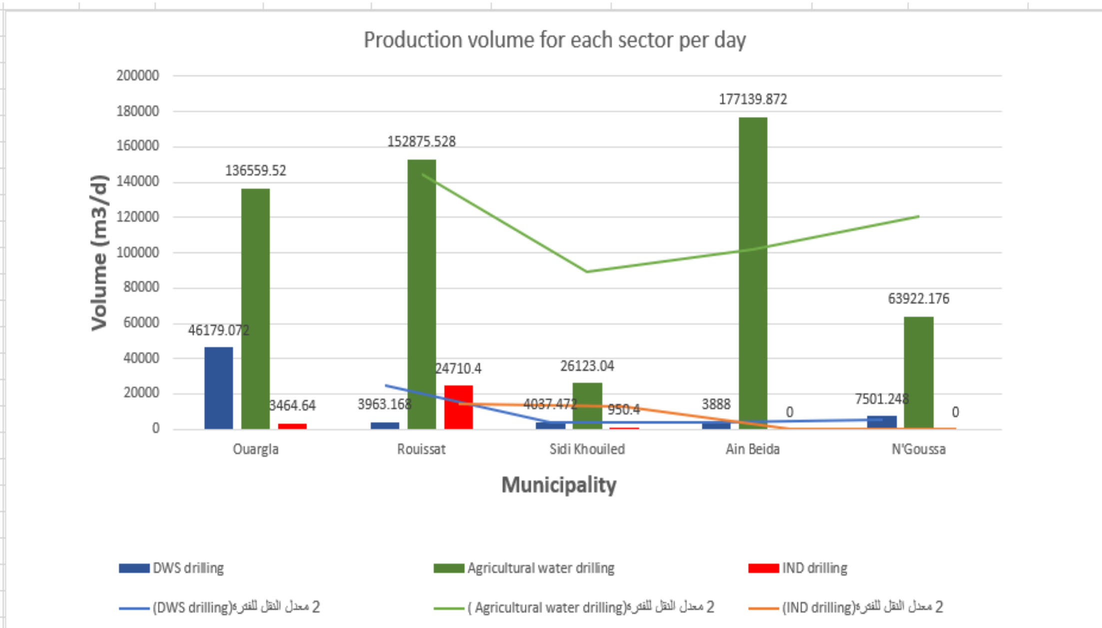


Fig.IV.3. A bar chart representing the Production volume for each sector per day.[4]

The chart provides a detailed view of the production volume for different sectors per day across five municipalities: Quargla, Rouissat, Sidi Khouiled, Ain Beida, and N'Goussa. The sectors included are DWS drilling, agricultural water drilling, and IND drilling.

Observations:

- ✓ **Ouargla** and **Rouissat** show significant production volumes, especially in agricultural water drilling, with Rouissat having the highest overall agricultural water drilling volume.
- ✓ **Ain Beida** recorded the highest agricultural water drilling volume among all municipalities, at 177,139.872 m³/d, but has no IND drilling.
- ✓ **Sidi Khouiled** has moderate volumes across all types but significantly lower than Ouargla and Rouissat.
- ✓ **N'Goussa** has substantial agricultural water drilling but no IND drilling recorded.

- ✓ **DWS drilling** volumes are relatively lower across all municipalities compared to agricultural water drilling.

This chart helps visualize the disparity in drilling production volumes across different sectors and municipalities, indicating where the focus and resources are concentrated.

Tab.IV.2. The area of water bodies is in square metres, and the volume of water in them is in cubic metres[5]

The area of water bodies is in square metres, and the volume of water in them is in cubic metres					
year	2000 _ 2005	2005_2010	2010_2015	2015_ 2020	2020_ 2024
area in sqm	2282.77	2282.77	27391.84	19033	29033
volume in cubic metres	4565.453	4565.453	54783.69	38066.64	54783.69

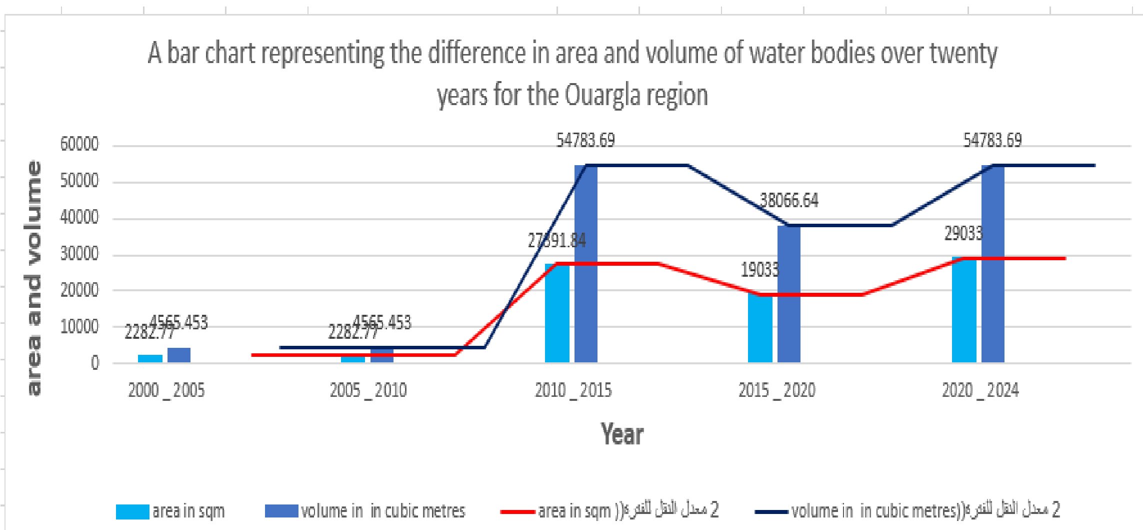


Fig.IV.4. A bar chart representing the area of water bodies is in square metres, and the volume of water in them is in cubic metres.[6]

This chart illustrates the dynamic changes in water bodies over the past twenty years in the Quargla region, highlighting periods of stability, significant growth, reduction, and subsequent recovery in both area and volume of water bodies.

Observations:

- ✓ From 2000 to 2010, both the area and volume of water bodies remained constant at 2,285 sqm and 455.453 m^3, respectively.
- ✓ A significant increase occurred in the period 2010-2015, where the area increased to 27,691.84 sqm and the volume surged to 54,783.69 m^3.

- ✓ In the period 2015-2020, there was a decrease in both the area and volume to 19,036 sqm and 38,066.64 m^3, respectively.
- ✓ The period 2020-2024 shows a rebound with the area increasing to 29,035 sqm and the volume returning to 54,783.69 m^3, matching the peak observed in 2010-2015.

Trends:

- ✓ **2000-2010:** Stability in both area and volume of water bodies.
- ✓ **2010-2015:** Significant growth in both area and volume.
- ✓ **2015-2020:** Reduction in both parameters.
- ✓ **2020-2024:** Recovery and return to high volume, with a substantial increase in area.

Tab.IV.3. Vegetation area in hectares[7]

year	2000_2005	2005_2010	2010_2015	2015_2020	2020_2024
Vegetation area in hectares	471.538	766.96	653.253	566.397	680.188

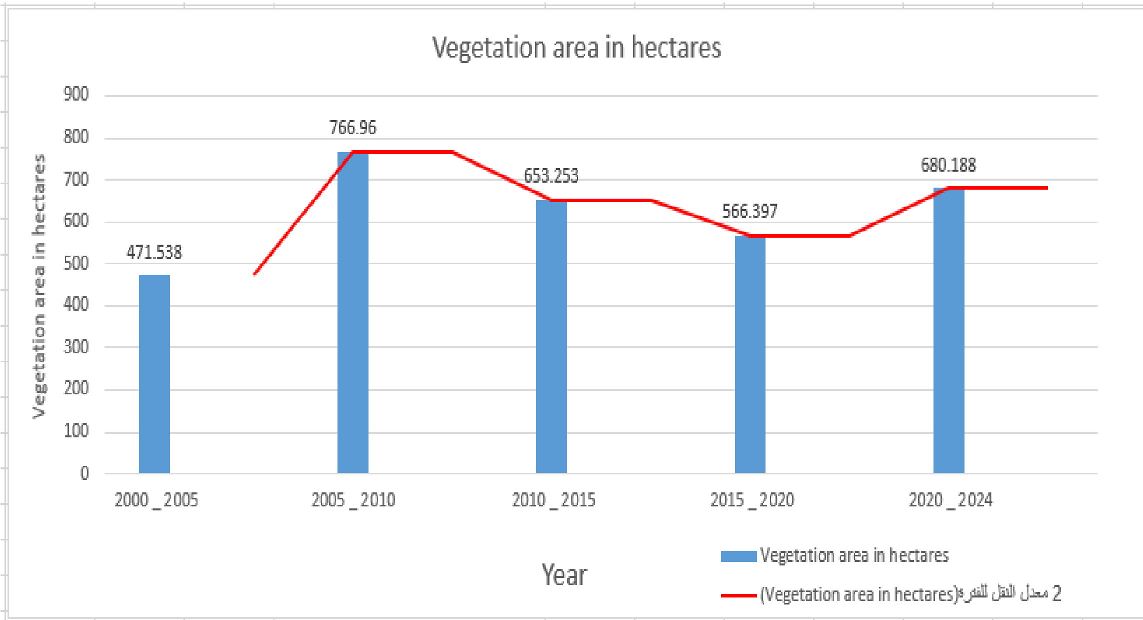


Fig.IV.5. A bar chart representing Vegetation area in hectares[8]

This chart illustrates the changes in vegetation area over different periods, highlighting a peak in 2005-2010, followed by a decline, and a subsequent recovery in 2020-2024.

Observations:

- ✓ **2000-2005:** The vegetation area starts at 471.538 hectares.
- ✓ **2005-2010:** There is a significant increase in the vegetation area to 766.96 hectares, marking the highest value recorded.
- ✓ **2010-2015:** A decline in the vegetation area is observed, reducing to 653.253 hectares.
- ✓ **2015-2020:** The decline continues with the vegetation area dropping further to 566.397 hectares.
- ✓ **2020-2024:** The vegetation area shows recovery, increasing to 680.188 hectares.

