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Water resources and water demand management by using WEAP model at Gareat El Tarf catchment (Constantine's Highlands, Northeast Algeria)

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Abstract

Water is a key driver of sustainable growth and poverty alleviation as an input to almost all production, in agriculture, industry, energy, transport and so on. Using water in an efficient manner and managing competing demands is essential step to ensure that water is no longer undervalued and misused. The object of this study is the water resources management in Gareat El Tarf, its semi-arid catchment of North East of Algeria, characterized by a conspicuous water demand for irrigation and limited groundwater and surface water resources. Agriculture is not only the largest consumer of water at the basin level; it is also the first water waster. A gravity fed irrigation system is the most used irrigation system, with efficiency of 40 to 60%. In addition, the water losses in the drinking water distribution network reached 50%. 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 passive scenario and in water demand management scenario change to 2050.Our findings reveal that In 2010, Supply of water requirement for all demand sites is 226 million m3. In 2050 it increases to 322 million m3 for Reference scenario, while for Water Demand Management scenario it decrease to 121 million m3. In the absence of intervention, the water deficit will worsen in the future. The policy of mobilization of water resources, must be supported by a management of the demand for water.

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Introduction

In Algeria, the pressure on water resources will continue to grow under the combined effects of population growth and applied on water-consuming activities (UNDP, 2009), as well as episodes of water use. prolonged drought (Medejerab, 2011).In 2020, more than 11 billion m3 of water should be mobilized, while the country's theoretical water capacity is estimated at 6 billion, a real challenge, but above all a strategy and a policy to be defined (Kettab, 2001). In the 2000, only 40% of agricultural water needs were met (Mouhouche *et al.*, 2004).The regions most concerned by the issue of water scarcity are the arid and semi-arid areas, and especially those subject to high population growth (Treyer, 2005). However, aggregating the issue of water resources management at the national or regional scale does not take into account the variability of water availability in space, variability that can, therefore hide localized problems (Margat, 2002).In this paper, we will test the effectiveness of a water demand management on the scale of a watershed of an average size (about 2430 km²) and which has an agricultural vocation, it is the Gareat El Tarf watershed (North-East Algeria). The basin is under heavy demographic pressure in the face of limited water resources due to its semi-arid climate.

Our methodological approach relies on the modeling supply system in Gareat El Tarf catchment using the WEAP software. WEAP (Water Evaluation and the Planning) model is an entirely integrated water resources system analysis tool (Yates *et al.*, 2005).

WEAP is a flexible model with which users can define their region (Strzepek *et al.*, 1999), its ability to integrate demand and supply of water accounting with management strategy (SEI, 2007). WEAP has been the subject of several applications in arid and semi-arid zones (Demertzi *et al.*, 2014;Walker *et al.*, 2015; Bakken *et al.*, 2015; Jingjing *et al.*, 2016; Gopal *et al.*, 2017;Kiniouar, 2017).The formulation and application of models depends on an important element that is the availability of data (Hypatie, 2012).

Material and methods

Water Evaluation and Planning system (WEAP)

Water Evaluation And Planning system (WEAP), was established in 1988 by the Stockholm Environment Institute (SEI), with the aim of being a flexible, integrated and transparent planning tool for evaluating the sustainability of demand modulation and current distribution and to explore alternative long-term scenarios (SEI, 2007).

