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The Use of Remote Sensing and GIS in Studying the Dynamics of Irrigated Space in Guercif Plain (Morocco)

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Abstract

The use of remote sensing and Geographic Information System (GIS) are among the most efficient modern tools to study the varied natural resources in terms of localization, identification of characteristics, and the study of its dynamics. Thus, the aim of this study is to show the importance of remote sensing and Geographical Information System in studying the Guercif irrigated plain. We will first process and analyze satellite images using the program (Erdas IMAGINE 15. 00) and then create thematic maps illustrating the irrigated area's evolution (ArcGIS 10.8). The results revealed that since the late 20th century, the area of Guercif Plain has expanded significantly, with the total irrigated space that has been doubled many times by 2021. Significant landscape transformations accompanied this evolution, for Guercif Plain has turned from a barren and dry to a green agricultural space.

Keywords: Remote sensing, Geographic information system, dynamics, Irrigated space, Guercif plain.

1. Introduction

For several decades, a group of rain-fed regions in Morocco has experienced an important field dynamic associated mainly with their territorial resources. Similarly, Guercif Plain has undergone rapid transformations, which manifested in the formation of irrigated spaces spontaneously in different areas of the plain, accompanied by significant changes in the morphology of the geographical landscape of the plain. Essential parts of its arid lands have transformed into green areas where olive grass was known to be widespread. Through this research paper, we will show the stages of the evolution of this irrigated space in Guercif plain by adopting a geomatical approach.

The geomatic approach we adopted in this study required us to rely on GIS by working on the program "ArcGIS 10.8". The production of thematic maps to highlight and localize the space distributions and tracking the chronology of the evolution of the irrigated space in the Guercif Plain forced us to rely on remote sensing technology. The aim is to process and interpret land sat satellite images data through the program "ErdasIMAGINE 15.00."

The remote sensing on which we have relied mainly in this study is "one of the several powerful present techniques for monitoring morphological changes" [1], and it refers to the

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entire processes by which data can be obtained from a particular geographical phenomenon on the Earth's surface. This can be done without direct contact between the phenomenon and the data capture device, but terrestrial targets rely on electromagnetic waves to control their locations and structures and follow their distributions.

2. Study Area

The Guercif Plain is a vast depression located in the eastern Maghreb between longitudes 2°55' -3°50' W and between latitudes 34°35' -34°55' N, extending over an area estimated at 6000 km^2 [2]. In this depression, four small plains constitute what we call Guercif plain. In the same respect, Mohamed Bengrich has stated: "…It is spread over wide plains basin, and is in fact one plain, but the multiplicity of watercourses has divided it into several semi-homogeneous plains..." [3]. These plains are Tafrata plain, Ejjel plain, Sangal plain, and Maarouf plain. From the administrative side, this depression belongs to Guercif province, a part of the orient region, Figure 1.