Trends:

- ✓ **2000-2005:** Baseline period with moderate vegetation area.

- ✓ **2005-2010:** Significant growth period with the highest recorded vegetation area.
- ✓ **2010-2015:** Period of decline in vegetation area.
- ✓ **2015-2020:** Continued decline reaching the lowest point since the peak in 2005-2010.
- ✓ **2020-2024:** Recovery period with an increase in vegetation area.

I.1. General conclusions from the four charts:

- ✓ The data presented across the four charts provides a comprehensive overview of various aspects of environmental and resource changes in the Ouargla region. By analyzing the evolution of drillings, production volumes, water bodies, and vegetation area, several key conclusions can be drawn:

1.1. Prevalence of Agricultural Water Drilling:

- ✓ Agricultural water drilling is the most common type of well across all municipalities, with particularly high numbers in Ouargla and Ain Beida. This indicates a strong focus on agriculture and irrigation in the region.

1.2. Disparities in Drilling Production Volumes:

- ✓ The production volumes of agricultural water drilling are significantly higher compared to DWS and IND drillings. Rouissat has the highest overall agricultural water drilling volume, while Ain Beida records the highest individual volume at 177,139.872 m^3/d but lacks IND drilling. This highlights the region's prioritization of agricultural needs over industrial uses.

1.3. Dynamic Changes in Water Bodies:

- ✓ Over the past twenty years, the area and volume of water bodies have shown periods of stability, significant growth, reduction, and subsequent recovery. The data suggests resilience and adaptability in water resource management, with current levels matching previous peaks.

1.4. Fluctuations in Vegetation Area:

- ✓ The vegetation area has experienced a peak in 2005-2010, followed by a decline and a recent recovery in 2020-2024. This trend indicates variability in land use and vegetation health, potentially influenced by changes in water availability and agricultural practices.

I.2. General Conclusions:

Resource Management and Prioritization:

- ✓ The data indicates that the Ouargla region prioritizes agricultural water needs, which is reflected in both the number of wells drilled and the production volumes. This focus on agriculture aligns with the observed trends in vegetation area and water bodies.

Environmental Resilience and Adaptation:

- ✓ Despite fluctuations in water body volumes and vegetation areas, the recent recovery in these metrics suggests an ability to adapt and recover from environmental changes. This resilience is crucial for maintaining the sustainability of the region's natural resources.

Municipality-Specific Characteristics:

- ✓ There are notable disparities between municipalities in terms of drilling activity and production volumes. For example, Ain Beida and N'Goussa lack industrial drilling, while Rouissat leads in agricultural production volumes. Understanding these local differences is key for targeted resource management and policy-making.

Overall, the data paints a picture of a region heavily invested in agricultural development, with dynamic environmental conditions that require careful management to ensure long-term sustainability and resilience.

II. NDVI Maps:

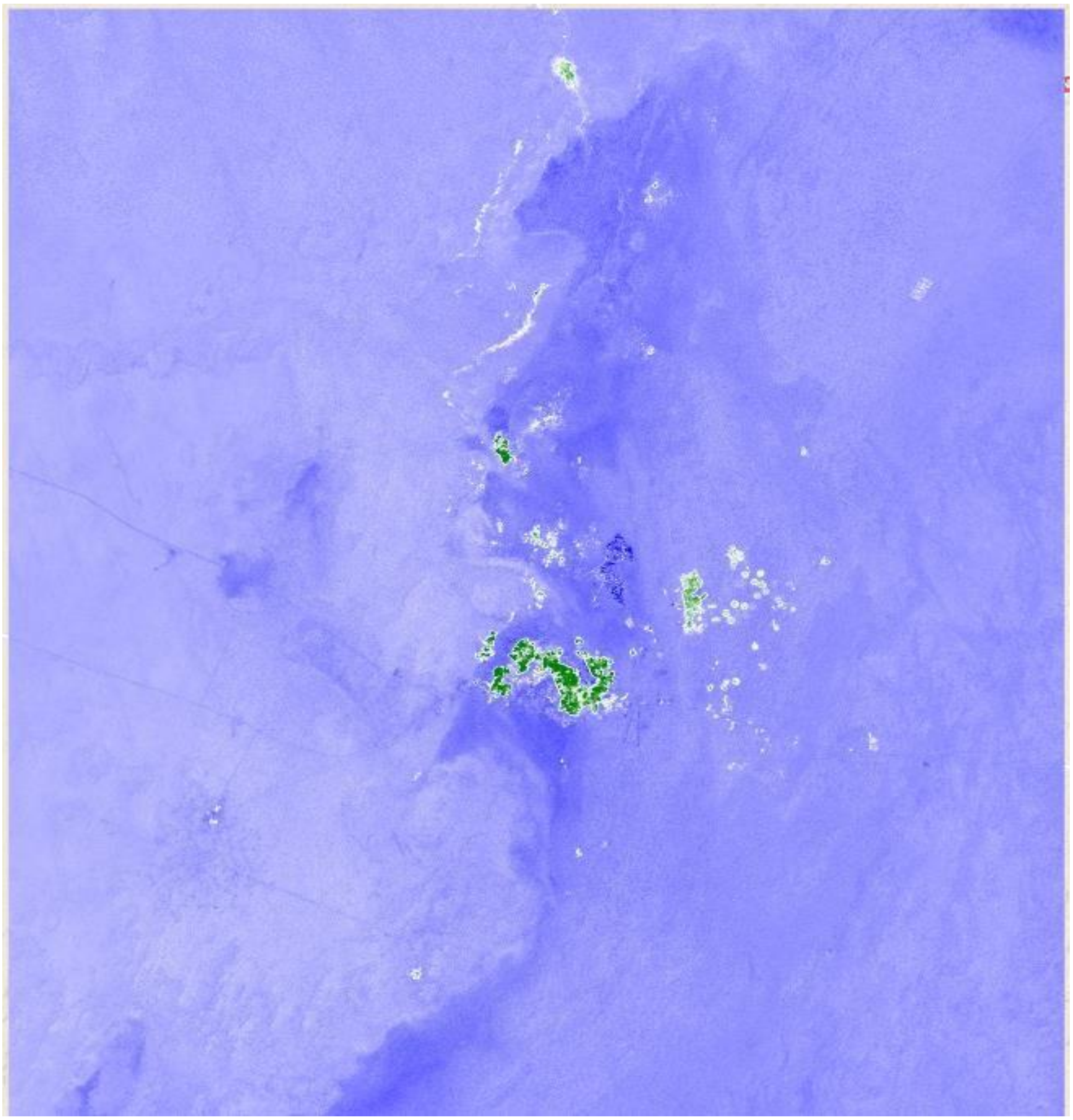


Fig.IV.6. NDVI maps of Ouargla Basin from 2000 to 2005[9]

II.1. Image {Fig.IV.6} Description :

1. Geographic Context:

- ***Region:*** Ouargla Basin, Algeria.

- ✓ ***Time Frame:*** The map represents vegetation data from the years 2000 to 2005.

2. Color Scheme:

- ✓ **Green Areas:** These represent regions with significant vegetation, likely corresponding to oases, agricultural fields, or areas near water sources.
- ✓ **Blue to Purple Shades:** These indicate areas with minimal to no vegetation, typical for desert regions.

3. Vegetated Area:

- ✓ **Approximate Area:** 471.53 hectares of vegetation within the Ouargla Basin during the specified period. This is a relatively small fraction of the basin, indicative of the sparse vegetation in this arid environment.

4. Interpretation:

- ✓ The map shows that vegetation in the Ouargla Basin is highly localized and limited. The green patches indicate zones where conditions are favorable for plant growth, likely due to irrigation or natural water availability.
- ✓ The predominant blue and purple shades underscore the extensive desert areas with little to no vegetation.