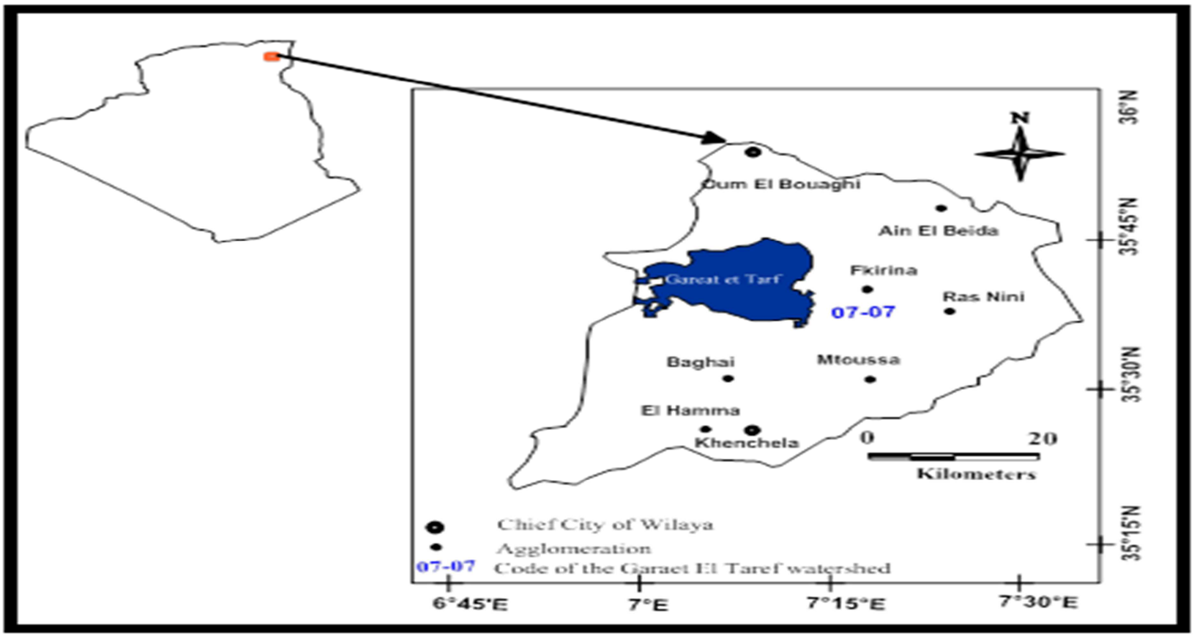

Fig. 1. Geographical location of the study area (Constantine's Highlands, Northeast Algeria).

WEAP, is one of many different IWRM (Integrated Water Resources Management) models, and is an exemplary application linking supply and demand site requirements. Allowing scenario analysis, changes in supply and demand structures can be simulated in order to discover potential shortages and the effects of different management strategies (Yates *et al.*, 2005).