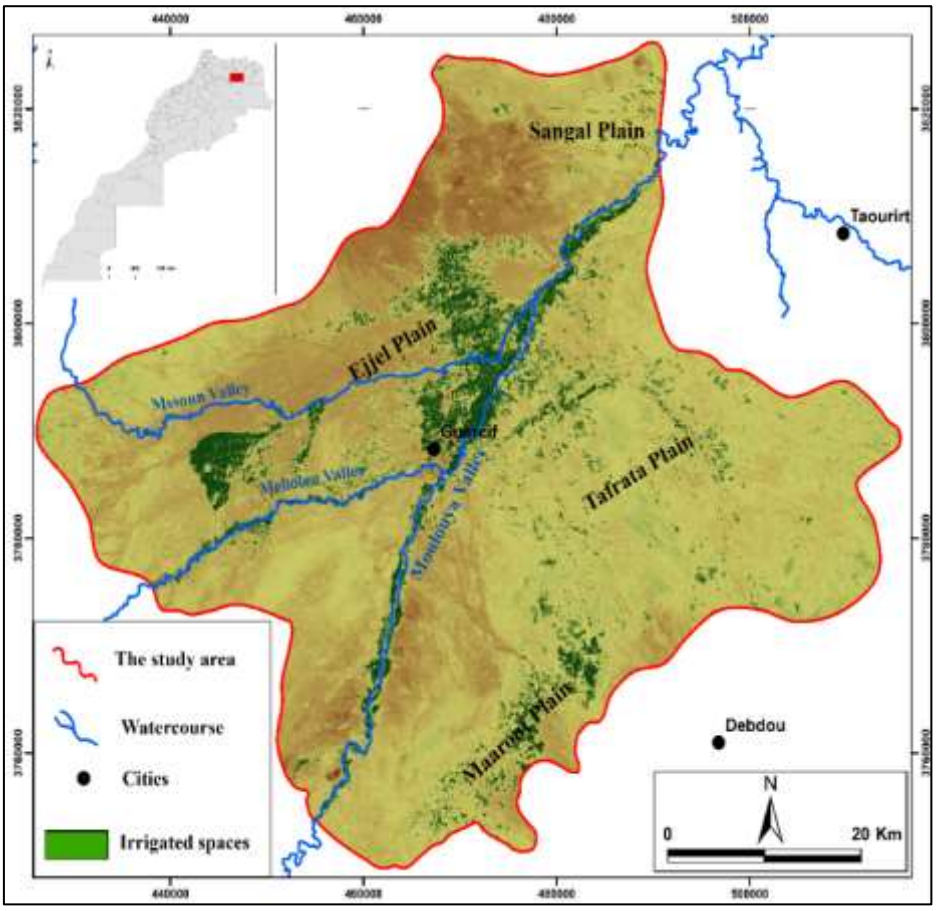

Figure 1: Localisation of the study area

3. Methodology

3.1 Data Collection

In the study of the evolution of the irrigated space in the Guercif Plain, a range of sources were used to collect geographical data, the most important of which are:

- Topographic maps that cover the study area, particularly maps of Guercif, Mssoun, Dabdou, and Berkine (scale 1/100.000);
- Satellite images of Landsat in 1985,1996, 2002, and 2021, in addition to Google Earth space images;

- Official data from the relevant administrative facilities and administrative offices related to the subject of the study, particularly the Regional Directorate of Agriculture, the National Bureau of Agricultural Consultation in Guercif, and the Water Basin Agency of The Moulouya, Oujda
- Condemnable visits to verify the extent to which the results of the applied study match reality.

3.2 ata Analysis:

To understand the dynamic size of the irrigated space in our studied area, we have resorted to processing and analyzing satellite images based on the ERDAS IMAGINE 15.00 program. This latter allows us to calculate the Normalized Difference Vegetation Index (NDVI), as it is, in fact, a statistical indicator that enables us to know the rate of plant activity in the plain by sensing chlorophyll in plants. It can be obtained by combining the red bands and near-infrared bands. "This index is calculated by subtracting the red reflectance from the NIR reflectance, and isolating the two together" [4]. This index is calculated using the following equation:

NDVI= (NIR-RED) / (NIR+RED)

where NDVI= Normalized Difference Vegetation Index,

NIR= Reflection in the near-infrared spectrum,

RED= reflection in the red range of the spectrum.

The results obtained through this index range from -1 as the lowest value to the maximum of +1, where the higher the positive values are, the more they express the gradual transition from bare soil (rocks, buildings, soil...) to green areas, and negative values indicate the presence of water surfaces such as rivers and snow. Regarding Guercif Plain, the dry climate and the brazenness of its space have made its agricultural activity mainly based on the crops. On the other hand, the rain-fed agriculture, whose area is very poor, has helped us distinguish between the values of NDVI, which refer to irrigated and the other irrigated spaces.

By utilizing those applications, we concluded that the rate of NDVI referring to the presence of the irrigated space varies from one satellite image to another. After collecting the statistical values of NDVI from satellite images using Erdas IMAGINE software, a supervised classification tool was utilized. The aim was to distinguish between bare soil and steppe plant formation from one side and irrigated spaces from the other. At a later stage, the software ArcGIS was used to convert the produced maps after the classification from the formula of Raster to the Vector formula. The aim is to calculate the total surface of each of the previous two levels.

The NDVI was applied to four stime-varying satellite images of Landsat to obtain more accurate expressive results on the evolution of the irrigated surfaces during (36 years); satellite images were selected to be taken in the driest month of the year, August, when only the spaces that are watered by groundwater remain in the field.

4. Results and Discussion

4.1 Study Results

The results concluded that the series of transformations of the irrigated space in Guercif Plain was rapidly developed over the last two decades. The irrigated space was confined to the traditional spaces irrigated by both Molouya and Melloulou rivers until the beginning of the current century, but then the modern irrigation systems were apparent in different parts of the plain (Figure 2).