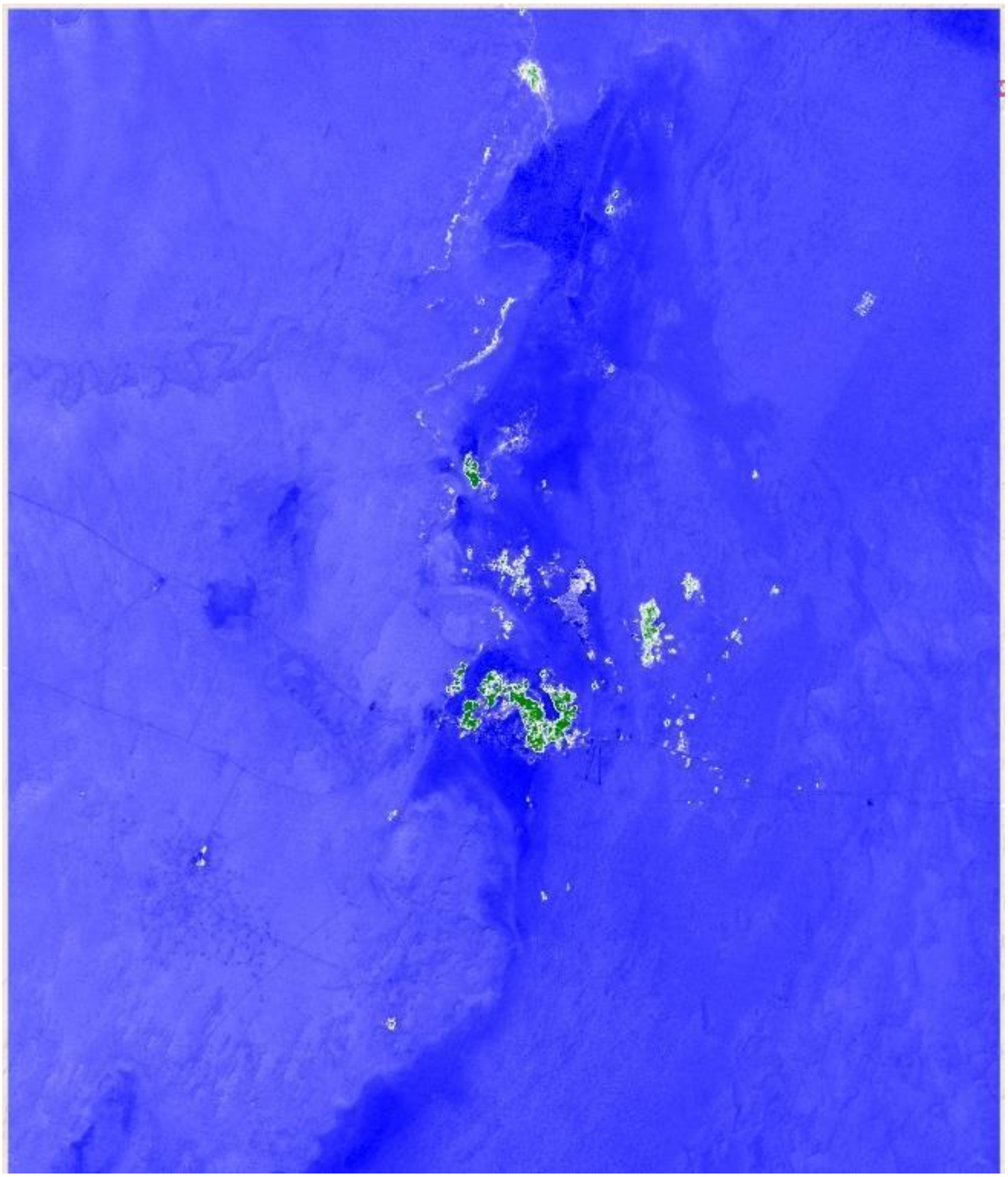


Fig.IV.7. NDVI maps of Ouargla Basin from 2005 to 2010[10]

II.2. Image {Fig.IV.7} Description :

1. Geographic Context:

- ✓ ***Region:*** Ouargla Basin, Algeria.
- ✓ ***Time Frame:*** The map represents vegetation data from the years 2005 to 2010.

2. Color Scheme:

- ✓ ***Blue to Purple Shades***: These colors indicate areas with little to no vegetation. This encompasses the majority of the Ouargla Basin, consistent with its arid and semi-arid conditions.
- ✓ ***Green Spots:*** These represent areas with significant vegetation. The brighter and more numerous green spots suggest healthier and denser vegetation.

3. Vegetation Distribution:

- ✓ ***Green Areas:*** The map shows several scattered green patches, indicating zones of significant vegetation. These areas are likely associated with oases, agricultural fields, or regions near water sources.
- ✓ ***Concentration:*** The vegetated areas appear more concentrated and possibly more widespread compared to the previous period (2000-2005), suggesting an increase in vegetation.

4. Comparison with Previous Period (2000-2005):

- ✓ ***Vegetated Area:*** The vegetated area increased from approximately 471.53 hectares in 2000-2005 to 766.96 hectares in 2005-2010. This indicates a substantial increase in vegetation cover over the five-year period.
- ✓ ***Changes in Vegetation:*** The increase in green patches signifies improved vegetation conditions, which could be due to various factors such as better water management, increased agricultural activities, or favorable climatic conditions.

5. Interpretation:

- ✓ The image indicates an increase in vegetated areas within the Ouargla Basin from 2005 to 2010 compared to the previous period (2000-2005).
- ✓ The larger and more numerous green patches suggest better vegetation health and density during this period.
- ✓ This increase in vegetation could reflect improvements in irrigation, agricultural practices, or other environmental management efforts.

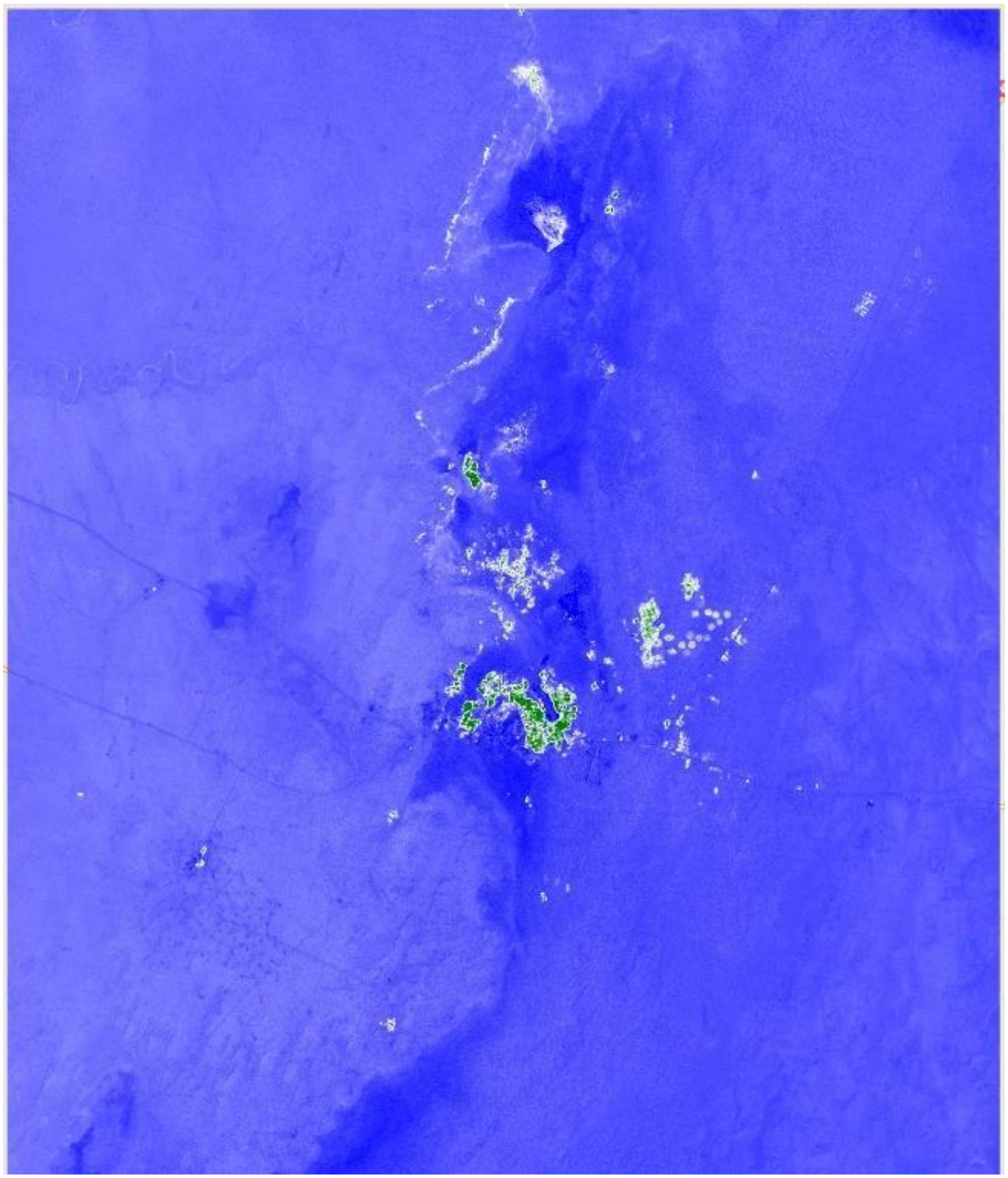


Fig.IV.8. NDVI maps of Ouargla Basin from 2010 to 2015[11]

II.3. Image **{Fig.IV.8}** *Description :*

1. Geographic Context:

- ✓ Region: Ouargla Basin, Algeria.
- ✓ Time Frame: The map represents vegetation data from the years 2010 to 2015.

2. Color Scheme:

- ✓ ***Blue to Purple Shades:*** These colors indicate areas with little to no vegetation. This is consistent with the arid nature of the Ouargla Basin.
- ✓ ***Green Spots:*** These represent areas with significant vegetation, indicating the presence of oases, agricultural zones, or regions near water sources.

3. Vegetation Distribution:

- ✓ ***Green Areas:*** The map shows scattered green patches, which are indicative of vegetation. These patches are concentrated in specific areas, suggesting localized zones of higher vegetation density.
- ✓ ***Concentration:*** The green patches are relatively well-distributed, though they appear slightly less concentrated than in the previous period (2005-2010).

4. Comparison with Previous Periods:

- ✓ ***Vegetated Area:*** The vegetated area for this period (2010-2015) is approximately 653.25 hectares. This is a decrease from the 766.96 hectares observed in the previous period (2005-2010), but still more than the 471.53 hectares from 2000-2005.
- ✓ ***Changes in Vegetation:*** There is a noticeable decrease in vegetated area compared to the 2005-2010 period, indicating a possible decline in vegetation health or coverage. This could be due to a variety of factors such as changes in water availability, agricultural practices, or climatic conditions.

5. *Interpretation:*

- ✓ The map indicates a decrease in the total vegetated area in the Ouargla Basin from 2010 to 2015 compared to the previous period (2005-2010).
- ✓ The green patches still highlight significant areas of vegetation, though there has been some reduction in their extent.
- ✓ This decline could point to challenges in maintaining vegetation in this arid region, possibly related to environmental or human factors.

