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Original Research Article

PLANNING AND MANAGEMENT OF WATER RESOURCES IN THE CONTEXT OF ECONOMIC DEVLOPMENT AND CLIMATE CHANGE IN ALGERIAN HIGHLANDSBY THE WEAP MODEL, CASE OF THE GAREAT EL TARF BASIN (NORTHWESTERN ALGERIA)

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Abstract

Water in the Gareat El Tarf basin, is affected by climatic and economic constraints; while its development is based on the agricultural sector, which creates pressure on water resources. The objective of this study is to analyse the performance of the national water plan to accompany this policy, and the impact of climate change on water resources. The methodology adopted is the application of the WEAP(Water Evaluation and the Planning)software, in order to build a model for the allocation of water resources, up to 2050. The results obtained confirm that the impact of the economic policy shows a very important deficit that exceeds 400 million m^3 in 2050. To face this challenge, it is recommended to adopt an economic strategy based on the protection of water resources and adapted to the supply capacities of renewable water resources.

Keywords: Gareat El Tarf, WEAP, climate change, senario, water, managment, demand, supply, Algeria

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1. INTRODUCTION

In Algeria, the availability of water per inhabitant is 600 $m^3 \cdot inhabitant^{-1} \cdot year^{-1}$, thus placing Algeria in the category of countries poor in water resources with regard to the shortage threshold set by theUnited Nations Development Programme (UNDP), or the scarcity threshold set by the World Bank at 1000 m^3 /inhabitant/year [16].The development strategy of the water sector by 2030 in Algeria is outlined by the National Water Plan (NWP), which identifies a set of structuring projects and programmes to be carried out by five-year periods [18]. Algerian water management policy has, over the past ten years or so, been more focused on the mobilisation of new resources than on the search for a better use of the resources already available. Priority has been given to the development of 'supply' and not to demand management [1].

The second national communication on climate change to the UNFCCC (United Nations Framework Convention on Climate Change) predicts that climate change will manifest itself in the Mediterranean region through an increase in seasonal temperature of 0.8 to 2.2°C and a decrease in seasonal rainfall of 6 to 22% [10]. Changes in average annual precipitation, as well as its spatial and temporal distribution, influence the overall water balance, including groundwater recharge. The effects of climate change will be felt by humans primarily through its impact on global water resources, including groundwater [4, 22].

The most affected regions in Algeria are the High Plateaux and the Steppe. These constitute transition zones between the North and the South of the country and cover about 70% of the viable land in the North. They constitute real agricultural potential and ensure the country's food security. Climate change may be an aggravating factor in the degradation of these regions [9].

The basin of Gareat El Tarf, is part of the Algerian highlands. Within the framework of the SNAT (National Spatial Planning Scheme) for 2030 and 2050, the development of the Gareat El Tarf basin is mainly oriented towards the agricultural sector. To meet this economic ambition, the PNE for 2030 envisages in its programme multiple projects for mobilising water resources [3].

In this paper, we will analyse the performance of the national water plan, on the level of the Gareat El Tarf catchment area, and compare it to a possible water demand management policy in the short and long term (2030, 2050). As well as the study of the impact of climate change on his water resources.

Water management in the climate change vision requires a scenario-based approach [17]. Our methodological approach is based on the modelling supply system using the WEAP (Water Evaluation and the Planning) software. This tool has been the subject of several applications in arid and semi-arid zones.

2. STUDY AREA

2.1. Geographical location and climat

Covering an area of 2432 km^2,The Gareat El Taref basin extends between latitude 35°22’ and 35°56’ N and longitudes 6°49’ and 7°34’ E, at the extreme northeastern of Algeria.It’s characterised by a semi-arid climate type. With a dry season lasting six months (May to October), an average temperature of 15.7 °C and an average annual rainfall of 450 mm·year $^{-1}$ during the period (1996-2015).

