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# Modelling current and future supply and water demand in the northern region of the Seybouse Valley

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## Abstract

Water in the Seybouse River basin is getting scarce, yet it is the key to its economic development. A fast growing population, expanding agricultural and industrial sectors and the impacts of climate variability, create demands for new water sources and innovative management of water resources and services. The object of this study is the water resources management in the lower Seybouse basin characterized by a steady increase of water demand to meet different uses. This study takes into account changes in water demand of different urban, agricultural and industrial supply process. Our approach is to integrate data in WEAP modelling software to simulate current and future water balance and then to analyse the situation of water in different scenarios, socio-economic development and climate change to 2050. This software is based on the representation of the feeding system in a form of the network of water demand and supply. Our findings reveal the vulnerability of the region in its ability to the pressures resulting from the increase of needs of different sectors at the horizon of the forecasted period. They also indicate the need for larger mobilization of new resources into the system and lay the foundations for a sustainable water policy in the northern region of the Seybouse valley.

**Key words:** *climate change, resources, Seybouse River basin, supply, water demand, WEAP model*

## INTRODUCTION

The lower Seybouse sub-basin (Fig. 1) is developing rapidly and accompanied by a high population rise along with improved standards of living. This demographic and economic growth requires huge amounts of water for different human sectors (urban, industrial and agricultural) which lead to an increased demand for new water resources [BABEL *et al.* 2005]. It is almost dependent on water that originates from El Taref region. This dependency makes the challenges of water resources management in this region extremely difficult [MCCARTNEY *et al.* 2009].

As indicated by Intergovernmental Panel on Climate Change (IPCC 2007) methodology [BENNANI *et*

*al.* 2001], there will be significant changes in precipitation in terms of annual and seasonal trends and extreme events of flood and drought. Annual rainfalls are expected to decline in much of Mediterranean Africa and the northern Sahara, with a great probability of reduction in precipitation as we approach the Mediterranean Coast [PACHAURI, REISINGER (eds.) 2007]. Mediterranean region is considered as a world “hotspot” in terms of climate variability and change [GIORGI 2006].

Variation of intensity and frequency of rainfall will affect the stream flows as a result will increase the intensity of floods and droughts, with substantial impacts on water resources at local and regional levels [ROCHDANE *et al.* 2012].

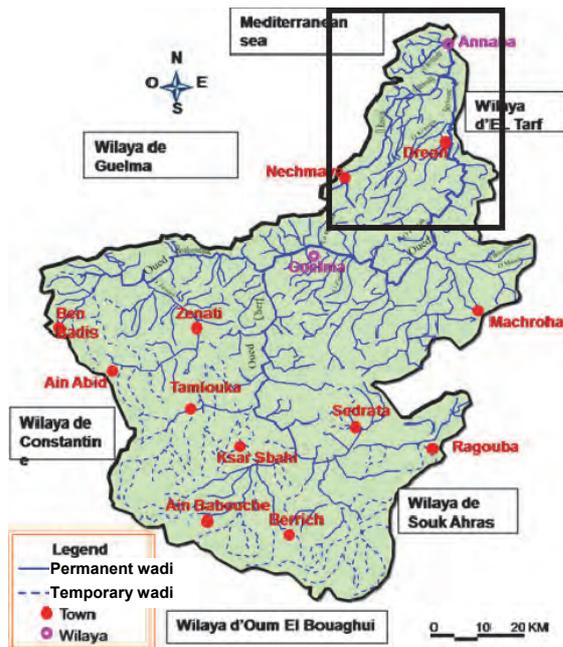


Fig. 1. Location of the Seybouse River Basin; own elaboration

One of the most important consequences of climate variation is the increasing frequency of drought episodes and the growing impact of aridity [SALVATI *et al.* 2013]. Variation in temperature and precipitation patterns can affect the hydrologic processes and water resources availability for agriculture, population and industry. Climate changes will accelerate the global hydrologic cycle with increase in the surface temperature, modification in precipitation patterns and evapotranspiration rates [VICUÑA *et al.* 2011].