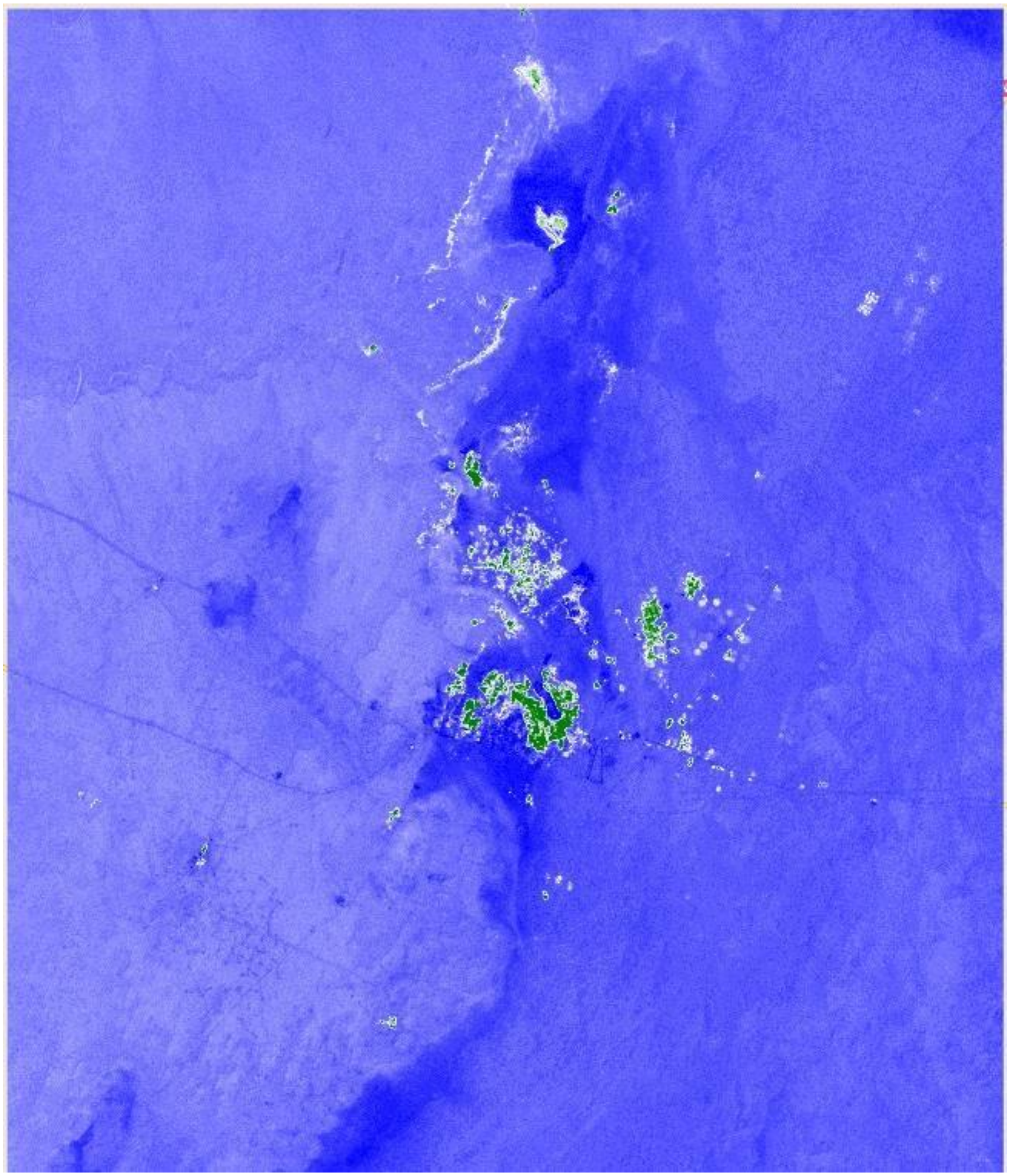


Fig.IV.9. NDVI maps of Ouargla Basin from 2015 to 2020[12]

II.4. Image {Fig.IV.9} Description :

1. Geographic Context:

- ✓ ***Region:*** Ouargla Basin, Algeria.
- ✓ ***Time Frame:*** The map represents vegetation data from the years 2015 to 2020.

2. Color Scheme:

- ✓ ***Blue to Purple Shades:*** These colors indicate areas with little to no vegetation, which is typical for the arid environment of the Ouargla Basin.
- ✓ ***Green Spots:*** These represent areas with significant vegetation, suggesting regions of higher vegetation density and health, likely oases or irrigated agricultural zones.

3. Vegetation Distribution:

- ✓ ***Green Areas:*** The map shows scattered green patches, indicating localized zones of significant vegetation. These green patches are indicative of areas where vegetation is concentrated.
- ✓ ***Concentration:*** While there are still green areas, they appear less concentrated than in some previous periods, reflecting a possible reduction in vegetation density or extent.

4. Comparison with Previous Periods:

- ✓ ***Vegetated Area:*** The vegetated area for this period (2015-2020) is approximately 566.39 hectares. This is a decrease from the 653.25 hectares observed in the previous period (2010-2015).
- ✓ ***Changes in Vegetation:*** There is a noticeable decrease in vegetated area compared to the 2010-2015 period, indicating a reduction in vegetation health or coverage. This could be due to factors such as changes in water availability, agricultural practices, or climatic conditions.

5. *Interpretation:*

- ✓ The map indicates a decrease in the total vegetated area in the Ouargla Basin from 2015 to 2020 compared to the previous period (2010-2015).
- ✓ The green patches still highlight significant areas of vegetation, but the reduction in their extent suggests challenges in maintaining vegetation in this arid region.
- ✓ This decline could be related to environmental changes, reduced water availability, or other factors affecting vegetation growth and sustainability.

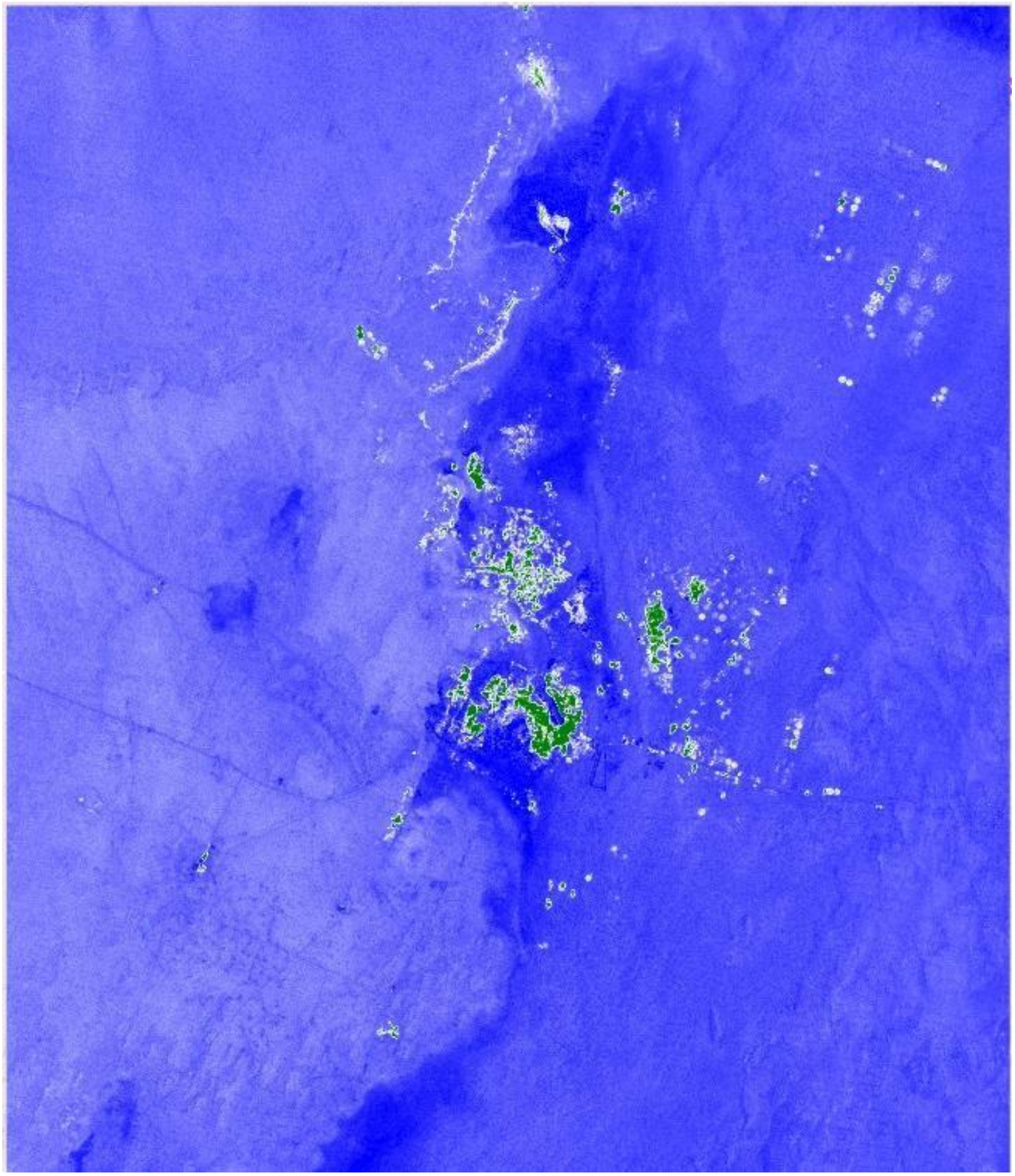


Fig.IV.10. NDVI maps of Ouargla Basin from 2020 to 2024[13]

II.5. Image {Fig.IV.10} Description :

1. Geographic Context:

- ✓ ***Region:*** Ouargla Basin, Algeria.
- ✓ ***Time Frame:*** The map represents vegetation data from the years 2020 to 2024.

2. Color Scheme:

- ✓ ***Blue to Purple Shades:*** These colors indicate areas with little to no vegetation, characteristic of the arid Ouargla Basin.
- ✓ ***Green Spots:*** These represent areas with significant vegetation, suggesting regions of higher vegetation density and health, likely oases or irrigated agricultural zones.

3. Vegetation Distribution:

- ✓ ***Green Areas:*** The map shows scattered green patches, indicating localized zones of significant vegetation. These green patches are more concentrated compared to previous periods, suggesting an increase in vegetation density.
- ✓ ***Concentration:*** The green patches appear more densely packed and slightly more widespread compared to the previous period (2015-2020).

4. Comparison with Previous Periods:

- ✓ ***Vegetated Area:*** The vegetated area for this period (2020-2024) is approximately 680.18 hectares. This is an increase from the 566.39 hectares observed in the previous period (2015-2020).
- ✓ ***Changes in Vegetation:*** There is a noticeable increase in vegetated area compared to the 2015-2020 period, indicating an improvement in vegetation health or coverage. This could be due to factors such as increased water availability, improved agricultural practices, or favorable climatic conditions.