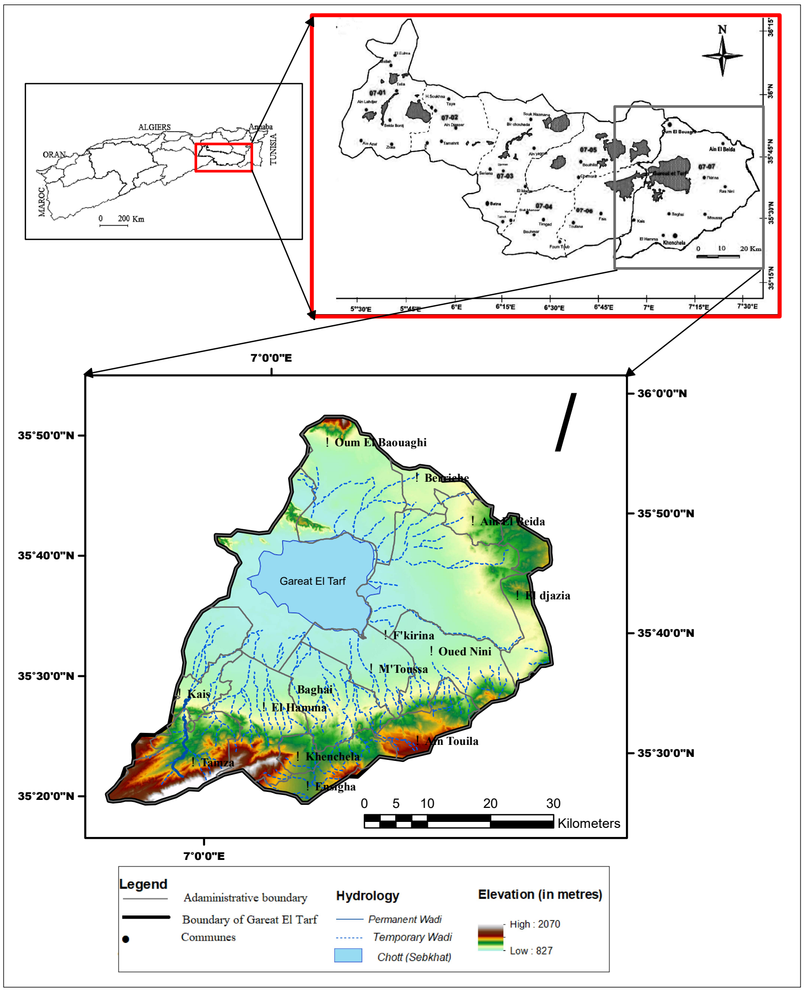


Fig.1. Geographical situation and administrative division; source: own elaboration

2.2. Groundwater

The Gareat El Tarf basin is based on three hydrogeological units. To the east is the unit of the Remila plain, in which the most important and most exploited aquifer is the Mio-quaternary aquifer. Towards the West it is the unit of the region of Oum El Bouaghi-Ain El Beida which is based on the Mæstrichtiens aquifer [18]. South-eastwards the hydrogeological unit of Meskiana, it covers only a very limited area of the basin but remains important for the water supply of the Meskiana region.

The groundwater potential is estimated at 37 mln $m^3 \cdot year^{-1}$for an average year, whereas in a dry year it can drop to half [18] (Tab. 1).

Table 1. Volume of the mobilized groundwater per hydrogeological units in the Gareat El Tarf basin

Hydrogeological unit	Area (km^2)	Renewable water resources (mln m^3)	
		Average year	Dry year
Unit Om El Boughi–Ain El Beida area	950	17.7	11
Unit of Remila-Khenchela plain	1340	17.5	7
Unit of Meskiana plain	272	4.80	1.5

Source: own elaboration based on data of: [18] and Hydric Water National Agency (ANRH)

2.3. Surface water

Due to its semi-arid climate, the surface water resources in our basin are rather scarce, it is a silted dam, some hill reservoirs. The majority of the Oueds are endoric; they flow towards the salt lakes. Wadi Gueiss is the only permanent wadi. Its average annual flow measured for a period of 33 years (1970-2005) is about 0.38 $m^3 \cdot s^{-1}$ [3]. Temporary Oueds drain the south of the basin while Faids (flooded plain) characterize the north part. The total calculated annual gross water runoff volume over the whole province is 189 mln m^3.

The Gareat El Tarf basin does not have a hydraulic dam on its territory. Nevertheless, regarding its needs for drinking water, it carries out transfers of water by adduction from the big hydraulic system of Beni Haroun, through the Koudiat Medouar dam and the Ourkiss dam. The total storage capacity of these dams is 215 mln $m^3 \cdot year^{-1}$.

