AFRICAN SCIENTIFIC JOURNAL
MANAGEMENT AND ECONOMIC DEVELOPMENT

African Scientific Journal
ISSN : 2658-9311
Vol : 03, Numéro 29 Avril 2025

The Problem of Deteriorating Water Resources and State Intervention: Rescue the Chtouka's Oulja as an Example.

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Déclaration de divulgation : L'auteur n'a pas connaissance de quelconque financement qui pourrait affecter l'objectivité de cette étude.

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Pour citer cet article : MADHOUM .O, KHANNOUS .A & KHYATI .S (2025) «The Problem of Deteriorating Water Resources and State Intervention: Rescue the Chtouka's Oulja as an Example », African Scientific Journal « Volume 03, Numéro 29 » pp: 0698 – 0713.

DOI : 10.5281/zenodo.15332108

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ISSN : 2658-9311
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Abstract

The Oulja of Chtouka is a large natural zone which lies close to the Atlantic coast, between the city of Casablanca to the northeast and the city of El Jadida to the southwest. Back to the period of the Moroccan protectorate, it has seen intense agricultural activity. This activity has grown steadily with the introduction of market garden crops, taking advantage of the "Coastal Chaouia" water table's proximity. However, since the beginning of the last two decades, there has been a decline in this activity, with the closure of many wells, either due to their drought or their high salinity, indicating a quantitative and qualitative deterioration in water resources. As part of the Green Morocco Plan, the government has developed a project to rescue these agricultural activities. The purpose of this document is to identify the changes that have impacted water resources and agricultural activities in the Oulja of Chtouka. We have adopted a systemic approach that aims firstly, to analyze the factors that have led to the quantitative and qualitative degradation of water resources. Then, find the correlation between this degradation and the decline in agricultural activities by using the "NDVI" vegetation index, and analyze how greenhouses diffuse over time using topographic maps and google earth images. Finally, validation of these results has been through field work. We will also highlight some individual initiatives aimed at overcoming these constraints, culminating in state intervention through the "Chtouka's Oulja rescue" project. The adopted approach resulted in obtaining several key findings. Firstly, the intensification of agricultural activities since the Protectorate has led to both qualitative and quantitative degradation of groundwater. Secondly, this degradation has had a negative impact on farming activities. Thirdly, while several individual initiatives were launched, they were limited in their effectiveness. Finally, the state attempted to address the issue by launching a program aimed at saving farmland using Oum Er-Rbia water.

Keywords: Oulja of Chtouka - Coastal Chaouia Aquifer – Qualitative Degradation of Groundwater - Quantitative Degradation of Groundwater - Landsat Satellite Images.

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Introduction

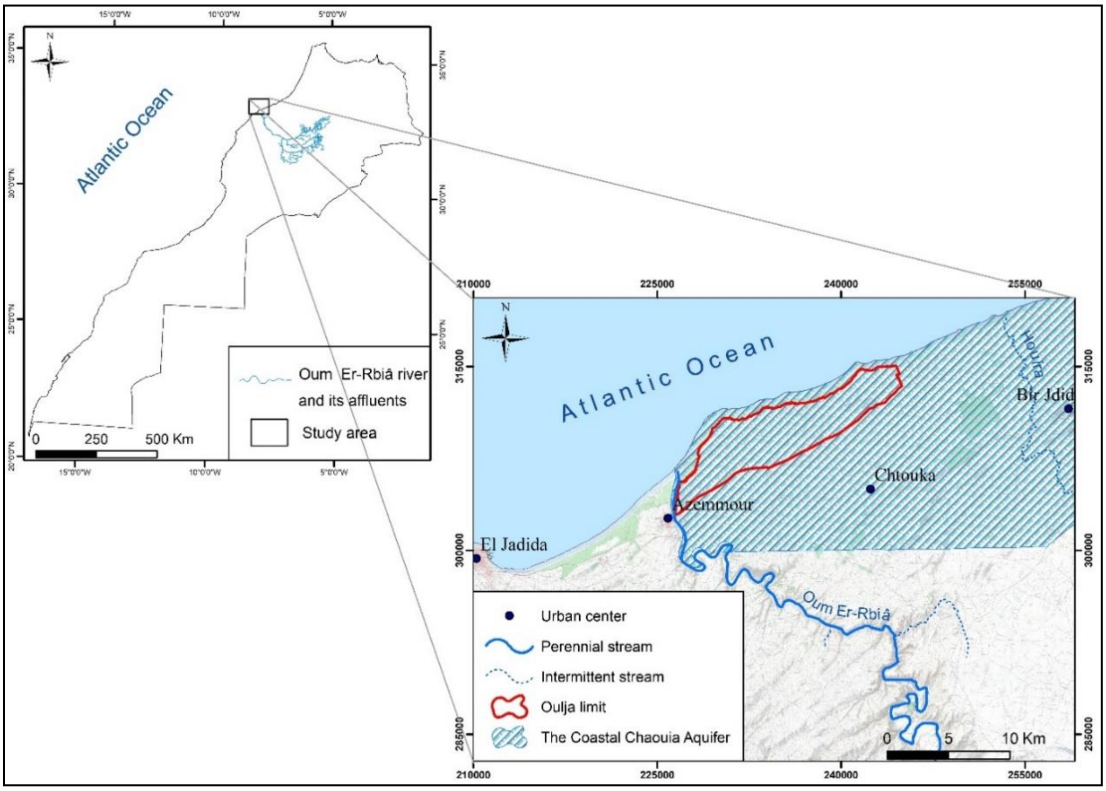
Water resources, through their abundance or scarcity, play an important role in the process of land formation. And with climate change and heavy overexploitation, these resources are becoming increasingly scarce. Also, since Morocco is in semi-arid climatic zones, it is not excluded from this situation. (Blaghi, R., & al, 2007). As an important agricultural area, Oulja of Chtouka has undergone major agricultural changes, due to the use of groundwater and modernization introduced during the protectorate. This agriculture evolved from traditional rain-fed agriculture before the Protectorate to modern, intensive, irrigated, and commercialized agriculture during and after the Protectorate. This transformation caused quantitative and qualitative degradation of groundwater resources, and a consequent decline in agricultural activities. To overcome this situation, the state had to draw up an intervention plan to save agriculture in Oulja de Chtouka. At the root of this discussion lies our **problematic**, which aims to **study and discuss the impact of water resource degradation on agriculture, forms of adaptation among certain farmers and state intervention**.

