



## RESEARCH PAPER

## OPEN ACCESS

## Modeling approach to identify vulnerability of water resources to environmental changes. Application in the basin of the Kebir-Est River (El-Tarf region, Algeria)

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Article published on March 23, 2018

**Key words:** Climate change, Vulnerability, Water resources, Modelling, WEAP.

### Abstract

Water resources evaluation in Kebir-East river slope basin is also an evaluation of this resources vulnerability facing environmental changes particularly climate change by water precipitation's fluctuation which it is a large part of the earth. The aim of this project is to evaluate present and future water resources in two cases of climate changes: the first one is a case of flood and the second one is a case of drought. GIS techniques were used to quantify the spatial and temporal stream flow. The Water Evaluation and Planning (WEAP) model was applied to evaluate water resources development based on an equilibrium scenario of the current water demand and then two different future scenarios are simulated. Water use was simulated for five different sectors (domestic, livestock, wildlife, irrigation and reserve). The analyses revealed that the software WEAP's application on Kebir-Est's river basin allowed us to compare two scenarios. The first one is based on hydrologic year and the second on climate changes. So, climate change does not spare our study Kebir East River watershed. Indeed, for decades there has been an irregular rainfall in the region. This leads to reflect on the different situations that may be the population in the future. Thus, different scenarios indicate that the region would face water stress in the future while others suggest the opposite. In order to attain both economic and ecological sustainability, water requirements of various competing sectors in the Kébir East basin must be matched with the available water resources.

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## Introduction

During the last five decades, environmental changes particularly global climate fluctuations have raised many questions about the durability and severity of the phenomenon (Jabrane and Taiqui, 2014). In its 4th report, the Intergovernmental Panel on Climate Change "IPCC" (GIEC, 2001) states that land is subject not only to natural variations in climate but also to climate change due to human activity. The latest 2013/2014 reports from the same group of experts confirm that climate change is unequivocal (GIEC, 2014).

The low-hanging fruit; no-regret options, should be identified with stakeholders and assessed against future changes in water availability and demand, for comparing effectiveness and robustness. Such integrated basin-scale assessments, including reservoir catchment and command areas, can suitably inform adaptation decision-making (Bhave *et al.*, 2016).

Inadequate water resources management and a general decline in rainfall have aggravated water scarcity problems. Furthermore, water use conflicts have escalated in recent decades due to increased competition for available water resources. Excessive abstraction of the declining river water mainly for irrigation often leads to reduced water flow during the dry seasons, greatly affecting downstream water users (Mutiga *et al.*, 2010).

Hydrological modeling has become an indispensable component of water resources research and management in large river basins. Hydrological models help understand the past and current state of water resources in the basin, and provide a way to explore the implications of management decisions and imposed changes such as climate change (Johnston and Smakhtin, 2014).

The extreme north-east of Algeria is not spared by the effects of climate change. As a result, major floods and droughts have been recorded during

these last years in the wilaya of El-Tarf especially at the level of the zone of plains (Labar, 2003; Kabirou, 2015). It is within this framework that we have found it useful to contribute to the understanding and therefore the solution to this problem in this region.

However, any environmental study can only be done at the scale of a watershed.

That's why we chose the sub-watershed of Kebir-East River, which is fully concerned by this scourge of climate change.

The aim of this project is to evaluate present and future water resources in two cases of climate changes: the first one is a case of flood and the second one is a case of drought. Also, the goal of this study was to match the water requirements of various competing sectors in the Kébir East basin with the available water resources in order to attain both economic and ecological sustainability. For this reason, GIS techniques were used to quantify the spatial and temporal stream flow. The Water Evaluation and Planning (WEAP) model was applied to evaluate water resources development based on an equilibrium scenario of the current water demand and then two different future scenarios are simulated.

