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Desertification In Irrigated Areas in Mediterranean Environments, Case of Tadla's Irrigated Perimeter.

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Abstract. Increasingly, desertification within the Mediterranean region's irrigated areas is largely attributable to climate change and unsustainable agronomic, hydrological, and environmental factors. The case study presented in the Tadla irrigated perimeter, in the semi-arid southern central Moroccan region, illustrates this phenomenon. Over the past several decades, a rise in climate variability, increased frequency of drought conditions, and higher overall temperature ranges have profoundly reduced the amount of available water to farmers. There is increasing stress on both surface and groundwater resources. The irrigated perimeter of Tadla suffers from a major environmental problem that manifests itself in the phenomenon of climate change which represents a desertification that affects the irrigated area, this is reflected in a very alarming way at the level of the lowering of the piezometric levels either of the groundwater and also the deep groundwater which is not renewable and also the salinity of the soils which becomes very acute; This is leading to an environmental disaster, with a general water shortage threatening agriculture, drinking water supplies and a general reduction in agricultural production. The objective of this study is to identify how desertification is treated within the context of the Tadla irrigated area; to describe how climate change influences vulnerability and resilience in Mediterranean agricultural-hydrology systems through irrigation practices; and to understand how this relationship has developed over time.

1 Introduction

Climate change, increased agricultural production and population growth over the past 30 years have placed enormous pressure on local water supplies as a result of changing weather patterns and rising temperatures. All aquifers (both near surface and deep) within this region have shown extreme decreases in water levels over the last several years. Deep aquifers are of particular concern, since they are largely devoid of recharge under current human activity levels. This creates an urgent need for governments, water resource managers, and water users to work collaboratively to create strategies that will address the structural risks associated with continued utilization of these aquifer systems and ensure the long-term

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viability of the region's water supply. Desertification is a phenomenon that affects most of the world's countries, especially those in dry areas. In general, desertification refers to the degradation or loss of the productive capacity of land in arid and semi-arid environments, as a result of a combination of several factors, including climatic variations (changes) and human activities. The manifestations of this scourge can be seen concretely in the soil salinity, the lowering of the ground water and the decline of biodiversity, all of which have an impact on crop yields in irrigated perimeters such as that of Tadla. In order to face up to these problems linked to desertification, we consider that it is crucial and urgent to deal with this issue, which revolves around -Desertification in irrigated areas in Mediterranean environments.

1.1 Study area

The Tadla irrigation perimeter, located in central Morocco, is part of the Béni Mellal-Khénifra administrative region and is one of the largest areas of agricultural development in Morocco. The Tadla plain is located between the Middle Atlas Mountains to the north/northeast and the Phosphate Plateau to the west. The Tadla plain is a relatively flat alluvial depression with an average elevation between 350m and 450m above sea level; this geomorphological setting has allowed for agriculture to expand historically and provided conditions for the development of hydrological functions of surface and ground water resources in this region (AGHZAR et al, 2002, p 463). The phosphate plateau, which forms the margin of the Oued Zem Cretaceous plateau, lies to the north of the plain, which is 125 km long and 40 km wide.
Béni Mellal and Azilal are two provinces to the south, separated by the Middle Atlas range. It narrows to the east between the Atlas Mountains and the Oued Zem plateau.
- The Oued El Abid defines the regional border with Bahira (Province of Kalaa Srarhna) to the west.