Our paper is organized as follows. First, Section 2 presents the methodology for analysing and understanding Oulja's changes. Following this, Section 3 then presents the results obtained using the research methodology, starting with **the impact of agricultural expansion on groundwater resources**, followed by **the impact of groundwater depletion on agriculture**, then **the forms of farmer intervention** and finally **State intervention.** The report concludes with a summary of the significant findings and suggestions for future work.

1. Study area

Geomorphologically, Oulja of Chtouka is a depression that stretches along the Atlantic coast from the river Oum Er-Rbia to the north-west over a length of 21 km, while its width does not exceed 4.5 km. Its surface area is approximately 6935 ha (**Figure 1**).

Figure N°1: Location of Chtouka's Oulja on the general map of Morocco



Source: Agence du Bassin Hydraulique du Bouregreg et de la Chaouia, 2015 ; Morocco general map ; topographic maps (2011).

2. Methods

A systemic approach was adopted to tackle this problem, especially the factors that caused this degradation, and some attempts to overcome the latter, to finally arrive at the "**rescue of the Chtouka's Oulja**" program.

Firstly, we will diagnose the state of groundwater resources for different years (depth of wells, piezometric levels, etc.), using statistics from public institutes, especially those of the Bouregreg and Chaouia Water Basin Agency. Our results are presented using the IDW interpolation tool in the Spatial Analyst Tools within Arcgis software, in the form of maps showing the situation of the Chaouia coastal water table.

The changes affecting irrigated agriculture will be monitored in two stages:

- Extract the irrigated area of the years 1973, 2018, 2021 and 2023 using the "Nearest Neighbor Classification" approach (Lamhamdi, B. E., & al., 2017), based on the NDVI index which will be calculated, on Envi and Arcgis software using Landsat satellite image bands, by applying the following equation:

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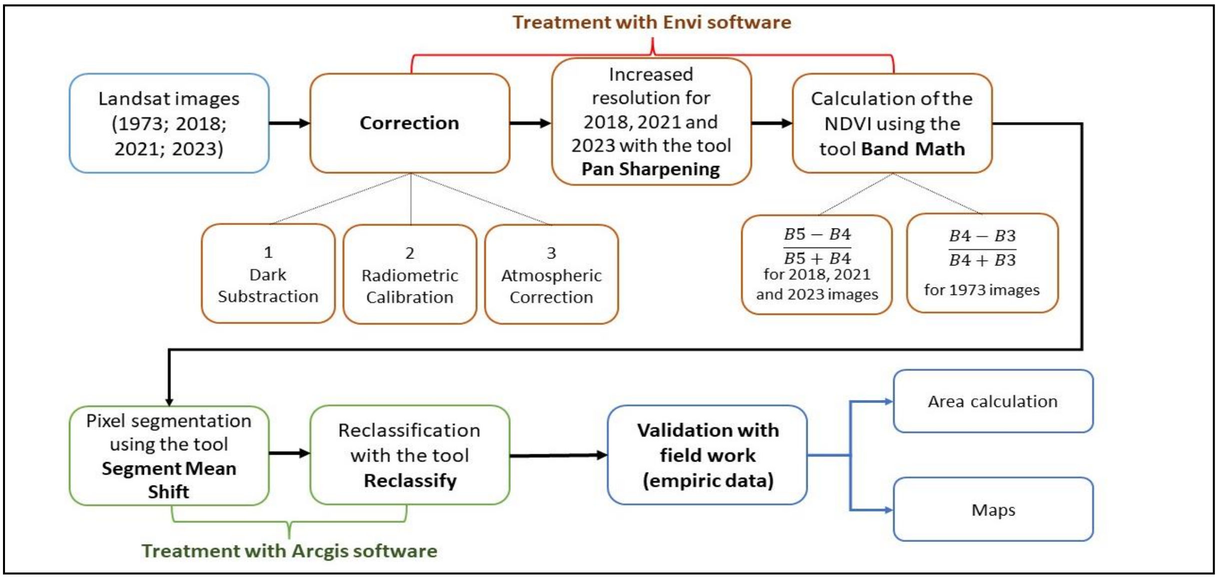
$$NDVI = \frac{(Band\ Nir - Band\ Red)}{(Band\ Nir + Band\ red)}$$

The extraction will be carried out following a series of operations shown in **Figure 2**.

- Select points at random from the results of the first stage and check the degree of validation by carrying out field visits (fieldwork).

