

## LONG-TERM WATER DEMAND ASSESSMENT USING WEAP 21: CASE OF THE GUELMA REGION, MIDDLE SEYBOUSE (NORTHEAST ALGERIA)

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### ABSTRACT:

The Guelma sub-basin, an integral part of the Middle Seybouse basin, covers a surface area of 818 km<sup>2</sup>, subject to subhumid climate. The main surface water reservoir is the Bouhamdane dam with a regulated volume of 55 hm<sup>3</sup>. The main underground reservoirs are found in the aquifer systems of the Guelma plain, the Bouchegouf plain, the H'lia water table and the Heliopolis karst. To enable the rational use of water resources in the study region, integrated management of these resources remains essential. In this work we used WEAP 21 software (Water Evaluation and Planning), for the modeling of water resources, considering the year 2017 as the reference year for 2020-2050, with a base scenario «water demand». The results of the simulation show a significant water shortage of around 50.5 hm<sup>3</sup>, marking a scarcity of the resource, noticed from the reference year 2017, because of the unfavorable climatic conditions which significantly impacted the water reserve in the municipalities of the watershed. This shortage will decrease to a volume of 31 hm<sup>3</sup> in 2024, and 104.20 hm<sup>3</sup> in 2050.

**Key-words:** *water resources, integrated management, Middle Seybouse basin, climate change, WEAP21, water demand*

### 1. INTRODUCTION

The discussion of aspects of the integrated water resources management is one of the major problematics raised in Algeria today. It is becoming an absolute necessity for a good management of water resources allocation in order to equitably satisfy the drinking water needs of the population and the economic sectors. (Zerkaoui et al., 2018, Al-Shutayri, et Al-Juaidi, 2019, Alemu et Dioha, 2020, Ali et al., 2014).

It is a vital necessity to maintain water resources in the face of increasing demands in agricultural, industrial and municipal uses. Production of crops and livestock is water consuming; agriculture alone accounts for 70% of all water consumption (www.unesco.gr). The world will need 50% more food supply for the population estimated at 9.5 billion for 2050 (Singh, 2014). It is estimated that the water consumption for both rainfed and irrigated agriculture will increase by approximately 19% by 2050. About 30% of fresh water on earth is stored in aquifers (Shiklomanov and Rodda 2003).

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Since the late 1970s the occurrence of drought years increases in North Africa is presenting a major constraint to the future development of these regions. According to the IPCC conventions, a general decrease in rainfall together with a prominent surface heating can be expected for sub-Saharan Africa and north of the Sahara until 2050, resulting in further decreasing fresh water availability (Klose et al., 2008).

In Algeria, the multiplication of water needs linked mainly to the demographic expansion, the irrational exploitation of resources and the development of economic and agricultural activities has significantly increased the demand for water. (Kiniouar et al., 2017, Hamlat et al., 2013, Kahlerras et al., 2018).

Models are among the most useful devices in water supply management, and especially multi-objective modeling tools that involve stakeholders and facilitate decision making. They can be utilized in gathering data and improving the process of planning and managing the water supply systems (Sulis et Sechi, 2013, Shahraki, et al., 2016, Léville et al., 2003, Saadoun et al., 2014), combining physical and socioeconomic parameters. In the WEAP (Water Evaluation and Planning System) model (Stockholm Environment Institute 2005) standard linear programming is used for the water allocation problems.

Using WEAP a water planner can analyse a full range of water issues through a scenario-based approach. Scenarios could include climate variability and change, watershed condition and changes, anticipated demands, ecosystem needs, the regulatory environment, operational objectives and available infrastructure (Yates et al., 2005 Husain et Rhyme, 2021).

The software, developed by the Stockholm Environment Institute, has shown its performance in many cases in terms of simulation for the choice of scenarios of development and management of the water resource in the medium and long term and decision-making which are needed (SEI 2008). This model is a decision support system (DSS) and provides a complete analysis of water supply and demand at present and estimation for the process in the future (Yazdanpanah, et al., 2008 Höllermann et al., 2010). This software is used when there is multipurpose and competitive demand and allows the analysis of different management patterns (Seiber, et al., 2005 Husain et Rhyme 2021, Xue et al., 2015).

The main objective of this study is to assess the impact of additional water demand in the Guelma region, Middle Seybouse, in long-term, using the Water Evaluation and Planning system (WEAP).