We are conducting a study to assess current and future water demand and supply to meet different uses, thus analysis of climate change scenario impact, based on the hypothesis of global warming caused by emissions of greenhouse gases [ALFARRA *et al.* 2012], scenario is run for a period (2010–2050) [ROCHDANE *et al.* 2012].

Our methodological approach relies on the modeling supply system in lower Seybouse basin (also known as the Maritime Seybouse) using the WEAP software. WEAP (Water Evaluation and the Planning) model is an entirely integrated water resources system analysis tool [YATES *et al.* 2005b].

It is a model of simulation at physical base which integrates water demands from all sectors directly with water supply elements like rivers, tanks, groundwater, channels, desalination and hydropower projects [RAYEJ 2012]. This software is based on the representation of the water system in network form whose nodes (catchment basins, demand sites, different supply sources) are linked through transmission and return flow links [BOUKLIA-HASSANE *et al.* 2016].

WEAP has been used mainly to assess both the current and future water management, and projecting the impacts of climate changes [MCCARTNEY *et al.* 2009; RAYEJ 2012], it uses an approach based on sce-

narios which facilitate the exploration of a large range of variants in order to satisfy demand in a balanced way. Flexibility of the tool and its adaptation to the requirements of different data and environment allows the modelling of a basin like Seybouse, where the data are rare and the conflicts between the various water users are very current [AOUN-SEBAITI *et al.* 2013].

The majority of data plugged into the WEAP model were obtained from Direction of Agricultural Services (DSA), Companies of potable water (ADE), Water and Sewerage Companies, Hydrographic Basin Agencies, National Office for Irrigation and Drainage (ONID). All data were checked and harmonized. The WEAP data input via spreadsheets simplifies the update of parameters (rainfall, rivers flow, water demand, water supply, etc.).

The transmission links between nodes and water allocation rules (the priority application and supply) are also taken into account. We included as much details as needed to correctly characterized demand and supply source, subject to the availability of field data [ALFARRA *et al.* 2012].

## MATERIALS AND METHODS

### STUDY AREA

Seybouse River Basin covers an overall area of 6471 km<sup>2</sup> and it's located in the northern part of Algeria. The river basin lies within the provinces of the territories Guelma, El Taref and Annaba. It is bordered to the north by the Mediterranean Sea, in the south by the Wilaya of Souk-Ahras, in the west by Ain Berda, the Edough Massif, and Lake Fetzara and in the east by Annaba plain (Fig. 1).

It has three distinct parts: the high plains (High Seybouse), southern (Seybouse Average) and the northern (Lower Seybouse) [DJABRI *et al.* 2003]. The study area covers lower Seybouse sub-basin (code 1408).

The global population estimate in lower Seybouse is over 679 938 inhabitants in 2010, it is highly concentrated in the largest towns and cities.

The climate of the sub-basin varies from typical Mediterranean along the coast to semi-arid. The precipitation is unevenly distributed varies between 700 mm and 400 mm from North to South, reaching a monthly in the range of 90–120 mm in December–January. Minimum and maximum temperatures are observed in December–January (less than 10°C) and in July or August (between 25 and 30°C).

Lower Seybouse basin is characterized by agriculture contributing to food production in the country, it's modernly-equipped, main crops irrigated in perimeters comprise cereals and vegetables.

The industrial activities are very important and mostly concentrated around the Annaba city (steel, chemical fertilizers, and industrial tomato industries) and Guelma (sugar industry and motorcycle manufacturing).

**METHODS**

**WEAP model application.** The computation of the model was done by calculating the entire model for the reference [AZLINDA, MOHD 2012], we use the Water Evaluation and Planning (WEAP) model [YATES *et al.* 2005a]. WEAP model was developed by the Stockholm Environment Institute to assess water demand and to evaluate Water resource development projects, climate change impacts and water management scenarios [SEI 2011].