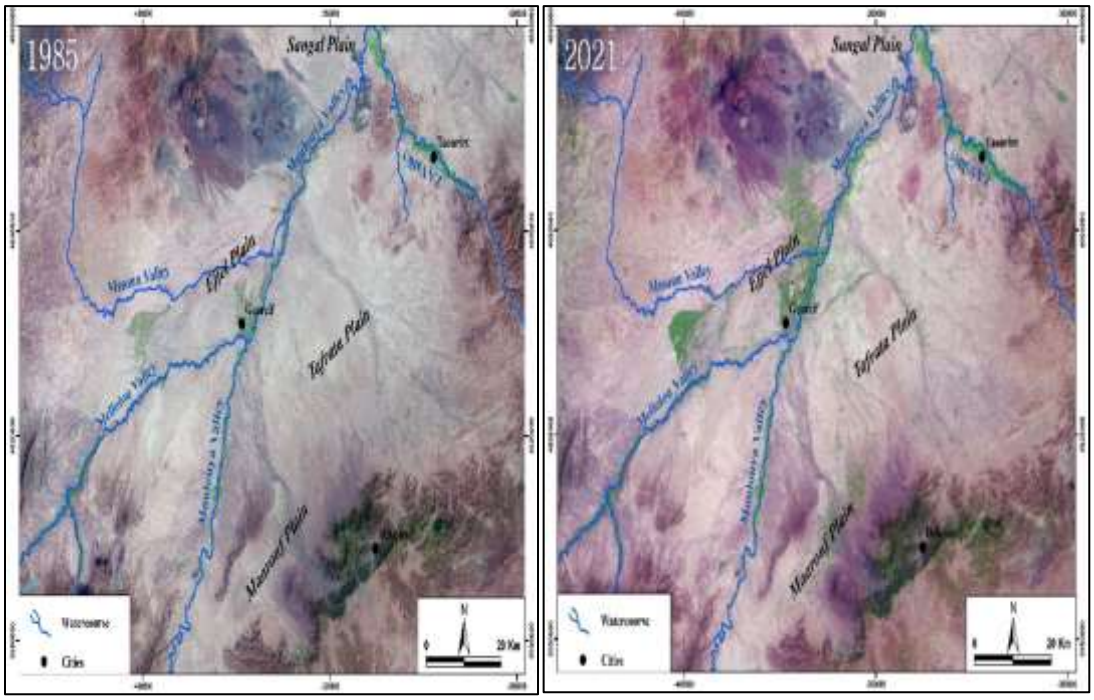

Figure 2: The evolution of the irrigated space in Guercif Plain in 1985 and 2021

After applying the NDVI to study the plant coverage size in Guercif Plain, the results showed significant changes in the activity of the chlorophyll between 1985 and 2021; it manifested by the variation of minimum and maximum values of the NDVI during this period (Figures 3 and 4).

As illustrated by the results obtained, the minimum values of the NDVI vary by period, as they are more robust in 1985 than in 2021; negative values often refer to the existence of a water surface. Thus, it can be said that in August of 1985, surface water was more abundant than in the same month of August 2021. This indicator may suggest the extent to which surface water resources have decreased in the plain after flowing before the formation of dams upstream. The climate change negatively affects water imports in the heights of the Middle Atlas and Rif that supply watercourses of the space. The maximum values that refer to the irrigated space know oscillation during the period when the survey was conducted. Its value moved from 0.67 in 1985 to 0.69 in 1996 but decreased later to 0.45 in 2002. Then it rose again to 0.58 in 2021.