5. *Interpretation:*

- ✓ The map indicates an increase in the total vegetated area in the Ouargla Basin from 2020 to 2024 compared to the previous period (2015-2020).
- ✓ The green patches highlight areas with significant vegetation, and their increased density suggests improved conditions for vegetation growth in this arid region.
- ✓ This increase could be related to better water management, enhanced agricultural techniques, or more favorable environmental conditions.

II.6. General Summary of NDVI Images for Ouargla Basin (2000-2024):

The provided NDVI images illustrate the changes in vegetation cover in the Ouargla Basin, Algeria, over four distinct periods from 2000 to 2024. Here's a summary of the observed changes in vegetation cover for each period:

1. 2000 to 2005:

- ✓ ***Vegetated Area:*** Approximately 471.53 hectares.
- ✓ ***Description:*** The map shows sparse green patches indicating areas of significant vegetation. Vegetation is limited, reflecting the arid nature of the region with concentrated areas of vegetation likely representing oases or irrigated zones.

2. 2005 to 2010:

- ✓ ***Vegetated Area:*** Approximately 766.96 hectares.
- ✓ ***Description:*** There is a noticeable increase in the extent and density of green patches compared to the previous period. This suggests an improvement in vegetation cover, possibly due to increased water availability or better land management practices.

3. 2010 to 2015:

- ✓ ***Vegetated Area:*** Approximately 653.25 hectares.
- ✓ ***Description:*** The green patches remain relatively consistent, although there is a slight decrease in the overall vegetated area compared to 2005-2010. This period

shows stable but slightly reduced vegetation coverage, indicating possible environmental or resource challenges.

4. 2015 to 2020:

- ✓ ***Vegetated Area:*** Approximately 566.39 hectares.
- ✓ ***Description:*** There is a further decrease in the extent of vegetated areas. The green patches are less dense compared to the previous periods, indicating a reduction in vegetation cover, which could be due to factors like reduced water availability, climate change impacts, or land-use changes.

5. 2020 to 2024:

- ✓ ***Vegetated Area:*** Approximately 680.18 hectares.
- ✓ ***Description:*** The vegetated area increases again, showing more densely packed and widespread green patches compared to the 2015-2020 period. This suggests improved conditions for vegetation growth, potentially due to better water management, agricultural practices, or favorable climatic conditions.

II.7. Overall Observations:

Trend: The Ouargla Basin shows fluctuations in vegetation cover over the 24-year period. There is a general increase in vegetation from 2000 to 2010, followed by a decrease until 2020, and then an increase again up to 2024.

Environmental Impact: These changes in vegetation cover could be influenced by a variety of factors, including water availability, climatic conditions, agricultural practices, and land management strategies.

Significance: Understanding these trends is crucial for managing the ecological health and agricultural productivity of the Ouargla Basin, particularly in an arid environment where vegetation is a key indicator of ecosystem health and resource availability.

III. NDWI Maps:

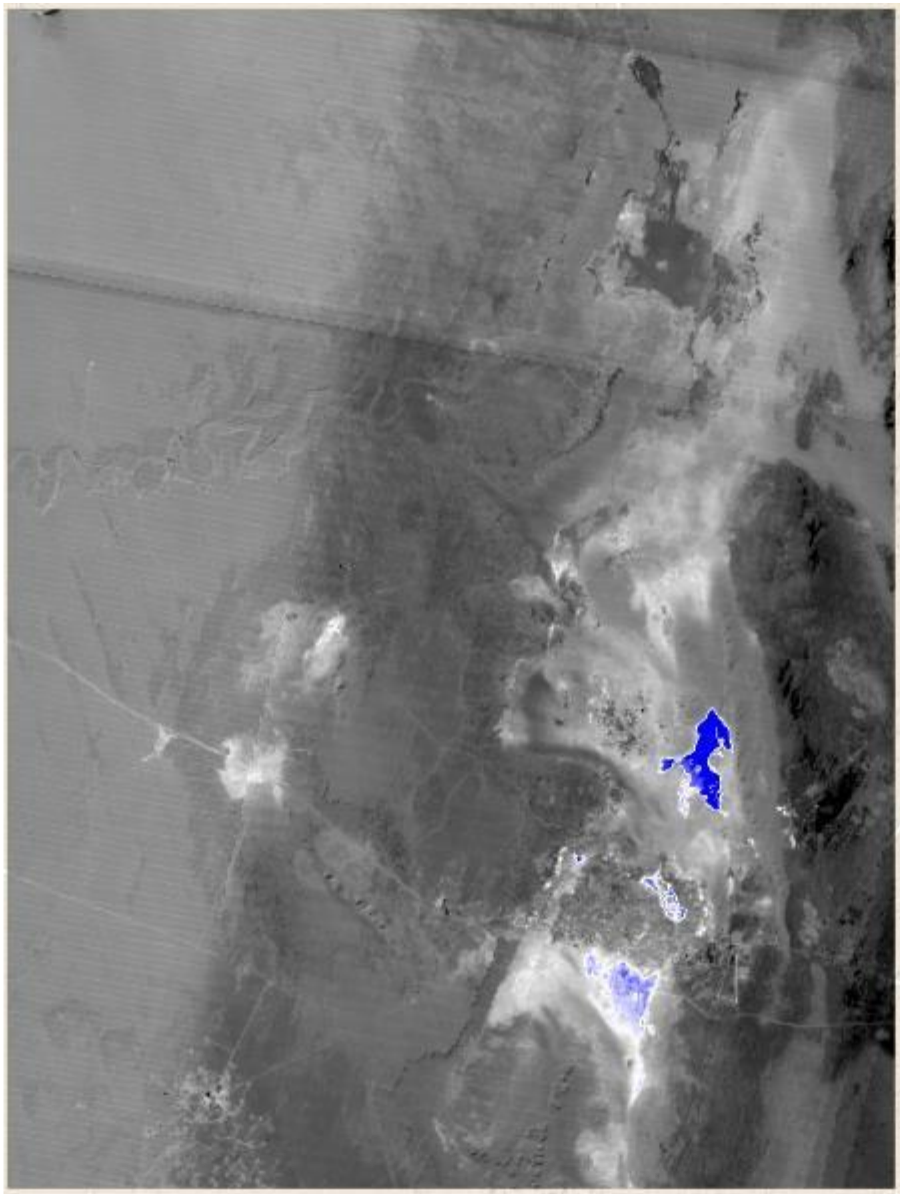


Fig.IV.11. NDWI maps of Ouargla Basin from 2000 to 2005[14]

The image is a Normalized Difference Water Index (NDWI) representation of the Ouargla Basin region, highlighting water bodies in blue. The NDWI is used to detect and monitor water bodies by leveraging the different reflective properties of water and other surfaces in specific wavelength bands.

key details:

- ✓ ***Region:*** Ouargla Basin
- ✓ ***Time Period:*** 2000 to 2005
- ✓ ***Purpose:*** To highlight water bodies using the NDWI technique
- ✓ ***Water Bodies:*** Shown in blue
- ✓ ***Approximate Area of Water Bodies:*** 2282.77 square meters
- ✓ ***Estimated Volume of Water:*** 4565.453 cubic meters

III.2. Description of the Image {Fig.IV.11}:

1. ***Gray-scale Background:*** The gray areas represent the land surface and other non-water features in the Ouargla Basin.

2. ***Blue Areas:*** These are the regions identified as water bodies based on the NDWI calculation. The presence and extent of these water bodies have been highlighted for the period between 2000 and 2005.

3. ***Spatial Distribution:*** The water bodies are scattered across the region, with varying densities and sizes.

1. Analysis:

- ✓ The NDWI effectively differentiates water bodies from other land features, providing clear visualization of water presence in the Ouargla Basin.
- ✓ The total area covered by these water bodies is approximately 2282.77 square meters.
- ✓ The volume of water contained within these bodies is estimated to be around 4565.453 cubic meters.

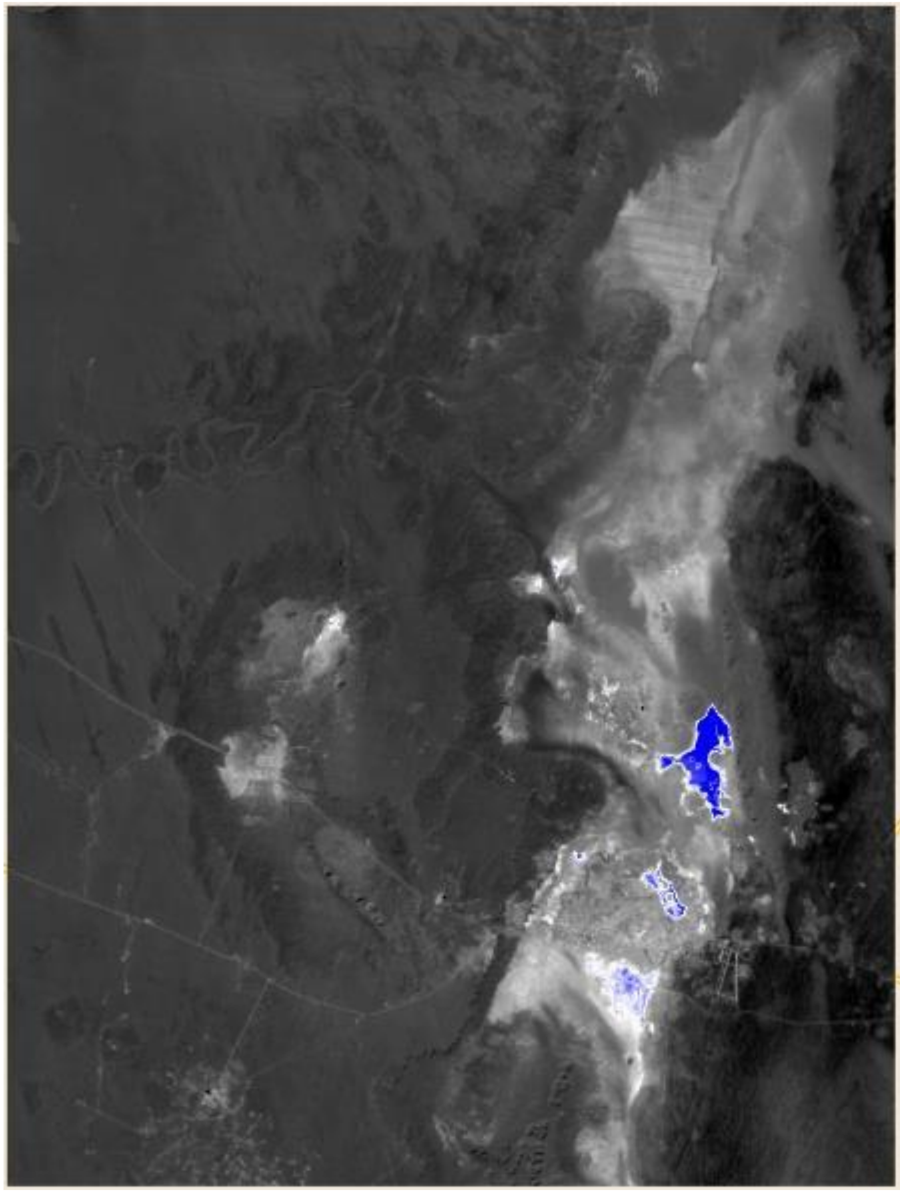


Fig.IV.12. NDWI maps of Ouargla Basin from 2005 to 2010[15]

