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Prospects for a larger integration of the water resources system using WEAP model: a case study of Oran province

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ABSTRACT

An integrated water resource management that takes into account the long-term hydrosystem development is important, in particular in regions facing water stress, and thus having to manage the distribution conflicts of these resources and the rhythm of their exploitation. To address these issues, we conduct a study of hydrological situation prospects in Oran, the second largest region in Algeria and a major Southern Mediterranean metropolis, employing alternative development scenarios of its water resources throughout 2011–2030 period. The aim of this work is to investigate the management of water resources in this region in a unified framework that takes into account both the evolution of the water demand of the different sites and the hydrological processes in the watersheds that largely determine the volume of mobilizable water resources. Our findings reveal the vulnerability of the region in its ability to face the pressures resulting from the increase of needs of different sectors at the horizon of the forecasted period. They also indicate the need for a larger integration of the agricultural sector into the rest of the water system to lay the foundations for a sustainable water policy in Oran region.

Keywords: Integrated water resources management; Irrigation; Hydrological modeling; Oran province; Simulations; Water policies; WEAP model

1. Introduction

Integration of water resource management in an urban planning process is essential for a sustainable management of these resources, in particular when mobilizable water volumes do not ensure the long-term fulfillment of the needs of the region [1,2]. Oran, a major Southern Mediterranean metropolis and the second largest region in Algeria in terms of the level of economic development and population size, is greatly affected by this issue.

With a low density of its water system, combined with a population of about 1.5 million inhabitants, growing at a rate of 1.9% per year [3] and an industry and agriculture in a rapid development, this region will face a strong pressure on its water resources in the upcoming years. This perspective calls for new

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management of water resources to cope with these developments. However, an efficient management of water resources is a complex process, in view of the interlinks between the physical dynamics governing the water system (climate, topography, land nature, surface, and groundwater hydrology) and the social and economic dynamics that determine the priorities in meeting the demand of different users, as well as the supply sources for this purpose [4,5]. As mentioned by Yates et al. [6], this complexity of water resources has often driven the researchers to tackle the water demand management of the different demanding sites separately from the study of the hydrological process in the catchment basins that determine the supply of water resources. Our work contributes to the effort to close this gap by addressing these two issues in a unified framework, which enables taking into account the interactions between these different hydrosystem levels.

More generally, this work contributes to the prospective study of the hydrological conditions in the region and to the analysis of alternative development scenarios of water resources on 2011–2030 horizons. These prospects are important, since they allow integrating the management of these resources within a planning process, which enables assessing the long-term needs of the region and accurately forecasting the investments and management improvements required to meet the water demand in the study area [7].

Our methodological approach relies on the modeling of the hydrological system of the study area by using the software "Water Evaluation and Planning System" [6,8]. This software is based on the representation of the hydrological system in the form of a network, where nodes (catchment basins, demand sites, different supply sources) are interrelated through transmission and return flow links or run-off/infiltration. Each demand site is given a level of priority, as well as a preference system with respect to alternative supply sources, in order to solve the water allocation problem. Hence, multiple water resource management scenarios can be analyzed within the planning horizon of the study.

The paper is organized as follows. In the first section, we present briefly Oran region and its conventional, non-conventional water, and groundwater resources. Given the current disconnection of the drinking water sector from that of the irrigation, in the second section, we analyze, under different scenarios, the prospects of water needs of the entire sectors, excluding agriculture, as well as the capacity of the projected infrastructure to satisfy them. The third section is reserved for the discussion of the sustainability of current groundwater withdrawals and the examination of the expected long-term developments of the irrigation demand. Finally, in section four, we present a scenario of integration of the agricultural sector into the remaining water system—currently decoupled—by the substitution of non-conventional resources (from the wastewater treatment plants [WWTPs]) to the current underground withdrawals. In this context, we evaluate the potential extension of irrigated areas enabled by this scenario under the constraint of sustainability of groundwater withdrawals.

2. Study area and water resource assessment

The province of Oran is located in the northwest of Algeria and is one of the largest metropolises in the Maghreb. It is a seaside town on the Mediterranean Sea coast and covers an area of more than 2,100 km^2.

The relief of Oran consists of two types of geomorphologic formations: the littoral and sublittoral plains (Bousfer, Andalouses, Es Senia, Misserghin, Boutlelis, and Hassi Mefsoukh), which cover about 70% of the total area of the region, and the coastal mountains that extend from the southwest to the northeast of the region.