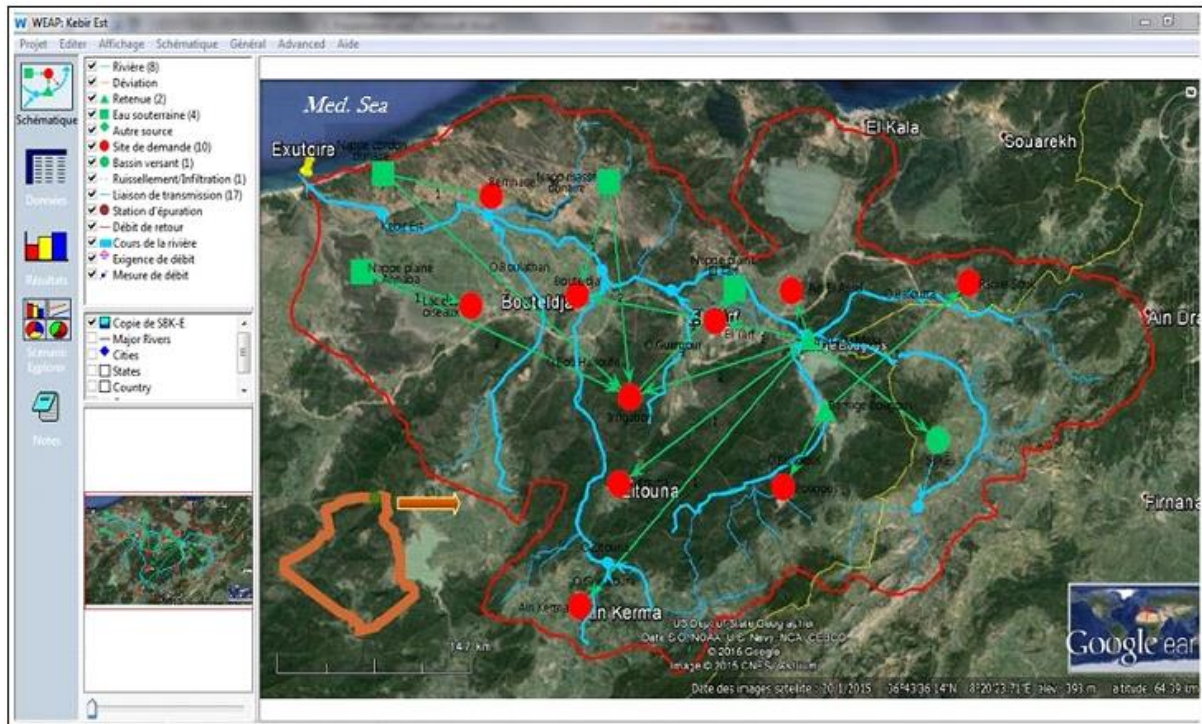
## Materiel and methods

### Study site

Located in the northeastern Algeria (Fig. 1), the catchment area of El Kebir-Est (El-Tarf department), belongs to the East Constantine coastal basin, occupies an area of 1700 km<sup>2</sup> (Labar, 2003; Tourki, 2010), with a humid Mediterranean climate marked by an annual rainfall of 1200 mm this climate favors a large flow of surface water among which the natural depressions (Mexa dam With a retention capacity of 30,27 Hm<sup>3</sup>): and Bougous: for a 66.20 Hm<sup>3</sup> of retention capacity, Bird Lake, Lake Oubeira ...) that promote the accumulation of large amounts of rainwater (Labar, 2003; Bentouili, 2007). According to the hydraulic management of the department of El-Tarf, the area receives 503,000,000 m<sup>3</sup> of rainwater annually (Labar, 2003; Tourki, 2010).

The Kebir-East river has its source in the mountainous altitudes of the Algerian-Tunisian border. It is the confluence of two main tributaries, the wadi Ballouta from the East and the Wadi

Bougous from the West, the groundwater represented by the aquifer systems of the plain of Annaba-Bouteldja, and the aquifer of the plain of El-Tarf Ain Assel.



**Fig. 1.** Demand sites and water resource in the study “Kebir-Est” watershed.

*Data processing tools*

For data processing, we chose the computer tool WEAP (water evaluation and planning system) which is a software that was created by Stockholm Environment Institute “SEI” (Sieber and Purkey, 2015), the WEAP is used for the planning of the exploitation of all water resources as rainwater, surface water and groundwater to facilitate the task to the water specialists in the evaluation, the quality control, the management, the planning and the distribution. WEAP is hydrological modeling software for the integrated and sustainable management of water resources.

In our work, we also used cartographic computer software: geographic information system (GIS), Google Earth to better locate and calibrate our study area using latest google earth satellite images. WEAP is software that requires the respect of a number of steps in the process to follow. These steps are thus described by (Rakotondrabe, 2007).

*Modelling and WEAP Steps*

*Study area creation*

In our case, the Kebir-East River is a small watercourse on a global scale, so we used the map that was established with Google Earth as a background Raster. The next step is to import the previously prepared map with Google Earth to serve as a background image for further work (Fig. 1).

This map helps us to have the precise location of each element of the WEAP model and to well establish demand sites, agglomerations, cultivated land, dams and water retention as well as also to follow the exact layout of the Kebir-East River (Fig. 1).

*Assumptions and references creation*

The assumptions are variables defined by software users. They serve as the main keys for the analysis. In our study, we have three (03) key assumptions used as baseline data for household water use software, water requirements for irrigation and climate data in the watershed.

The references are necessary to have a year or a reference period to serve as a model. We used 2014 as a current account, reference period of (2015-2020) and (2050) as a reference period of climate change. These 03 references are defined as below:

First, a current account reference (2014) is used to represent the system as it is in a point of time when you know the data that characterizes the system. The reference scenario is developed from a real current account data. It serves as a basic model for scenarios modeled by WEAP in the coming years.

Second, (2015-2020) reference: It is the scenario that is created from the current account. WEAP uses all the previous parameters and data (current account of the year 2014) and models a reference scenario. This will in turn serve as a basis for modeling a problematic potential. This scenario starts from the year following that of the current account. A relatively short period is chosen relative to that of future projections. In our case, this period starts in 2015 and ends in 2020, five years.

Third, (2050) reference: In this scenario, we will consider the impacts of climate change in the sub-watershed. WEAP does not suggest these changes. It is up to the user to choose and enter them. Thus, we will model two distinct periods in the future i.e. a period during which there is too much rainfall, and period during which there is too little rainfall.

These two real-life situations of climate change could affect our sub-watershed. We will therefore evaluate their impact on the availability of water resources and therefore on the supply and demand of this precious commodity that is water.

*Drink water demand*

The consumption and use of water are proportional to the number of inhabitants of a region. Thus, we have introduced the number of inhabitants of each commune with the growth rates according to the last general census of the population and habitats dating from 2008.

WEAP is responsible for calculating the population of the current account (2014) and the population of the future (year-end scenario) using to its integrated formulas.

*Irrigation water demand*

Despite the heavy rain that falls every year on this sub-watershed, agriculture is poorly done. Thus only 2613.84 (Labar *et al.*, 2013, Medjani *et al.*, 2016) Ha of its area are cultivated (less than 2%). According to the Direction of Agricultural Services (MADR, 2014), 3333.4 m<sup>3</sup> of water was allocated to agriculture in 2012.

This gives 1.28 m<sup>3</sup> / Ha. Among the data required by WEAP in the irrigation section is the extent of the irrigated area. We calculated it by adding the areas irrigated by commune. There is also the annual water consumption in m<sup>3</sup> per hectare that we calculated using the following formula (Sieber and Purkey, 2015):

$$C = \frac{\sum Cc}{\sum Sc} \left\{ \begin{array}{l} Cc = \text{annual water consumption per hectare (m}^3/\text{Ha)} \\ Cc = \text{water consumption per commune (m}^3\text{)} \\ Sc = \text{irrigated area per commune (Ha)} \end{array} \right.$$

After analyzes and the application of WEAP in the current account (year 2014) carried on the sub-watershed of the Kebir-East river, we turn now to the modeling of possible scenarios. Indeed, scenario analysis is a central element of WEAP. Scenarios are used to explore the model with a huge range of questions.

In our case, we will focus on what could happen to water resources if climate change is accentuated in the watershed.

**Results and discussion**

*Actual Situation "Current account"*

The demand for drinking water varies by municipality. Thus, the population is a factor of the first order in the classification of municipalities that consume the most water. Here, the unit of measurement is " person " registered in the software

by the "cap" nomination which refers to "capacity" or annual water consumption capacity. The analysis of these two Figs (2 and 3) shows that the number of population is not the only factor in measuring water

consumption. Habits, the availability of water resources and the characters of people are also factors to consider.