Key Details:

- ✓ ***Region:*** Ouargla Basin
- ✓ ***Time Period:*** 2005 to 2010
- ✓ ***Purpose:*** To highlight water bodies using the NDWI technique
- ✓ ***Water Bodies:*** Shown in blue

- ***Approximate Area of Water Bodies:*** 2282.77 square meters
- ***Estimated Volume of Water:*** 4565.453 cubic meters

III.3. Description of the Image {Fig.IV.12}:

1. Gray-scale Background: This part of the image represents the land surface, including soil, vegetation, and other non-water features within the Ouargla Basin.

2. Blue Areas: These areas have been identified as water bodies through the NDWI process. They represent the extent and distribution of water during the years from 2005 to 2010.

3. Spatial Distribution: The blue regions, indicating water bodies, are dispersed throughout the Ouargla Basin, with varying sizes and densities.

1. Analysis:

- The NDWI effectively distinguishes water bodies from other land cover types, providing a clear visual representation of water presence in the Ouargla Basin.
- The total area covered by these water bodies is approximately 2282.77 square meters.
- The volume of water in these bodies is estimated to be around 4565.453 cubic meters.

2. Observations:

- The water bodies appear as distinct blue areas against the grayscale background of the land.
- This image, compared to the previous period (2000 to 2005), can be used to analyze changes in water distribution and volume over time.
- The provided data helps in understanding the dynamics of water resources in the Ouargla Basin, which is essential for effective water resource management and planning.

This NDWI image provides valuable insights into the hydrological characteristics of the Ouargla Basin for the specified period, aiding in the monitoring and management of the region's water resources.

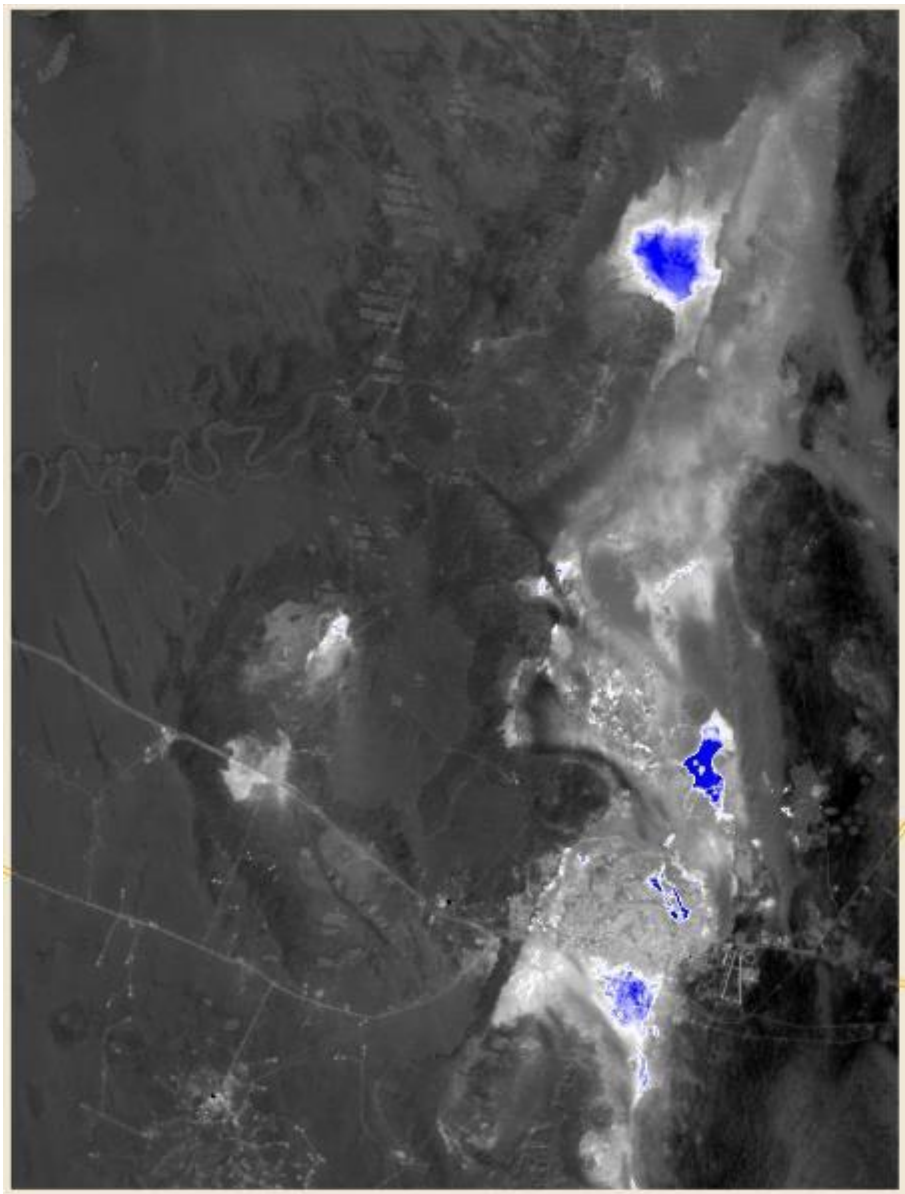


Fig.IV.13. NDWI maps of Ouargla Basin from 2010 to 2015[16]

Key Details:

- ✓ ***Region:*** Ouargla Basin
- ✓ ***Time Period:*** 2010 to 2015
- ✓ ***Purpose:*** To highlight water bodies using the NDWI technique
- ✓ ***Water Bodies:*** Shown in blue
- ✓ ***Approximate Area of Water Bodies:*** 27,391.84 square meters
- ✓ ***Estimated Volume of Water:*** 54,783.69 cubic meters

III.4. Description of the Image {Fig.IV.13}:

1. Gray-scale Background: The gray areas represent the land surface, including soil, vegetation, and other non-water features within the Ouargla Basin.

2. Blue Areas: These regions have been identified as water bodies through the NDWI process. They represent the extent and distribution of water during the years from 2010 to 2015.

3. Spatial Distribution: The blue regions, indicating water bodies, are dispersed throughout the Ouargla Basin, with varying sizes and densities. Notably, there is a large water body visible towards the upper part of the image.

1. Analysis:

- ✓ The NDWI effectively distinguishes water bodies from other land cover types, providing a clear visual representation of water presence in the Ouargla Basin.
- ✓ The total area covered by these water bodies is approximately 27,391.84 square meters.
- ✓ The volume of water in these bodies is estimated to be around 54,783.69 cubic meters.

2. Observations:

- ✓ The water bodies appear as distinct blue areas against the grayscale background of the land.
- ✓ Compared to the previous periods (2000 to 2005 and 2005 to 2010), there is a significant increase in the area and volume of water bodies, indicating changes in water distribution and volume over time.
- ✓ The provided data helps in understanding the dynamics of water resources in the Ouargla Basin, which is essential for effective water resource management and planning.

This NDWI image provides valuable insights into the hydrological characteristics of the Ouargla Basin for the specified period, aiding in the monitoring and management of the region's water resources.