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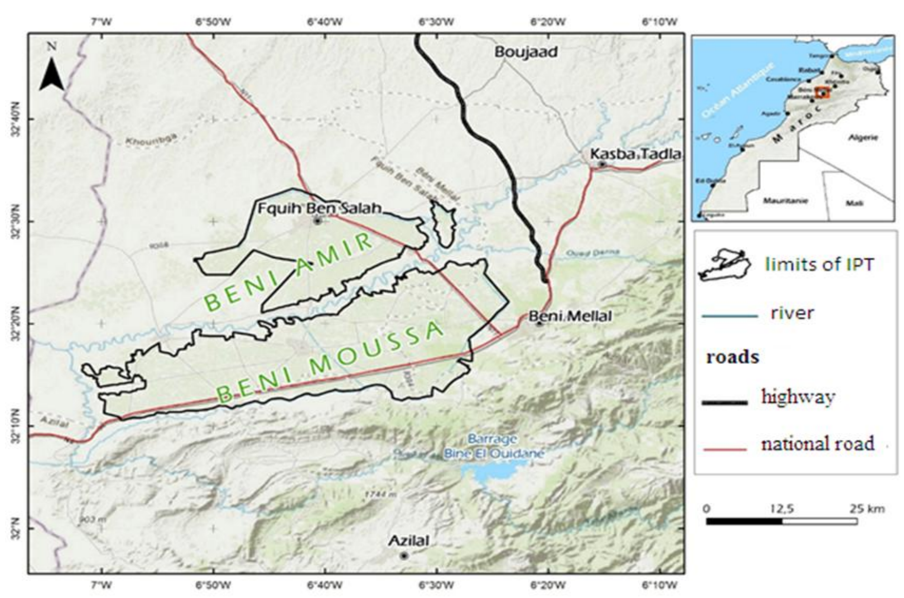

Fig. 1. map of irrigated perimeter of TADLA.

2 Issues, objectives and methodology

2.1 Issues

The injustice of groundwater resources, which suffer from a very significant deficit throughout the country, especially in irrigated areas like the irrigated area of Tadla, is evidence that the problem of climate change is becoming widespread in most of the world's countries, especially those located in arid and semi-arid zones like Morocco. In terms of meeting the demands of agriculture, which is starting to experience a global water deficit, this presents a risky problem. This issue has led us to address a concern that centers on " case of Tadla's irrigated perimeter- in order to control the harmful effects of this phenomenon and suggest solutions to mitigate its damaging effects".

2.2 Objectives

To raise awareness of protecting water supplies through pollution and waste, as well as to create an awareness of the need to protect water resources in order to maintain their viability for both current and future generations, we have chosen to highlight this issue. We have identified three key areas that can be used to address the problems that exist with water resource pollution and waste management:
- Manifestations of desertification in the irrigated perimeter of Tadla
- The main causes of desertification in the irrigated perimeter of Tadla
- Solutions to mitigate the effects of desertification in the irrigated perimeter of Tadla.

2.3 Methodology

This study employs a scientific approach through a territorial (exploratory) study based upon a sample (simple random sampling), and completes 660 surveys of responding farmers located in the Tadla irrigated perimeter. Collected data on climate and piezometric will be processed and displayed using graphing software (SPSS and Excel). The other data related to the piezometric level will be displayed using maps created via ARGIS with the spatial interpolation method (kriging).

Understanding how agriculture and climate change affect the environment, with a focus on groundwater resources in particular, is the foundation of the methodological approach used. Several stages were necessary to do this: The goal of the documentary research phase on the topic was to define the water problem, create a typology, analyze how it appears at the local and national levels, how it is handled, and how it might be avoided. The goal of the field visit phase was to meet representatives from environmental observatories and pertinent institutions, particularly at ORMVAT, ABHOER, and DPA. An assessment of the measures taken by ORMVAT to monitor and protect water resources inside the irrigated perimeter, as well as a compilation and analysis of historical and contemporary data on climate parameters and piezometric level evolution. Phase of map and graph development: employing spatial interpolation techniques, graphs and corresponding maps of precipitation and piezometric levels were created during this phase. Since universal kriging provided the most accurate and representative models and showed the best match to field conditions, it was selected. The primary goal of the territorial survey phase is to gather information and facts that are not already available in current papers and references. This phase is mostly based on field surveys, and in order to get reliable and robust data, it employs a scientific approach spread across numerous stages.

3 Results and discussion

3.1 Decrease in piezometric levels in Tadla's irrigated area

The main phases in the evolution of the ground water in the irrigated perimeter of Tadla can be illustrated by the evolution of the piezometric level shown in the figure above. Thus, six periods were observed in the evolution of this ground water.