The Gareat El Tarf basin, is served by three wastewater treatment plants. The total volume purified by these three stations is 47062 $m^3 \cdot day^{-1}$, for the irrigation of about 490 hectares of agricultural land [18]. Two other stations will be commissioned by the year 2025.

2.4. Socio-Economic Insight

According to the National Statistics Office (ONS), based on the RGPH (General Census of Population and Housing) from 1998 to 2008 The Gareat El Tarf basin includes about 455 000 inhabitants spread over 16 municipalities, with an average annual growth rate of 1.25%. This rate varies widely from one municipality to another, ranging from 2.3% to - 0.2%.

The Gareat El Tarf basin has a purely agricultural vocation, with a useful agricultural area (UAA) of approximately 276,192 hectares. The part of irrigated agriculture is reduced, and represents only 5.3% of the UAA [11]. The basin is characterised by poor industrial development reduced into two small industrial zones, the first in the commune of Khenchela with a surface area of 68.72 hectares and the second in the commune of Ain El Beida with a surface area of 121 hectares [13,14].

3. METHODOLOGY ADOPTED

Presentation of WEAP

WEAP (Water Evaluation and Planning Assessment System) is a flexible, integrated and transparent planning tool for assessing the sustainability of current demand and distribution patterns and exploring alternative, long-term scenarios. WEAP was created in 1988 by the Stockholm Environment Institute (SEI), with the aim of providing a flexible, integrated and transparent planning tool for assessing the sustainability of current demand and distribution patterns and exploring alternative, long-term scenarios [20]. The first major application of WEAP was in Central Asia (Aral Sea) in 1989 [24]. This has been followed by several applications in various regions, including: China[5]; the United States [15]; Turkey and Kenya [6,7]; the Nile Basin [19]; South Africa [12]; In Algeria, some applications have been carried out in the last ten years in semiarid regions [2], and regions with a Mediterranean climate [8]. There are several reasons for choosing WEAP: it is a flexible model with which users can define their region [21]. The data structure and level of detail can be easily customized to meet the requirements of a particular analysis and to reflect the limitations imposed where data is limited. WEAP21 can describe a region's water-related infrastructure and institutional arrangements in a comprehensive, neutral, and results-oriented planning environment that can inform strategies and help assess freshwater ecosystem services [23]. The data used are collected from the NAP update report [18]. and from several administrations, such as ABH (Hydrographic Basin

Agency), ANRH (National Water Resources Agency), NMO (National Meteorological Office), DES (Directorate of Agricultural Services), ONS (National Statistics Office), ONID (National Irrigation and Drainage Offices) and ADE (Algérien des Eaux).

4. RESULTS AND DISCUSSIONS

4.1. Creation of the current account

In this study, we take 2010 as the current year, because it is the base year taken by the Ministry of Water Resources for the updating of the national water plan for 2030 [18], and on this occasion the minister carried out a massive data collection around the water sector on the national territory. This choice will enable us to use the most reliable data possible and also to carry out a scenario that corresponds to this national plan. Data introduced for the current account are summarised in Table 2. For the creation of this account, rivers, dams, groundwater resources are digitised. The schematic of the Gareat El Tarf basin is shown in Fig. 2.

