Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2013.855662

52 (2014) 2114–2119
February

Taylor & Francis
Taylor & Francis Group

Simulation of water supply and water demand in the valley of Seybouse (East Algeria)

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Received 30 November 2012; Accepted 4 September 2013

ABSTRACT

The Seybouse river basin is subject to extreme and increasing water scarcity. Management of water resources in the basin is closely intertwined with use conflicts in the region. A fast growing population and expanding agricultural and industrial sectors create demands for new water resources. In this research, a microcomputer model, the water evaluation and planning system (WEAP), has been developed for simulating current water balances and evaluating water management strategies in the Annaba region. WEAP treats water demand and supply issues in a comprehensive and integrated fashion. The scenario approach allows flexible representation of the consequences of alternative development patterns and supply dynamics. This research then describes four alternative water supply scenarios for the Seybouse valley: increased use of treated wastewater in irrigation, climate change, and two combined scenarios—climate change with increasing reuse and altered patterns of agriculture to compute the impact on the demand supply gap by the year 2050.

Keywords: Seybouse valley; Water evaluation and planning system; Climate change

1. Introduction

In many basins worldwide, the growing demand for water leads to overexploitation of the limited water resources. This overexploitation is more pronounced and more frequent in areas where resources are scarce [1]. Although the principle of integrated water resources management (IWRM) [2], which uses a multidimensional approach, is often admitted, the response of decision-makers often focuses on the supply management [3], which includes performing large-scale infrastructure such as dams, reservoirs, and water transfers. Seybouse basin is no exception to this rule, the management of water resources in this basin is further complicated by the nature of the conflicts between different water uses and existing or prospective level of satisfaction [4,5]. The issues of water scarcity in the Seybouse basin are so pronounced that many proposals are initiated. To date, although several tools have been developed to manage water resources [5],

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Presented at the 6th International Conference on Water Resources in Mediterranean Basin (WATMED6), 10–12 October 2012, Sousse, Tunisia

none has been finalized for the integrated management of supply and demand. The objective of the study is to develop a tool IWRM quantitative and spatially explicit tool for the IWRM that could be used in future studies to assess and compare the different scenarios of water management taking into account variations of evolution of future water demands. We use the code water evaluation and planning system (WEAP) to develop a planning tool for Seybouse basin water resources. This tool aims at providing a consistent approach across this basin. This model considers the analysis of many variants of water management such as the transfer of new nonconventional water resources, land use conflicts, reducing water losses in the networks, wastewater reuse, rainwater harvesting, etc. This model will also allow to pursue the analysis of different combinations in the case of climatic and socioeconomic changes.

2. Materials and methods

2.1. Study area

Seybouse basin (Fig. 1) is subject to extreme water scarcity. Precipitations in the basin are highly variable in space and time. They range from more than 800 mm per year in the North to less than 450 mm in the South with an occurrence mainly during the winter. Water supplies in the region of low Seybouse are generated for the majority from the water resources of the region of El-Tarf, located to the East of the basin (Table 1) [6].

Consequently, the northern sector of the basin, the object of this research is highly dependent on water transfers from the region of El-Tarf, where water resources are much greater. The main aquifers of low Seybouse are indeed overexploited: withdrawals in some wells may reach 13 m below sea level [5]. Water demand is expected to worsen in the future, given the increase in population and economic growth in the region [7].

To remedy the water shortage, the authorities of water management in the lower valley of the Seybouse launched numerous measures based primarily on supply management. In recent decades, water withdrawals and transfers reduced flows in the valley of the Seybouse at almost 1/10th of its historical level [8]. To overcome this shortage, several major projects were initiated for a few years with the construction of dams (Mexa, Bouhamdane, Bouhalloufa) and a sea water desalination plant. This latter is in progress.