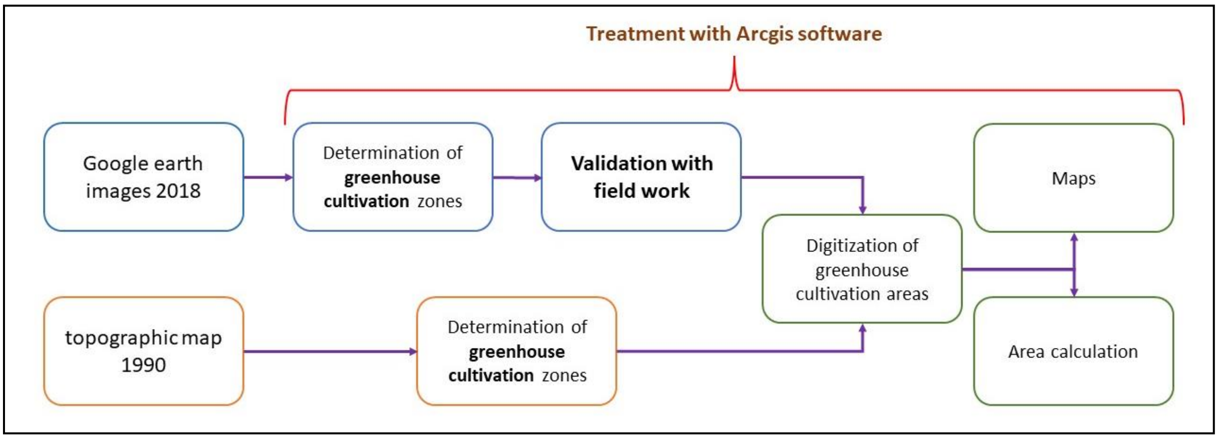
Figure N°2: Methodology used to extract and monitor the irrigated area



Source: Lamhamedi B. E., & al, 2017; Madhoum, O., 2022; Skittou, M. & al, 2020; Field work

Our methodology is also based on tracking the spatial diffusion of greenhouse crops over time by using topographic maps from 1990 and Google Earth from 2018. **Figure 3** shows the steps used to determine the greenhouse crops. The method is based on visual digitization of the greenhouses, which is then consolidated by fieldwork to validate the results obtained.

Figure N°3: Methodology used to extract and monitor the areas of greenhouse crops



Source: Skittou, M. & al, 2020; Field work

The previous steps will be followed by an analysis of the results obtained to deduce the correlation between the degradation of water resources and the evolution of the spread of greenhouses and irrigated areas, and hence the decline in agricultural activities.

The validation of the results will occur as the work progresses through fieldwork. (farm visits, interviews with farmers, etc.).

3. Results and Discussion

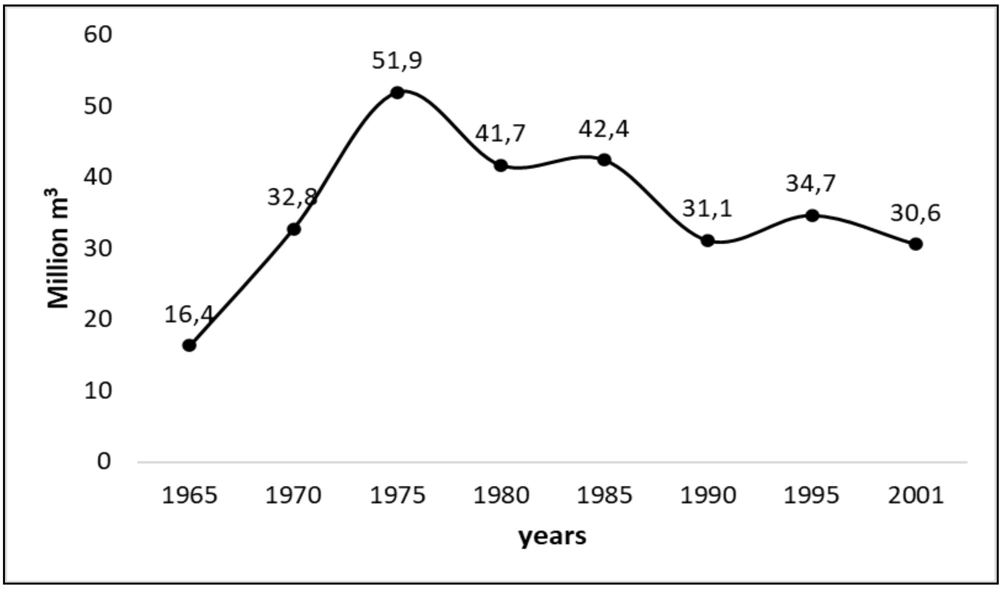
3.1. The impact of expanding agricultural activities on groundwater resources

Modern techniques introduced by the French colonists expanded the use of groundwater for irrigation. This encouraged farmers to expand the cultivation of vegetables, especially tomatoes under glass, thanks to the spread of motor-driven pumps after the Second World War.

Indeed, the number of motor-driven pumps distributed multiplied after independence, reaching 500 in 1970, with an irrigated area of 1,319.3 ha (M. AYAD, 1982).