- Between 1975 and 1980, the failure to modernize the main canals in the perimeter led to considerable losses of irrigation water, which caused the piezometric level of the soil to rise and drainage problems in the plots. The average of ground water during this period was between 0 and 4 m.
- The period from 1981 to 1985 was characterized by severe drought, with low rainfall of no more than 100 mm and surface water that could no longer meet crop water requirements, leading to a significant increase in agricultural pumping, which lowered the ground water.
- From 1986 to 1991, a return to normal was observed, once again causing the groundwater level in the two wells to rise.

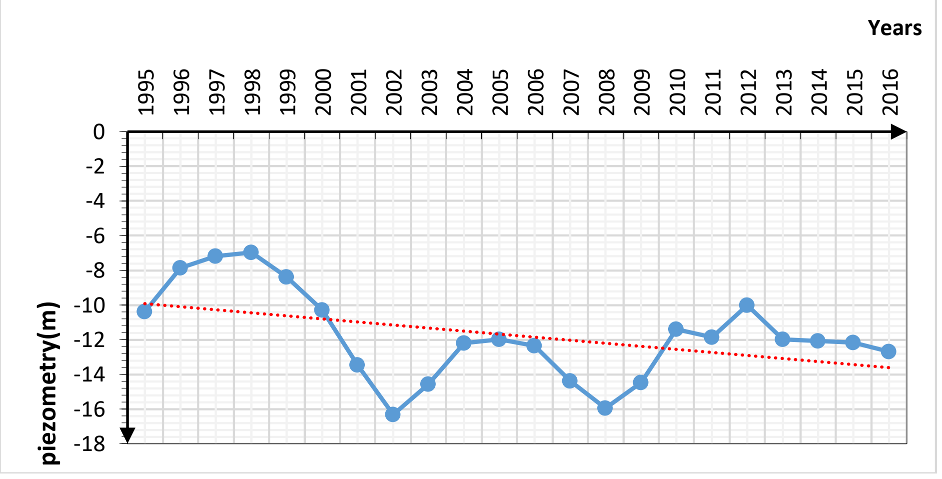

Fig. 2. Changes in the average piezometric level of the groundwater of Tadla.

Source: ORMVAT (reproduced and adapted).

- 1991 to 1996: this was a period characterized by unfavorable climatic conditions (low rainfall, shortage of surface water). So, in order to find palliative solutions, farmers developed more pumping to not only supplement the volumes of water allocated by ORMVAT, but also irrigate at any time without waiting for the water turn. The current trend in Beni Moussa Est is for the proliferation of boreholes, which provide higher flow rates than wells, although the cost of building the two types of structure is not the same.
- Between 1997 and 1999, the situation returned to normal, hence the rise in the ground water observed during this period in the two wells selected.
- After 1999, there was a marked drop in the ground water. This situation can be linked to several factors: not only are the pumping stations not well identified, but the means have not yet been found to accurately determine the volumes withdrawn from the ground water at these stations.

Indeed, the growing number of pumping stations - over 6630 wells and boreholes in the Beni Moussa area alone - is a source of concern for the sustainability of water resources in Tadla. Measures must therefore be taken to preserve it, by regulating the digging of wells, especially those that tap into the deep aquifers for irrigation purposes, which are used to supply drinking water to the many town centers in the region.

On the scale of the irrigated perimeter of Tadla, the piezometric level varied from a minimum of 6.5 m to a maximum of 16.2 m between 1995 and 2016, a variation illustrated by the above diagram.

Pic. 1. wilting the farms of olive tree in the irrigated perimeter of Tadla.

Source: Photography najat AKHAL 15/ 03/2025.

Pic. 2. wilting of olive trees in the irrigated perimeter of Tadla.

Source: Photography najat AKHAL 12/ 03/2025.