The study area covers three subwatersheds belonging to the Coastal Oranais basin: the Coastal Ain Turk (code 403) located to the west and on the north side of the Murdjadjo mountain; the Sebkha of Oran (code 404), which is an endorheic basin characterized by the particularity of having a surface water rich in salt, and the Saline of Arzew (code 405) in the northeast of the region [9] (Fig. 1).

Oran is characterized by an insufficiently developed hydrographic network, given that a large part of the region belongs to the endorheic basin of Sebkha of Oran. Since the 80s, the region has been affected by a chronic drought cycle, which depleted the water reservoirs and seems persistent. This deficit in surface water does not favor the development of large hydraulic installations and explains why this region has been, thus far, supplied by water coming mainly from external resources (adductions of Beni Bahdel and Tafna in the west and those of Fergoug and Gargar in the east).

This drought in the region led to the mobilization of non-conventional resources, mainly through seawater desalination, aimed at compensating for the deficit in surface water resources. However, the most important desalination plants are located outside the region and supply it by means of an inter-regional transfer system —Chatt el Hilal desalination plant (200,000 m^3/d) in Temouchent region and Macta (500,000 m^3/d) in Mostaganem region. A demineralization unit operating in Bredeah (18,000 m^3/d) further contributes to fulfill

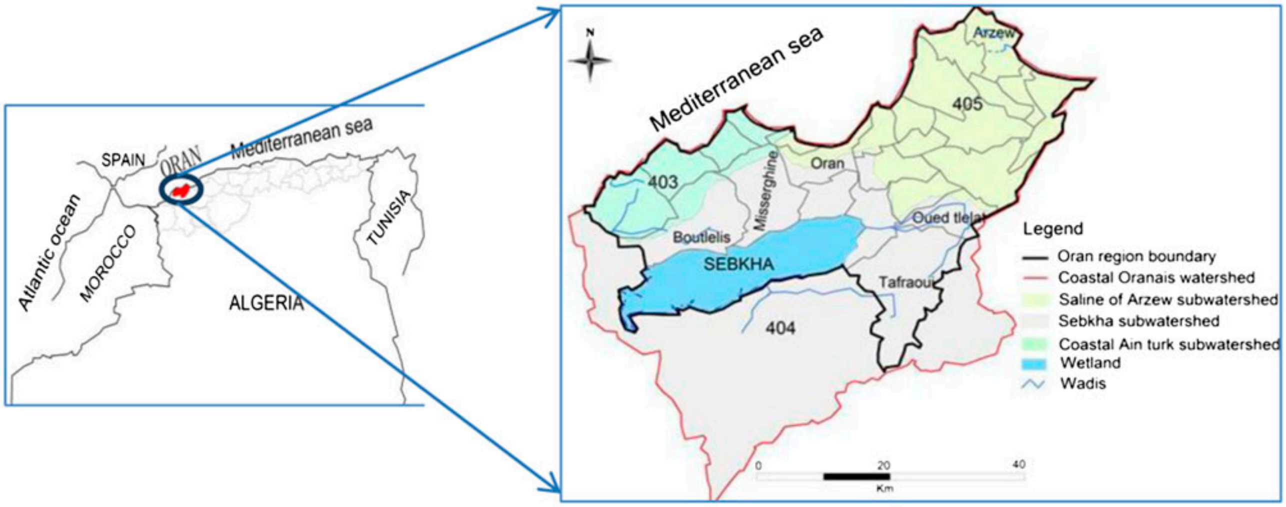

Fig. 1. Map of Algeria with the study area.

the drinking water needs of the region. In addition, small WWTPs are installed in El Kerma, Ain Turck, and Bethioua. However, the Sebkha basin or the sea remains as the main recipients of the treated water.

In terms of groundwater resources, the Oran region includes four large hydrogeological units [8,9]:

(1) The groundwater of the Coastal plain of Ain Turk (Ain Turk groundwater), which consists of multilayer aquifers with an unconfined aquifer and one or many deep aquifers.
(2) The groundwater of Bredeah plain (Bredeah groundwater), bordering Sebkha of Oran, which extends to the eastern part of M'leta plain.
(3) The karst groundwater of Murdjadjo (Murdjadjo groundwater), which consists of a calcareous part and an alluvial part, and includes Murdjadjo Mountain and its geological extension to the east.
(4) The groundwater of Arbal located in the Sebkha subwatershed (Tafraoui groundwater), to the south from Bredeah groundwater.