Overexploitation of groundwater has led to quantitative and qualitative degradation of the coastal Chaouia aquifer. **Figure 4** shows that the quantity of water exploited from this aquifer fell from 52 million m^3 in 1975 to just 30 million m3 in 2001 (L. LAKFIFI et al., 2004). The coastal Chaouia aquifer is experiencing quantitative degradation, with piezometric contours (isopiezes) migrating from south-east to north-west between 1971 and 2016 (**Figure 5**). On the other hand, imports of fresh water into groundwater decreased from about 65 million m3 in 1961 to only 46 million m3 in 2000. (Zerouali, A., & al., 2001).

Figure N°4: Evolution of the volume of water extracted from the coastal Chaouia aquifer between 1965 and 2001



Source : Lakfifi, L. & al., 2004.

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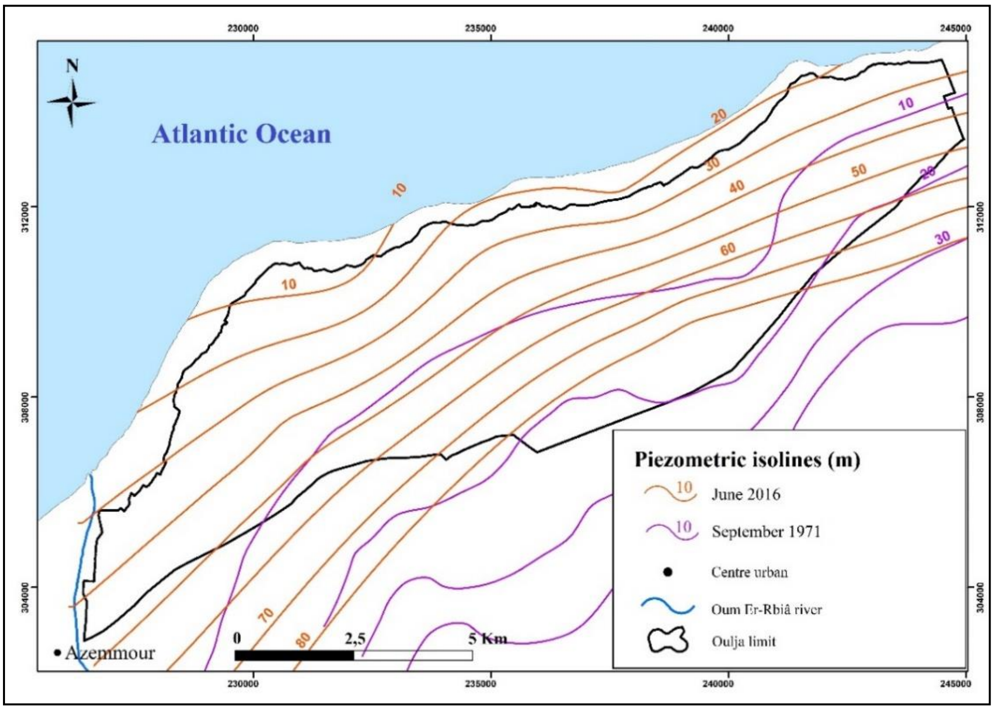
Figure N°4: Changes in the piezometric level of the coastal Chaouia aquifer between 1971 and 2016

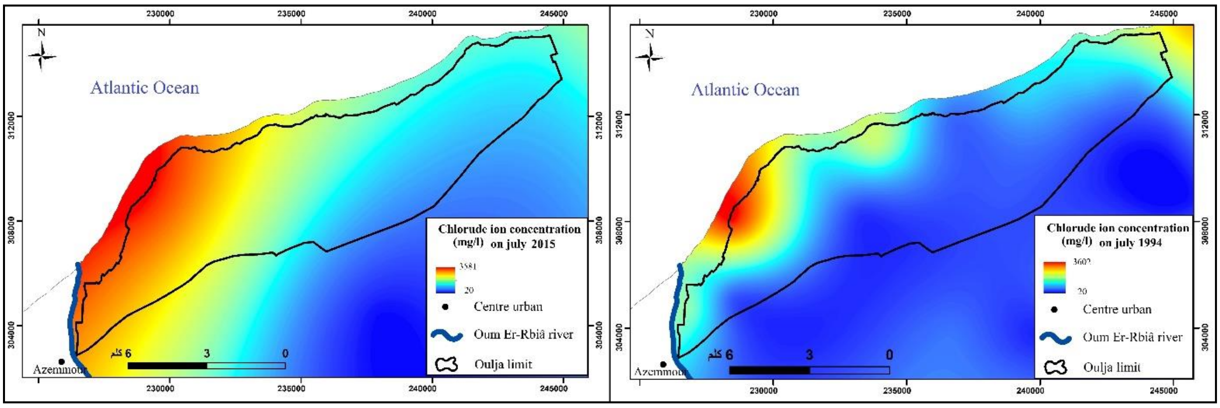


Source: Data from Bouregreg and Chaouia Water Basin Agency (2017); Bentayeb, A. & Leclerc, C., 1975

The declining capacity of the coastal Chaouia **aquifer** to supply irrigation water is due to overexploitation, climate change (Drought) and the numerous dams built upstream of Oued Oum Er-Rbia. These factors have led to an imbalance in water exchanges in the aquifer; a simulation of the water balance in the aquifer has shown that it has been in deficit since the 1980s, which has increased the share of seawater in inputs due to marine intrusion. Indeed, in 1995 it exceeded 4 million m^3 (Lakfifi, L. et al., 2004).