WEAP is single in its manner integrated for the evaluation of the water systems by its political orientation [SEI 2011]. It can act like a database to preserve the demand for water and to provide information, and like a tool of forecast to estimate the water resources (surface water, groundwater, water transfer, and storage), demand (irrigation, domestic and industrial supply), and storage [CHINNASAMY *et al.* 2015].

As a rule the model is first configured to simulate a reference scenario, whose amount of water available and demands can be determined in all confidence. It is then used to simulate alternative scenarios to evaluate the impact of the development and management various options which aims at maximizing the water provided to demands sites, according to a set of user-defined priorities [MCCARTNEY *et al.* 2009].

In this study, the model was setup to simulate three scenarios:

- i) current account (year 2010),
- ii) reference scenario1,
- iii) scenario 2: climate change scenario using extended dry climate sequence.

The impact of future climate change is evaluated by comparing various WEAP outputs between the future scenario extended dry climate sequence and reference conditions.

**CURRENT ACCOUNT (YEAR 2010)**

In this study, the Current Accounts is set to be year 2010, which provides a snapshot of actual water demand, resources, and supplies for the system [AZLINDA, MOHD 2012].

**Water supply.** The majority of water supplies in lower Seybouse sub basin are generated from water resources of El Taref region, situated to the East of the basin (Tab. 1, 2) [BOUKLIA-HASSANE *et al.* 2016].

Therefore, the northern sector of the basin, the subject of this research is highly dependent on water transfers from the region of El Taref where water resources are much greater and lesser extent from Guelma regions [MCCARTNEY *et al.* 2009].

In response to uneven distribution of available water resources over space [ANZAB *et al.* 2016], water surface is transferred to El Taref region through two main water pipeline, from two dams: Cheffia (initial capacity: 171 hm<sup>3</sup>, volume regularized 95 hm<sup>3</sup> for irrigation about 45 hm<sup>3</sup>, to supply drinking water

about 44 hm<sup>3</sup>) and Mexa (initial capacity: 45 hm<sup>3</sup>, volume regularized: 33 hm<sup>3</sup>). Water is treated in water treatment plants Chaiba and Mexa. The two facilities respectively have a capacity 1000–800 dm<sup>3</sup>.s<sup>-1</sup>.

A third dam Bougous is entry into service since 2010 (initial capacity: 60 hm<sup>3</sup>), it's interconnected to the dam Mexa where water release occur usually during the summer season.

To overcome this water shortage, management authorities in the lower Seybouse valley (Fig. 2), initiate several major projects for a few years were based primarily on supply management, as the construction of dams (Bouguousse, Bouhamdane, Bouhalloufa) and planning a sea water desalination plant [BOUKLIA-HASSANE *et al.* 2016].



Fig. 2. Schematic representation of the study area using Water Evaluation and Planning application; source: own study

**Table 1.** Surface water transferred to lower Seybouse sub-basin (in hm<sup>3</sup>) – 2010

Localisation	Dam name	Dam capacity	The annual regulated	Allocated to sub-basin
From El Taref	Cheffia	171	95	44
	Mexa	45	33	21
	Bougous	60	33	–
From Guelma	Bouhamdane	220	55	13.56
<b>Total</b>		<b>496</b>	<b>216</b>	<b>78.56</b>

Source: own study.

**Table 2.** Groundwater transferred to lower Seybouse sub-basin (in hm<sup>3</sup>) – 2010

Localisation	Volume
From El Taref	14.40
From Guelma	1.56
From sub-basin	18.34
<b>Total</b>	<b>34.30</b>

Source: own study.

A large proportion of water that is supplied is lost, ranging up 50% of the initial volume, caused by dilapidation and leakage of mains and distribution networks, we notes that water losses from larger diameter pipes are the most significant.