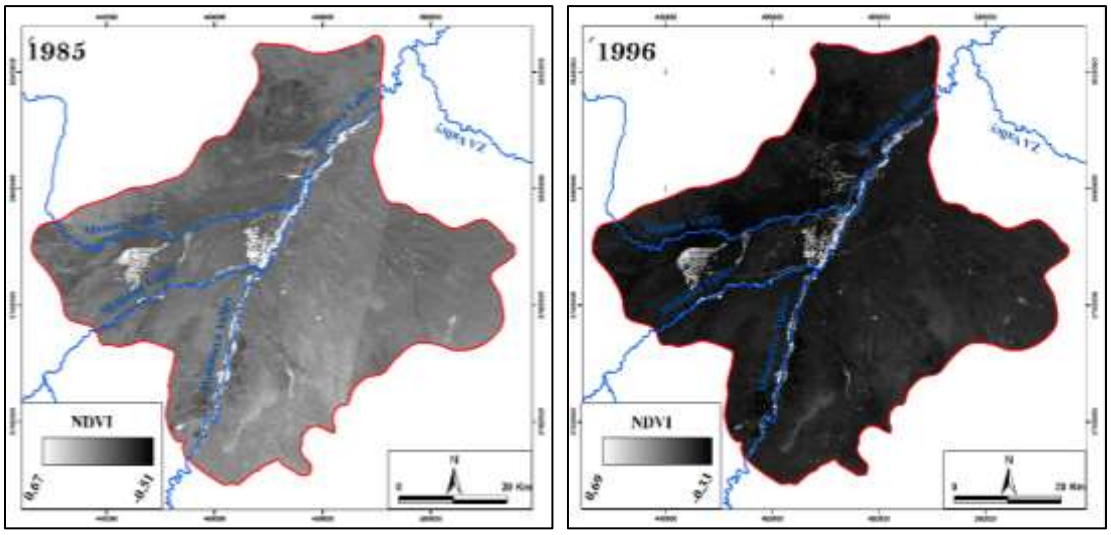

Figure 3: The value of the NDVI in The Guercif Plain evolution in 1985 and 1996

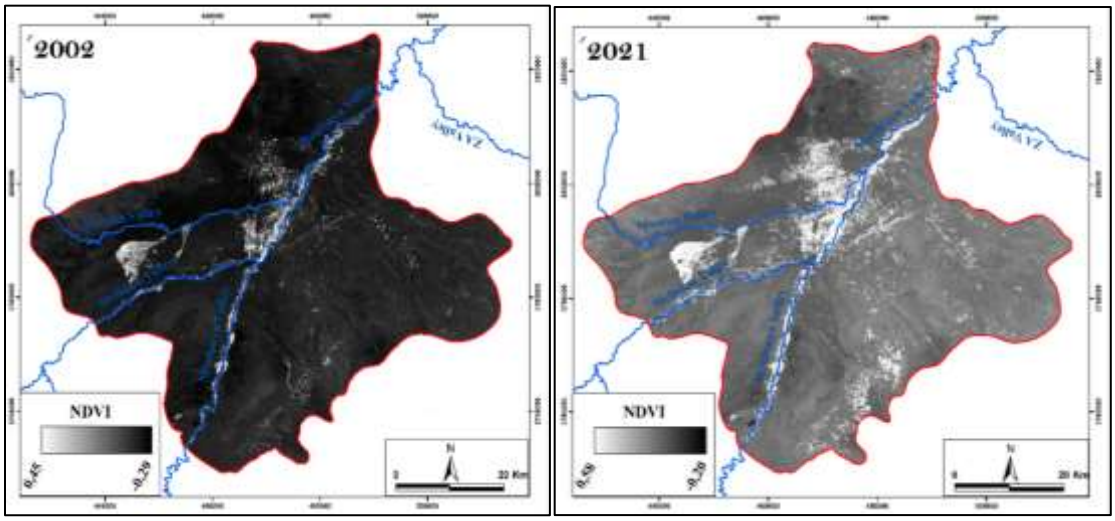

Figure 4: The value of the NDVI in The Guercif Plain evolution in 2002 and 2021

The fluctuation in the maximum values of NDVI is explained by the dimensions adopted in the calculation, particularly biomass and chlorophyll, which is due to natural conditions impaction. Therefore, rising or reducting in plant activity affects the NDVI results positively or negatively, Table 1.

Table 1: The evolution of the values of the NDVI in the Guercif Plain between 1985 and 2021

The year	1985	1996	2002	2021
Maximum value	0.67	0.69	0.45	0.58
Minimum value	-0.51	-0.33	-0.29	-0.20
Average NDVI	0.08	0.18	0.08	0.19

The revealed variation at the minimum and maximum level is evidence of the NDVI average evolution, which is on an upward trend. The NDVI average increased from 0,08 to 0,19 from 1985 to 2021, respectively, except for 2002, when the NDVI average fell to the lowest level at a value equal to the same in 1985, Figure 5. This period can be explained by

the coincidence of a four-year drought from 1999 to 2002 that swept through the entire Moroccan sphere, which adversely affected the watercourses of the study area, whose waters irrigate two important substantial spaces of the plain (the irrigated perimeter of Taddart, and the irrigated perimeter of Ejjel).