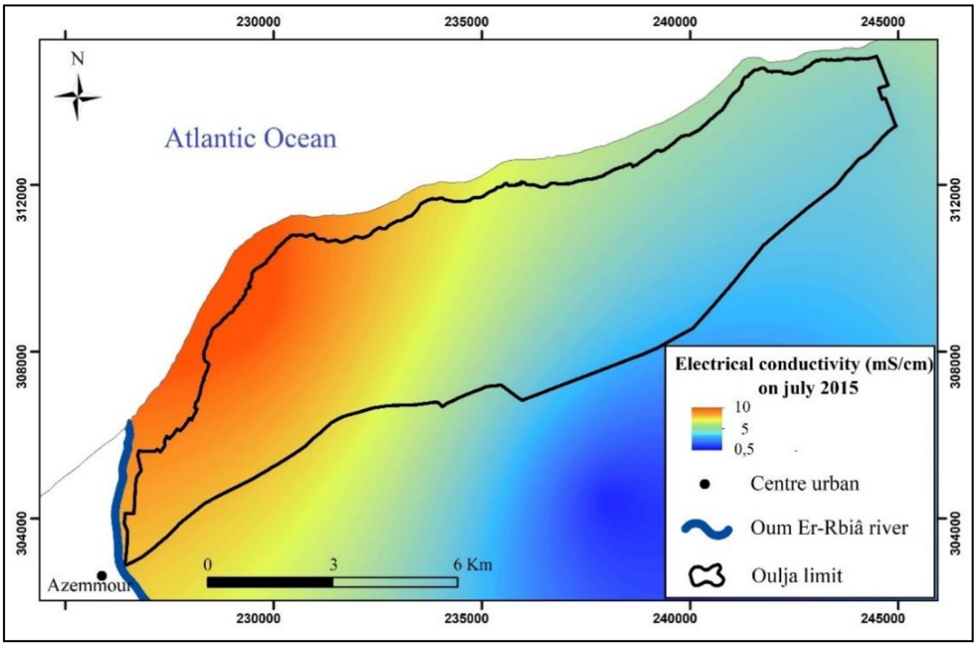
Marine intrusion was the main cause of groundwater salinity. **Figure 6** show the evolution of the chloride ion (Cl^-) concentration (one of the components of sodium chloride), with an increase in the concentration of this ion in the north-western part of the aquifer (over 2g/l), with a conductivity exceeding 6 mS/cm (**Figure 7**).

Figure N°6: Changes in the concentration of chloride ions in the coastal Chaouia aquifer



Source: Bouregreg and Chaouia Water Basin Agency, 2015; Younsi, A. et al, 2001

Figure N°7: Electrical conductivity in the coastal Chaouia aquifer



Source: Bouregreg and Chaouia Water Basin Agency, 2015

The deterioration in the quality of groundwater is also reflected in the concentration of nitrates (NO_3^-). This exceeds 50 mg/l throughout the aquifer, and 200 mg/l in the north-west (**Figure 8**). The high concentration of nitrates is due to the heavy use of chemical fertilizers by farmers (around 380 kg/ha) since Ulaanbaatar is an area of intense market gardening (Madhoum, O. & Khannous, A., 2019).

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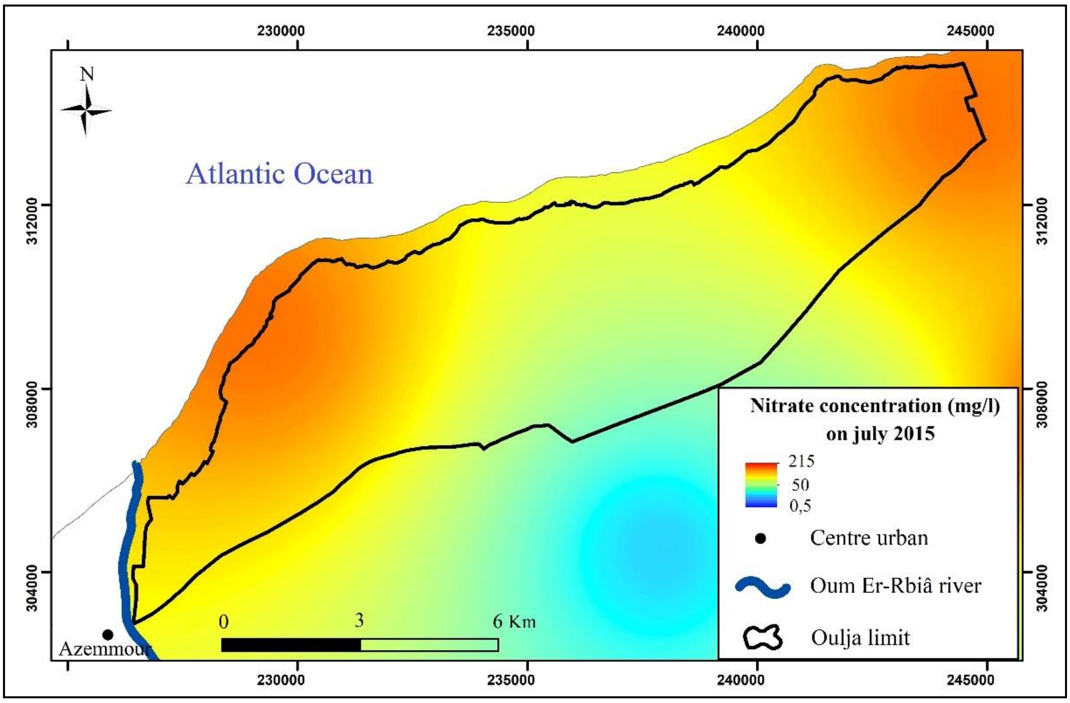
Figure N°1: Nitrate concentration in the coastal Chaouia aquifer