## 2. MATERIALS AND METHODS

### 2.1. Description of the study area

#### 2.1.1. Geographic location

Covering an area of approximately 818 km<sup>2</sup>, the sub-catchment area of the middle Seybouse is located northeast of Algeria, 60 km south of the Annaba city between latitudes 36°14' and 36 ° 35' north and longitudes 7 ° 16' and 7 ° 44 'east, drained by the main stream which is the Seybouse which flows from west to east over a distance of 55.30 km (**Fig.1**).

The population was estimated at the end of 2017 at around 355,250 inhabitants, with a density of 334 inhabitants / km<sup>2</sup> (Algerian national statistics office 2008). The basin of the middle Seybouse is subject to a Mediterranean climate, rainy and cold in winter and hot and dry in summer. The mean annual rainfall for a 30-year observation period is of the order of 615.8 mm, with a mean annual temperature of around 18.26 ° C.

From a hydrogeological point of view, this is a collapsing zone filled with very permeable alluvial deposits, which contains a significant water table supplied by infiltration water and by lateral contributions from the Seybouse watershed (**Fig. 2**).

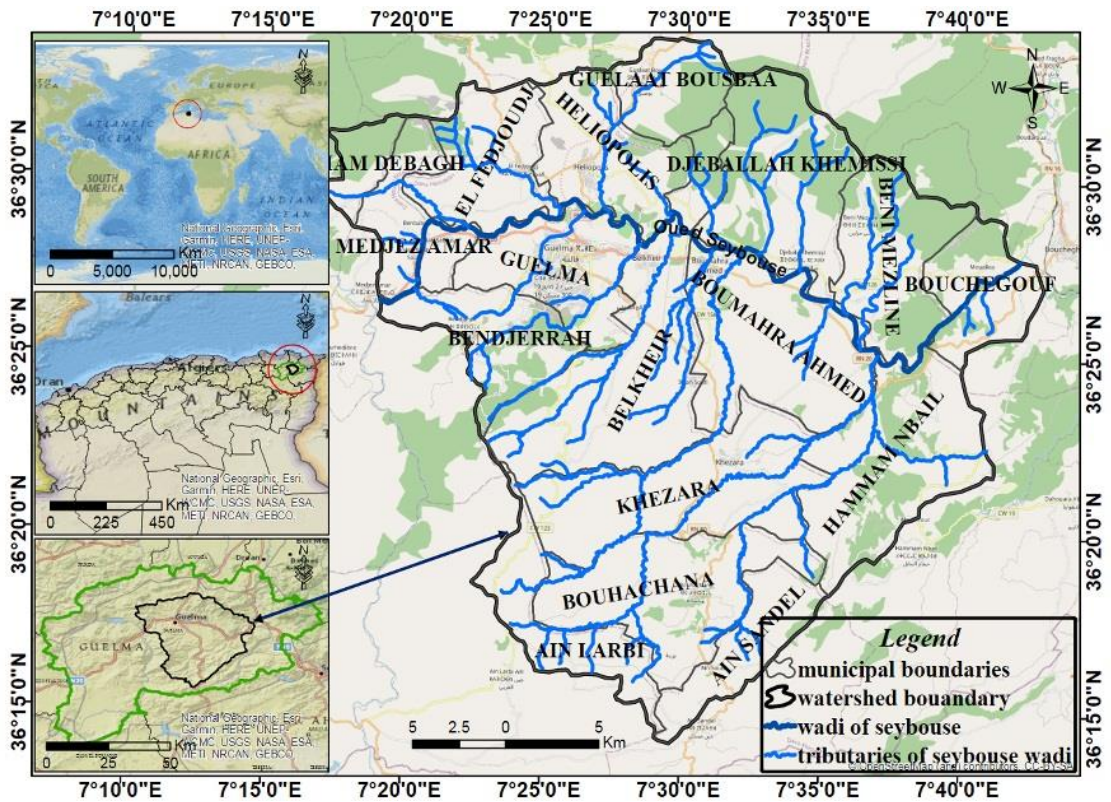


Fig. 1. Location map of the study area.