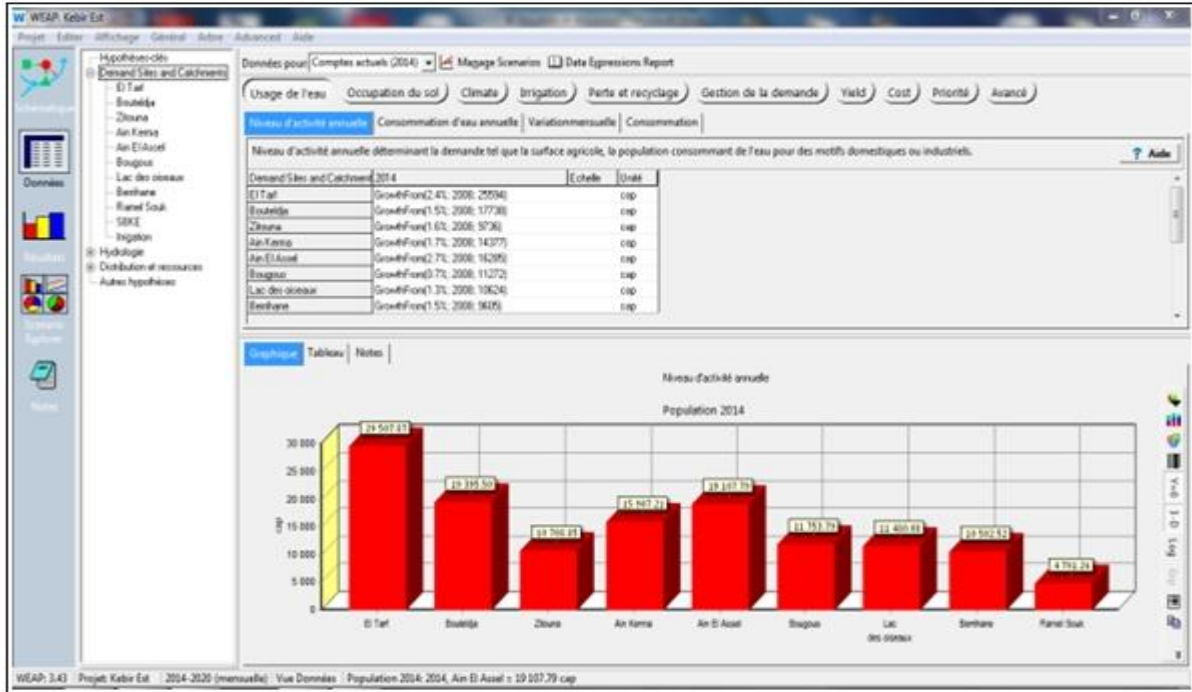


Fig. 2. Population of current account 2014.



Fig. 3. Consumption of current account 2014.

Thus, El-Tarf which has the largest population (29,507 inhabitants), is not the commune that consumes the most drinking water (89.79 m<sup>3</sup>/person/year). It is the municipality of Ain El Assel which comes at the top of the consumption with

102.93 m<sup>3</sup>/person/year for a population of 19 107 inhabitants (ranked 3rd most populous municipality after El-Tarf and Bouteldja). The inhabitants of Zitouna are the least wasteful of all the sub-watershed with 39.10 m<sup>3</sup>/person/year.

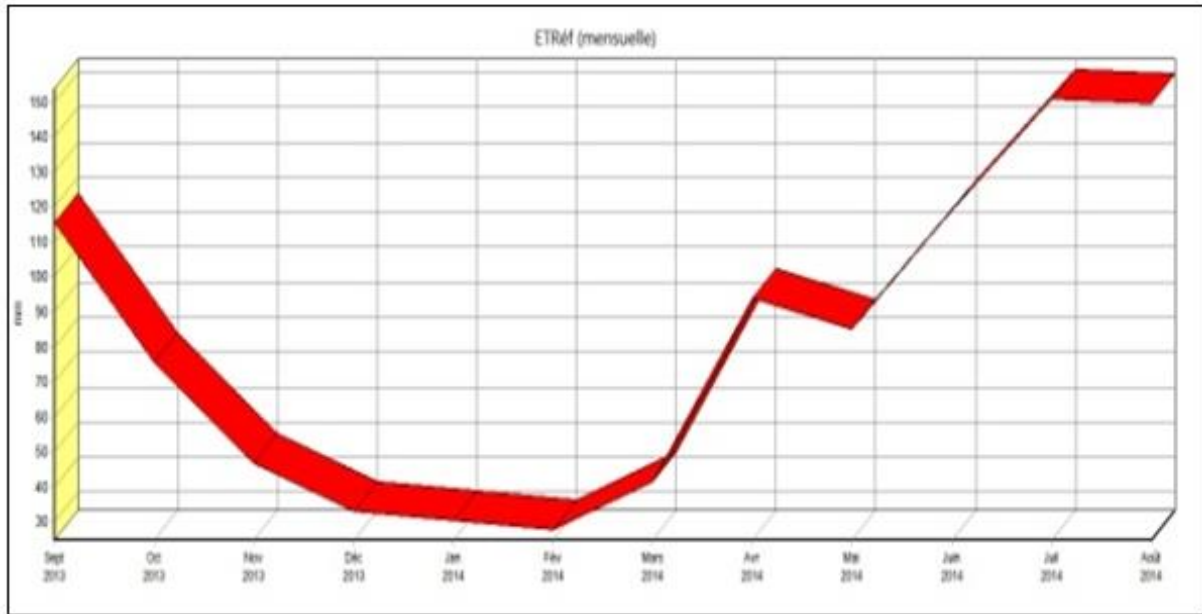


Fig. 4. Evapotranspiration (ET mm) monthly variations.