Source: Bouregreg and Chaouia Water Basin Agency, 2015

3.2. The impact of the quantitative and qualitative deterioration of groundwater levels on agricultural activities

Agriculture in the Oulja of Chtouka has undergone radical changes; following the degradation of groundwater, many market garden crops have suffered setbacks. For example, the area under citrus trees fell between 1974 and 1990 from 650 ha to just 132 ha, finally reaching 3.6 ha in 2018. The decline has not only affected arboriculture, but also all irrigated crops, including greenhouse farming.

The methodology adopted enabled us to calculate the area of irrigated land, for both open field and under glass. The former increased from 2,204 ha in 1973 to 1,475 ha in 2018, while the latter increased from 392 ha in 1990 to 196.7 ha in 2018.

From the analysis of **Figure 9**, it can be concluded that there has been a change in the spatial diffusion of the irrigated areas. In 1973, they were grouped along the coast, whereas in 2018 they are more dispersed in the interior of the Oulja of Chtouka. However, between 1990 and 2018, the spatial diffusion of greenhouses has decreased (**Figure 10**). The last ones are concentrated in the center of the Oulja of Chtouka, away from areas with very high salinity in its groundwater.

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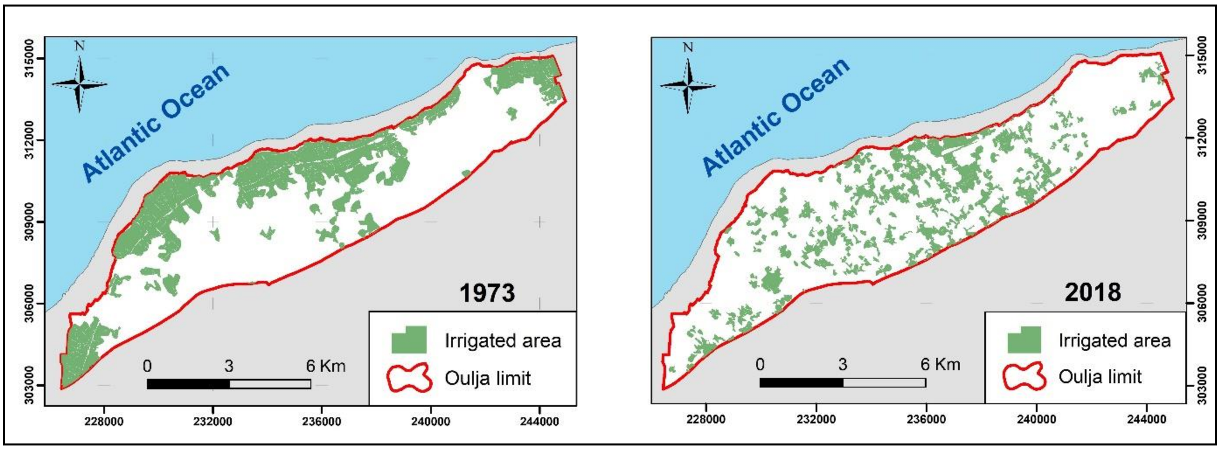
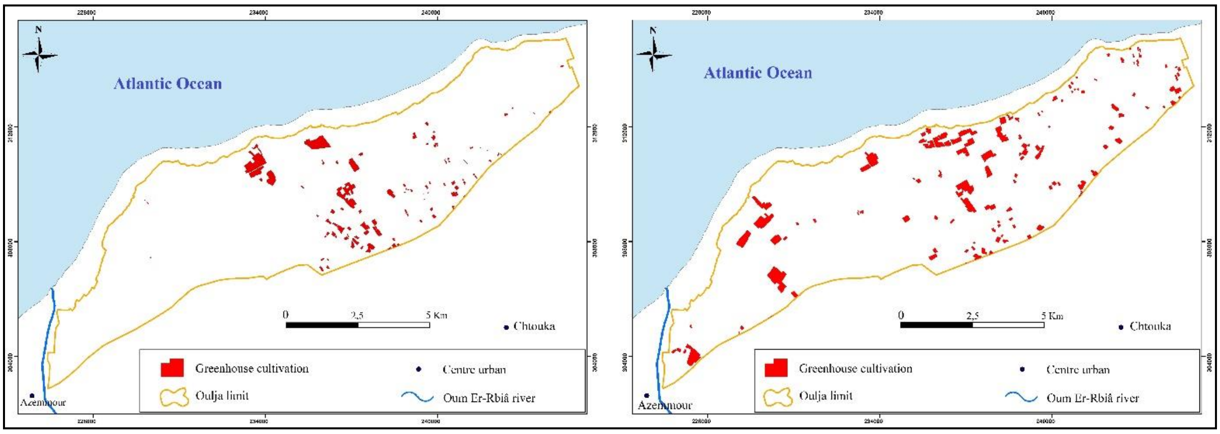
Figure N°2: Changes in the spatial diffusion of irrigated areas between 1973 and 2018



Source: Landsat images 1973 and 2018

Figure N°3: Changes in the spatial diffusion of greenhouses between 1990 and 2018



Source: topographic map 1990 and Google Earth images 2018

3.3. Farmers take action to overcome the situation

The situation of the coastal Chaouia aquifer has prompted farmers to look for solutions. Some of them have decided to adopt crops that are resistant to water salinity, such as cauliflower (**Image 1**), which can withstand water conductivity of up to 6 mS/cm (FAO soils bulletin 55, 1985), while others have abandoned irrigation in favour of rain-fed farming, particularly wheat (**Image 2**).