According to the SOGREAH survey [9], the exploitation of groundwater resources is mainly performed by means of wells, which contribute to the withdrawal from aquifer by 94%, with the remaining 6% arising from drilling.

As shown in Table 1, Oran region is characterized by a very weak exploitation of surface resources, due to the insufficient density of the hydrographic network, which is limited to only one operating hillside dam.

However, irrigation by withdrawals from aquifers shows a reasonable intensity of exploitation of Ain Turck Coastal, Murdjadjo Complex, and the Tafraoui groundwater. In contrast, the withdrawals from Bredeah groundwater—which supplies the two largest municipalities (Misserghine and Boutlelis)—are clearly unsustainable with an exploitation ratio exceeding 170%.

In summary, the marginal mobilization of the surface run-off resources as a result of the weak hydrological network and the systematic exploitation of the groundwater for irrigation needs make the hydrological system of the region particularly vulnerable. These conditions force, to a large extent, the recourse to external water supply resources, in order to meet the demand of various sites.

3. Modeling of non-agricultural sectors

To highlight the future constraints on the ability to meet the water needs—other than irrigation—we first build a model of water demand and calibrate it in order to replicate the data pertaining to 2011 which constitutes the base year. In the second step, we develop a baseline scenario that simply extends the current trends of the hydrosystem. Finally, we evaluate the effects on water availability of changes in several parameters, including unit water needs of households and industry, resource management efficiency, and in water policy through the development of new infrastructure elements.

We assume that domestic water demand arises from households, public sector providing utilities, and industry. Moreover, the total household demand

Table 1
Comparison between withdrawals and mobilizable resources—2011

Hydrogeologic units	Mobilizable surface resources (10^3 m^3)	Withdrawals (10^3 m^3)	Exploitation rate of surface resources (%)	Mobilizable groundwater resources (10^3 m^3)	Withdrawals (10^3 m^3)	Groundwater exploitation rate (%)
Coastal Ain Turck	1,803	440	24	5,408	2,691	50
Bredeah groundwater	2,867	0	0	8,600	14,681	171
Murdjadjo groundwater	8,170	0	0	24,509	12,448	51
Tafraoui groundwater	467	0	0	1,401	92	7
Total region	13,306	440	3	39,918	29,913	75

Source: SOGREAH [9] and authors' calculation.

depends on the population size, the rate of linkage to the drinking water, and the unit water needs of households linked to the drinking water network. Due to the absence of accurate information, it is assumed that the public sector water demand is proportional to that of the households, whereas the total water demand of the industrial sector depends on the size of the industrial activities and the unit water demand of this sector. Note that, due to the unavailability of regional industrial accounting, the industrial activity growth is estimated based on the growth rate of the areas of the industrial estates located in the region [10].

$$B_{hh} = N * tx_{link} * Bunit_{hh} \quad (1)$$

$$B_{ps} = \alpha * B_{hh} \quad (2)$$

$$B_{ind} = Ind * Bunit_{ind} \quad (3)$$

$$D_{tot} = B_{hh} + B_{ps} + B_{ind} \quad (4)$$

$$P_{tot} = (B_{hh} + B_{ps} + B_{ind})/tx_{eff} \quad (5)$$

where B_{hh} = total water needs of households; $Bunit_{hh}$ = unit water needs of households; B_{ps} = total water needs of the public sector; B_{ind} = total water needs of the industrial sector; $Bunit_{ind}$ = unit water needs of the industrial sector; Ind = size of industrial activities; N = size of the population; α = the proportion of water demand arising from public services; Tx_{link} = ratio of linkage of households to drinking water network; Tx_{eff} = the distribution network efficiency rate; P_{tot} = total water withdrawal.

The proportion of public sector demand (α) was set at 20% (the same value was adopted by Treyer [11]) and the distribution network efficiency rate Tx_{eff} was set at 70%, according to the information obtained by interviewing several officials of the region's hydraulic department. The unit needs of households and industries must be set so that the model reproduces the total water consumption of these sectors during 2011. This is achieved with $Bunit_{hh}$ = 143.4 l per person, per day and $Bunit_{ind}$ = 12.3 m^3 per hectare, per day for the industrial sector [12].