**Water demand.** Three types of sectorial demand included which are: household, agricultural and industrial.

1) Household water demands

The water supply is for the most part intermittently, as well as a majority of cities in Algeria. Total water consumption of these sectors during 2010, is estimated to 43.88 hm<sup>3</sup> annual or 120.219 m<sup>3</sup> per day (Fig. 3).

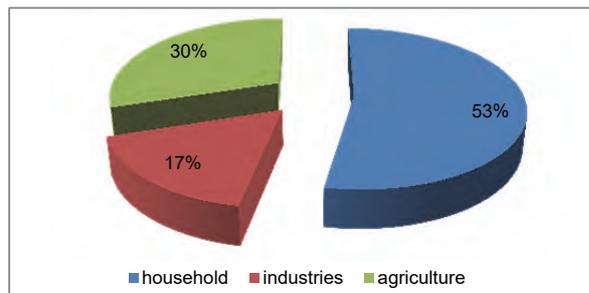


Fig. 3. Percentage of total water consumption by sector; source: own study

2) Industry water demands

Industries in the Seybouse basin are mainly grouped in lower Seybouse sub-basin. It is in major cities such Annaba, El Hadjar, El Bouni and Sidi Amar, where the industrial fabric is the densest.

Three industry categories were observed:

- heavy industries;
- chemical industry;
- and finally the food industry represented by small businesses.

Industrial water demands are currently dominated by the steel plant Arcelor Mital [DJABRI *et al.* 2003]. Totals industrial demand in the sub-basin is about 14.33 hm<sup>3</sup> annual or 39.26 m<sup>3</sup> per day (Fig. 3).

3) Agriculture water demands

Agriculture is observed over the entire area, with a wide variety of crops, market garden and orchard.

The total Irrigated area in the lower Seybouse basin is 4885 hectare, characterized by using modern

techniques (sprinkler), water agriculture demand about 24.60 hm<sup>3</sup> or 67.400 m<sup>3</sup> per day (Fig. 3).

Total water demand in the sub-basin of lower Seybouse is 82.64 hm<sup>3</sup>. In the simulations, we further assume that 53% of the consumption of the demand sites is oriented towards households with 43.88 hm<sup>3</sup>, being the largest user of water.

The water demand of agricultural sectors 24.42 hm<sup>3</sup> which represents 30% of total demand, being the second largest user of water, irrigation is the first sector to lose out as water scarcity increases.

REFERENCE SCENARIO

The “reference scenario” includes the current accounts data into the entire project specified (2010–2050) [AZLINDA, MOHD 2012].

The industry water demand is 14.33 hm<sup>3</sup> accounting 17%. It is the least consumer water sector in the sub-basin.

**Future overall water demand.** Figure 4 shows the projected water demand for the year of 2010–2050. From the result, it was projected that in the year of 2050, the total water demand is increased to 178.04 hm<sup>3</sup>.

Figure 5 shows the projected **household water demand** for the year of 2010–2050. From the result, it was projected that in the year of 2050, the water household demand is increased to 64.8 hm<sup>3</sup>.

Figure 6 shows the projected **agriculture water demand** for the year of 2010–2050. From the result, it was projected that in the year of 2050, the water demand is increased to 79.12 hm<sup>3</sup>.

Figure 7 shows the projected **industrial water demand** for the year of 2010–2050. From the result, it was projected that in the year of 2050, the water demand is increased to 34.13 hm<sup>3</sup>.

**Future overall unmet water demand (quantity of water that cannot be physically delivered to the demand).** The simulation of this reference scenario shows that in the absence of intervention, the water deficit in 2050 will worsen in the future (Fig. 8).