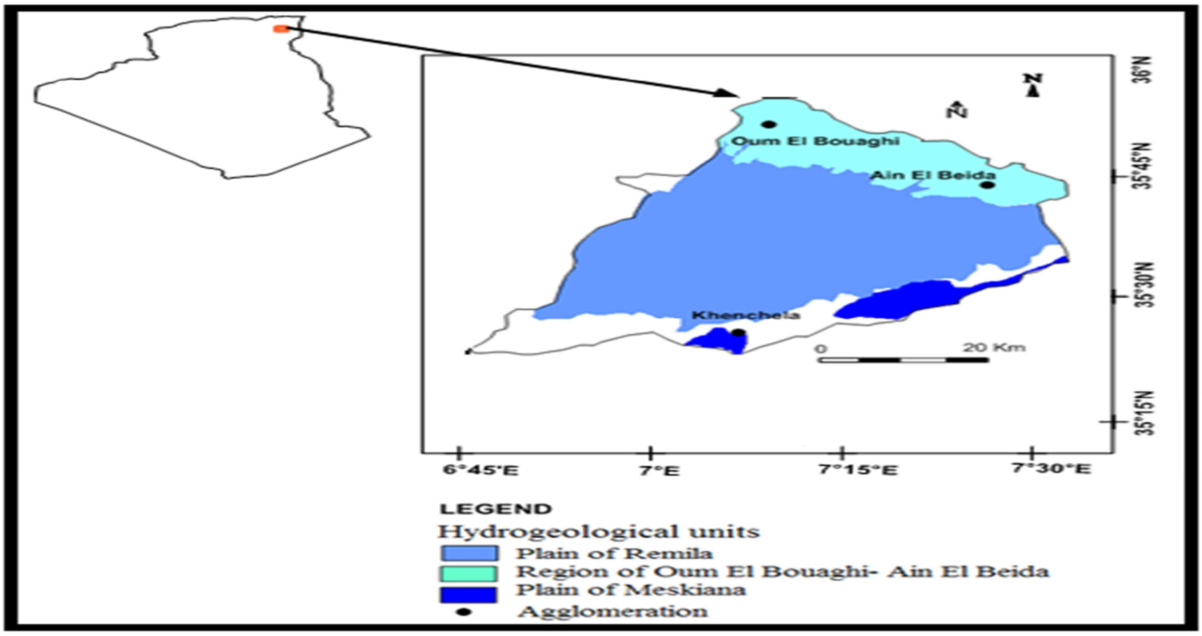

Fig. 2. Hydrogeological Units at the Garaet El Tarf Watershed (Constantine's Highlands, Northeast Algeria**).**

In this paper we will use WEAP for the simulation of a demand management scenario for a period of 40 years (from 2010 to 2050), and compared to a baseline scenario for the same period.

As a rule, the model works as follows:

a) Creation of the study area: In this part, it is a question of creating a map of the study area. Maps processed with map processing software (GIS) can be used (Fig.3);

b) Creation of a current account: The purpose of the creation of this account, is to calibrate the model to reproduce the water situation of the basin in a given year;

c) Creation of Scenarios : Scenarios analysis is a central element of WEAP (SEI, 2007). It is :

a. Reference Scenario (R): takes current account data in the specified project period, and uses it as a point of comparison for other scenarios. A reference scenario is established to simulate the same evolution of the system without human intervention.

b. Alternative Scenarios: used to evaluate the

c. Impact of development and management various options that aims to maximize water delivered to demand sites, according to a set of users (MCCARTNEY *et al.*, 2009), and to evaluate the effects of changes in policies and / or technologies.

Data input

Study area*:* The Gareat El Tarf basin, is located in the northeastern part of Algeria; at the extreme east of the high steppe plains between the Tellian Atlas in the North and the Saharan Atlas in the South (Aurès massif) (Dali, 2009).

The catchment is part of all the basins of the Constantine's highlands according to the agency of the basins (Fig.1). It covers an area of 2432 km². It is located between latitude 35°22 'and 35°56' N and longitudes 6°49' and 7°34' E. The center is marked by an endorheic depression (Gareat) better known under the name sabkha (salt lake) and covers an area of 200 km².It is a diversity of landscapes showing sometimes in relief sometimes in low zones (Benabbas, 2006).