To assess the impact of future development of the region on water demand of non-agricultural sectors, a baseline scenario is established as a continuation of the trend observed during the past period without modification of model parameters. It thus stipulates the growth of the household withdrawals on the basis of population growth, i.e. a rate of 1.9% per annum over 2011–2015 period, 1.7% over 2016–2020 period, 1.5% for 2021–2025, and 1.2% for 2026–2030, in order to take into account the demographic transition of Algeria. As previously noted, the needs of the public sector mimic those of the household, whereas the withdrawals by the industry increase with the size of the sector, i.e. 5% per annum [10].

The simulation of this baseline scenario—in which the needs of households take precedence over those of the industry—shows that in the absence of intervention, the water deficit in 2030 will amount to 54 million m^3 per year, of which 15 million m^3 for households and communities and 39 million m^3 for the industry (Fig. 2).

The persistent downward trend in the level of supply in the industrial sector, and in the final period, in the household sector undermines human and economic development in the region.

However, this scenario is passive, as it is based on the assumption that the managers have taken no infrastructure development action in response to the increase in population size and in the number of firms. In fact, the hydraulic department is currently developing several projects, such as the extension in

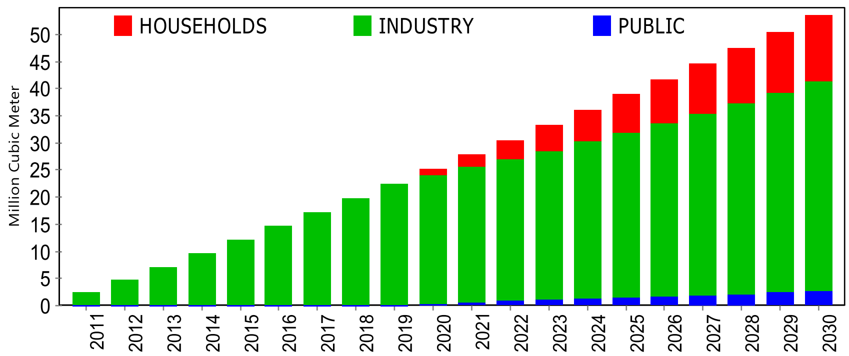

Fig. 2. Unmet demand by sectors: baseline scenario.

seawater desalination and the installation of WWTPs, which will increase the capacity of water resources in the region. In addition, this scenario supposes that the water unit demand remains unchanged throughout the simulation period. However, we expect that the unit demand for drinking water will increase, contributing to a greater overall demand in the region due to different factors such as the increase in the standard of living, the growth of demand for urban housing, the increase in the migration of people to cities, or the improvement of the rate of connection to the distribution network. The unit demand of the industrial sector is also subject to change, depending on the technological developments in this sector. Therefore, it is important to ascertain whether the future demand of different sectors will be fulfilled by the infrastructure that will be installed in Oran region, and if the latter will succeed in ensuring the water self-sufficiency in that region. For that purpose, we proceed with the simulation of an alternative scenario involving the three following key developments [7]:

(1) The increase in the water unit demand at different sites: Under the combined effect of three factors—the ratio of linkage to the drinking water network, the rate of occupation of houses, and the increase in the living standard—we can assume that the consumption per capita in Oran region will increase by 2.5% per annum over the studied period. For the industrial sector, the evolution of the unit demand depends on the direction of technological changes, which typically contributes by reducing the water unit consumption in the industry. Thus, we hypothesize that the water consumption per hectare of industrial estate for the industrial sector will shift progressively from 4,495 m^3/hectare in 2010 to 4,000 m^3/hectare in 2030.

(2) The increase in water resource capacity: The development of new infrastructure elements, including those envisaged in the development plan of the region, consists in the installation of a desalination seawater plant with the treatment capacity of 50,000 m^3 per day (250,000 m^3 to full throttle), as well as the entry into operation of a WWTP with a treatment capacity of 300,000 m^3 per day by 2030. We assume that the increase in the production capacity of these installations follows a logistic curve. In the simulations, we further assume that 60% of the consumption of the demand sites (households, communities, and industry) is oriented towards WWTP, with the remaining 40% being rejected to other recipients (Sebkha basin and sea). In this scenario, the WWTP supplies exclusively the industrial sector, with any surplus of treated water rejected to the sea.