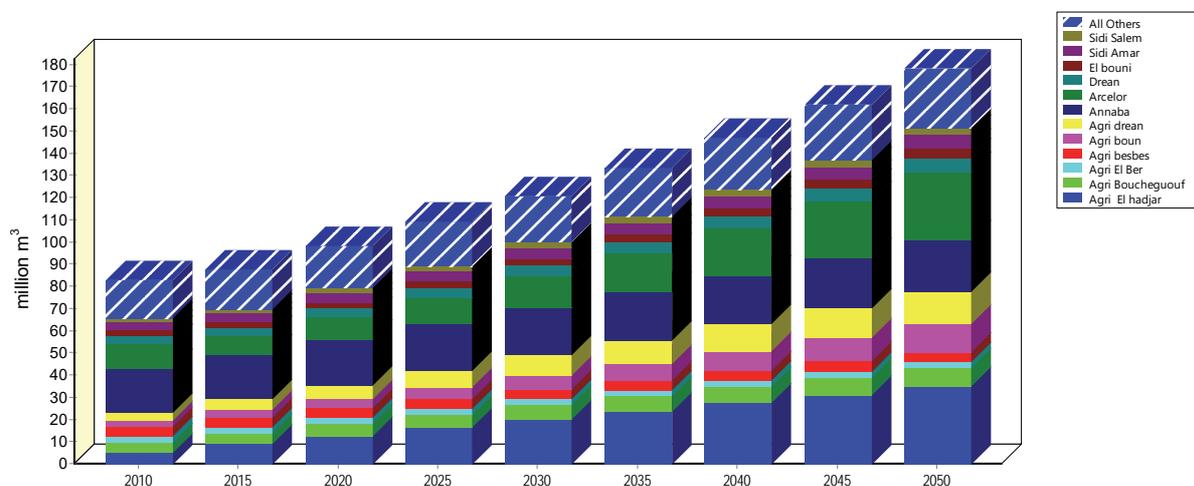


Fig. 4. Overall result of water demand; scenario: reference, all months; source: own study

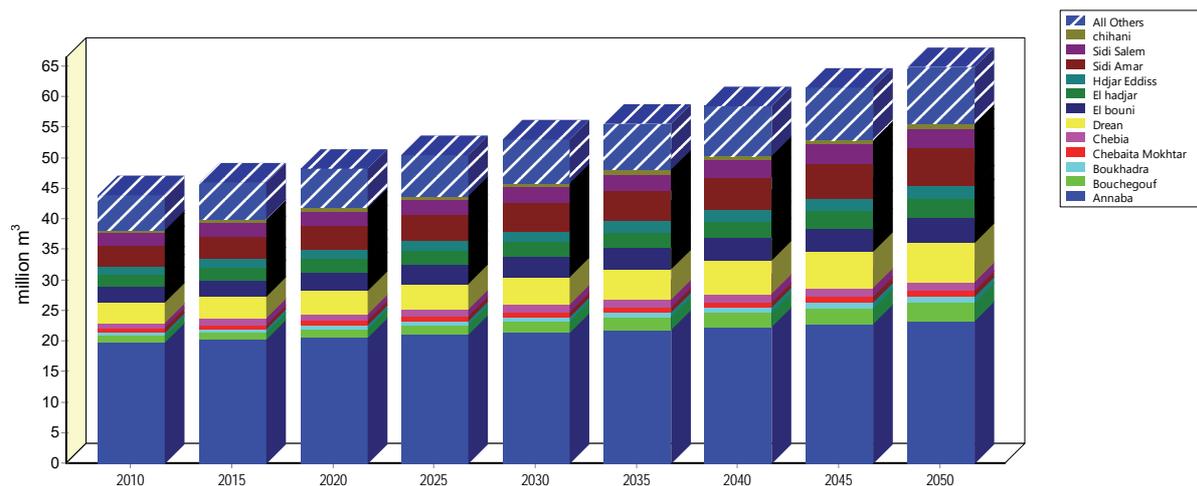


Fig. 5. Household water demand; scenario: reference, all months; source: own study