3.2 Soil salinity in the irrigated perimeter of Tadla

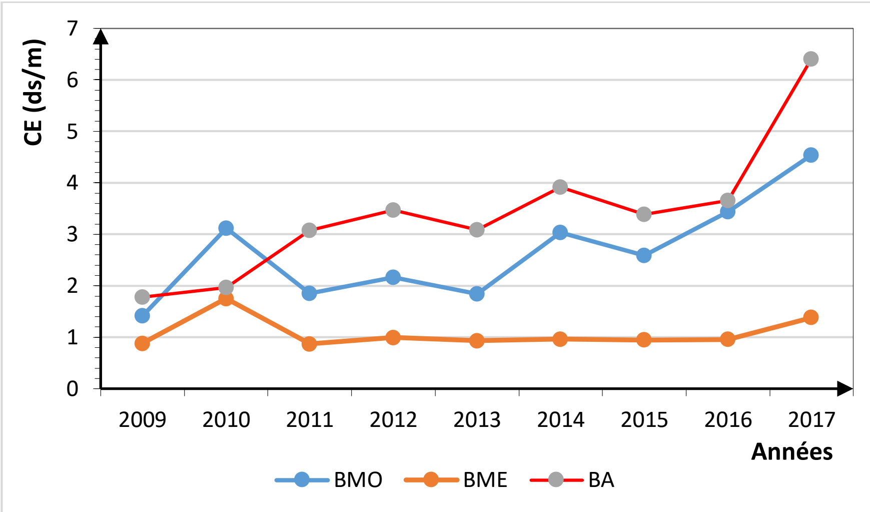

Fig. 3. Evolution the average of soil salinity in the BA, BME and BMO sectors from 2009 to 2017.

Source: ORMVAT (reproduced and adapted).

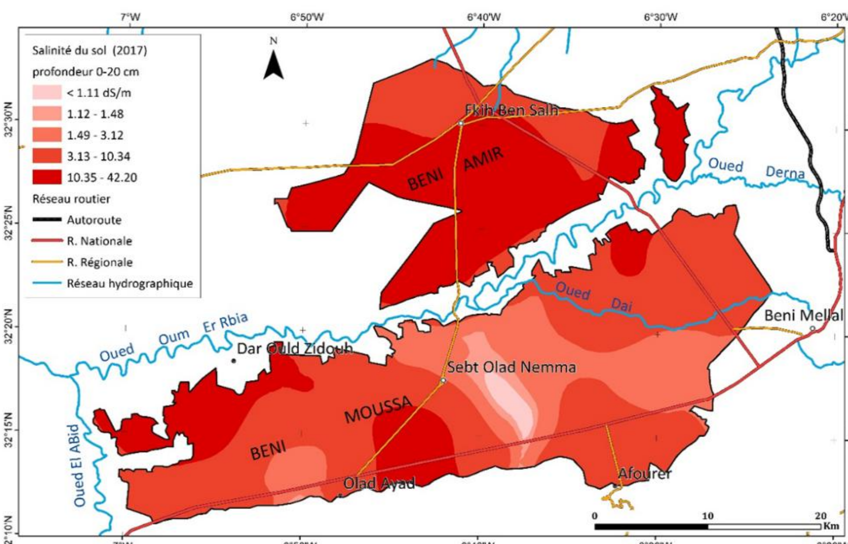

Fig. 4. Distribution of soil salinity in the irrigated perimeter of Tadla in 2017 (depth 0-20cm).

Source: ORMVAT (reproduced and adapted).