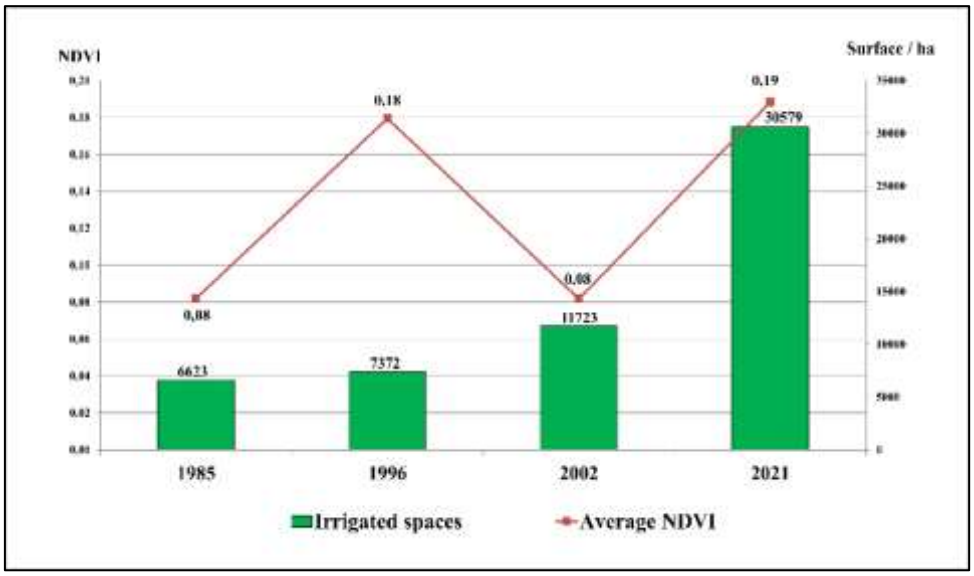

Figure 5: The evolution of the average NDVI and the irrigated space of Guercif Plain between 1985 and 2021

After using GIS to convert the statistical indicators into a mapping expression to show the dynamism of irrigated space in Guercif Pla, the cartographic work results showed that in 1985 the irrigated area was only 2% of the total area of the plain, 6623 ha. The area expanded significantly up to 30579 ha in 2021, constituting 9% in the total area of Guercif Plain (Figure 6), with an increase of 661 ha/year between 1985 and 2021.

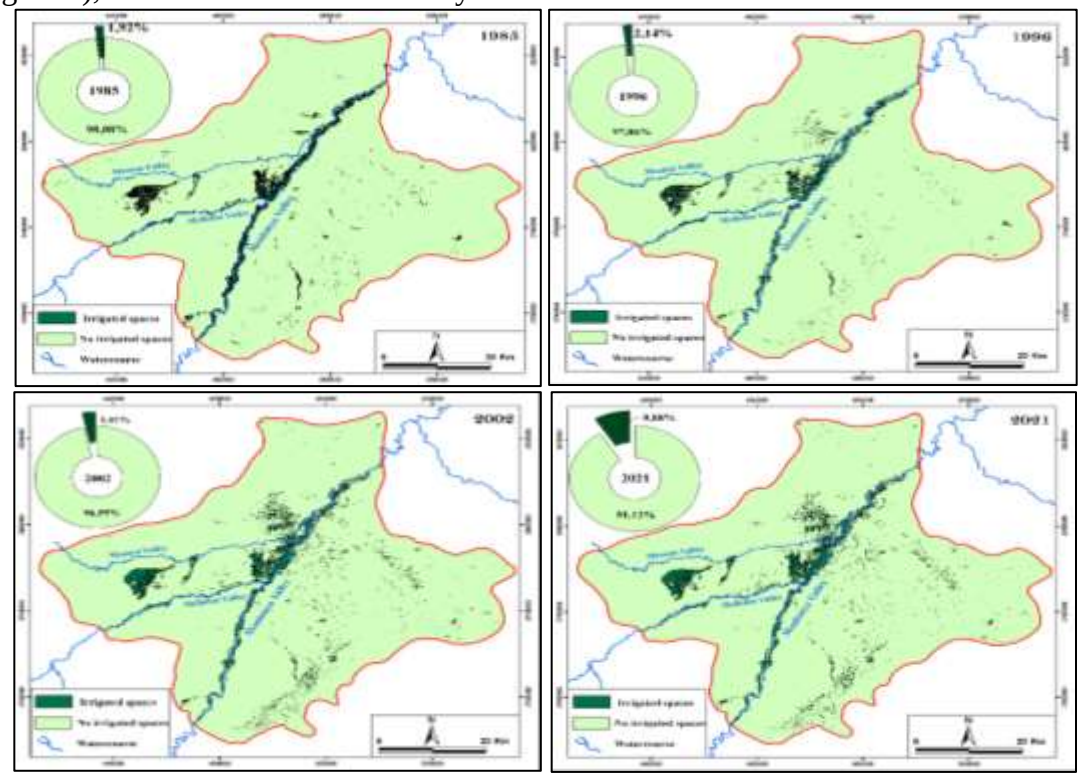

Figure 6: The evolution of the irrigated space in Guercif Plain between 1985 and 2021