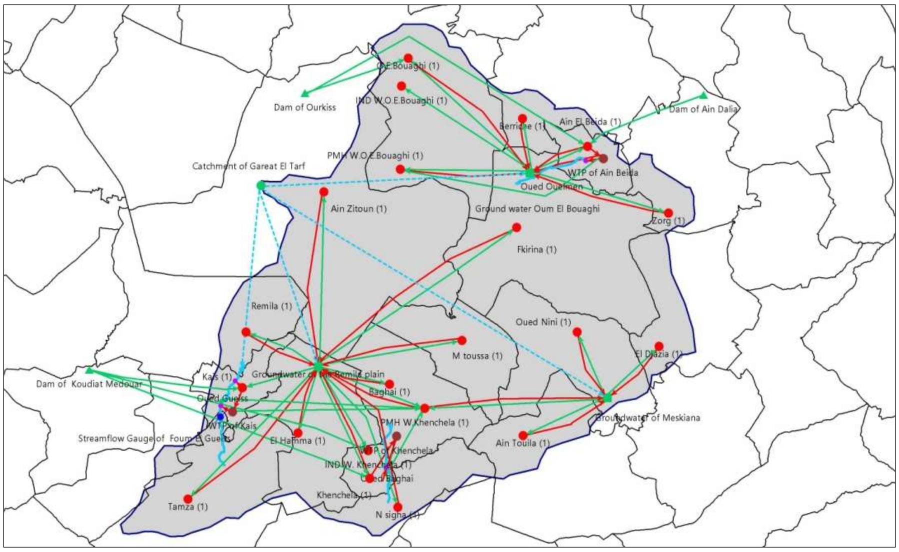


Fig. 2. Schematic of the WEAP model for the Gareat El Tarf basin. Red points are waterdemands; the green square is groundwater source, the green and red arrows are the transmission link (which link water sources and sinks); source: own elaboration

Three types of water users are known in the Gareat El Tarf catchment: households, irrigation, industry.

Table 2. Data used by WEAP to model demand sites on the current account for domestic, Irrigation and industrial sectors

Demand sites	Level of annual activity		Unit water demand	Monthly breakdown	Consumption rate (%)	Loss rate (%)
Domestic sector						
Communes	Number of population	Growth rates (%)				
Khenchela	108580	2.3				
Kais	34383	1.8				
Remila	5606	-0.2				
Tamza	8617	0				
El Hamma	12051	1.2				
Ensigha	9257	1.6				
Baghai	6676	0.4		Proportional to the number of days in a month		
M'toussa	5981	0.8	39.42 (m^3·person^1·year^1)		20	45
Ain Touila	16845	1.3				
O.E.Bouaghi	80359	3				
Oued Nini	5119	0.5				
El Djazia	3878	1.6				
F'kirina	12318	0.8				
Zorg	2281	2.8				
Ain Beida	118662	2.6				
Berriche	17609	0.8				
Ain Zitoun	5948	-0.1				
Irrigated agriculture sector						
Irrigation perimeters (IP)	Area (Hectares)	Growth rates (%)	5100 (m^3·hectares^{-1}·year^{-1})	Nov. At Mai 0% Jun 25% Jul. 30% Aug. 25 Sep. 10% Oct. 10%	96	40
IP of Khenchela	2944	2.5				
IP of O.E.Bouaghi	11683					
Industrial sector						
Industrial zones	Area (Hectares)		Water demand	Proportional to the number of days in a month		
IZ of Khenchela	68.72	-	815200		-	
IZ of O.E.Bouaghi	121		36500 (m^3·year^{-1})			

Source: own elaboration based on Data from: ONS (National Statistics Office), DES (Directorate of Agricultural Services), ONID (National Irrigation and Drainage Offices, [11,18]

Annual water demand by sector in 2010 is represented in Fig.3, it's shows that irrigated agriculture, is by far the largest consumer of fresh water available, it consumes more than 75 % of the total fresh water with more then 60 mln m^3, between surface and groundwater. The next largest demand is comes from domestic water tof cities wich have a large number of inhabitants: Khenchela, Ain Beida and Oum El Bouaghi, are the cities that consume the most drinking wate with. Industry being the last site to use water.

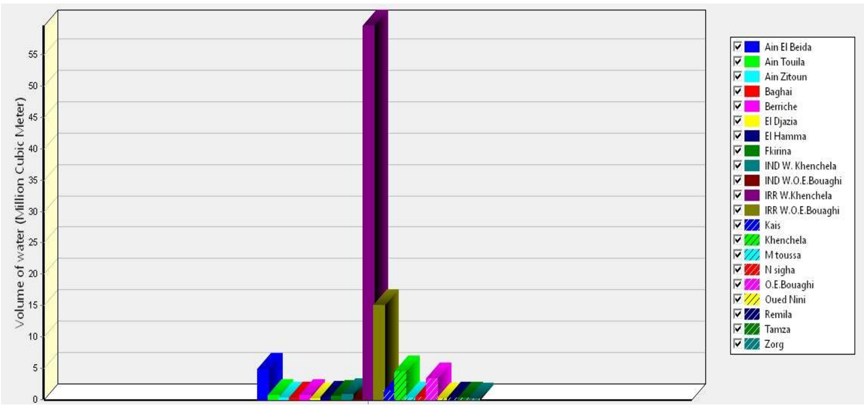


Fig. 3. Annual water demand per sites in the Gareat El Tarf basin (2010); source: own elaboration