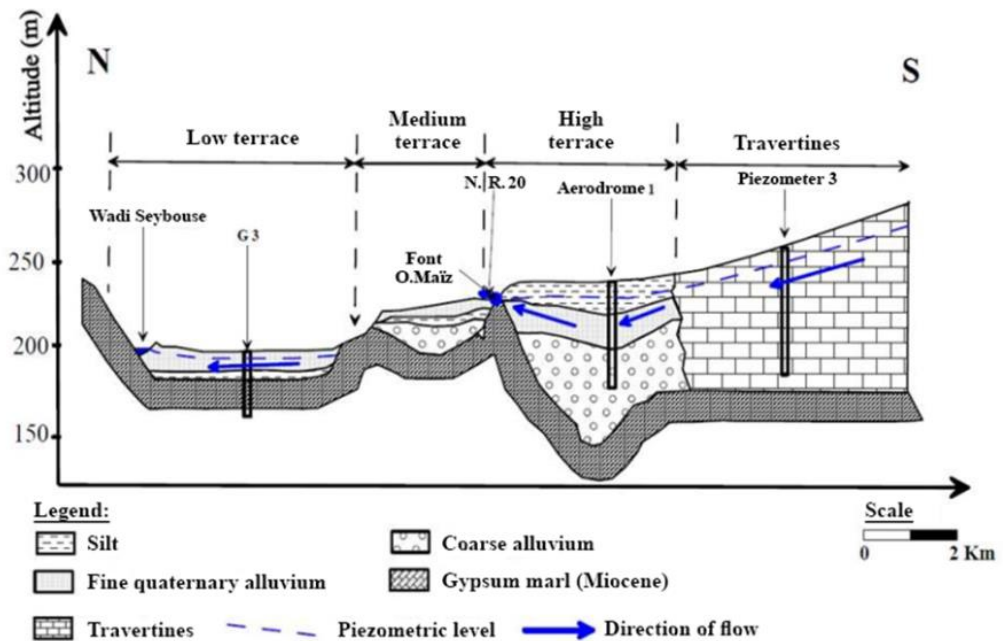


Fig. 2. Hydrogeological cross-section in the study area (B. Gaud ,1974).

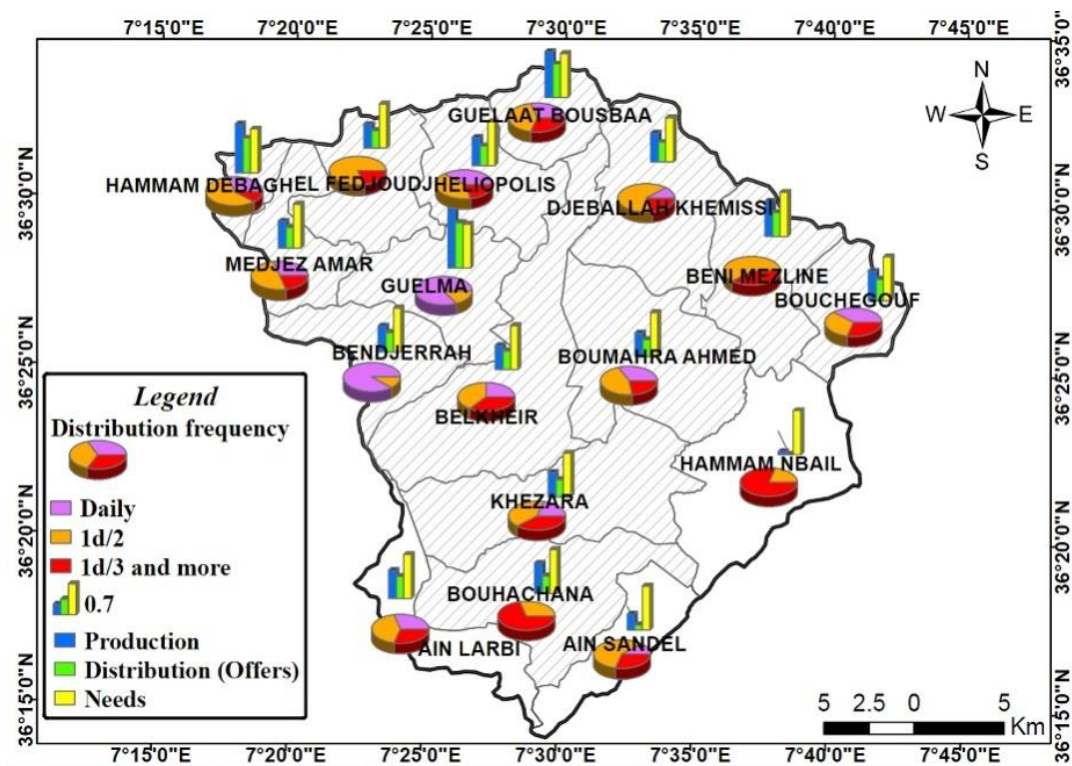
### 2.1.2. Distribution of water resources