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Image N°1: Cauliflower growing on one of the farms irrigated with groundwater

Source: researcher snapshot in spring 2019

Image N°2: Rain-fed cereals on one of the previously irrigated farms

Source: researcher snapshot in spring 2019

The large landowners turned their attention to finding new sources of water outside the Oulja of Chtouka. The first attempts were made by the "**Najah association**", set up by 17 large landowners from the Oulja. This association succeeded in obtaining an authorization to exploit the surface water of Oued Oum Er-Rbia. Approximately 3.7 million m3 was transported from the Sidi Daoui dike into l'Oulja (**Figure 12**) to irrigate 458 ha (**Table 1**). The high cost of using water and the fall in prices forced most farmers to abandon the association. In the end, only 3 farmers continued to use water from Oum Er-Rbia (about 185 ha devoted to rose and avocado cultivation), while two others (about 21.75 ha devoted mainly to avocado cultivation), among those who left the association, tried to bring water from wells outside the boundaries of the Oulja de Chtouka (**Figure 12**).[1]

[1] Data from the Azemmour Agricultural Advisory Centre

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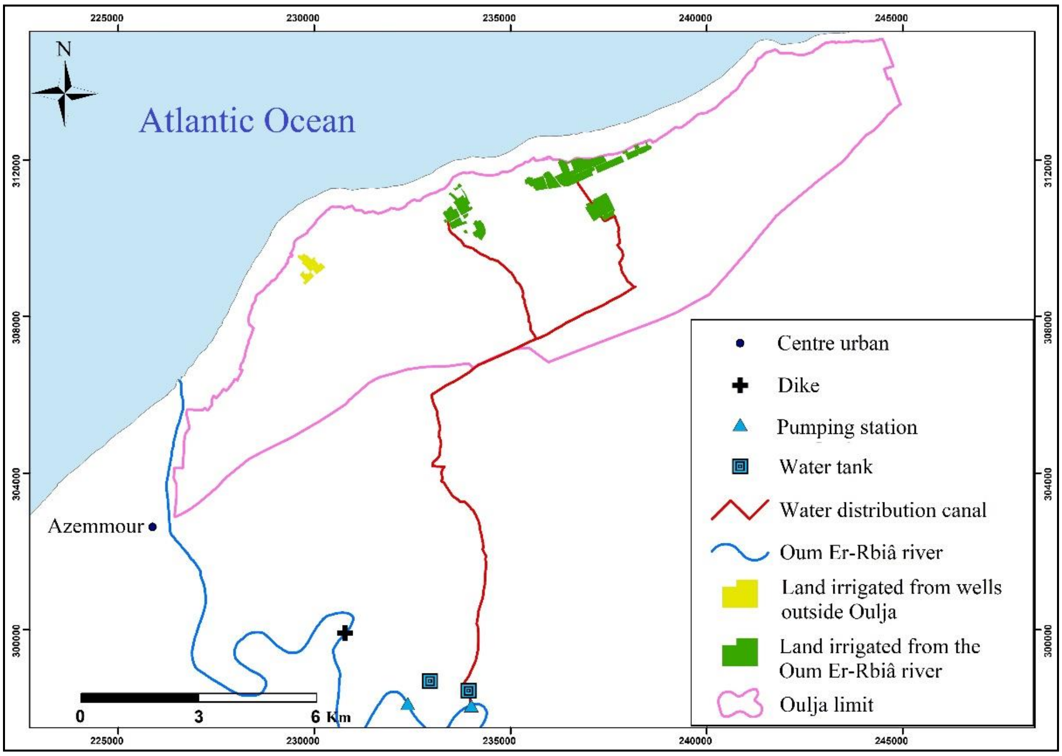
Figure N°4: Land irrigated from a water source outside the Oulja of Chtouka



Source: working in the field summer 2020

Table N°1: Distribution of the areas that benefit from the water of Oum Er-Rbia river in the framework of the Najah Association

Type of crops	Area in hectares
Tomatoes (greenhouses)	150
Tomatoes (open field)	53
Horticulture (seasonal)	62
Bananas (greenhouses)	4
Citrus	96
Roses (greenhouses)	44
Other crops	49

Source: Agricultural Advisory Centre of Azemmour

3.4. State intervention to safeguard agriculture in the oulja of chtouka

Faced with the critical situation of agricultural activities affected by the degradation of groundwater in the coastal Chaouia aquifer, the State has implemented a project aimed at reviving agricultural activities in the Oulja of Chtouka, covering an irrigable area of 3,100 ha, by building an irrigation system that uses 15 million m^3 of surface water annually from the