4.2. Development of scenarios

4.2.1. Socioeconomic scenarios

Many variations can be created and simulated by intro-ducing changes to the current account to assess the effects caused by changing the rules and technologies of water management [2]. In this project, we devloped three socioeconomic scenarios,wich are:

- Reference senario (R): established for the current situation (2010) and extended to maturity (2050), where the acquired data are introduced, with a view to simulating the evolution of the system, without any change in the increase of agricultural domestic, and industrial demand,as demonstrated in Table 2.
- Scenario of National Water Plan (NWP): under the hypothesis of:
  - Maximum mobilisation of resources in aux supported by water transfers.
  - Birth control "which" causes the population to stabilise around the year 2030.
  - Increase in the growth rate of irrigated areas with 4.1%.
- Demand management Scenario (DM): under the hypothesis water saving by:

- Rehabilitation of drinking water distribution networks gradually from 45% to 20%.
- Reduction of losses in irrigation networks gradually from 40% in 2010 to 10% in 2050.

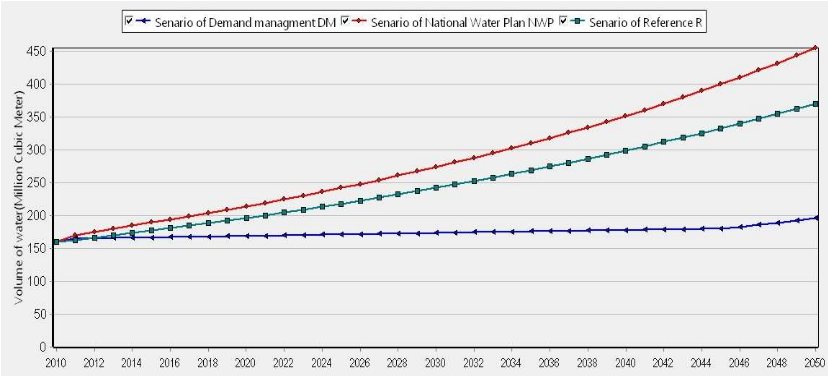
a) Water Demands

The evolution of annual water demand including loss, reuse per senario, can be seen in Fig. 4a, it's showing that in 2010 demand for the different sectors (domestic, industrial, irrigated agriculture) is around 160 mln m^3, it's constantly increasing from year to year, in a different way from one scenario to another:

- For the NWP scenario demand in 2030 increases by about 100 mln m^3,for 2050 it's almost three times higher than demand in 2010 with 450 mln m^3.
- For the R scenario, it increases with about 100 mln m^3 once in 2030, and a second time in 2050 to reach 370 mln m^3.
- For the DM scenario, in 2030, it increases only by about 13%, to reach 170 mln m^3 and 25% in 2050 to reach 200 mln m^3.

From the comparison of the evolution of demand for the three scenarios, we conclude that the GD scenario is the one that ensures that demand remains stable from 2010 TO 2050.

a)



b)

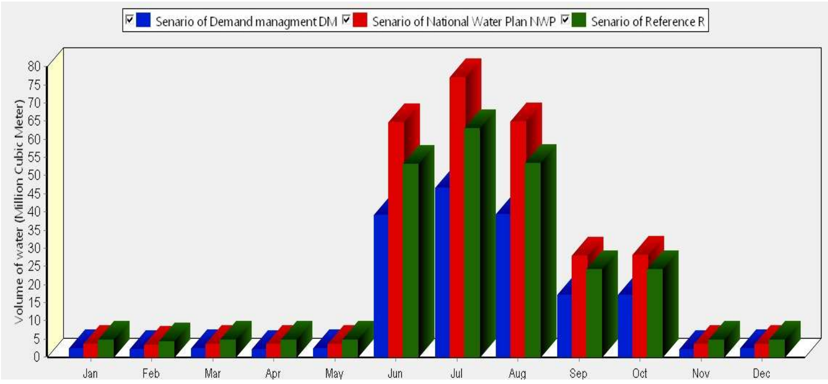


Fig.4. The evolution of water demand (including loss, reuse) per senario for the periode 2010 to 2050: a) annual demand, b) monthly demand

Water demand increases during the period from Jun to October and reaches in july its maximun for all of senarios; with 75 mln m^3 for NWP senario, 60 mln m^3 for R senario and 45 mln m^3 for DM senario (Fig. 4a).This monthly variation is caused bay the monthly share of water demand for irrigation.