The population is supplied with drinking, irrigation and industrial water in the middle Seybouse basin, provided by groundwater extracted from the catchment areas of Héliopolis, OuedH'lia, the plains of Guelma and Bouchegouf with an estimated volume of  $17 \text{ hm}^3/\text{year}$ , as well as treated water from the Bouhamdane dam, with a volume of more than  $63 \text{ hm}^3/\text{year}$ , including  $18 \text{ hm}^3/\text{year}$  for drinking water supply (four municipalities out of seventeen), and more than  $45 \text{ hm}^3/\text{year}$  for the large irrigation scheme (Guelma-Bouchegouf) (Water Resources Department, 2018).

The distribution of drinking water in our study area encounters difficulties which make the management of these resources difficult (Fig. 3).

We can cite:

- the distribution time slots are insufficient in relation to the volume distributed;
- the delivery pipes are very old and generate a loss of more than 30% compared to the volume produced and distributed;
- the endowment is low compared to the Algerian standard.



**Fig. 3.** Map of the production and distribution frequencies of water drinking water in the study area.

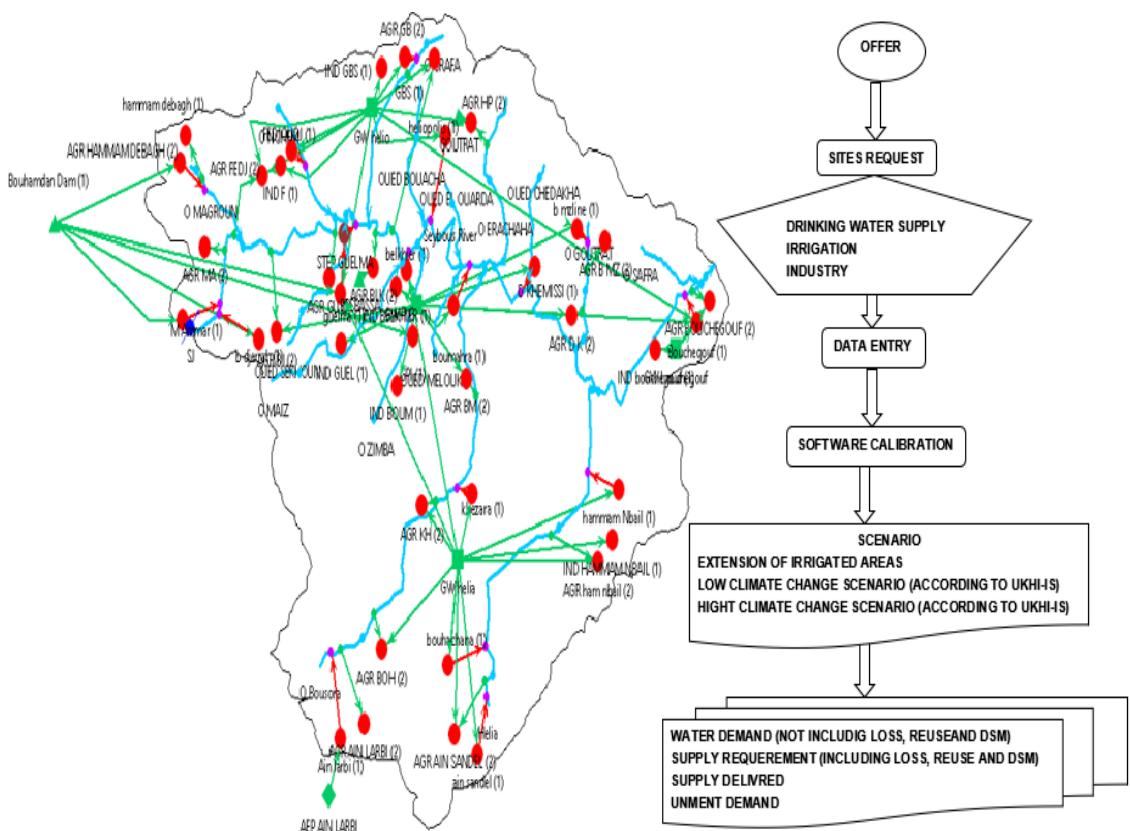
The irrigated perimeter, covering a surface area of 9,250 ha, also encountered several problems, mainly due to the mixed distribution network, which plays the dual role of backflow and distribution. The breakdown and dilapidation of this network in addition to frequent power cuts at pumping stations have reduced the volume allocated to irrigation to more than 35%. The 2017 season irrigation campaign at the Guelma-Bouchegouf perimeter took place under exceptional conditions, given the drop in the water level of the Hammam Debagh dam, the main source of power for the perimeter which was deprived of power for the year 2017-2018.