2.2. Methods

WEAP system was used to simulate the current and future water management. It is a modeling and water resources planning, which in its simplest form is a structure similar to other tools for decision: MODSIM, RiverWare, HEC-ResSim, and Oasis. It also

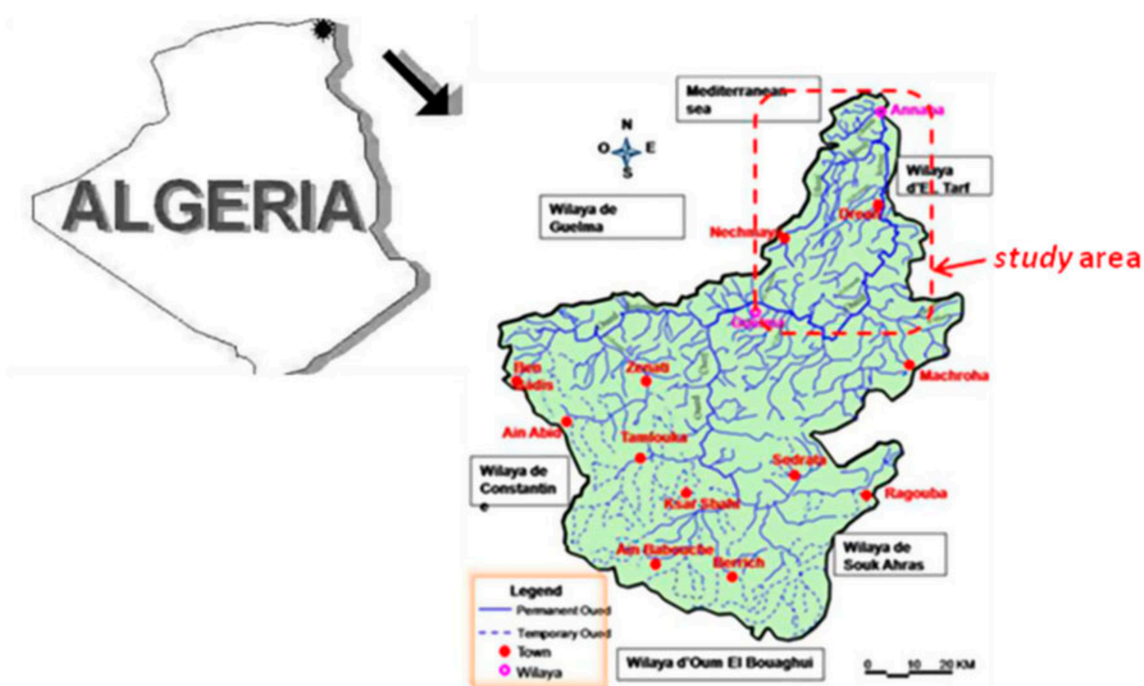

Fig. 1. The Seybouse basin.

Table 1
Approximate balance for an average year (million m^3)

Resources/demands	Volumes (Mm^3 per year)
Surface water	120
Ground water	95
Total resources en eau total resources	215
Drinking water and industrial water demand	140
Agricultural water demand	7
Total water demand	216

provides advanced features allowing a quick access to other models and software, such as QUAL2K, MODFLOW, PEST, Excel, and GAMS. The flexibility of the tool to adapt to different data requirements and to environment allows modeling a basin like Seybouse, where data are scarce and conflicts between different water users are high.

WEAP is widely used in dozens of basins around the world [9], for assessing the planning of water resources by providing a common analysis and data management framework to mobilize stakeholders and decision-makers in open planning process.

WEAP system was chosen for modeling Seybouse basin because it uses an approach based on scenarios that facilitate exploring a wide range of variants in order to satisfy the demand in a balanced way. A detailed description of WEAP is availabal in website code WEAP [9].

In the Seybouse basin, the WEAP model provides a coherent framework dealing with technical, socioeconomic, institutional, and political management of water. As described below, these aspects are integrated in WEAP through different scenarios; for example, technical development, the efficiency of water use, and the socioeconomic development represented by the population. The institutional and political aspects were represented in WEAP through the development of scenarios with stakeholders such as farmers, industrialists, and riparian.

Most of the data plugged into the WEAP model were obtained at the departmental direction for hydropower, agriculture, and Seybouse Mellègue basin agencies. All data were checked and harmonized. The WEAP data input via spreadsheets facilitates the update of parameters (rainfall, rivers flow, agricultural water demand, water supply demand, etc). WEAP recalculates the simulation results based on the most recent data.