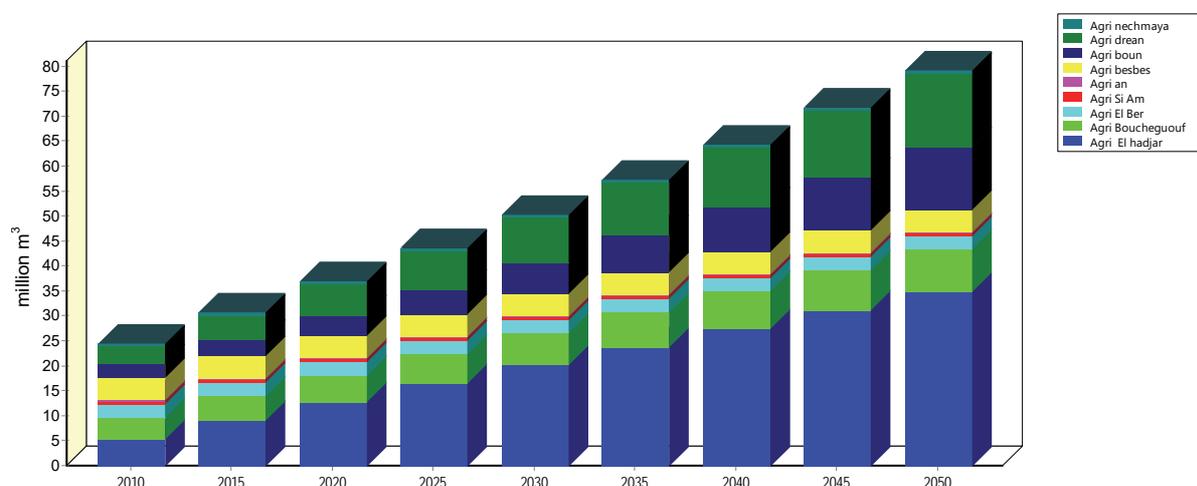


Fig. 6. Agriculture water demand; scenario: reference, all months; source: own study

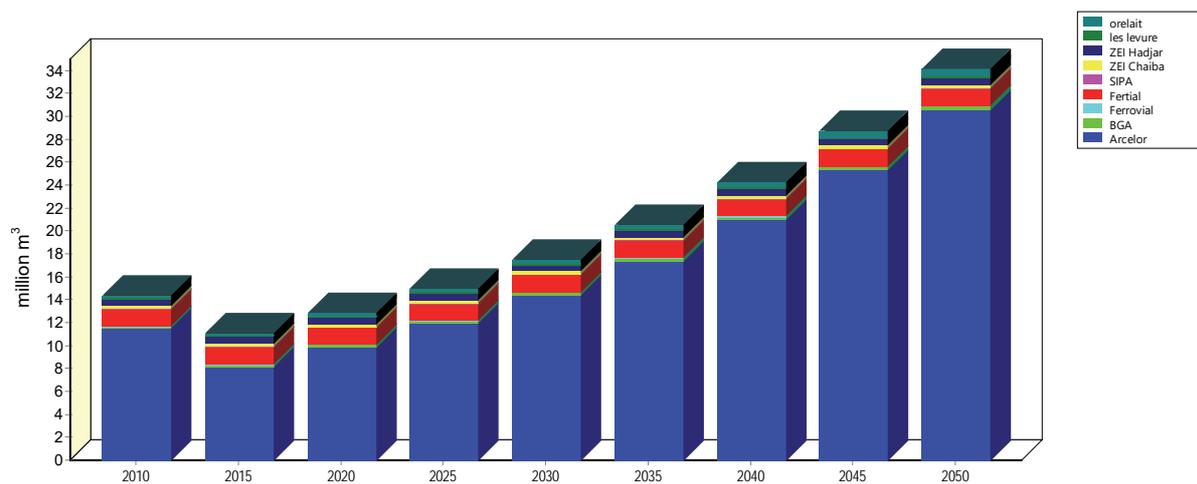


Fig. 7. Industrial water demand; scenario: reference, all months; source: own study

However, this scenario is passive, since it is based on the assumption that the managers took no infrastructures development measure in answer to the increase in population size and the number of companies.