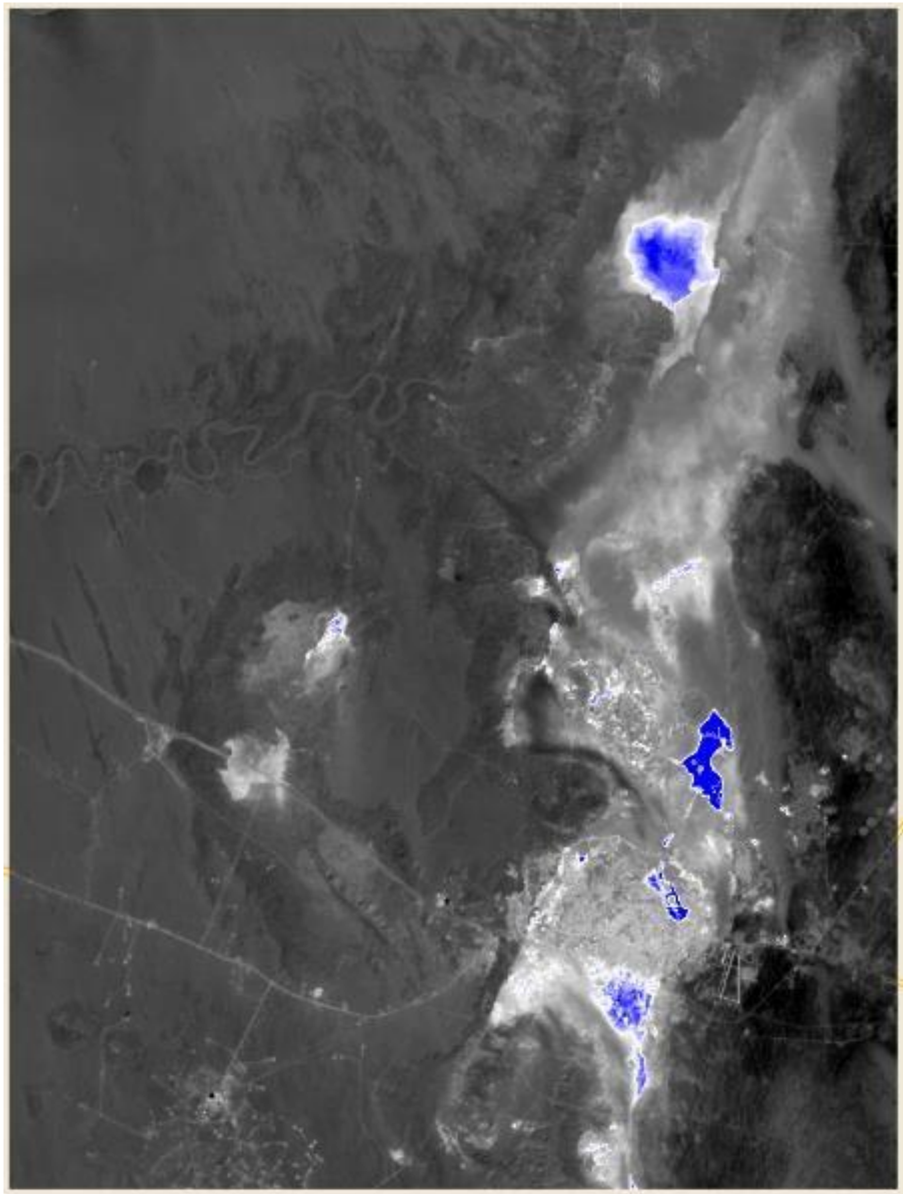


Fig.IV.14. NDWI maps of Ouargla Basin from 2015 to 2020.[17]

Key Details:

- ✓ ***Region:*** Ouargla Basin
- ✓ ***Time Period:*** 2015 to 2020
- ✓ ***Purpose:*** To highlight water bodies using the NDWI technique
- ✓ ***Water Bodies:*** Shown in blue

- ✓ ***Approximate Area of Water Bodies:*** 19,033 square meters
- ✓ ***Estimated Volume of Water:*** 38,066.64 cubic meters

III.5. Description of the Image {Fig.IV.14}:

1. Gray-scale Background: This part of the image represents the land surface, including soil, vegetation, and other non-water features within the Ouargla Basin.

2. Blue Areas: These regions have been identified as water bodies through the NDWI process, representing the extent and distribution of water during the years from 2015 to 2020.

3. Spatial Distribution: The blue regions, indicating water bodies, are dispersed throughout the Ouargla Basin, with varying sizes and densities. Notably, there is a large water body in the upper part of the image and smaller water bodies scattered across the central and lower parts.

1. Analysis:

- ✓ The NDWI effectively distinguishes water bodies from other land cover types, providing a clear visual representation of water presence in the Ouargla Basin.
- ✓ The total area covered by these water bodies is approximately 19,033 square meters.
- ✓ The volume of water in these bodies is estimated to be around 38,066.64 cubic meters.

2. Observations:

- ✓ The water bodies appear as distinct blue areas against the grayscale background of the land.
- ✓ Compared to the previous period (2010 to 2015), there is a decrease in both the area and volume of water bodies, indicating changes in water distribution and volume over time.

- ✓ The provided data helps in understanding the dynamics of water resources in the Ouargla Basin, which is essential for effective water resource management and planning.

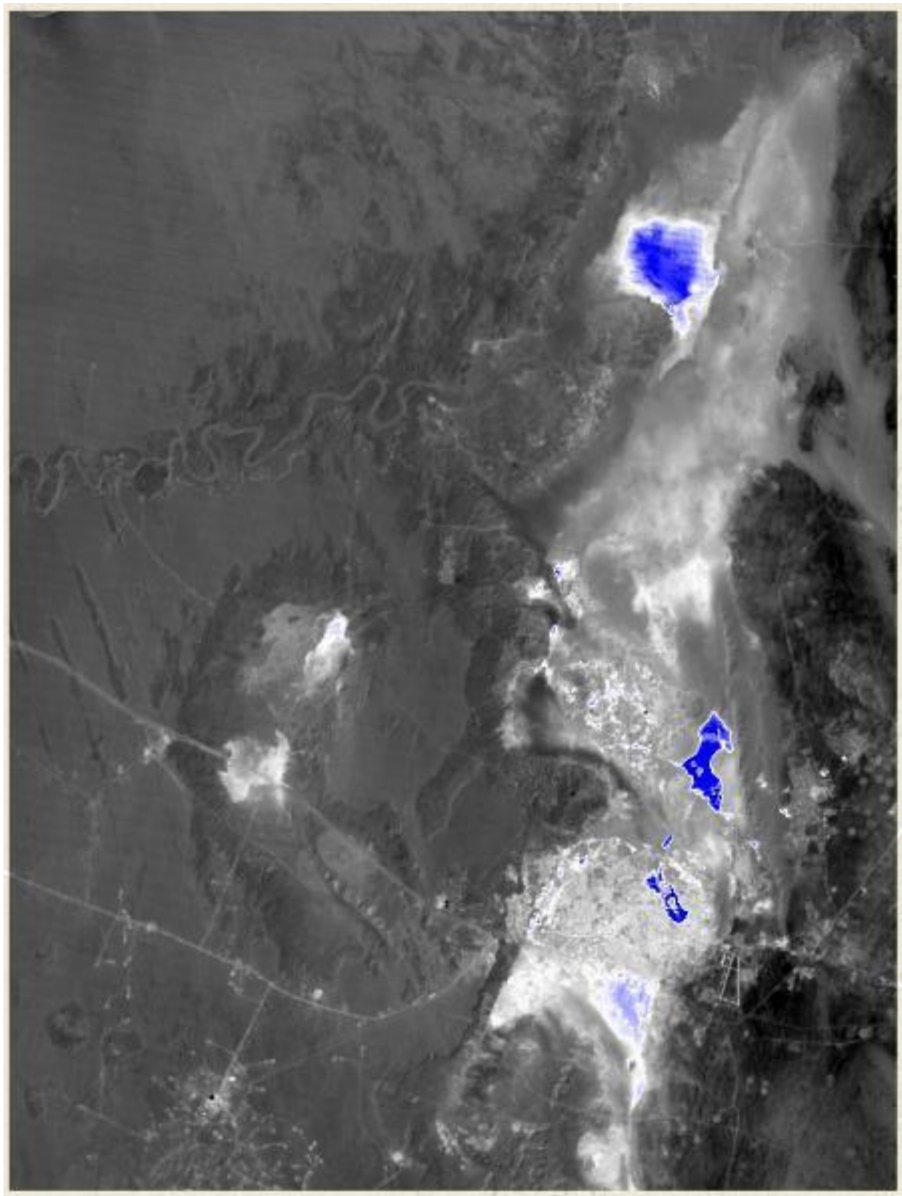


Fig.IV.15. NDWI maps of Ouargla Basin from 2020 to 2024[18]

Key Details:

- ✓ ***Region:*** Ouargla Basin

- ✓ ***Time Period:*** 2020 to 2024
- ✓ ***Purpose:*** To highlight water bodies using the NDWI technique
- ✓ ***Water Bodies:*** Shown in blue
- ✓ ***Approximate Area of Water Bodies:*** 29,033 square meters
- ✓ ***Estimated Volume of Water:*** 54,783.69 cubic meters

III.6. Description of the Image {Fig.IV.15}:

1. **Gray-scale Background:** This portion of the image represents the land surface, including soil, vegetation, and other non-water features within the Ouargla Basin.

2. **Blue Areas:** These regions have been identified as water bodies through the NDWI process, representing the extent and distribution of water during the years from 2020 to 2024.

3. **Spatial Distribution:** The blue regions, indicating water bodies, are scattered throughout the Ouargla Basin, with notable concentrations in the upper, central, and lower parts of the image.

1. Analysis:

- ✓ The NDWI effectively distinguishes water bodies from other land cover types, providing a clear visual representation of water presence in the Ouargla Basin.
- ✓ The total area covered by these water bodies is approximately 29,033 square meters.
- ✓ The volume of water in these bodies is estimated to be around 54,783.69 cubic meters.

2. Observations:

- ✓ The water bodies appear as distinct blue areas against the grayscale background of the land.
- ✓ Compared to the previous period (2015 to 2020), there is an increase in both the area and volume of water bodies, indicating changes in water distribution and volume over time.

- ✓ The provided data helps in understanding the dynamics of water resources in the Ouargla Basin, which is essential for effective water resource management and planning.

III.7. General Summary of NDWI Images for Ouargla Basin (2000-2024):

The series of NDWI images for the Ouargla Basin, spanning from 2000 to 2024, provides a detailed visualization of the region's water bodies over five distinct periods. Here is a comprehensive summary based on the provided data and images:

1. Period: 2000 to 2005

- ✓ ***Approximate Area of Water Bodies:*** 2282.77 square meters
- ✓ ***Estimated Volume of Water:*** 4565.453 cubic meters
- ✓ ***Description:*** During this period, the NDWI image shows scattered small water bodies. The distribution is limited with relatively low total area and volume of water bodies compared to subsequent periods.

2. Period: 2005 to 2010

- ✓ ***Approximate Area of Water Bodies:*** 2282.77 square meters
- ✓ ***Estimated Volume of Water:*** 4565.453 cubic meters
- ✓ ***Description:*** The water bodies remained relatively stable in area and volume compared to the previous period. There are no significant changes observed in the spatial distribution or size of the water bodies.

3. Period: 2010 to 2015

- ✓ ***Approximate Area of Water Bodies:*** 27,391.84 square meters
- ✓ ***Estimated Volume of Water:*** 54,783.69 cubic meters
- ✓ ***Description:*** This period saw a significant increase in both the area and volume of water bodies. A large water body is notable in the upper part of the image, indicating a substantial change in water availability and distribution.