## 2.2. Methodology

The Water Assessment and Planning System (WEAP21) (<http://www.weap21.org/>), is a modeling and planning tool, developed by the Stockholm Environment Institute. It has enough flexibility to adopt different levels of data availability with a friendly graphical user interface. It is a useful tool for water resources management, which includes both water supply and demand issues, in addition to water quality and ecosystem preservation, such as required by an integrated approach to watershed management (Agarwal et al., 2019, Górska, 2020, Omar and Moussa, 2016, Mostafa and Sarjoughian, 2021). **Fig. 4** summarizes the steps followed for the realization of the model.

Data for 2017 are used in our study for all water resources and water demand by municipality as a unit. For this purpose, we have on the one hand for each municipality a drinking water demand site, a farming water demand site and an industrial water demand site if it exists, considering evaporation as a demand for water, and on the other hand water supply elements such as groundwater extracted from aquifers and surface water from the dam and hill reservoirs and finally rainfall and runoff in the sub-basin (**Fig. 4**). The database of the study area which allows the application of the model is collected from many administrations, such as Hydrographic Basin Agency, National Agency for Hydraulic Resources, National Meteorological Office, Directorate of Agricultural Services, National Statistics Office, National Office for Irrigation Perimeters, Algerian Water and the two existing meteorological stations in the middle Seybouse sub-basin Hammam Debagh and Belkhier stations for hydrological data.



**Fig. 4.** Conceptual model of water resources distribution.

In this part, the time parameters should be resolved. Create a year of current accounts for the project. for that, we have chosen the year 2017 as the reference year for all information on the system:

demand sites, supply data, consumption, transmission link. The baseline scenario is established from the current account, in which all data base are introduced, to simulate the same system evolution without intervention (SEI,2008). For our study, the reference scenario covers the period (2020 - 2050), It translates simply a projection of trends current without major changes, and serves as a point of comparison for others Scenarios in which changes in system data can be realized. To carry out our work well, we have adopted the scenarios: climate change with its two hypotheses (high and low) and extension of irrigated areas. The study duration is from the year 2020 until 2050.

### 2.3. Climate change scenarios (CCS)

According to the results of the national project ALG / 98 / G31, northeastern Algeria is subject to the consequences of global warming with reduced inputs and increased temperature (Abdelguerfi, 2003). According to the UKHI (United Kingdom Meteorological Office High Resolution). model, the IPCC “IS92a” scenario with the two high and low assumptions was adopted (**Table 1**).

**Table 1.**  
**The GIEC “IS92a” scenario with the two high and low hypotheses.**

Season	Climatic parameters	2020		2050	
		Low	High	Low	High
Autumn	T° C (+)	0.8	1.1	1.2	2.2
	P % (-)	6	8	10	15
Winter	T° C (+)	0.65	0.8	0.95	1.6
	P % (-)	10	10	16	16
Spring	T° C (+)	0.85	0.95	1.25	1.9
	P % (-)	5	9	10	20
Summer	T° C (+)	0.85	1.05	1.25	2.1
	P % (-)	8	13	15	22

In this study, the statistical downscaling model LARS-WG 6.0, which is a stochastic generator of meteorological conditions based on observed data (Semenov et al. 1998), was used to extract future precipitation and temperatures at the local scale from the MCGs of CMIP5 under two scenarios RCP 4.5 and RCP 8.5. It should be noted that all climate model outputs are in general biased due to the systematic errors that occur after the discretization and the spatial averaging in grid cells and due to the imperfect conceptualization of the models themselves (Teutschbein and Seibert 2012). Using the models’ outputs as they are can lead to significant errors in impact evaluations. Thus, it is necessary to apply bias correction to the models’ outputs before their use in impact analyzes (Teutschbein and Seibert 2012). The version 6.0 of LARS-WG (Semenov & Stratonovitch, 2015)) provides for a chain of measurement allowing the correction of the bias of the GCM outputs at the time of the extraction and the generation of climate data from the CMIP5 models.

## 3. RESULTS AND DISCUSSION

### 3.1. Irrigated land extension scenario (ILES)

Due to the low use of irrigated land in relation to useful agricultural land (UAA), the agricultural services of the Guelma province, foresees an increase rate of 50% every 10 years in these irrigated lands. (Five- years project 2014-2019 (WRD, 2017).