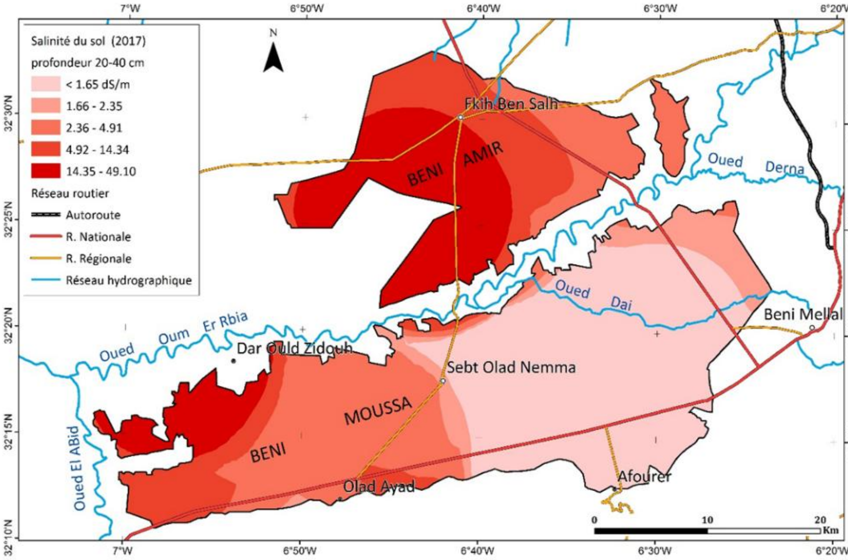

Fig. 5. Distribution of soil salinity in the irrigated perimeter of Tadla in 2017 (depth 20-40cm).

Source: ORMVAT (reproduced and adapted).

In general, we found that the sector most contaminated by salinity is the Beni Amir sector, where the risk of salinity remains high compared to the other two sectors. There, the electrical conductivity is higher, fluctuating between 4 and 6 dS/m, but the sector in second place is the BMO sector, which has a lower salinity than the BA sector. It remains stable in general, except for 2012, which saw a remarkable increase compared to other years.

This increase in salinity is due to a number of reasons, including the use of Oued Oum Er Rbia water, especially in the BA sector, and also to the BMO. When we carried out surveys, we found quite a few farmers who secretly use the water from this river, especially those who have farmland bordering Oued Oum Er Rbia. The latter is characterized by acute salinity. Another factor is the excessive use of fertilizers in the various sectors of the IPT. The salts that become more concentrated in the soil infiltrate the groundwater either through irrigation or rainfall.

As far as the BME sector is concerned, average salinity remains low in general despite the intensive use of fertilizers. The only thing that reduces the problem in this area is the use of water with zero salinity, especially the water from the Bin El-Ouidane dam, and also groundwater that is too pure due to the proximity of the mountains, which always contribute to the renewal of the groundwater.

Roughly speaking, the high salinity zone is located in the Beni Amir area, where electrical conductivity varies between 2.24 dS/m and 9.44 dS/m, with an average value of around 5 dS/m. Salinization follows an increasing gradient from upstream to hydraulically downstream. Chemically, these waters have a sodium chloride type facies in most of the area and irrigation with these salty waters constitutes a possible risk to the sodicity of the soils.

From this study we discovered that 70% of the farmers and their families who live at the IPT do not drink the groundwater because it is very salty. The majority of these people settle in the Beni Amir area.

3.3 Main causes of desertification in the irrigated perimeter of Tadla

The Tadla's plain has a semi-arid Mediterranean climate, with a continental character marked by a cold, wet winter from November to March, and a hot, dry summer from April to October, but the autumn season is virtually unmarked. The climatic characteristics are based on data provided by the Ouled Sidi Driss Agro-Meteorological Station (one of the oldest stations, located at Beni Amir in the perimeter) and the most recent Station at Beni Mellal, located to the south-east of the perimeter, as well as other meteorological stations.

3.3.1 Precipitation

Average annual rainfall over the last five years has been about 100 mm, with uneven distribution in time and space. Average annual rainfall for 2023/2024 varies between 119,1mm at Mchrar Dahk station, and 90.9 at Ouled Sidi Dris. This rainfall is concentrated between October and April. Rainfall is frequently grouped together for a few days a month and rarely exceeds sixty days a year. In 2023/2024, rainfall was limited to less than 20 days. Summer is characterized by an absence of rainfall, with the exception of rare sudden showers in the foothills. The trend in rainfall over the year is shown below and the distribution of monthly rainfall is shown in the diagram.