(3) The improvement of water resources management: An active management of water resources allows achieving water savings which may be important and contributes in reducing the deficit in the region (reduction of loss in transmission links, recycling wastewater used by the industrial firms, awareness campaigns targeting the population, aiming to reduce the losses in drinking water, etc.). In this scenario, we simulate a reduction in the loss of water, which follows a gradual decreasing trend, from 20% in 2011 to 10% in 2030. Furthermore, the rate of recycling in the industrial sector increases from 0% of the industrial consumption in 2011 to 20% in 2030.

These projected developments in the hydraulic infrastructure and the water policy of the region allow fulfilling the needs of the entire consumer sectors, excluding agriculture [Fig. 3(a)] with 100% recovery rate in 2030, as shown in Fig. 3(b).

Moreover, the introduction of a WWTP with a high treatment capacity and the improvements in the water resources management allow increasing the return flows of the WWTP. In 2030, more than 65 million cubic meters of residual water will be treated by the WWTP, thereby improving the quality of environment.

However, if the various users will be supplied without resorting to the inter-regional transfers between 2014 and 2022, the necessity of the external transfers resumes again from 2023 until 2030 (Fig. 4). Thus, and despite the increase in the non-conventional water resources, Oran region will still not be unable to reach the water self-sufficiency. Consequently, at the beginning of the next decade, it will resume dependence on the external transfers.

4. Modeling the of agricultural sector and prospect of the irrigation demand

In this section, we determine the dynamics of the agricultural sector irrigation demand, which is—given the decoupling of the agricultural sector from the rest of the water system—currently fulfilled owing to the effective rainfalls and withdrawals from groundwater resources and, to a lesser extent, from superficial water resources. Both the baseline scenario and the variants based on the projects announced by the hydraulic department in Oran show a deficit that the region will be facing in the near future.

We model the agricultural sector by means of a rainfall-run-off model incorporated in the WEAP. The first part of the model (Eqs. (6)–(12)) determines the evapotranspiration in each of the hydrologic units of the region by means of cultural coefficients and the reference evapotranspiration using FAO approach "E_0K_c" [13,14]. Taking into account the effective rainfalls, this method determines the required irrigation, i.e. the irrigation that cannot be guaranteed by the effective rainfalls. In the second part of the model (Eqs. (13)–(15)), the water not subject to evapotranspiration is simulated as a run-off, which is divided into the surface run-off and infiltration.

The equations of the model are:

$$P_{\mathrm{eff}} = P_{\mathrm{t}} * R_{\mathrm{Peff}} \tag{6}$$

$$V_{\mathrm{Peff}} = P_{\mathrm{eff}} * S \tag{7}$$

$$V_{\mathrm{Peff,Ir}} = P_{\mathrm{eff}} * S_{\mathrm{Ir}} \tag{8}$$

$$\mathrm{ET}_{\mathrm{C,Ir}} = \mathrm{ET}_{0,\mathrm{Ir}} * K_{\mathrm{C,Ir}} * S * \mathrm{RS}_{\mathrm{Ir}} \tag{9}$$

$$\mathrm{ET}_{\mathrm{C,NIr}} = \mathrm{ET}_{0,\mathrm{NIr}} * K_{\mathrm{C,NIr}} * S * (1 - \mathrm{RS}_{\mathrm{Ir}}) \tag{10}$$

$$D_{\mathrm{Ir}} = \mathrm{ET}_{\mathrm{C,Ir}} - \mathrm{VP}_{\mathrm{eff,Ir}} \tag{11}$$

$$\mathrm{Pr} = \sum_{\mathrm{Hu}} \left(\frac{D_{\mathrm{Ir}}}{R_{\mathrm{effi,Ir}}} \right) \tag{12}$$

$$\mathrm{Run}_{\mathrm{Off}} = P_{\mathrm{t}} * (1 - R_{\mathrm{Peff}}) + (1 - R_{\mathrm{eff,Ir}}) * \mathrm{Pr}_{\mathrm{Ir}} \tag{13}$$

$$\mathrm{SRun}_{\mathrm{Off}} = \mathrm{Run}_{\mathrm{Off}} * R_{\mathrm{SRun}} \tag{14}$$

$$\mathrm{Inf} = \mathrm{Run}_{\mathrm{Off}} * (1 - R_{\mathrm{SRun}}) \tag{15}$$

with the following notations (variables are given per hydrologic unit):