In the three scenarios adopted and for the seventeen municipalities of the watershed, the number of inhabitants increases from 346,342 in 2017 to 688,091 inhabitants in 2050, i.e., an increase of 50.33% and the surface area of irrigated land jumps from 14,302.5 ha (i.e. 18.65% of UAA) in 2017 to 37,228.61 ha, or (48.54% of UAA) in 2050 (Fig. 5).

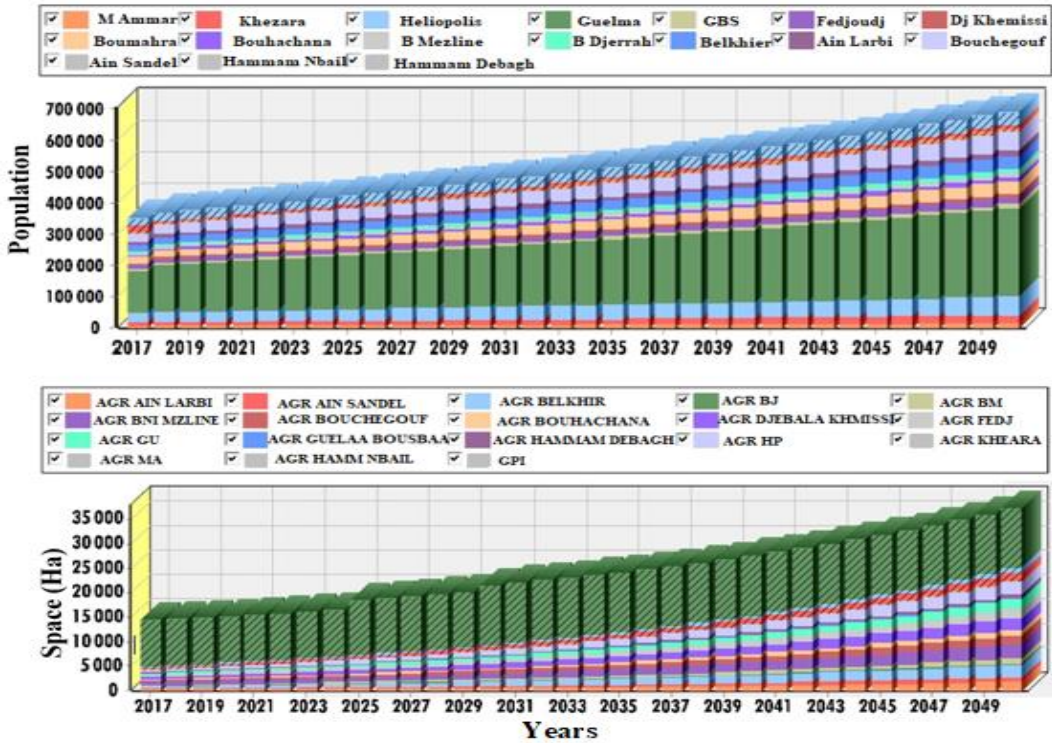


Fig. 5. Evolution of inhabitants and irrigated areas by scenarios.

For water needs, we notice a clear increase from a volume of 80.92 hm<sup>3</sup> to more than 194.83 hm<sup>3</sup> in all the scenarios adopted, mainly linked to the extension of the irrigated land areas. For the reference scenario, a slight increase in water needs is recorded, varying from 80.92 hm<sup>3</sup> in 2017 to 91.10 hm<sup>3</sup> in 2050, following a moderate increase in the population (Fig.6).

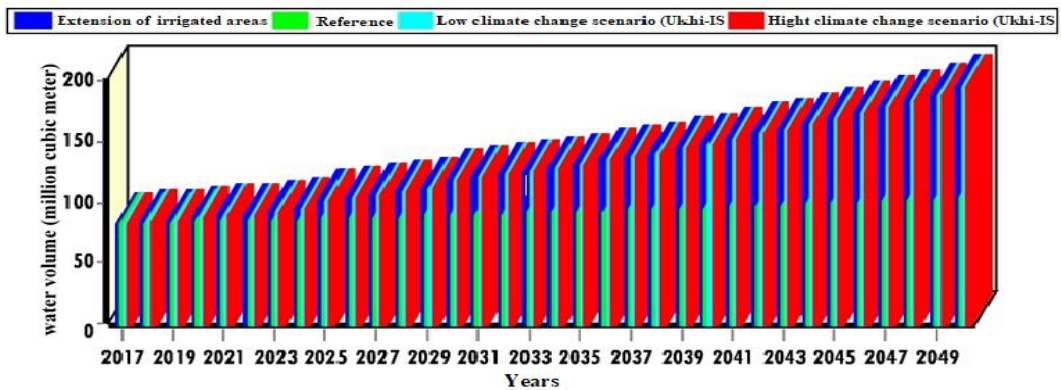


Fig.6. Water demand by scenario (2017-2050).