The WEAP model is executed at monthly time steps, so that all input data, regardless of their original temporal resolution, are allocated on the basis of a monthly resolution.

3. Results

3.1. Network topology

The WEAP model reproduces the main characteristics of water management in the watershed of the lower Seybouse. This geographical representation includes major tributaries, groundwater, the main reservoirs or lakes (wadis, dams, etc), large irrigation canals, the water transfer pipes, agricultural and industrial water demands, and the consumption of drinking water.

Fig. 2 shows how the main features of the water system in the basin of the valley were grouped and represented in WEAP for both the supply and the demand as nodes. Transmission links between the nodes and the rules for water allocation (priority demand and supply) are also taken into account.

3.2. Water supply and water demand

Collected data are used to identify the spatial and temporal distribution of different resources and water needs in the basin. In general, the data show many gaps particularly regarding flow measurement of various tributaries of Seybouse river. Table 1 gives the mean values for resource availability and demand. Depending on the type of data, different historical periods were used:

- The rates of major streams in Seybouse basin are observed during 1980–2007.
- The same period was used to groundwater.

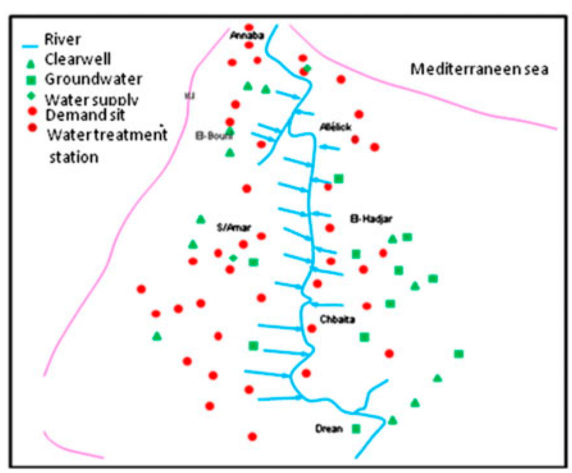

Fig. 2. Conceptual model of water distribution in the basin of lower Seybouse.

- The groundwater resources have been quantified using the code ModFlow with piezometric measurements recorded from 2001 to 2008. Data collection on water demand covers the period 2000–2008.

The data suggest that on the basis of an average year, 95% of consumption would be met. When we take into account operational constraints and timing of peak demands, we find, however, that the total demand is rarely fully satisfied. In addition, we calculate the demand for agricultural water in irrigated areas associated to the crop water demands and not the real food demands of the population who are mainly supported by the importation of food in order to save amount of water that would be required for local production, also called virtual water.

3.3. Validation levies in the aquifer of the plain of Annaba

Water needs in the coastal plain of Annaba are partly covered by water services due to groundwater pumping carried out in the gravel's tablecloth of Annaba plain and the transfer of water from boreholes of Bouteldja massif dune (El-Tarf). Groundwater withdrawals in Annaba are introduced into WEAP to meet the demand for potable water according to priorities. Next, we validated the collected volumes by comparing rates at the output of drilling, simulated by WEAP, with the rates of levies provided by the hydraulic services for the years 2004–2009. Fig. 3 shows a good agreement between calculated and measured values.

3.4. Validation of piezometric levels

The gravel aquifer of the plain of Annaba constitutes by its extension and good hydraulic properties a source of water supply of capital importance. To validate the overall balance of the samples, carried out in the groundwater, the groundwater levels simulated by WEAP are compared to those observed in four water abstraction points (Fig. 4). The global balance and the general behavior of water stored in the aquifer are correctly reproduced.

3.5. Scenario analysis

Seybouse WEAP model as described above is used to analyze different scenarios of water management that can address a wide range of issues [7]. This allows us to assess the implications of various internal and external factors of change, and how the resulting changes can be mitigated by policies and/or technical interventions. For example, WEAP can be used to assess the water supply and the impact of the water demand, the effect of demographic development, land use, and climate. The results of these analyses can guide decision-makers to better adapt the infrastructure to improve the productivity of the water system. Four global climate models and regional models were tested to assess the availability of water in the future well as the future irrigation water demand. We are based in this analysis with WEAP on the assumption that assumes a moderate increase in emissions of greenhouse gas with a reduction in the water supply of 30% and an increase in demand for water irrigation of about 22% by the middle of the twenty-first century compared to the 1990s. For the final test, we tried to make linear reductions in average annual discharge and groundwater recharge for all supply nodes, and a linear increase in the demand for irrigation water for all nodes.