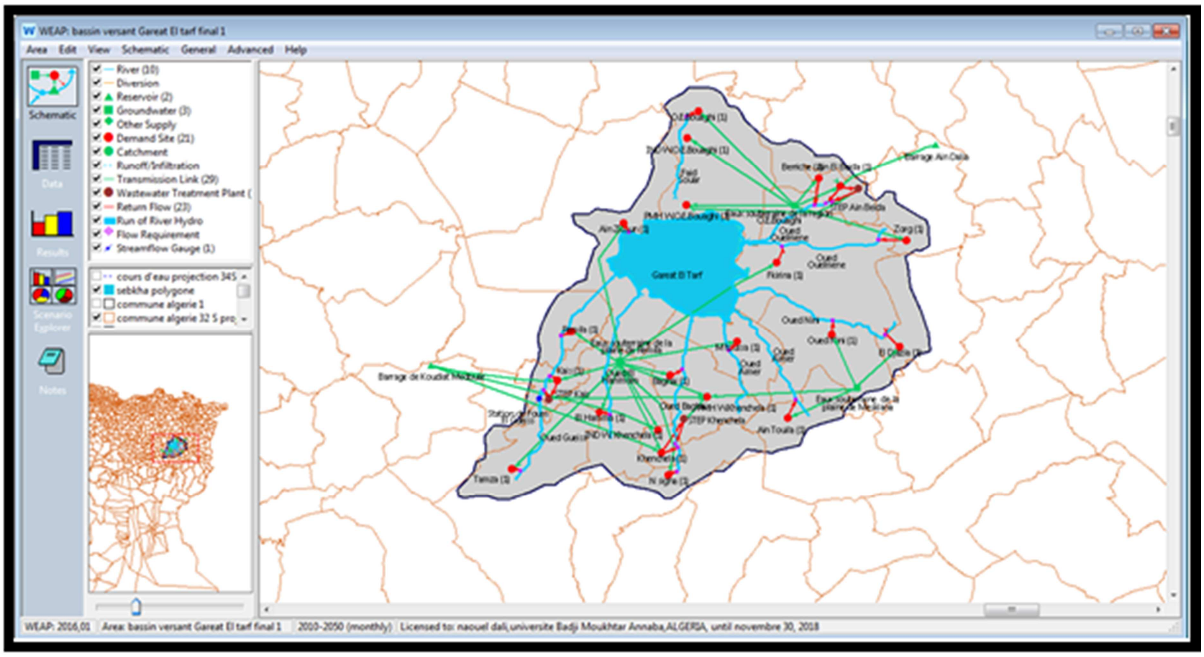

Fig. 3. Final map presentation of watershed by Evaluation and Water Planning (WEAP) model.

It is dominated by high plains strewn with chott depressions (Gareat El Tarf), with an altitude of about 830 m, the latter extending over 20 km long and 15 km wide of which only 1/4 is flooded. All around, there are satellites chotts merging with that of El Tarf during major floods. The perimeters of this salt lake are characterized by a flat level. The massifs that frame the basin exceed 2000 m. The southern and northern borders of the basin are marked by relatively large inclinations; because of tectonic activity affecting these regions, allowing a greater surface flow (Guiraud, 1973).

Water resources*:* Gareat El Tarf catchment is supplied by the combination of groundwater resources and surface water resources. It has two dams: first, Dam of Koudiat Medouar that can regularized 74.3 million m^3/year, with 20000 m^3 / day, for the drinking water supply of Khenchela Kais and El Hamma cities. Second, Dam of Ain Dalia, which regularized 45 million m^3 with 5000 m^3 / day intended for the drinking water supply of the city of Ain Beida.

The estimation of the potential water resources of the groundwater aquifers of the basin was the subject of simulation studies managed by the National Hydric Resources Agency. The studies concern three hydrogeological units: the Remila plain, the region of Oum El Boughi - Ain El Beida and the plain of Meskiana (Fig. 2). Renewable groundwater resources are estimated at about 40 million m^{3}for an average year and 19.5 million m^3 for a dry year.

Water demand: Demand water sites is about the three traditional users, the Domestic water Demand, the agricultural water demand and the industrial water demand. The majority of data of water needs, plugged into the WEAP model were obtained from Direction of Agricultural Services, Companies of potable water, 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.). Domestic water Demand: population growth is the determining factor in a forecast analysis of drinking water demand (Rinaudo, 2013).

The number of people at the river basin study object is approximately 455 000 inhabitants spread over 16 towns with an average annual growth rate of 1.25% this rate varies widely from one municipality to another (2.3% and -0.2). It involves a redeployment of populations from the scattered areas of these wilayas to the main and even secondary agglomerations, as well as an external contribution from the neighboring wilayas.

This growth rate remains below the national rate (1.6%). According to the SOGREAH / ICEA (2002) water pricing study for domestic and industrial use, the average value of drinking water distribution yield is 50%.

The total agricultural area is 276,192 ha, of which 14627 ha are irrigated in the form of Small and Medium Hydraulic (SMH) managed directly by farmers, the share of. The water used for irrigation is more than 85% of underground origin.

The normative demand for the irrigation of (SMH) is estimated at 5100 m3 / ha. It was made from the calculations of the inventory PMH -SOGREAH 2006, which calculated the theoretical requirements for average rotations from the conventional FAO Penman Revised method.