Figure 8 shows the overall result derived from the reference scenario, that unmet demand in year 2050 is increased over 172.78 hm<sup>3</sup>.

### SCENARIO CLIMATE CHANGE (EXTENDED DRY CLIMATE SEQUENCE)

The development of climate scenarios for northern Africa reveals a trend towards an increase in average annual temperature (between 0.6 and 1.1°C) and reduction in average annual precipitation volume by

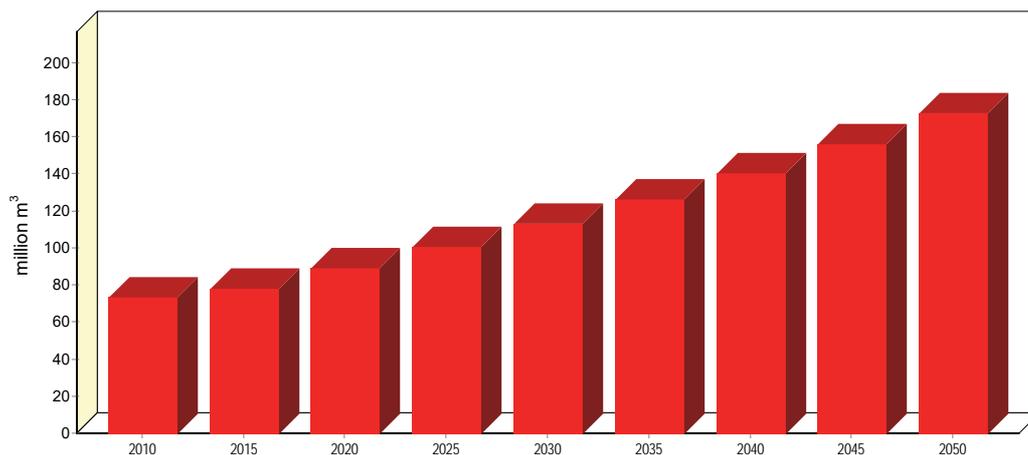


Fig. 8. Overall unmet demand: reference scenario; selected demand sites, all months; source: own study

about 4% in 2020 compared to 2000 levels [BENNANI *et al.* 2001]. To forecast climate change and model, scientists rely on a number of scenarios (IPPC).

Each storyline assumes a significantly different direction for future developments, covering a wide range of key “future” characteristics such as demographic change, economic development, and technological change.

Unmet demand analysis simulation was done in order to highlight the amount of deficits that resulting from the climate change scenario. Hence in this ana-

lysis, it is presented in Figure 8, namely unmet demand.

Simulation results in Figure 9 showed an increasing trend in water demand, demonstrating that the average annual unmet demand will dramatically increase, between a reference scenario and future projection under scenario of climate change. It clearly shows that by considering the change in climate, the unmet demand will increase in the future compared with reference scenario.