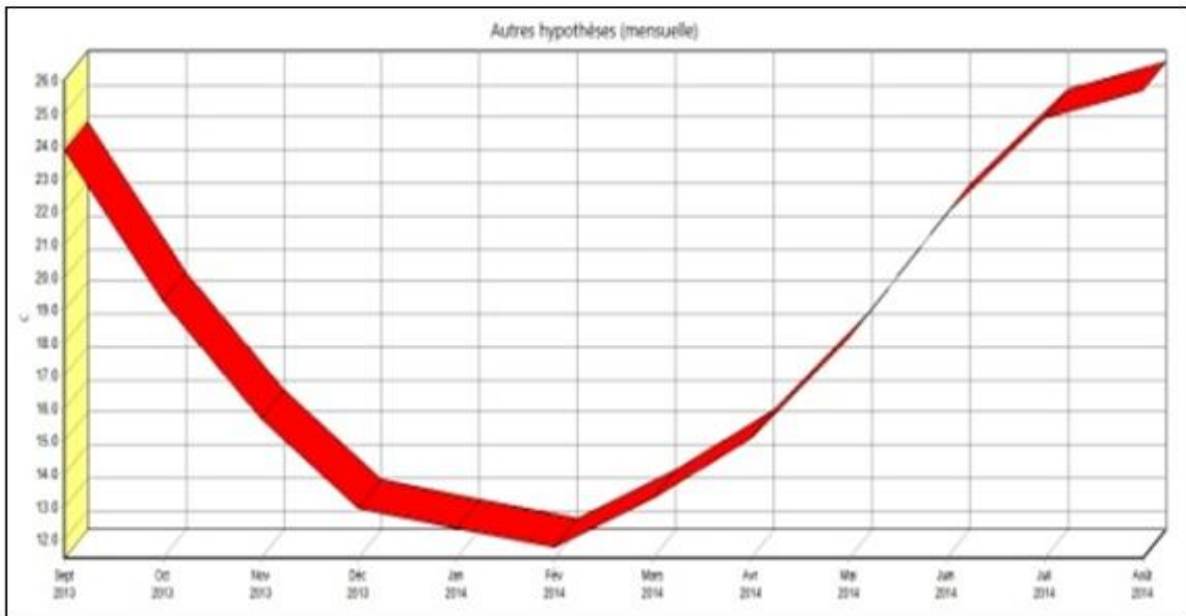


Fig. 5. Temperature (°C) monthly variations.

For irrigated area we considered that the irrigated area has not changed since 2010. So the amount of irrigation water has not changed. The watershed is poorly irrigated per year (1.28m<sup>3</sup>/Ha/year).

This may be due to the long period of rain or irrigation. In fact, in a large part of this basin, the sprinkler irrigation method is used.

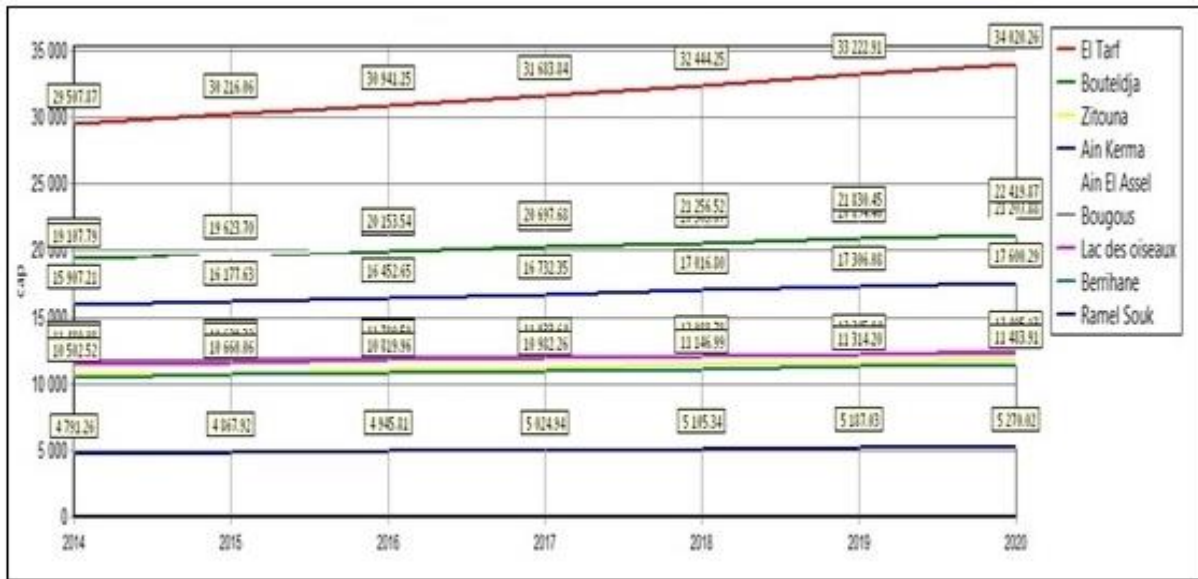


Fig. 6. Population forecast until 2020.

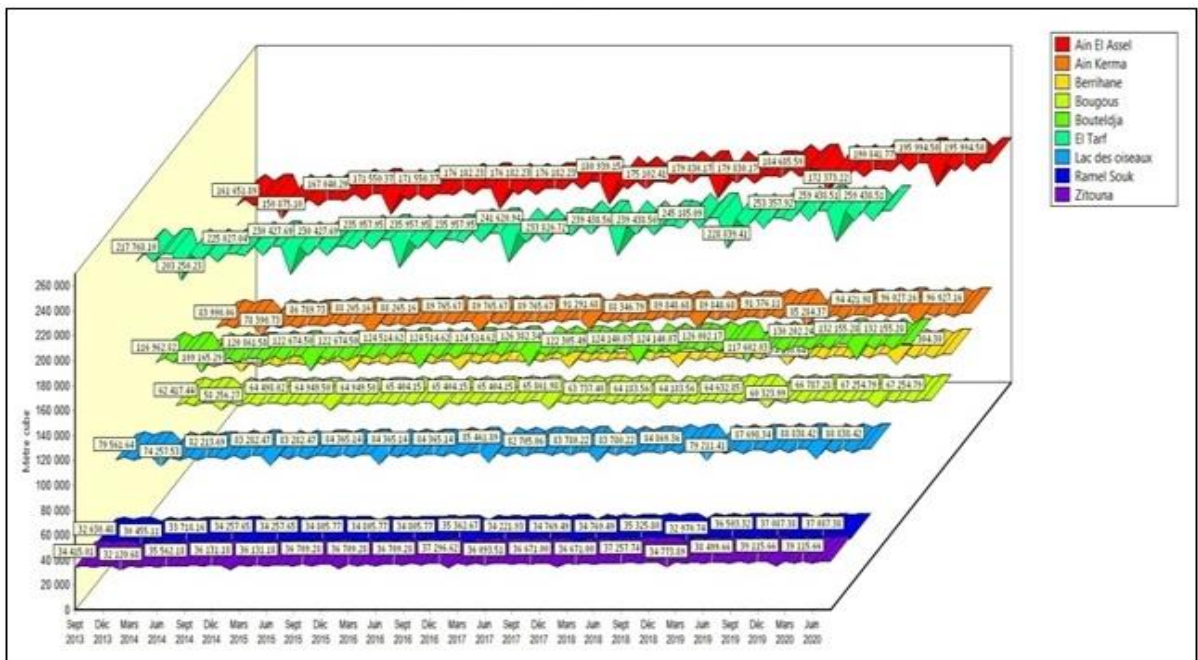


Fig. 7. Drink water (m<sup>3</sup>) demand simulation by 2020.