Although the pace of agricultural dynamism in the Guercif plain seems weak, it is essential. It is due to the large area of the plain and the harshness of the natural conditions, especially the lack of rainfall down to 170 mm/year, and the high temperature with an average of 20°C [5]. Each of the Ejjel plain, Maarouf, and Tafrata were considered among the areas that know some agricultural dynamism in the plain of Guercif (Figure 7).

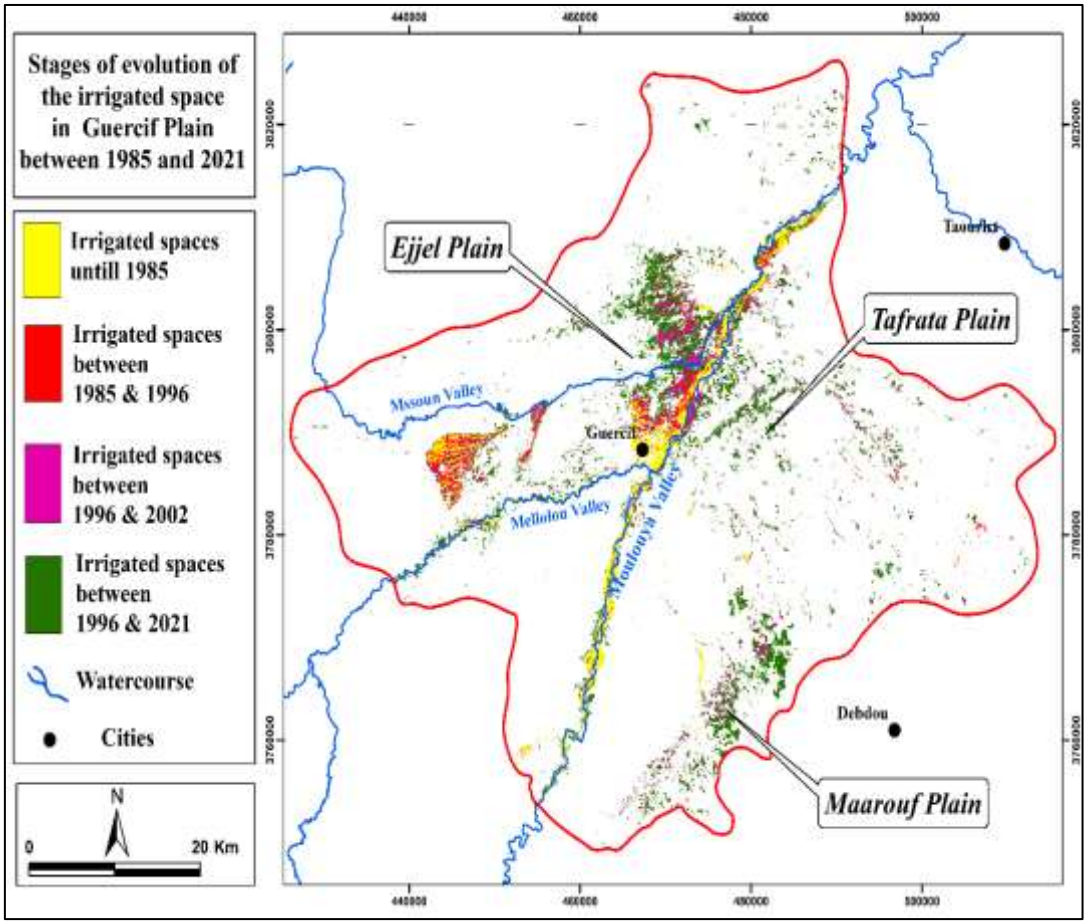

Figure 7: Stages of the irrigated space evolution in Guercif Plain between 1985 and 2021

4.2 Discussion

The Guercif Plain is affected by very important space transformations. Perhaps the most notable change is the expansion of the irrigated space, which has contributed to forming irrigated spaces that have extended over huge areas. Water transformation has played a crucial role, as Guercif Plain is surrounded by a mountain range that contributes to the supply of its water table and the supply of its hydrographic network (Moulouya and its affluents Mssoun and Melloulou). The most important feature of the hydrological system of this network is the irregular flow. Indeed, it recovers during rainy periods when the upstream receives significant amounts of rain and snow, while they know rain scarcity during dry periods (Figure 8).