This simplified approach shows that water scarcity can only get worse as the model of wet and dry years remains unchanged. In reality, droughts are likely to increase in frequency and intensity [6], which may cause more problems in the Seybouse river system. To assess the vulnerability of the system to these changes, it will be necessary to consider sets of scenarios describing the full range of hydro-climatological variability.

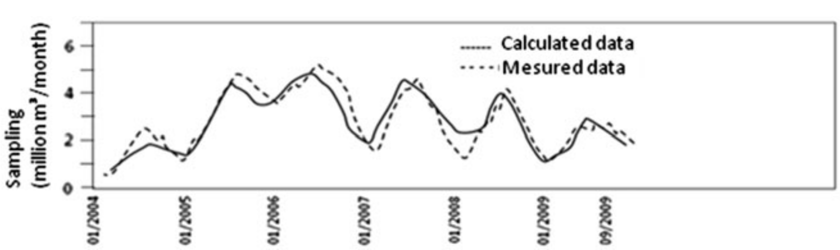

Fig. 3. Comparison of WEAP simulated values and measured pumping (million cubic meters per month).

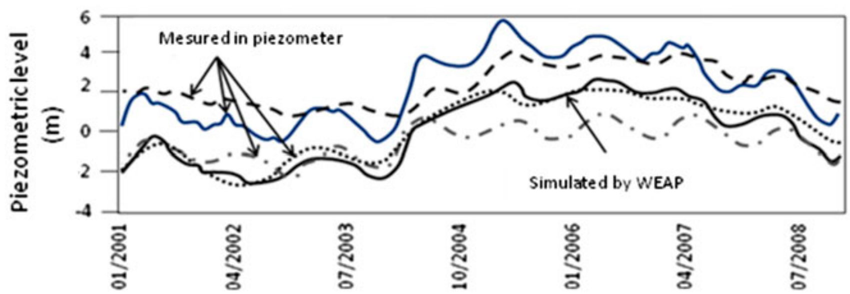

Fig. 4. Comparison of simulated piezometric levels (WEAP) and measured levels in wells' capturing. The Annaba gravel aquifer.

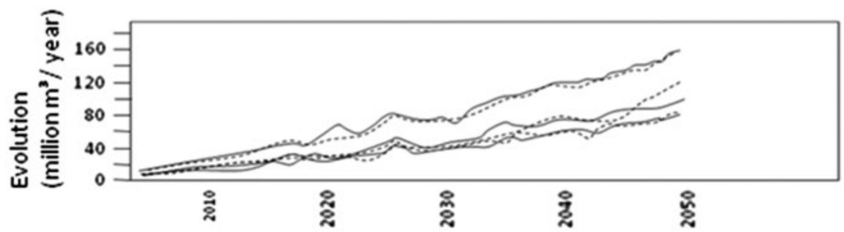

Fig. 5. Projections of annual unmet demand for four different socioeconomic scenarios and a climate scenario (basin scale).

4. Discussion

Sebouse basin today faces the problem of water scarcity. Over the next 20 years, increasing the demand for water is expected to worsen. Implementation of sustainable management of water, of a qualitative point of view as quantitative, is, therefore, imperative both for the future of the population of Seybouse basin and for ecosystems and determines social and economic development. Only an integrated approach, as used here with the development of WEAP model, offers the ability to manage these resources in respect of the natural environment, and the interests of those riparian and economic actors. It analyzes the complex situation of the studied basin by comparing supply and demand through a limited number of nodes and transmission links on the basis of available data collected and updated at different services. Fig. 5 shows a projection of annual unmet needs for the entire basin for four scenarios of socioeconomic demand (assuming the absence of climate change) and climate change (assuming no change in demand, except for the climate, additional demand for irrigation water) as described in the methods section.