We see that, demand management based on the reduction of losses at the level of the dinking and irrigation water distribution networks significantly reduces the demand for water for drinking and irrigation supply.

b) Unmet Water Demand

Results for the simulation period (2010-2050) for unment water demand, is shown in Fig. 5, it is clear that:

- In 2010 the unmet water demand by domestic and industry sector, is 6 mln m^3, which is not a significant volume compared to the uncovered demand of the irrigated agricultural sector, with about 127 mln m^3, in the same year.
- In 2050, the basin will be confronted with a water deficit of more than 300 mln m^3·year^{-1}, for R scenario (Fig. 5a). In the case of adopting an ambitious economic policy based on irrigated agriculture over very large areas, which is envisaged in the NWP scenario, the basin will face a deficit of more than400mln m^3·year^{-1}(Fig. 5b).A large percentage of this water is wasted due dilapidation and leakage of mains and distribution networksin addition to inefficient irrigation technique. That's why if we must focused on water saving, by adopting a demand management policy, with a less accelerated economic ambition; In 2050, the water deficit will show more or less stable figures compared to 2010 for the agricultural sector, and will mark a significant decrease for the other sectors (domestic and industry) with about 4 mln m^3·year^{-1} (Fig. 5c).

a)
b)
c)

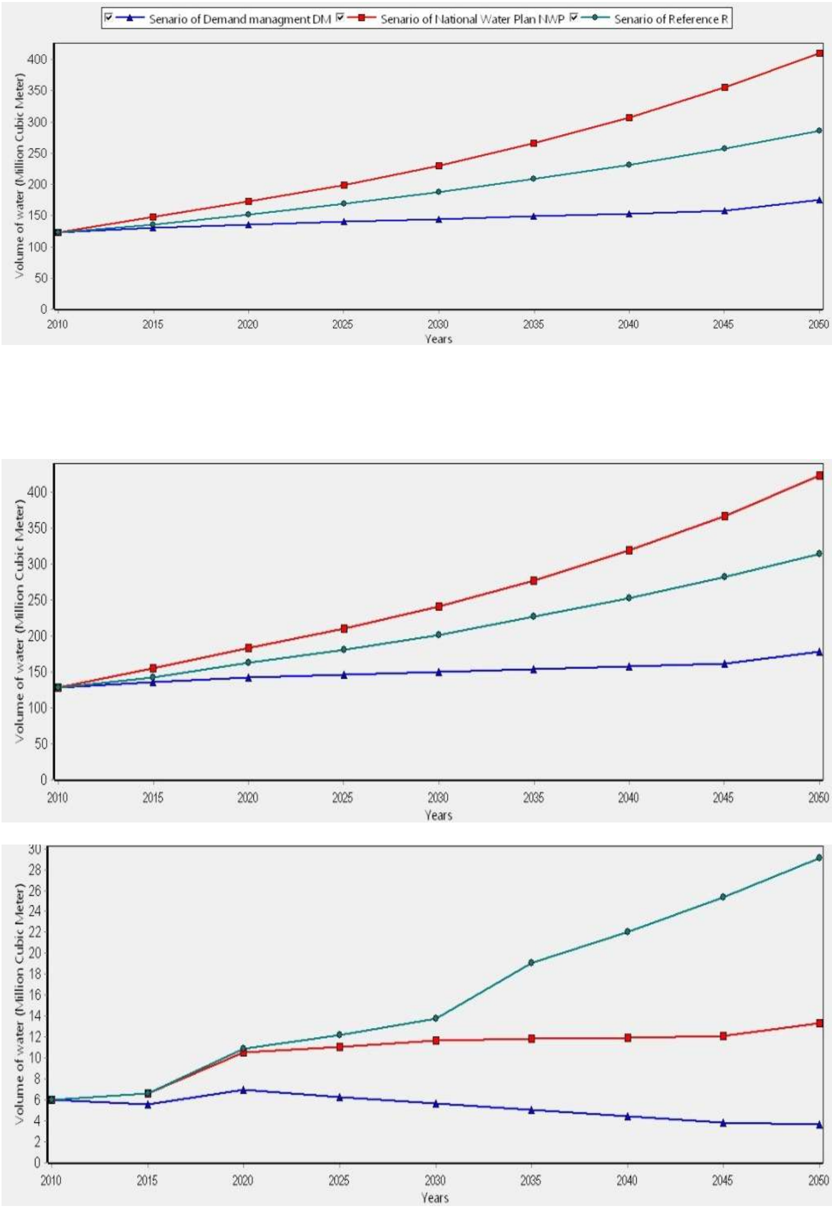


Fig.5. Evolution of Unmentwater demand in the Gareat El Tarf basin for all sectors for the periode 2010 to 2050: a) demestic and industrial, b) Irrigation, c), for Reference senario (R), Demand Managment senario (DM), and National Water Plan (NWP) senario; source: own elaboration

4.2.2. Climate Senarios