In general, we consider theoretical average efficiency estimated between 40% and 60%, for gravity irrigation, between 70% and 80% for sprinkling, between 80 and 90% for localized irrigation (Thivet *et al.*, 2007). the total industrial water demand was found about 851 700 million cubed meters.

Results and discussion

Current account: In this study we take 2010 as the current account year, because this is the base year taken by the Ministry of Water Resources for updating the national water plan to the horizon 2030 (SOFRECO, 2010), and on this occasion the ministry carried out a massive collection of data around the water sector in the national territory. This choice will allow us to use the most reliable data possible.

Table 1. Demand Requirement of water (including loss, reuse and DSM) (Million Cubic Meter).

Scenarios	Demand supply (Million Cubic Meter)								
Year	2010	2015	2020	2025	2030	2035	2040	2045	2050
Scenario 1 : Reference (R)	226	235	244	255	266	279	292	307	323
Scenario 2 : Water Demand Management (WDM)	226	202	183	168	155	145	135	127	121

Scenario 1: Reference (R): The reference period of the business model used is between 2010 and 2050, with a monthly time step taking 2010 as the base year. It is a simulation scenario of the evolution of the system already created in the current account without human intervention or climate change.

Scenario 2: Water Demand Management (WDM): This scenario consists of maintaining the water supply as it is in the baseline scenario and changing the water demand of the different sectors by a decrease in water losses. Drinking water distribution networks from 50% to 20% and a decrease of water loss to the plot to 10% in 2050.

Agriculture is the largest consumer of water in the Gareat El Tarf watershed. During 2010, 84% of water demand comes from the irrigation of small and medium hydraulic systems, while that drinking water supply requires only 15% of total water demand, the remaining one (1%) comes from industry (Fig. 4).

Simulation results in Table 1 shows the evolution of water demand requirement for the year of 2010–2050.In 2010, Supply of water requirement for all demand sites is 226 million m^3. In 2050 it increases to 322 million m^3 for Reference scenario, while for Water Demand Management scenario it decrease to 121 million m^3.