By comparing the changes over time between these scenarios, we observe great similarities between the unmet needs to meet the demand for socioeconomic and the climate projections (supply). In addition, this first analysis indicates that in the middle of the twenty-first century, the evolution of unmet need is likely to far exceed the current variability of unmet demand. Fig. 5 shows also that the hypotheses expressed in the socioeconomic scenarios on population and economic development have significant effects on the future of unmet demand. The Seybouse WEAP model, developed here, can be an excellent tool to communicate to water managers the effects of different scenarios and associated uncertainties, and to deepen the analysis of system responses to changes in the underlying assumptions [10]. We developed jointly with local partners a new database of the water basin scale and a planning tool. This tool allows, for the first time, the visualization of the combined effects of various changes in socioeconomic development under different assumptions. The climate scenario chosen for this study is based on the hypothesis of emissions of greenhouse gases, which are below the current trends [10]. For a more detailed analysis of the effects of climate change on the basis of more realistic trends, we can expect much higher reductions in the availability of water and a greater increase in demand for irrigation water. The socioeconomic scenarios were developed by a consensus process. Therefore, these hypotheses are a good knowledge of the relevant driving forces such as population growth, economic and technological development, land use, etc.

5. Conclusions

The WEAP model developed in this work shows that climatic variables and socioeconomic factors are the two main drivers of water scarcity in the basin in the future. This model can be used to support more detailed analysis of policies for managing water. According to the principle of maintaining code WEAP representation system as simple as possible without losing the structure and function keys, water supply and demands were represented as nodes highly aggregated. On the basis of this initial WEAP model for Seybouse, it is now possible to specify the characteristics of the system and to develop a more detailed analysis, for example, needs analysis for irrigation water for different crops, the technology to improve the efficiency of water use, restrictions related to water quality for certain uses, the benefits of institutional change and water-related reallocations, etc. depending on the question.

We limited the initial analysis of Seybouse 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.

References

[1] M. Falkenmark, D. Molden, Wake up to realities of river basin closure, Int. J. Water Resour. Dev. 24 (2008) 201–215.

[2] Global Water Partnership (GWP), Integrated Water Resources Management—(TAC background paper No. 4), GWP, Stockholm, 2000.

[3] J.A. Alan, The Middle East Water Question, Hydropolitics and the Global Economy, Tauris, New York, NY, 2001.

[4] A. Lamei, P. van der Zaag, E. von Munch, Water resources management to satisfy high water demand in the arid Sharm El Sheikh, the Red Sea, Egypt. Desalin. Water Treat. 1 (2009) 299–306.

[5] B. Aoun-Sebaiti, Gestion optimisée des ressources en eau d'une nappe côtière. Application à la plaine d'Annaba [Optimized management of water resources in a coastal aquifer. Application to the plain of Annaba], Thèse de Doctorat USTL, Lille 1, 2010, p. 211.

[6] B.C. Bates, Z.W. Kundzewicz, S. Wu, J.P. Palutikof, Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva, 2008, p. 210.

[7] J. Alcamo, A.J. Jakeman, Environmental Futures: The Practice of Environmental Scenario Analysis, Elsevier, Amsterdam, 2008.

[8] C. Le Quéré, M.R. Raupach, J.G. Canadell, G. Marland, L. Bopp, P. Ciais, T.J. Conway, S.C. Doney, R.A. Feely, P. Foster, P. Friedlingstein, K. Gurney, R.A. Houghton, J.J. House, C. Huntingford, P.E. Levy, M.R. Lomas, J. Majkut, N. Metzl, J.P. Ometto, G.P. Peters, I.C. Prentice, J.T. Randerson, P. Foster, S.W. Running, J.L. Sarmiento, U. Schuster, S. Sitch, T. Takahashi, N. Viovy, G.R. van der Werf, F.I. Woodward, Trends in the sources and sinks of carbon dioxide, Nat. Geosci. 2 (2009) 831–836.

[9] http://www.weap21.org/index.asp?Doc=05

[10] C. Bonzi, H. Hoff, J. Stork, A. Subah, L. Wolf, K. Tielbörger, WEAP for IWRM in the Jordan River Region. Bridging between scientific complexity and application, in: Proceedings of the Integrated Water Resources Management, Karlsruhe, Germany, 2010.