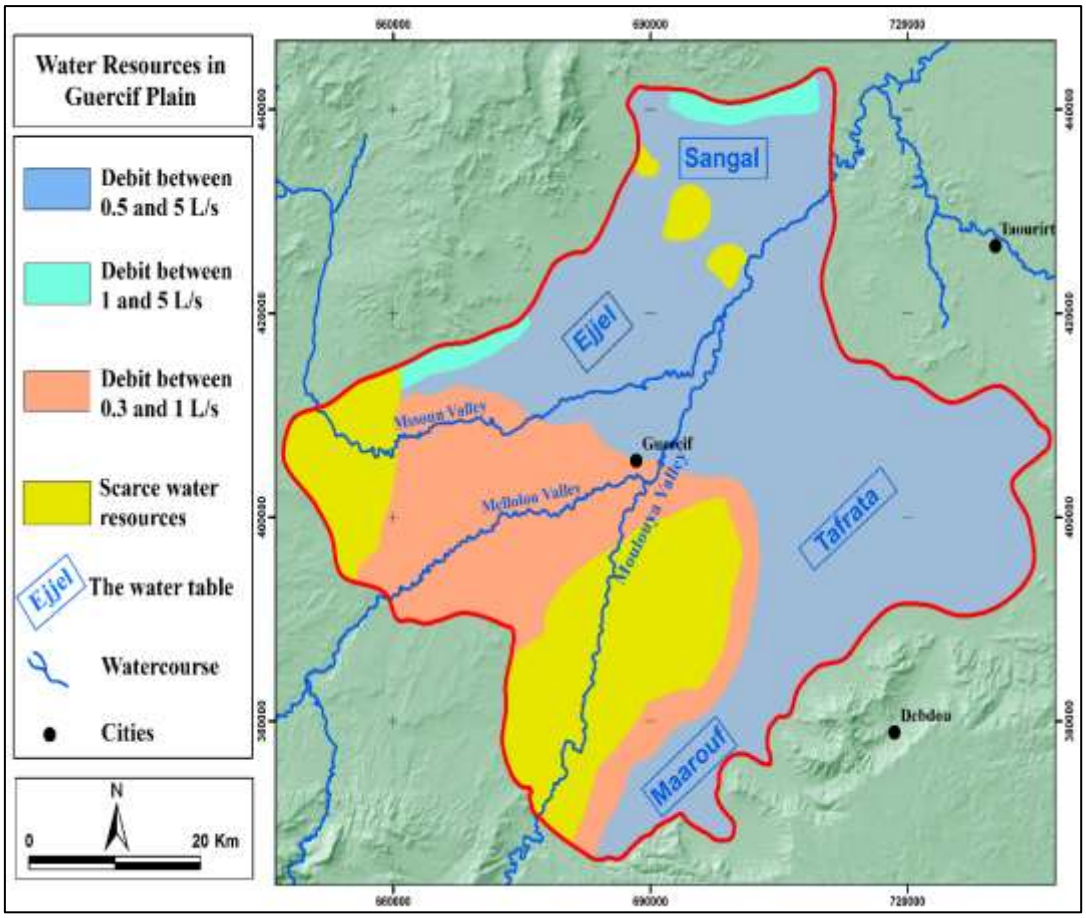

Figure 8: Groundwater and water table resources in Guercif Plain

As a result of the continental climate, Guercif Plain is characterized by preventing the area from benefiting from the humidity to meet the needs of rain-fed agriculture. Therefore, the only solution to secure the needs of the local population for irrigation water is the exploitation of esoteric water table and surface water, which poses a problem of its sustainability.

These water resources would not have contributed to the dynamism of the irrigated space in Guercif Plain if they had not interacted with other essential components. Perhaps one of the essential elements is the state's tendency to stimulate the private sector to invest in agricultural activity. It is due to the evolution of a motivating system that includes various inputs from the agricultural sector, often in the form of material and financial assistance from the office of the Agricultural Development Fund, which has been there since 1986.