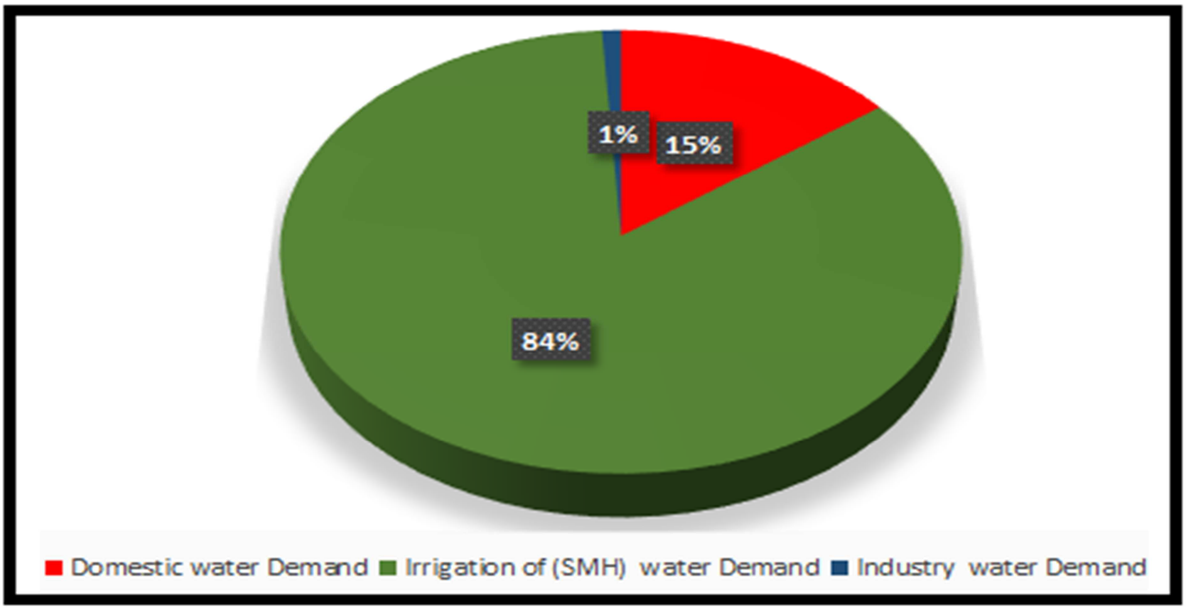

Fig. 4. Percentage of total water demand by sector.

Unmet demand analysis simulation was done in order to highlight the amount of deficits that resulting from the DWM scenario. Hence in this analysis, is presented in Fig. 5, namely unmet demand. The unmet water demand for the year 2010 is 165 million m^3 (73% of the request); it passes at 260$m^3$for the first scenario while for the second it goes to 80 million m^3. For this scenario, from the year 2016, the unmet demand concerns the irrigation of the small and medium hydraulic of khenchela and Oum El Bouaghi, water demand from other sectors will be 100% satisfied.

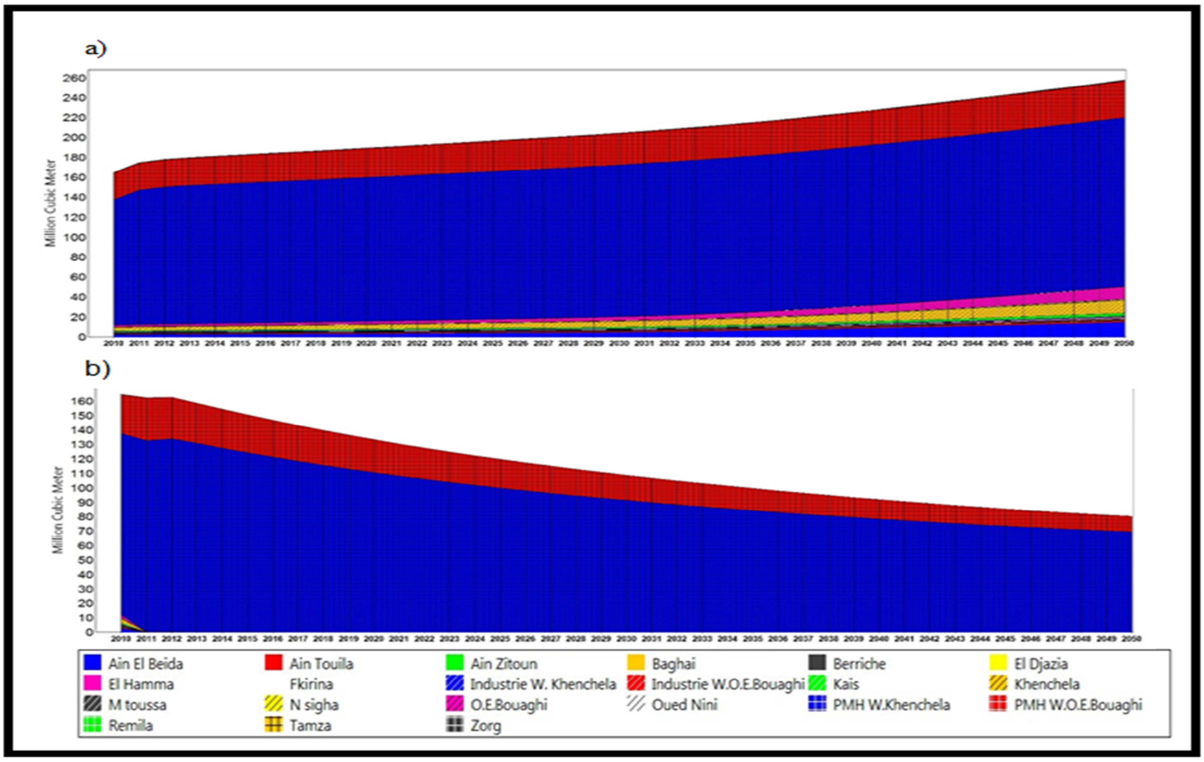

Fig. 5. Unmet water demand in million cubic meters a) Scenario 1:Reference (R) b) scenario 2: Management Water Demand (MWD).