The total water demand (including losses) in the study area is marked by a considerable increase in all the scenarios adopted (SCC and SETI), going from a volume of 105.23 hm<sup>3</sup> in 2017 to 226.95 hm<sup>3</sup> in 2050 for the reference scenario (RS), the increase in demand is low during the simulation period, ranging from 105.23 hm<sup>3</sup> in 2017 to 114.36 hm<sup>3</sup> in 2050 (Fig.7).

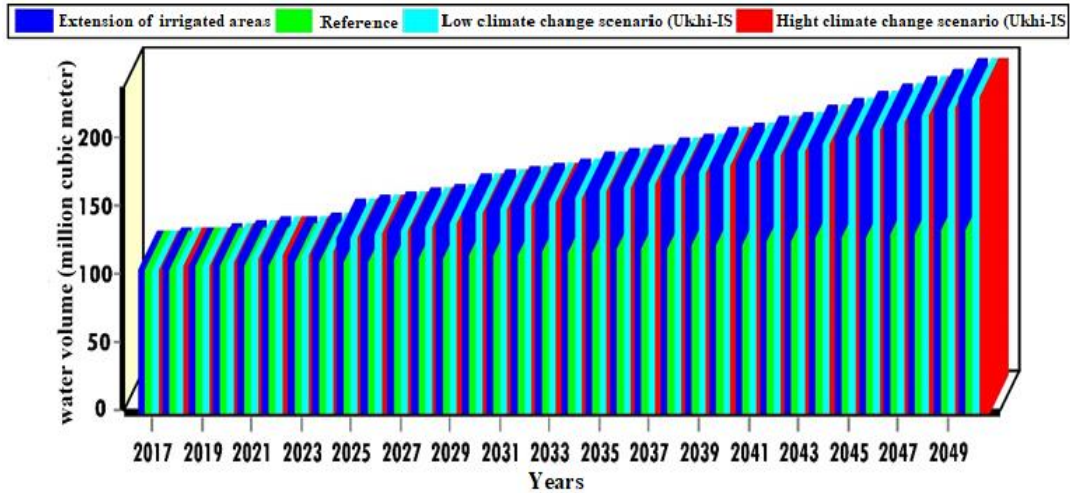


Fig.7. Water total demand by scenario (2017-2050).

For distributed water during 2017 and for all the scenarios adopted, the volume of water distributed is around 45.75 hm<sup>3</sup>. This volume increases to 89.08 hm<sup>3</sup> in 2025, which can be explained by the forecast to achieve an irrigation perimeter of 1700 ha in the Khezaras municipality and the construction of another irrigation perimeter of 1000 Ha at Bouchegouf by 2030. In the year 2050 this same volume increases to reach 123.39 hm<sup>3</sup> (Fig.8).