For the actual climatic situation, 2014 was a year more or less common and representative of the climate of the region. Precipitation peaks in November (203.20mm) and begins to drop in March (28.30mm) to nearly cancel out from May (5.70mm). These two Figs (4 and 5) show that the temperature and evapotranspiration follow the same rate and the same rhythm during the hydrological year.

They record their lowest points between the months of November and March and increase with the arrival of the summer from the month of May to wait for their peaks in August.

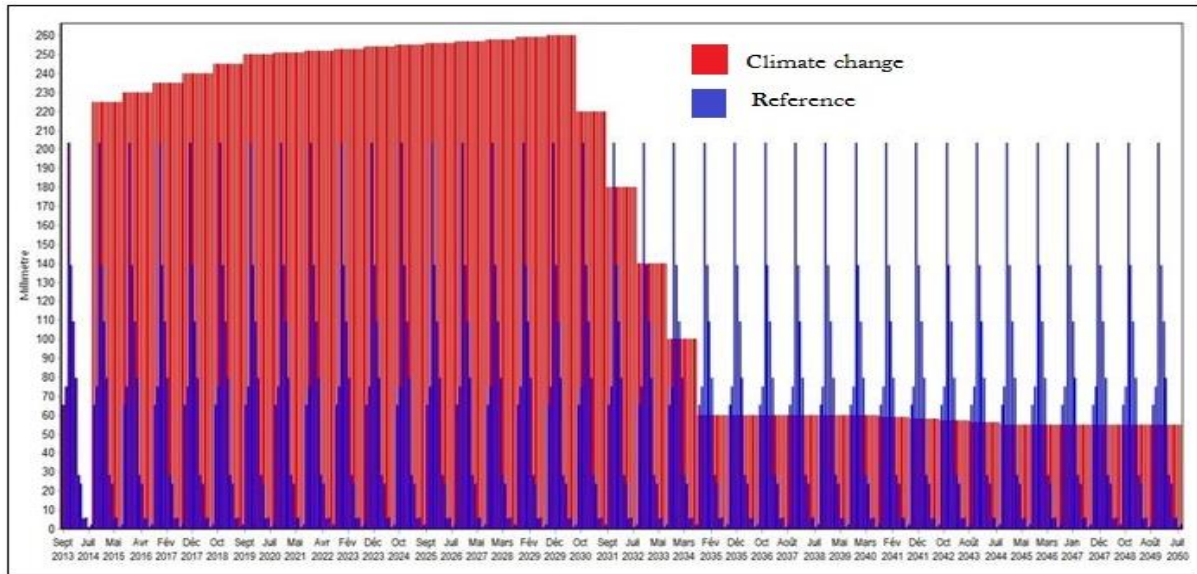
According to the results of the national project ALG/98/G31 (MATE, 2001), the Northeast Algeria did not escape the consequences of the global warming.

According to both digital models UKHI and ECHAM 3 TR, we registered an increase of temperature ranging between 0,8 and 1,1°C and a decrease of the precipitation between 6,75 and 6,50 % before 2020, respectively (Daifallah *et al.*, 2017).

*Scenario of 2020 reference*

Because the variation of this demand is favored by

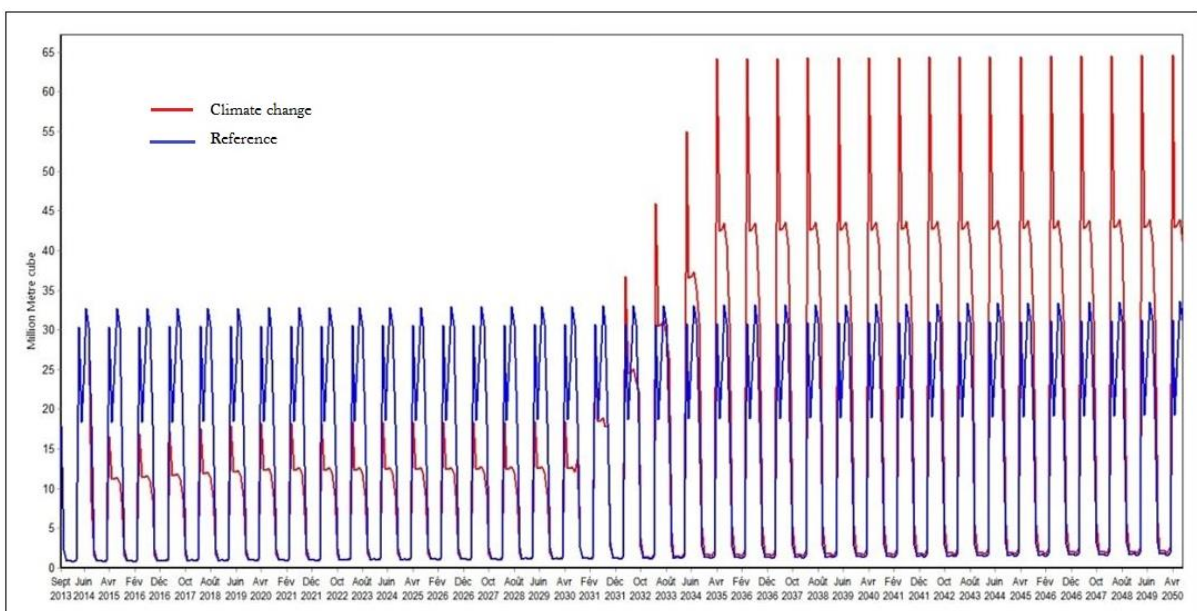
several factors, we chose to start with the increase of the population. The municipality of El-Tarf will remain the most populated municipality in 2020 with more than 34,000 inhabitants while that of Ramel Souk will observe a small increase (Fig.6). For drinking demand in 2020, the forecast is based on the case where there is no wastewater recycling or demand management but with a loss of 30%.