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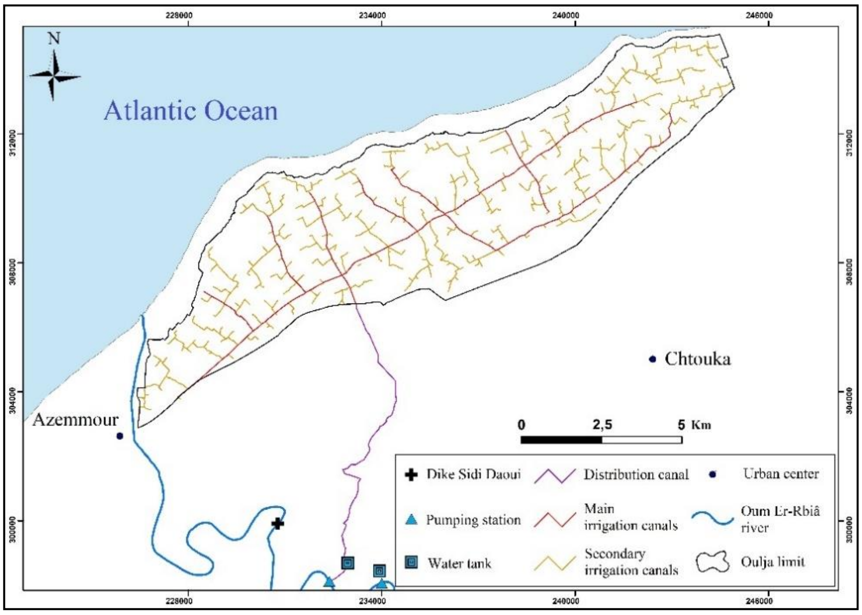
Oued Oum Er-Rbia, with an investment of 365.3 million DH, 87.82% of which was provided by the State, while the remainder was covered by the beneficiaries. Most of the money (more than 95.5%) was spent on infrastructure, in particular, the irrigation canals that covered the whole of the Chtouka's oulja (**Figure 12** and **image 3**). The price of a cubic meter of water was set at 1.3 DH.

Image N°3: Part of the irrigation canal construction work

Source: researcher's snapshot in summer 2020

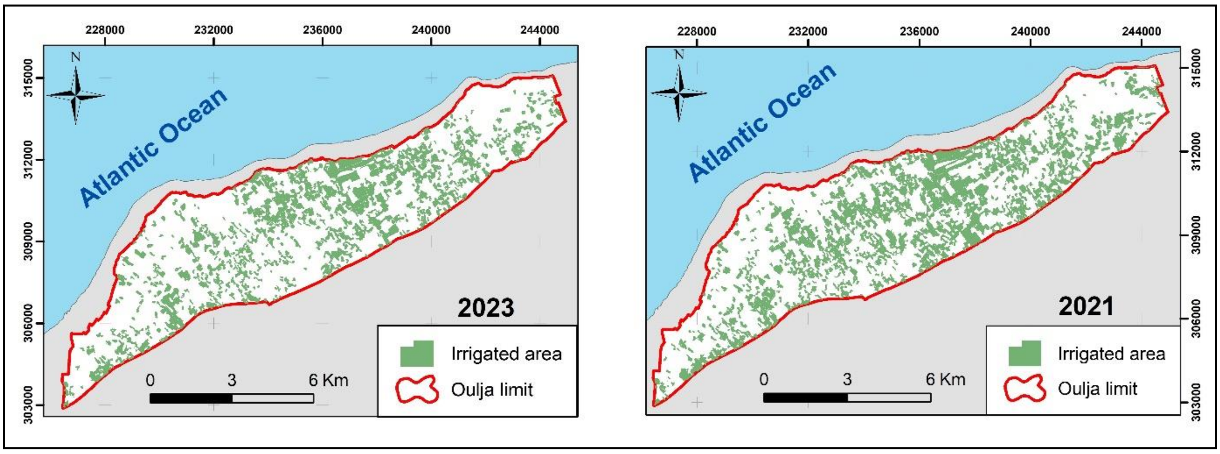
Figure N°5: Distribution of irrigation network completed in Oulja as part of government intervention project



Source: working in the field summer 2020

The fieldwork carried out in the summer of 2021 and the processing of satellite images from 2021 have shown that there has been an increase in agricultural activity compared with previous years (**Figure 14**). The total irrigated area reached 2,307 ha. Unfortunately, the drought that hit all of Morocco in 2021, 2022 and in 2023 had a negative impact on water reserves in all of Morocco's dams, and especially in the Oum Er-Rbia water basin. According to the General Directorate of Hydraulics of the Ministry of Equipment and Water, the filling rate of the dams in the Oum Er-Rbia hydraulic basin did not exceed 8.9% on 23 January 2023 (around 440 million m^3). Faced with this situation, the authorities have stopped supplying water to irrigate the Oulja farms. Fieldwork and analysis of satellite images for the year 2023 showed a decline in agricultural activity (**Figure 14**). The area irrigated at Oulja has shrunk to just 1,840 ha.

Figure N°6: Changes in the spatial diffusion of irrigated areas between 2021 and 2023



Source: Landsat images 2021 and 2023

Conclusion

Despite the efforts of both individuals and the state, the aim of safeguarding agricultural activities in the Oulja of Chtouka has still not been achieved. The climate variability that Morocco has experienced in recent years has limited the effectiveness of any intervention that relies on traditional water sources (surface and ground water). Today, Morocco is rising to the challenge of overcoming the recent water stress by relying on seawater desalination. And the Oulja of Chtouka, which is an important agricultural area, will benefit from this desalination project to revive agricultural activities. Our upcoming research project will investigate the usefulness and impact of this type of project on agricultural activities, particularly the cost of operation, which is expected to be higher than that of traditional sources such as surface and ground water.

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