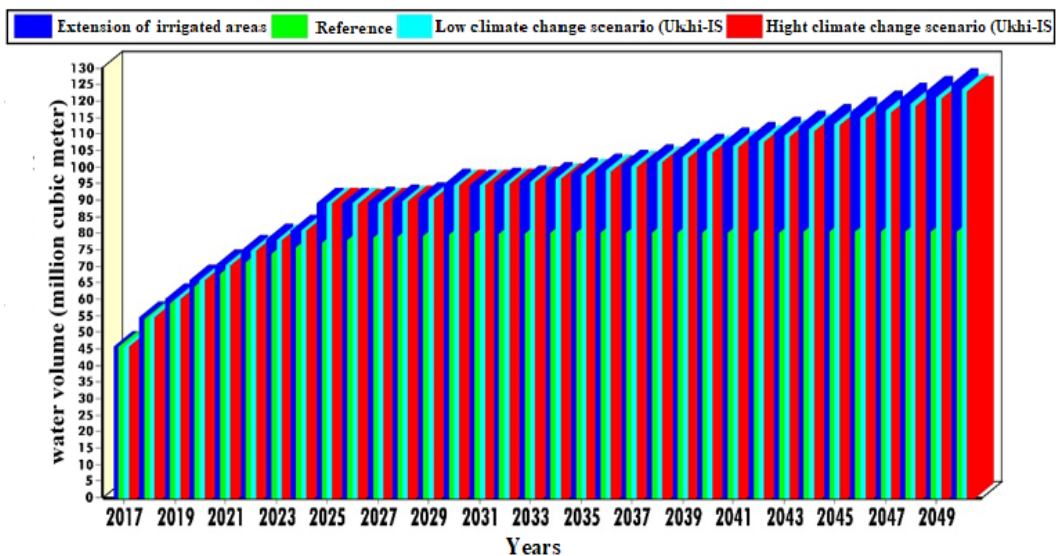
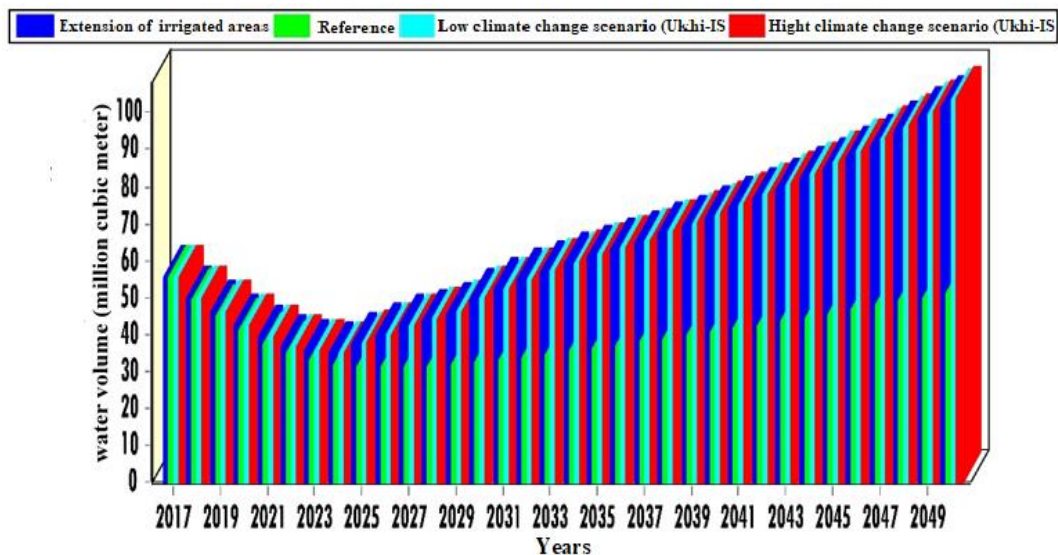


Fig. 8. Water distributed by scenario (2017-2050).



According to the **Fig. 9**, we see an unmet need for water estimated at a volume of  $55.5 \text{ hm}^3$  during the reference year 2017. This deficit distributed between irrigation water (around  $45 \text{ hm}^3 / \text{year}$ ) and drawdown slicks are mainly due to the lack of precipitation during this year. From the year 2025 begins a change resulting in an increase in the deficit interpreted by a lack of  $104.20 \text{ hm}^3$  at the end of the simulation period (2050).



**Fig. 9.** Unmet water demands by scenario (2017-2050).

#### 4. CONCLUSION

In this study we chose the WEAP software which gave us the opportunity to use our data on water resources to simulate their evolution and their users by 2050. The results obtained showed that the middle Seybouse basin is already under water stress, it suffers from water scarcity and is sensitive to drought conditions. The number of inhabitants increases from 346,342 in 2017 to 688,091 inhabitants in 2050, and the surface area of irrigated land jumps from 14,302.5 ha in 2017 to 37,228.61 ha in 2050. The amount of unmet demand for water is greater than the water supplied; available resources such as mean rainfall and outgoing water collection and storage infrastructure, including natural groundwater reservoirs, have failed to meet current and future needs in the middle Seybouse watershed. The scenarios of climate change and extension of irrigated land chosen for this study, show a water deficit from the reference year 2017 with a shortage of  $50.5 \text{ hm}^3$  which will be increasing to  $104.20 \text{ hm}^3$  in 2050. The catchment area of the middle Seybouse presents a glaring shortage at the end of the scenarios.

#### 5. RECOMMANDATIONS

It is urgent that those responsible for water participate seriously in solving this problem by using other resources, namely unconventional water, desalination and exploitation of surface water through the study and realization of dams.

#### Acknowledgements

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