**Fig. 8.** Precipitation (mm) forecast by 2050.

The commune of El-Tarf will be the first in demand for water with 259 400 m<sup>3</sup> in July 2020 while Zitouna will require less than 40 000 m<sup>3</sup> (Fig.7). The demand

for irrigation water remains stable until 2020 if we consider that the cultivated area remains stable.



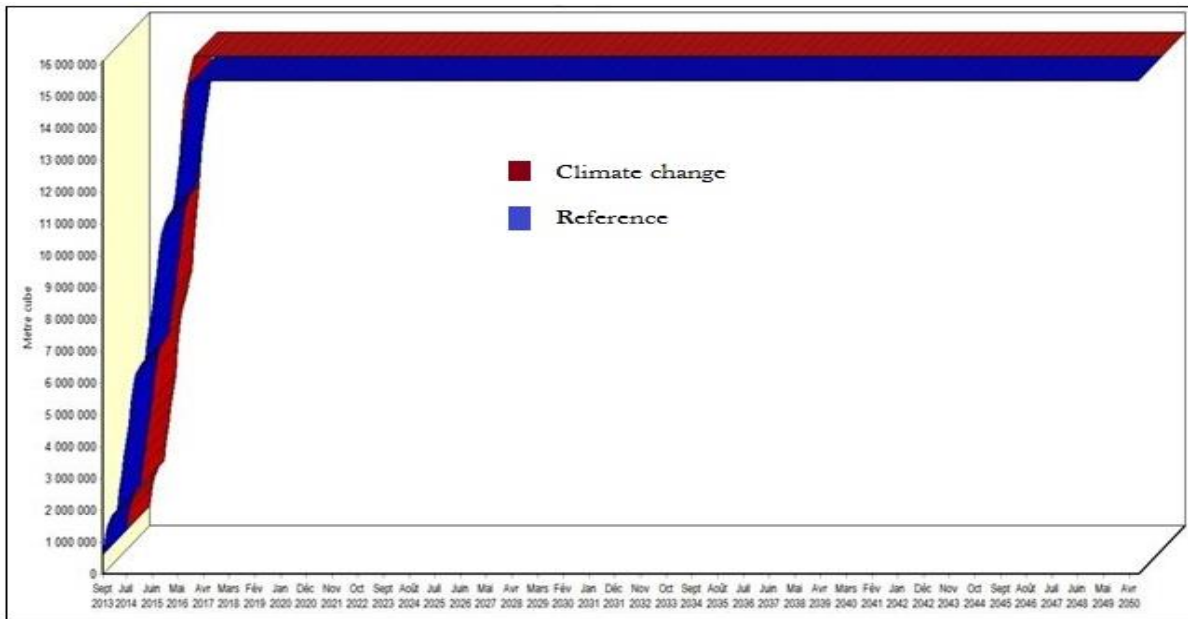
**Fig. 9.** Water demand (Million m<sup>3</sup>) simulation by 2050.



*Scenario of 2050 climate change reference*

The forecast of precipitation by 2050 is described in Fig. 8 as a simulation of precipitation during a very wet period and a dry period in the watershed of Kebir East River. This figure shows also a comparison between the all references precipitation and the climate change scenario. This Fig. 8 shows a very wet period during which floods are observed each year (2015-2030) and a period during which the rainfall is

insufficient where we could observe drought and a shortage of water resources notably to the low rate of feed the dams of Bougous and Mexa. WEAP modeled this precipitation based on the sequence of years we introduced. This software could model them with more affinity and accuracy if we had real statistical studies such as, for example, a rate of increase or reduction of precipitation per year.



**Fig. 10.** Groundwater (m<sup>3</sup>) storage simulation by 2050.

Water demand is the difference between the amount of water required and the amount of water served. It's a bit of the hollow between supply and demand. The more an area is not satisfied, the greater the demand. Thus, WEAP modeled this demand according to scenarios and periods. The Fig. 9 illustrates the comparison of water demands between the "Reference" and "Climate Change" scenarios. The reference scenario already shows a dissatisfaction of the sub-watershed with water supply. The demand can reach more than 30 Hm<sup>3</sup> some years. During the first period of the "climate change" scenario, this demand decreases to almost half. This is due to the sufficient amount of rainwater observed above. In the second period of the "climate change" scenario, the demand for water increases considerably. This is due to the period of insufficient rainfall observed from the year 2035.

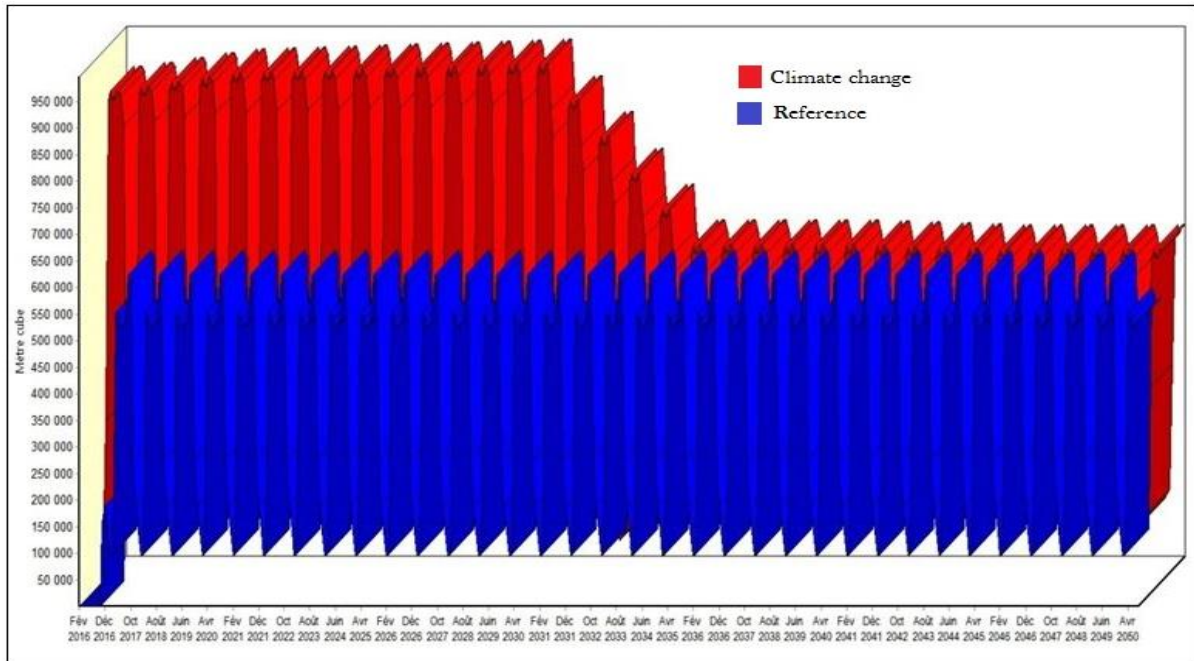
This demand grows to reach almost 65 Hm<sup>3</sup>. This period would be particularly difficult for the population living in the watershed, particularly due to insufficient drinking water or irregular taps. Also, farmers would also be affected by water scarcity since climate change is accompanied by poor harvests.