P_{t} = total rainfall;

P_{eff} = effective rainfall;

V_{peff} = volume of effective rainfall;

S = area of each hydrological unit;

$\mathrm{ET}_{\mathrm{C,Ir}}$ = potential evapotranspiration on irrigated area;

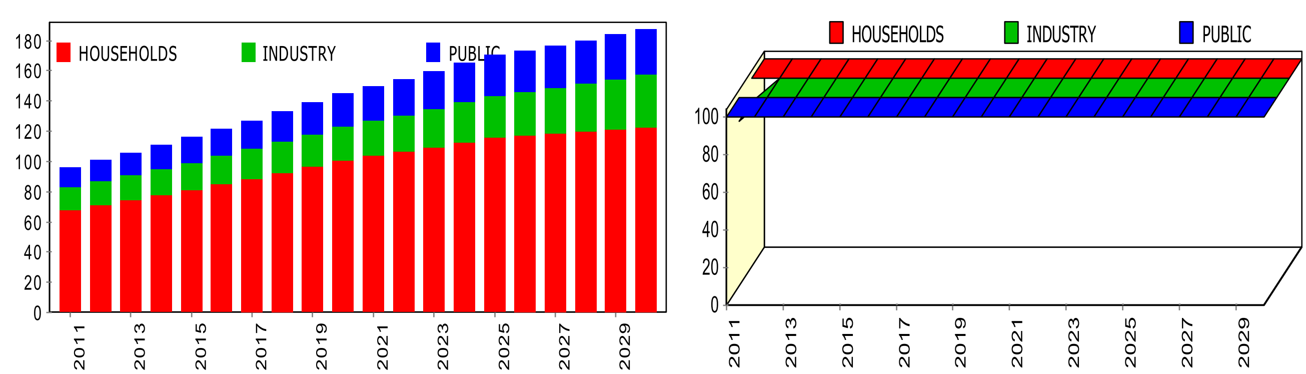

Fig. 3. (a) Evolution sectors water demand: alternative scenario (10^6 m^3). (b) Demand site coverage (percent).

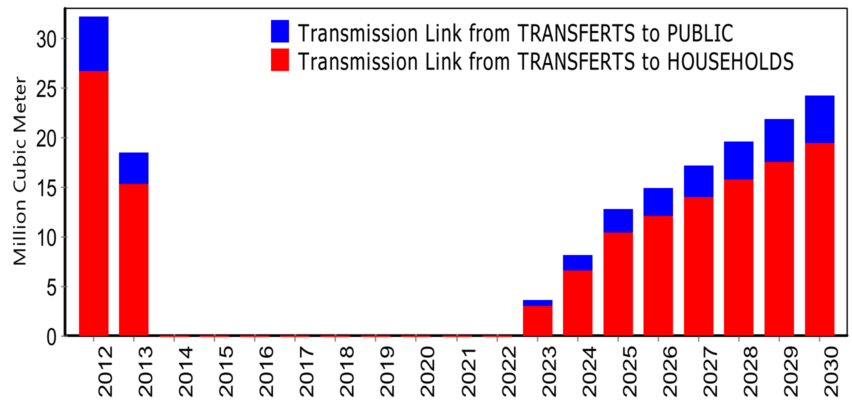

Fig. 4. Evolution of external transfers: alternative scenario.

$ET_{0,Ir}$ = reference evapotranspiration on irrigated area;
$K_{C,Ir}$ = cultural coefficient on irrigated area;
D_{Ir} = demand of irrigation on irrigated area;
Pr = withdrawal;
Run_{off} = run-off;
$SRun_{off}$ = surface run-off;
Inf = infiltration;
R_{Srun} = surface run-off rate;
R_{Peff} = effective rainfall rate;
RS_{Ir} = ratio of irrigated area;
$R_{eff,Ir}$ = irrigation ratio of efficiency;

The effective rainfall rate R_{Peff} for each hydrologic unit was estimated at 80%, according to the national water plan [15], whereas the fraction of surface run-off R_{Srun} was set at 25%, on the basis of the study conducted by SOGREAH [9].