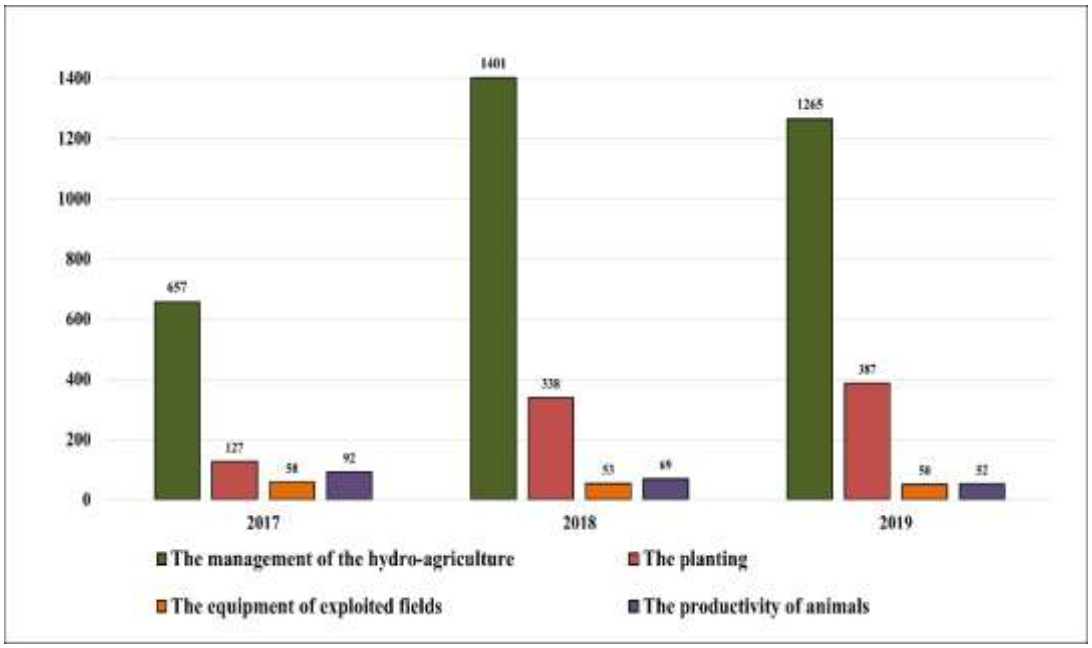

Figure 9: The evolution of aid forms according to the essential areas of support in Guercif between 2017 and 2019

On the other hand, from the agricultural dynamism that characterizes the Guercif depression, the depletion of water stocks has become a significant problem, especially in modern irrigated spaces where watering activity depends heavily on pumping processes. As a result, the level of the water table is known a continuous decrease, and many surveyed farmers expressed this in the field research, where they have all confirmed (100%) that the series of water table evolution is constantly decreasing. The level of its current depth, for example, in the Ejjel plain reached 60 meters in the past few years, while at the beginning of the first signs of the irrigating activity in the space did not reach more than 10 meters. This is due to increased well numbers that are not subjected to strict rules. Mainly, the energy used in water pumping is based on solar energy, which contributes significantly to water wealth wasting. Free energy to extract water would encourage farmers to waste and not appreciate the vital wealth value. One manifestation of the pressure on the water table is the growing phenomenon of drilling wells. This is evident through the increasing demand for well drilling permission, which is doubled nearly ten times between 2014 and 2016 [6], reflecting the extent of the decrease in the level of surface and groundwater resources on the one hand and the expansion of areas connected to Guercif Plain on the other.

5. Conclusion

The study shows that remote sensing in processing and interpreting satellite images has become essential because of contributing to addressing many problems associated with geographical research, as in the case of the subject we studied. These modern techniques have enabled us to monitor the dynamism of the irrigated space in Guercif plain and accurately draw back the curtain on its dimensions through different periods.

It has been concluded that since 1985 the area of Guercif Plain has significantly expanded. Its area was only 6623 ha that year but doubled by 2021, reaching 30579 ha. Significant landscape transformations accompanied this evolution, for Guercif Plain has turned from a barren and dry to a green agricultural space. This is mainly due to the influx of a group of private investors from the region who have employed the proceeds of their migration abroad in the irrigating activity, taking advantage of the water resources of these

plains and the essential real estate balance. However, this exploitation threatens the future of water resources, which is the primary driver of the various dynamism witnessed by Guercif Plain, particularly agricultural dynamism.

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