According to other works (UNDP, 2009; Daifallah *et al.*, 2017), in 2050 the discharge of the streams of the catchment in the north east of Algeria like the "Constantinois-Seybouse Melègue" will decrease with 17 % because of the increase of the average temperature which will achieve 3°C. Also, water retention in the dams will significantly decrease.

The storage of aquifers is modeled according to precipitation. However, only one can be supported by this software.

Our map presents four tablecloths. We chose the modeling of the El-Tarf plain water table because it is the only one that is entirely circumscribed in our sub-watershed. The others extend to the outside of this one. The exact capacity of this sheet is not known but we know that it has a profitability of 14 Hm<sup>3</sup> per year (ABH, 2014). The Fig. 10 shows that this water table reaches its maximum storage at just over 16 Hm<sup>3</sup> and

remains constant despite the variations in precipitation due to climate change (Fig. 10). This figure gives us an idea of the capacity of this tablecloth. It is thought to be dealing with a small aquifer. If this table easily reaches its maximum, we must also talk about the destination of the surplus. This is why WEAP is modeling an aquifer overflow scenario.



**Fig. 11.** Overflows (m<sup>3</sup>) simulation by 2050.

Fig. 11 shows the surplus of water from the water coming out either through an external exit or by feeding the Kebir-East River during the period of low water. In the climate change scenario, it varies according to periods or types of years. During the wet period it reaches a peak of more than 0.95 Hm<sup>3</sup> per year.

*Reflection and future outlook*

Harvesting rain and seawater is not enough to solve the problems of water demand. The quality also counts, as it says (Rodier, 2009): "When water is not able to be distributed like drinking water, it must be remedied by an appropriate treatment". Indeed, biological approach (Labar *et al.*, 2012; Trocchia *et al.*, 2015; Bartiromo *et al.*, 2013; Guerriero *et al.*, 2005; Guerriero *et al.*, 2004; Guerriero *et al.*, 2003) needs to be used to understand better all environmental

conditions and their relations with water quality and surface water changes like lakes (Benslimane *et al.*, 2015). Integrated approaches using Biological tools, participatory and modelling techniques for assessing water sector adaptation options can provide policy makers with hydrologically relevant information of locally suitable options which are legitimized by stakeholder involvement. Stakeholder engagement helps determine adaptation requirements and options linked to local biophysical and social vulnerabilities (Bhave *et al.*, 2016).

**Conclusion**

Environmental changes and particularly climate change does not spare our study area of Kebir East River watershed. Indeed, for decades there has been an irregular rainfall in the sub-watershed.

This leads to reflect on the different situations that may be the population in the future. Thus, different scenarios indicate that the region would face water stress in the future while others suggest the opposite. In the two scenario cases we have dealt with WEAP, we notice a demand for unsatisfied water in the watershed. As part of the resolution of this kind of problem, Algeria has embarked on a huge water management project that consists of feeding the coastal areas by desalination of seawater, the central regions by the waters of the aquifers. Coastal and southern regions by the waters of the desert fossil layers and the central aquifers. In the watershed of Kebir-East River, which is a region sufficiently watered by rainwater, a third water dam is under construction on Bouhalloufa River. This is the Bouhalloufa dam.

This solution will mitigate water problems in the area study and even in the adjacent basin. But for a sustainable development and management of water resources, a seawater desalination plant must be installed in the sub-watershed like that of El-Chatt. Results show also how climate change could increase vulnerability, and the necessity of planned adaptation. Such processes may also foster better knowledge exchange amongst stakeholders, thus improving relations. Adaptation needs to target specific vulnerabilities which may depend on climate change impacts at other locations. For example, change in reservoir catchment rainfall affects water availability for command area agriculture. Finally we recommend the integrated assessment which improves more understanding, modeling and analysis of such remote connected impacts and implications for adaptation. Observation and prediction changes in biological aspects, in climatic and non-climatic factors will inform the process of ascertaining adaptation requirements and are valuable inputs for the modelling process which provides credible qualitative and quantitative information.

#### Acknowledgement

The authors are pleased to acknowledge Badji Mokhtar Annaba University (UBMA) for providing the facilities for the research.

Also Directors, agricultural and water services of El-Tarf department in Algeria are gratefully acknowledged for providing us data and for their kind permission to use their facilities for our work.

#### References

**ABH.** 2014. Agence de bassin hydrographique Constantinois-Seybouse-Mellegue, Délégation Annaba, Schéma synoptique des transferts barrage Cheffia et barrage Mexa: différents champs captant. 3p.

**Bartiromo A, Guignard G, Barone Lumaga MR, Barattolo F, Chiodini G, Avino R, Guerriero G, Barale G.** 2013. The cuticle micromorphology of in situ *Erica arborea* L. exposed to long-term volcanic gases. *Environ Exp Botany* **87**, 197-206.  
<http://dx.doi.org/10.1016/j.envexpbot.2012.10.006>

**Benslimane F, Labar S, Djidel M, Hamilton CML, Djemai R.** 2015. Assessing of Tonga Lake Water Quality in the coastal basin of Northeastern Algeria. *International Journal of Scientific and Engineering Research* **6(3)**, 205-208.  
<http://dx.doi.org/10.14299/ijser.2015.3>

**Bentouili MY.** 2007. Inventaire et qualité des eaux des sources du parc national d'El Kala (N. Est Algérien). Magister thesis, Badji Mokhtar Annaba, university, Algeria, 134 p.