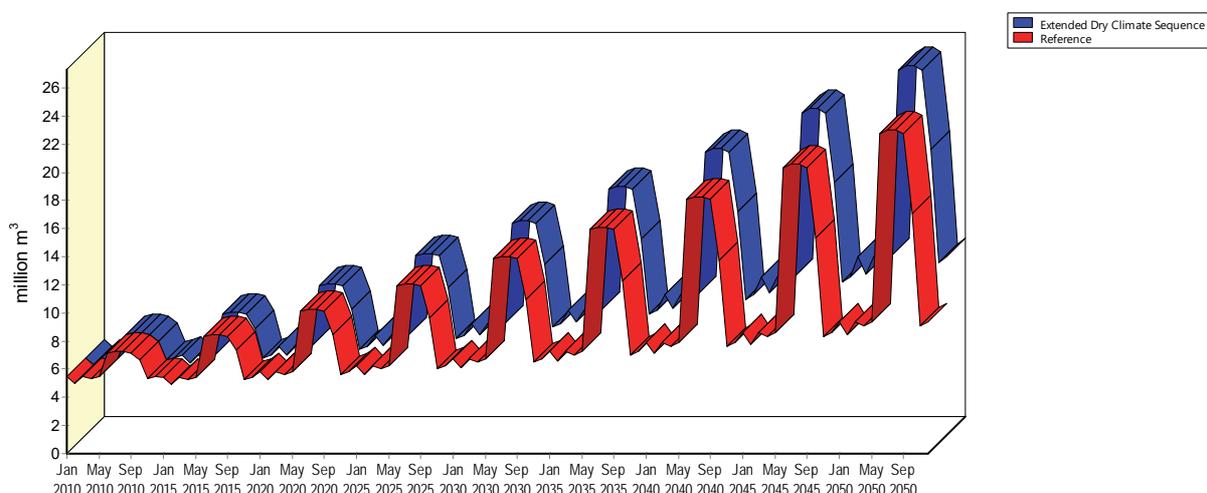


Fig. 9. Unmet demand for scenario 2: extended dry climate sequence in comparison with the reference scenario 1 (all months); source: own study

## CONCLUSIONS

This study has explored, in a modelling framework, using the water resources system evaluation model, Water Evaluation and Planning (WEAP), the importance of a prospective and integrated management of demand and water supply, in order to predict the future constraints.

Developing capacities which can meet the pressures resulting from the increase of demand from the different sectors due to population growth, climate

change and other socio economic factors on the horizon of 2050.

Moreover, WEAP simulated future water demand associated with the effect of climate change using the extended dry climate sequence.

The modelling has not only estimated the future water demand for all user sectors (households, industry, and agriculture), but also highlighted the vulnerability of the region in its ability to cope with the pressures, which resulting from the increased needs, due to:

- the very limited current resource capacity,
- the region's dependency on the El Taref region particularly.

This is further accentuated by the effects of climate change, where the results reveal that the average annual unmet water demand will dramatically increase coming decades, which will have undoubtedly affect water availability.

They also indicate the need for greater mobilization of new resources into the system and lay the foundations for a sustainable water policy.

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**Abdel-Fatah BERREDJEM, Azzedine HANI**

**Modelowanie obecnego i przyszłego zaopatrzenia i zapotrzebowania na wodę w północnym regionie Doliny Seybouse**

**STRESZCZENIE**

Zasoby wody w zlewni rzeki Seybouse są coraz skromniejsze, a przecież są one kluczowym elementem rozwoju gospodarczego. Szybko rosnąca liczba ludności, rozwój rolnictwa i przemysłu oraz wpływ zmienności klimatu tworzą zapotrzebowanie na nowe źródła wody i innowacyjne metody zarządzania jej zasobami. Przedmiotem badań było zarządzanie zasobami w dolnej części zlewni Seybouse. W badaniach uwzględnia się zmiany zapotrzebowania na wodę w miastach, rolnictwie i przemyśle. W pracy integrowano dane w programie WEAP w celu symulowania obecnego i przyszłego bilansu wodnego, a następnie analizowano sytuację w warunkach różnych scenariuszy społeczno-gospodarczego rozwoju i zmian klimatycznych do roku 2050. Program polega na przedstawieniu systemu zasilania w formie sieci potrzeb i zaopatrzenia w wodę. Wyniki badań ujawniły wrażliwość regionu na presję wynikającą z rosnących potrzeb wodnych różnych sektorów w prognozowanym horyzoncie czasowym. Wskazały także potrzebę uruchomienia nowych zasobów w systemie i stworzenia podstaw zrównoważonej polityki wodnej w północnym regionie doliny Seybouse.

**Słowa kluczowe:** *dostawy, model WEAP, zapotrzebowanie na wodę, zasoby, zlewnia rzeki Seybouse, zmiany klimatu*