We use WEAP model to to explore sensitivity of water resource to climate change. We carried two scenarios based on the model called «Water Year Method ».This method is a simple means to represent variation in climate data such as streamflow, rainfall, and groundwater recharge. The method first involves defining how different climate regimes (e.g., very dry, dry, very wet) compare relative to a normal year, which is given a value of 1. Dry years have a value less than 1, very wet years have a value larger than 1 (SEI2016). Scenarios are:

- Water Year Method Senario (WYM), which has a reference function, under the assumption of future climate stability.

The rainfall index (RI), is the ratio of the rainfall height of a year to the average annual rainfall height of the series. A year is said to be wet if this ratio is greater than 1 and dry if it is less than 1.

- Climate change senario (CC) "Severe dry climate sequence", under the assumptio.

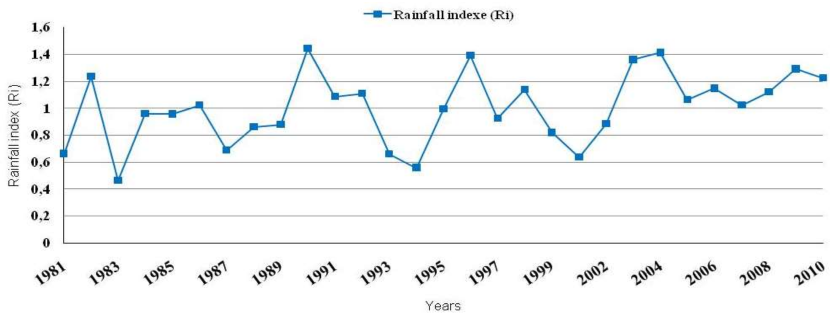


Fig.6. Rainfall indexe at the level of Foum El gueiss hydrological sation; Source: own elaboration

a) Climat change impacts on Wadi Gueiss streamflow

Fig.7 shows the streamflow of Wadi Gueiss, under a WYM and a CC senario, for the periode of 40 years from 2010 to 2050.We observed that streamflow of Wadi Gueiss is higher for the WYM scenario than for the CC scenario, with variable differences that can range from 0.2 to 0.7 mln $m^3 \cdot year^{-1}$.

Maximum streamflow of Wadi Gueiss under normal climatic conditions (WYH scenario) reaches 7.8 mln $m^3 \cdot year^{-1}$, while under a CC scenario does not exceed 7.3 mln $m^3 \cdot year^{-1}$. which represents a decrease of about 6% in its streamflow.

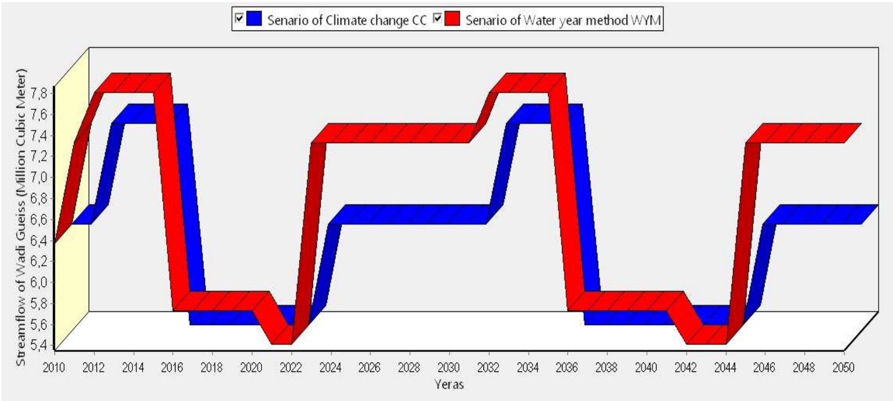


Fig. 7. Evolution of Wadi Gueiss streamflow for the periode 2010 to 2050, under senario 4: Hydrological Year Method (HYM) and senario 5: Climat Change (CC); Source: own elaboration