**Bhave AG, Mittal N, Mishra A, Raghuvanshi NS.** 2016. Integrated Assessment of no-Regret Climate Change Adaptation Options for Reservoir Catchment and Command Areas Water Resour Manage **30**, 1001.  
<https://doi.org/10.1007/s11269-015-1207-4>.

**Daifallah T, Hani A, Sayad M, Bouri S, Halimi S.** 2017. Climate change and users pressures in Kebir-West River basin (North-Eastern Algeria), using the WEAP model *Journal of Biodiversity and Environmental Sciences (JBES)* **10(4)**, 19-26.  
[www.innspub.net/jbes/water-resources-management-impact-climate-change-users-pressures-kebir-west-river-basin-north-eastern-algeria-using-weap-model/](http://www.innspub.net/jbes/water-resources-management-impact-climate-change-users-pressures-kebir-west-river-basin-north-eastern-algeria-using-weap-model/)

- GIEC.** 2001. Bilan des changements climatiques : les éléments scientifiques, rapports de synthèse, **3**, 97p.
- GIEC.** 2014. Bilan des changements climatiques. Rapport de synthèse, 40p.
- Guerriero G, Prins GS, Birch L, Ciarcia G.** 2005. Neuro-distribution of androgen receptor immunoreactivity in the male frog, *Rana esculenta*. Ann N Y Acad Sci. 1040, 332-336.  
[www.dx.doi.org/10.1196/annals.1327.054](http://www.dx.doi.org/10.1196/annals.1327.054)
- Guerriero G, Ferro R, Russo GL, Ciarcia G.** 2004. Vitamin E in early stages of sea bass (*Dicentrarchus labrax*) development. Comp Biochem Phys A. **138(4)**, 435-9.  
<http://dx.doi.org/10.1016/j.cbpb.2004.06.003>
- Guerriero G, Di Finizio A, Ciarcia G.** 2003. Oxidative Defenses in the Sea Bass, *Dicentrarchus labrax*. In: Dunn J. F., Swartz H.M. editors. Handbook of Oxygen Transport to Tissue XXIV. Advances in Experimental Medicine and Biology. ed. Springer. **530**, 681-688 p.  
[http://dx.doi.org/10.1007/978-1-4615-0075-9\\_68](http://dx.doi.org/10.1007/978-1-4615-0075-9_68)
- Jabrane M, Taiqui L.** 2014. Approche et Actions pour la Résilience au Changement Climatique. UICN, Malaga, 40p.
- Johnston R, Smakhtin V.** 2014. Hydrological Modeling of Large river Basins: How Much is Enough. Water Resour Manage **28**, 2695.  
<https://doi.org/10.1007/s11269-014-0637-8>
- Kabirou MM.** 2015. Approche de modélisation de la vulnérabilité des ressources en eaux aux changements climatiques. Application dans le bassin de l'oued Kébir-Est (Région d'El-Tarf, Algérie). Master thesis (Supervised by Prof. Labar S.), Chadli Bendjedid El-Tarf University, Algeria, 59 p.
- Labar S.** 2003. Contribution à l'identification des aires inondables et qualité physico-chimiques des eaux stagnantes temporaires dans la vallée de la Mafragh « Extrême Nord Est Algérien, Magister thesis, Badji Mokhtar Annaba, University, Algeria, 155 p.
- Labar S, Hani A, Djabri L.** 2012. Biochemical approach to assess groundwater pollution by petroleum hydrocarbons (case skikda Algeria). Journal of Water Resource and Protection **4(07)**, 493.  
<http://dx.doi.org/10.4236/jwarp.2012.47057>
- Labar S, Djidel M, Hamilton CML, Benslimane F, Hani A.** 2013. Assessing Inorganic Pollution in Ground Waters within an Agricultural Area of Northeastern Algeria. International Journal of Scientific and Engineering Research, **4(12)**, 1616-1620.  
<http://dx.doi.org/10.14299/ijser.2013.12>
- MADR.** 2014. Annuaire statistique du Ministère de l'Agriculture et du Développement Rural, MADR Algérie Série **B**, 77.
- MATE.** 2001. Elaboration de la stratégie et du plan d'action national des changements climatiques. Projet national alg/98/g31.
- Medjani F, Zaidi CA, Labar S, Djidel M.** 2016. Monitoring of Irrigation Water Quality from Bounamoussa River (Northeastern Algeria). International Journal of Scientific and Engineering Research **7(12)**, 1161-1165.  
<http://dx.doi.org/10.14299/ijser.2016.12>
- Mutiga JK, Mavengano ST, Zhongbo S, Woldai T, Becht R.** 2010. Water Allocation as a Planning Tool to Minimise Water Use Conflicts in the Upper Ewaso Ng'iro North Basin, Kenya. Water Resour Manage. **24**, 3939.  
<https://doi.org/10.1007/s11269-010-9641-9>
- Rakotondrabe F.** 2007. « Étude de la vulnérabilité des ressources en eau aux changements climatiques, modélisation par le logiciel WEAP 21 : cas du bassin versant de Morondava (Sud-ouest de Madagascar). DEA thesis, Antananarivo University, 113 p.
- Rodier J.** 2009. L'analyse de l'eau ». 9 édition. Paris: CHIRAT, 1959, 1404-1405. Coll. Dunod, n°5789.

**Sieber J, Purkey D.** 2015. WEAP User guide, Stockholm Environment Institute (SEI), U.S. Center, Somerville, MA 02144 USA. 400p.  
[www.weap21.org/downloads/WEAP\\_User\\_Guide.pdf](http://www.weap21.org/downloads/WEAP_User_Guide.pdf)

**Tourki M.** 2010. Étude de l'érosion et du transport solide dans le bassin versant de l'Oued Kébir Est Nord-Est Algérien, magister thesis, Badji Mokhtar Annaba, University, Algeria, 290 p.

**Trocchia S, Labar S, Abdel Gawad FK, Rabbito D, Ciarcia G, Guerriero G.** 2015. Frog Gonad as bio-indicator of Sarno River Health. International Journal of Scientific and Engineering Research **6(1)**, 449-456.

[www.dx.doi.org/dx.doi.org/10.14299/ijser.2015.1](http://www.dx.doi.org/dx.doi.org/10.14299/ijser.2015.1)

**UNDP.** 2009. Problématique du secteur de l'eau et impacts liés au climat en Algérie. 19 p.