4. Period: 2015 to 2020

- ✓ ***Approximate Area of Water Bodies:*** 19,033 square meters
- ✓ ***Estimated Volume of Water:*** 38,066.64 cubic meters
- ✓ ***Description:*** Compared to the previous period, there is a noticeable decrease in the area and volume of water bodies. The water bodies are still scattered, but their overall extent is reduced.

5. Period: 2020 to 2024

- ✓ ***Approximate Area of Water Bodies:*** 29,033 square meters
- ✓ ***Estimated Volume of Water:*** 54,783.69 cubic meters
- ✓ ***Description:*** This period shows an increase in both the area and volume of water bodies compared to 2015-2020. The water bodies are more prominent and extensive, suggesting an improvement or recovery in water availability.

Summary of Changes Over Time:

- ✓ ***2000 to 2005:*** Baseline period with smaller, scattered water bodies.
- ✓ ***2005 to 2010:*** Stability in water body distribution and size.
- ✓ ***2010 to 2015:*** Significant increase in water body area and volume, indicating higher water availability.
- ✓ ***2015 to 2020:*** Decrease in water body area and volume, suggesting a reduction in water resources.
- ✓ ***2020 to 2024:*** Recovery with increased water body area and volume, returning to higher levels of water availability.

III.8. Conclusion:

The NDWI images and data indicate fluctuating water body extents and volumes in the Ouargla Basin over the years. The period from 2010 to 2015 experienced the highest increase in water bodies, while 2015 to 2020 saw a decline. The latest period (2020 to 2024) shows a recovery, highlighting the dynamic nature of water resources in the region.

These observations are crucial for water resource management and planning in the Ouargla Basin, providing insights into trends and potential challenges in water availability.

IV. Comprehensive Analysis of Ouargla Basin:

1. Evolution of Drilling Activity:

The chart "Evolution of the number of drillings in the Ouargla basin" reveals a significant prevalence of agricultural water drilling across all five municipalities: Ouargla, Rouissat, Sidi Khouiled, Ain Beida, and N'Goussa. This is indicated by the green bars representing the highest number of wells in all locations, with Ouargla and Ain Beida having particularly high numbers (285 and 188, respectively). In contrast, DWS (Drinking Water Supply) and IND (Industrial) drillings, represented by blue and red bars respectively, are significantly lower. The trend lines for each category indicate that while agricultural drilling has increased steadily, the trends for DWS and IND drillings show minimal growth, underscoring the region's focus on agricultural needs.

2. Disparities in Production Volumes:

The production volumes per day for different sectors further emphasize the dominance of agricultural water drilling. Rouissat has the highest overall agricultural water drilling volume, while Ain Beida stands out with the highest individual volume (177,139.872 m^3/d) despite having no industrial drilling. Ouargla and Rouissat also show significant production volumes in agricultural water drilling. Conversely, Sidi Khouiled and N'Goussa exhibit moderate to low volumes, with N'Goussa lacking any IND drilling. This disparity highlights the varying focus and resource allocation among municipalities, with a clear priority given to agricultural needs over industrial and drinking water supply Which in the long term may lead to several problems with the increase in population and the expansion of residential areas at the expense of agricultural areas.

3. Dynamic Changes in Water Bodies:

The analysis of water bodies over the past twenty years in the Ouargla region shows periods of stability, growth, reduction, and recovery in both area and volume:

- ✓ **2000-2010:** Stability with an area of 2,285 sqm and volume of 455.453 m³.
- ✓ **2010-2015:** Significant growth with an area increases to 27,691.84 sqm and volume surge to 54,783.69 m³.
- ✓ **2015-2020:** Reduction with area decreasing to 19,036 sqm and volume to 38,066.64 m³.
- ✓ **2020-2024:** Recovery with area increasing to 29,035 sqm and volume returning to 54,783.69 m³.

These fluctuations indicate flexibility and adaptability in the management of water resources in the Ouargla region or problems in the management of water resources.the Ouargla region.

4. Fluctuations in Vegetation Area:

The changes in vegetation area over different periods show a peak, decline, and subsequent recovery:

- ✓ **2000-2005:** Vegetation area starts at 471.538 hectares.
- ✓ **2005-2010:** Significant increase to 766.96 hectares.
- ✓ **2010-2015:** Decline to 653.253 hectares.
- ✓ **2015-2020:** Further decline to 566.397 hectares.
- ✓ **2020-2024:** Recovery to 680.188 hectares.

This discrepancy indicates the lack of a systematic plan in the management of water resources directed towards agriculture, as the large volume of water resources directed to agriculture, at the very least, will lead to a significant recovery of vegetation cover, which is observed despite the observed improvement.

IV.1. General Conclusions from the Charts:

1. Prevalence of Agricultural Water Drilling:

- ✓ Agricultural water drilling is the most common, particularly in Ouargla and Ain Beida, reflecting a strong agricultural focus.

2. Disparities in Drilling Production Volumes:

- ✓ Agricultural water drilling volumes significantly outpace DWS and IND drillings. Rouissat leads in agricultural volumes, while Ain Beida has the highest individual volume without industrial drilling.

3. Dynamic Changes in Water Bodies:

- ✓ The Ouargla region has shown flexibility in the management of water bodies, as the current levels correspond to the peaks or can be considered problems in the management of water resources. The Ouargla region, where, judging by the nature of the region and assuming tight management, it is necessary to observe stability in the level of water bodies and not an irrational rise in the water level, as It was observed in the first decade of the new millennium

4. Fluctuations in Vegetation Area:

- ✓ The area of vegetation cover reached its peak in the period 2005-2010, followed by a recent decline and recovery, which indicates the variation in environmental conditions and practices and the lack of optimal exploitation of the huge resources directed to the agricultural sector.

IV.2. NDVI and NDWI Maps Analysis:

NDVI Maps: Vegetation Changes (2000-2024):

1. 2000-2005:

- ✓ Vegetation area: 471.53 hectares.

- ✓ Sparse green patches indicating limited vegetation.

2. 2005-2010:

- ✓ Vegetation area: 766.96 hectares.
- ✓ Increase in green patches, suggesting better vegetation conditions.

3. 2010-2015:

- ✓ Vegetation area: 653.25 hectares.
- ✓ Slight decrease in vegetation, indicating possible environmental challenges.

4. 2015-2020:

- ✓ Vegetation area: 566.39 hectares.
- ✓ Further decline in vegetation cover.

5. 2020-2024:

- ✓ Vegetation area: 680.18 hectares.
- ✓ Increase in vegetation, indicating recovery and improved conditions.

NDWI Maps: Water Bodies Changes (2000-2024):

1. 2000-2005:

- ✓ Water area: 2282.77 sqm; volume: 4565.453 m^3.

2. 2005-2010:

- ✓ Water area: 2282.77 sqm; volume: 4565.453 m^3.

3. 2010-2015:

- ✓ Water area: 27,391.84 sqm; volume: 54,783.69 m^3.
- ✓ Significant increase indicating improved water resource management.

4. 2015-2020:

- ✓ Water area: 19,033 sqm; volume: 38,066.64 m^3.

- ✓ Decrease in water bodies, reflecting environmental challenges.

5. 2020-2024:

- ✓ Water area: 29,033 sqm; volume: 54,783.69 m^3.
- ✓ Recovery in water bodies, indicating improved conditions.

V. Results and summary:

The Ouargla Basin has shown great fluctuations and flexibility in its environmental conditions over the past two decades. The region shows a strong focus on agricultural water needs, which is reflected in drilling activities and production volume. Despite the fluctuations in vegetation cover and water bodies that indicate the absence of a systematic plan to manage the large water resources directed to the agricultural sector at the expense of other sectors, despite this, recent trends indicate recovery and improvement, which indicates effective management of resources and the ability to adapt to... Environmental changes. Understanding these dynamics is crucial for sustainable development and policy making in this arid region.

Here we present some results and suggestions for better management of water resources in the region:

- ✓ The volume of agricultural water production far exceeds drinking and industrial water drilling, which leads to future problems.
- ✓ The region has shown flexibility in managing water bodies.
- ✓ The area of vegetation has witnessed fluctuations due to environmental changes and lack of optimal exploitation of resources.
- ✓ Development of drilling activity:
  1- Agricultural water drilling is the most common in all five municipalities, especially in Ouargla and Ain El Bayda.
  2- Drinking and industrial water drilling represents a small percentage compared to agricultural drilling.
- ✓ Production volume variation:

1- Ruwaisat Municipality records the highest daily production volume of agricultural water.
2- Ain Al Bayda is characterized by the highest individual volume of production despite the lack of artificial drilling.
3- The municipalities of Sidi Khouwild and Naqoussa record medium to low production volumes.

Suggestions to improve resource management in the Ouargla region:

1. **Developing water resources management plans:**
   - ✓ Develop long-term plans aimed at achieving stability in water bodies through modern irrigation techniques and effective management of water resources.
2. **Diversifying water uses:**
   - ✓ Achieving a balance between agricultural and industrial use and potable water, to meet the needs of population growth and urban expansion, as Ouargla has witnessed great growth and development in terms of population and urbanization.
3. **Promoting environmental sustainability:**
   - ✓ Supporting reforestation projects and planting drought-resistant plants, to help stabilize the vegetation.
4. **Improving irrigation techniques:**
   - ✓ Adopting drip irrigation and smart irrigation techniques to reduce water waste, solve the problem of rising water, and increase the efficiency of water use in agriculture.
5. **Continuous monitoring and analysis of data:**
   - ✓ Using remote sensing technology (GEE) and geographic information systems (GIS) to continuously monitor changes in water resources and vegetation and take the necessary actions in a timely manner.

6. **Community awareness:**
   - ✓ Increase awareness among farmers and residents about the importance of managing water resources efficiently and adopting sustainable agricultural practices.

By applying these suggestions, resource management in the Ouargla region can be improved, contributing to its long-term sustainability and prosperity.

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