The simulation of this reference scenario shows that in the absence of intervention, the water deficit will worsen in the future. Fig. 6 shows the evolution of unmet water demand in million cubic meters for scenario2: (MWD) relative to Scenario 1: (R).The curves of unsatisfied water demand for the two scenarios start to separate in 2011. The water deficit remains lower than that of the R scenario. It goes from zero in 2010 to 180 million m^3 in 2050.

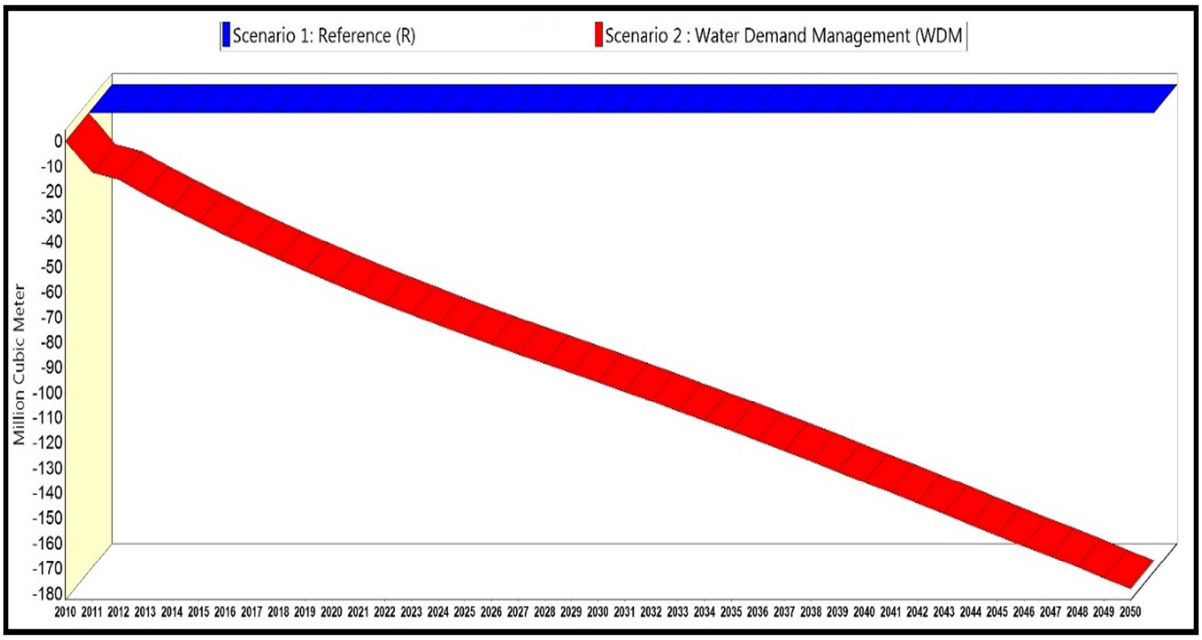

Fig. 6. Evolution of unmet Water Demand in million cubic meters for scenario2: Management Water Demand (MWD) relative to Scenario 1: Reference (R).

Conclusion

This study has explored, in a modelling framework, using the Water Evaluation and Planning (WEAP), a demand management scenario can eliminate water deficit for drinking water supply and industrial. In addition, reduce the deficit for irrigation water to than 80million m^3 year instead of 258 million m^3, if no action will be taken by 2050. The management of water demand scenario chosen for this study show that it integration with the system would lead to a significant reduction in unmet demands. The next step in this research is to study this problem in all its aspects including climate change.

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