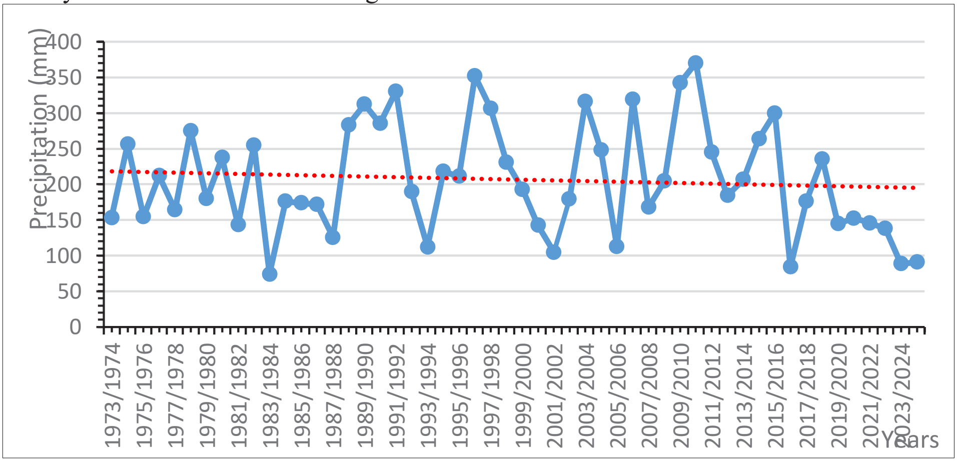

Fig. 6. Evolution of average rainfall in mm at irrigated perimeter of Tadla (1968/2017).

Source: Beni Mellal and Ouled Driss stations (reproduced and adapted).

3.3.2 Temperatures

Temperatures are subject to significant seasonal variations, with summer highs ranging between 39 and 45°C, with a maximum of 49.2°C in July 2024 as an average of the maximum temperatures recorded. On the other hand, winter lows are generally between -3 and 11C°. The minimum temperature recorded from September 2010 to August 2018 was -3°C in February 2018. The average annual of the temperature in this region is around 19.4°C, but daily temperature variations can exceed 20ºC.

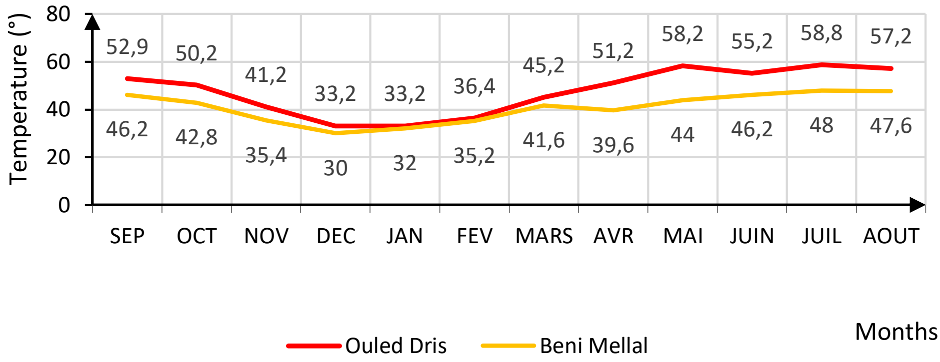

Fig. 7. Trends in maximum monthly temperatures at the Beni Mellal and Ouled Driss stations from 1985/86 to 2017/2018.

Source: ABHOER (reproduced and adapted).

Temperatures in this perimeter are characterized by a very sharp increase, as shown in the figures above, with maximum temperatures fluctuating between 42°C and 59°C depending on the Ouled Driss and Beni Mellal stations. This has an effect on the intensity of evaporation, especially during the summer period. On the other hand, average temperatures fluctuate between 20 and 25°C.

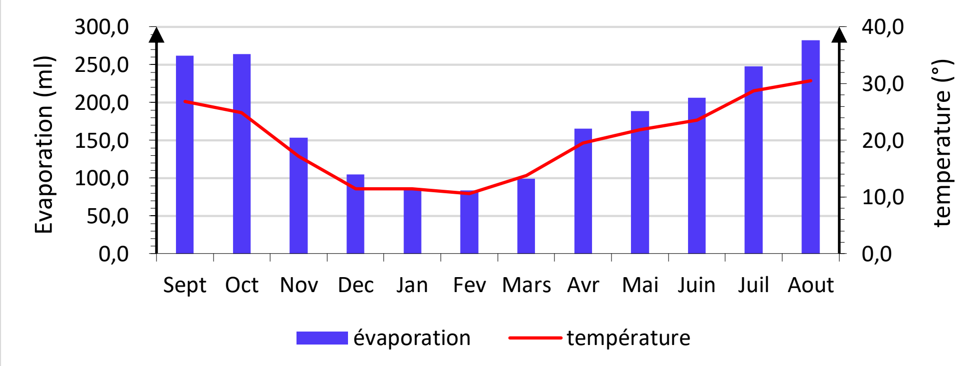

Fig. 8. Interactive relationship between evaporation and temperature in 2017/2018 at Beni Mellal station.