b) Climat change impacts on dams

From Fig.8, we can observe that ; The evolution of the monthly water volume stored at the Koudiat Medouar, Ain Dalia and Ourkiss dams, pour la période allant de 2010 à 2050. This volume varies according to the season and the exploitation, for both scenarios there is a decrease from May to October, corresponding to the period when the demand for water for irrigation increases. This variation in volume is also sensitive to the CC scenario by a decrease of between 2 and 2.5 mln m^3, which corresponds to about 7 to 8% of the monthly volume.

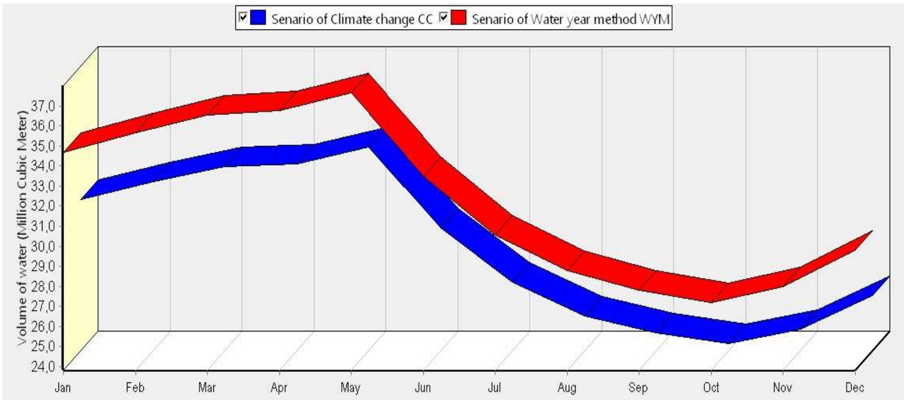


Fig. 8. The evolution of monthly water volume stored for the periode 2010 to 2050, at the Koudiat Medouar, Ain Dalia, and Ourkiss dams, under senario 4: Hydrological Year Method (HYM) and senario 5: Climat Change (CC); Source: own elaboration

5. CONCLUSION

The demand for water in the Gareat El Tarf basi, is under pressure from many factors: demographic, social, economic and climatic. The Water Evaluation and Planning System (WEAP) has been developed for simulating current water balances and evaluating water management strategies in this basin under socio economic and climate change senarios until 2050.

The results of the WEAP model show that water managment is a real challenge in this region. The impact of demographic economic politics based on agriculture shows a very large deficit that exceeds 400 mln m^3 in 2050. climate change may act an additional presion on water resources in the ftur, by affecting significantly water resources ; thes streamflow of Wadi Gueiss will decrease with a 6%.the volumes stocked at the dams that supply the catchment area in flows will also decrease with around 7 to 8%.

Even with a large mobilization of water resources, if an acceleration of the development of the agricultural sector is planned, without investing in the improvement and rehabilitation of drinking water distribution and irrigation networks, the demand for water will not be controllable in the near or distant future.

These problems can be solved by implementing a new strategy based on water demand management, raising users' awareness of water saving, improving distribution networks for both drinking water and irrigation, and adopted an economic strategy based on the protection of water resources to avoid the depletion of water resources.

It is important to indicate that it is not possible to quantify the error arising from the models in combination and the results should be considered indicative rather than absolute

We limited the initial analysis of Gareat El Tarf basin WEAP basic functions without using its simulation capabilities of hydrological processes and water consumption or coupling to a groundwater model (MODFLOW-WEAP). These options will be used for further analysis of some subsystems of Seybouse basin and mitigation potential of nonconventional water, reuse of wastewater, use of green water in storm water runoff and agriculture, etc.

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