Source: ABHOER (reproduced and adapted).

Evaporation varies considerably between the seasons, it increases during the dry period, which runs from April to October, due to the rise in temperature, which exceeds 38°C most of the time, especially from June to the end of August, and sometimes reaches 45°C, and also the decrease in rainfall or lack of it, which stimulates evaporation in the irrigated perimeter, which sometimes exceeds 500 ml. On the other hand, during the wet season, the evaporation rate decreased due to the decrease in temperature and the increase in rainfall, leading to an increase in atmospheric humidity.

3.4 Solutions to mitigate the effects of desertification in the irrigated perimeter of Tadla

Currently, the water supply system in the Tadla region has dramatically increased the amount of water being captured and taken away. A growing number of farmers are starting to draw water from deeper sources. As well, insufficient regulation of how farmers are permitted to use groundwater has caused some uncertainty about how far the groundwater level is dropping due to the excessive use of these resources by more than 88% of the farmers in the region who dug their wells without permission.

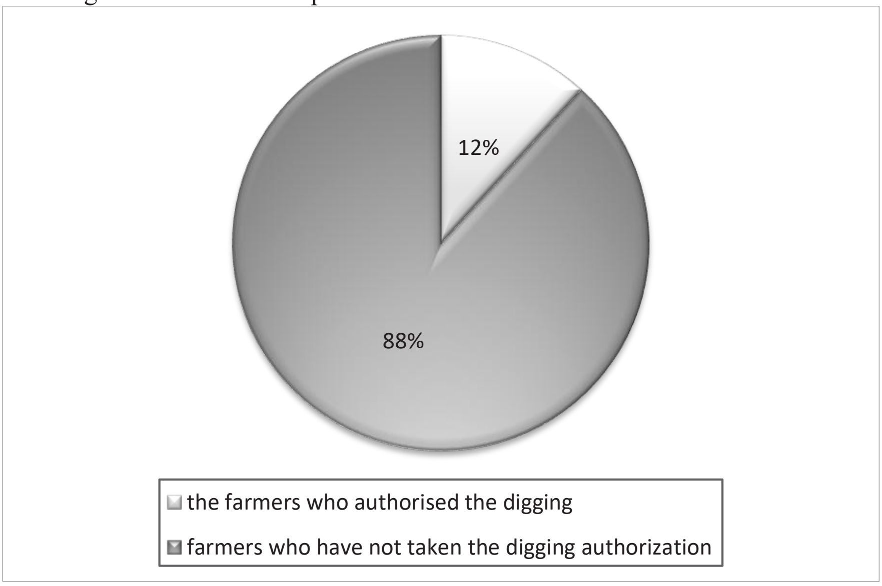

Fig. 9. Legislation for the digging of wells at PIT.

Source: Field work 2018.

A primary solution to this problem is to support farmers with the legal rights to create new wells since over 75% of them are currently acting without permission. A switch from existing crops that use a lot of water to less water-intensive crops will cut back on the amounts of water used through irrigation from underground aquifers. Educate farmers on the benefits and advantages of using local irrigation systems. Approximately 78% of these farmers do not have enough knowledge or understanding of the importance of implementing the local irrigation system project, therefore, creating disinterest in constructing local irrigation systems. In addition, 68% of farmers at the IPT are completely unaware of technical knowledge, and only 12% of them are familiar with localized irrigation techniques. (Field work 2018).

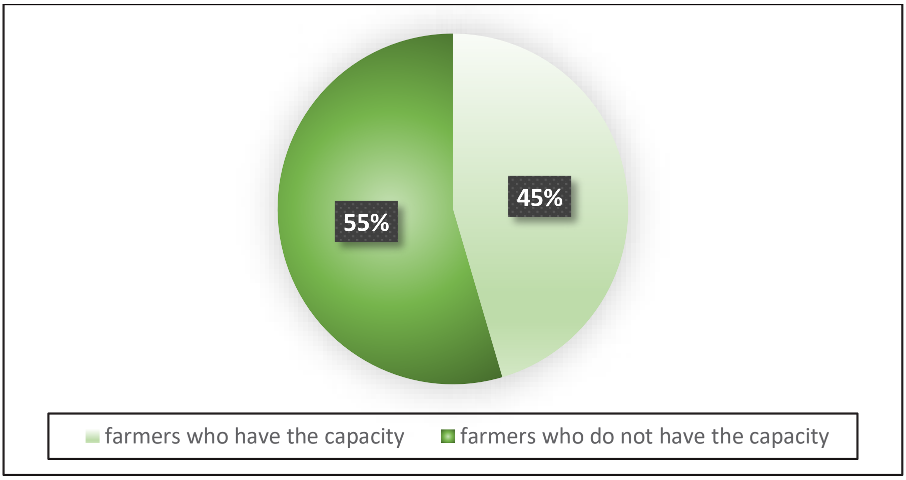

Fig. 10. Ability to install and renew localized irrigation equipment.

Source: Field work 2018.

Training farmers remains an urgent necessity, as around 80% of them are unaware of the equipment required for localized irrigation on their plots (Field work 2018). In this case, they would have to be persuaded to install this type of irrigation. Because around 42% are not convinced (Field work 2018).

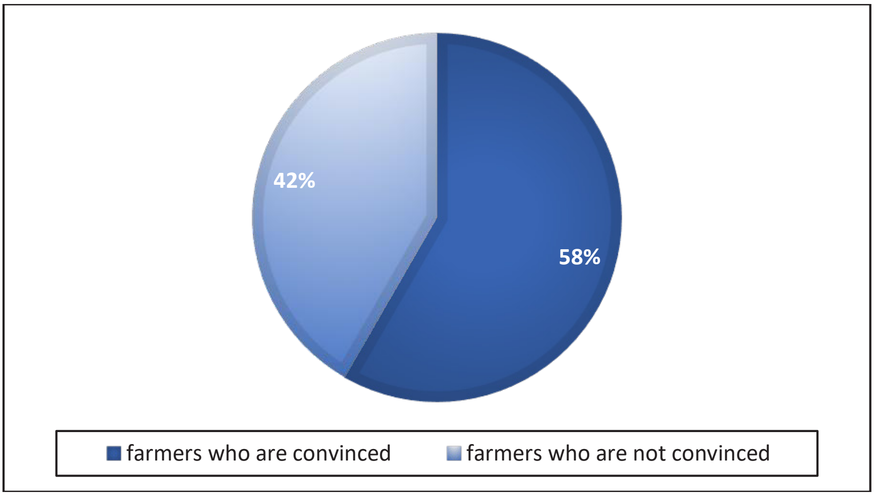

Fig. 11. Degree of conviction in the choice of localized irrigation at the PIT.

Source: Field work 2018.

4 Conclusion

Desertification of irrigated areas, like those found in semi-arid climates (Tadla Irrigation Perimeter), is directly and indirectly impacted by climate change. These areas are affected by climate conditions that make them more susceptible to desertification and also have an intensive agricultural system. As climate change continues to impact the enviroment in the coming years, the lowering of groundwater piezometric (i.e., groundwater average) levels and increased soil salinity will directly impact and cause environmental disaster. To reverse this trend, the following actions should be taken to provide to farmers the elements that they need to produce crops and mitigate groundwater overdraft: encourage the use of localized irrigation methods in order to avoid excess wastage of water; promote the planting of low-water-use crops; and limit or eliminate agrochemicals and fertilizers that impact soil salinity and test groundwater quality. We have concluded that so many soil salinity stimulants are found in the irrigated perimeter of Tadla, thanks to which salts accumulate on the soil surface and the piezometric drawdown continues to increase, as does the low rainfall and scorching temperature during most months of the year, which stimulates evaporation and evapotranspiration.

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