4.1. Determination of the current account

Solving the first part of the model allows estimating the region's overall need for water irrigation at 35.1 million m^3 per annum. More than half of the irrigation requirements (55%) arise from five municipalities only, namely, Misserghine, Boutlelis, Sidi Chahmi, Hassi Bounif, and Es Senia. At the other end of the distribution spectrum, the municipalities Hassi Mefsoukh, El Braya, Arzew, and Mers El Kebir each represent less than 1% of the overall needs of the region.

The second part of the model evaluates the water withdrawals required to fulfill the irrigation demand and allows establishing the water balance in the region (Fig. 5).

The water demand required for irrigation in the agricultural sector is estimated at 30.4 million m^3 and is divided between 29.9 million m^3 of withdrawals from groundwater and 0.44 million m^3 from surface water resources.

4.2. Scenarios analysis and prospective of agricultural sectors

To forecast the development of the irrigated agriculture sector in the region, we firstly establish a baseline scenario in which we keep all model parameters constant, except the irrigated area, which is assumed to grow at a rate of 3% per annum. Thus, the irrigated area increases from 6,085 hectares in 2011 to 10,990 hectares in 2030 [7].

In this scenario, the pressure on resources will be higher relative to the current period, as shown in Fig. 6, which depicts the progression of aquifer withdrawals during the forecast period.

On average, in the region, the groundwater exploitation rate increases from the current level of 76 to 137% in 2030, with a peak of 308% arising from excessive exploitation of Bredeah aquifer.

The strong solicitation of the groundwater resources indicates the necessity for their forward-looking management, which would facilitate responding to these developments. The alternative scenario that we explore is mixed, in which it integrates both the demand and the production of water.

With respect to the water demand, surface irrigation is presently the predominant irrigation technique. It represents about 60% of all irrigation methods employed in the region, although its efficiency is relatively low. The drip irrigation mode is used in 35% of the irrigated areas of the region only [9].

This dominance of an irrigation mode with low efficiency shows that great improvements in resource cost effectiveness may be still achieved. Thus, we simulate an improvement in the efficiency of the irrigation system, which increases the efficiency rate from 70% in 2011 to 85% in 2030, through greater utilization of the sprinkler and drip irrigation techniques. These

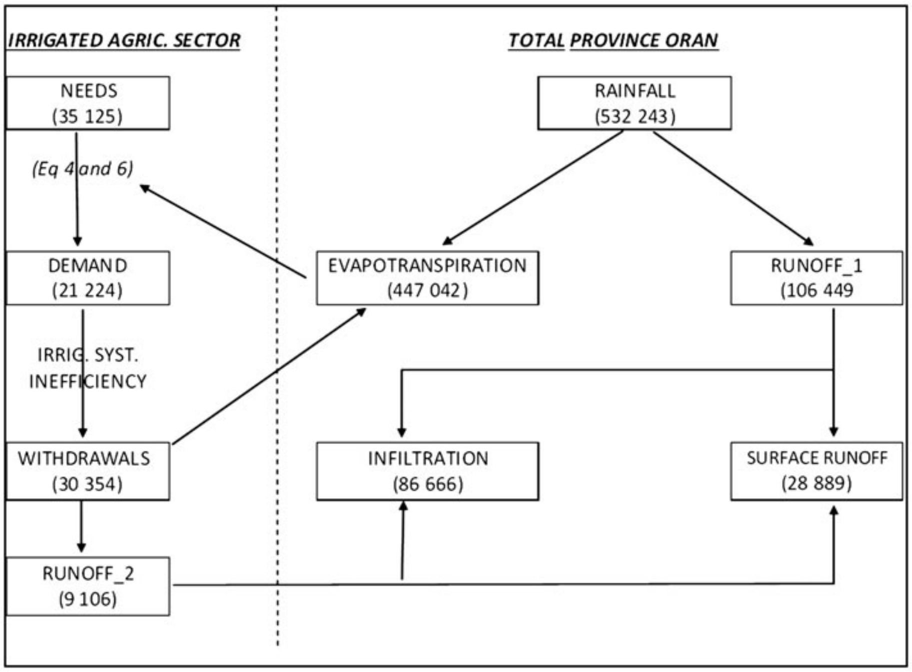

Fig. 5. Water balance of Oran region—2011 (10^3 m^3).

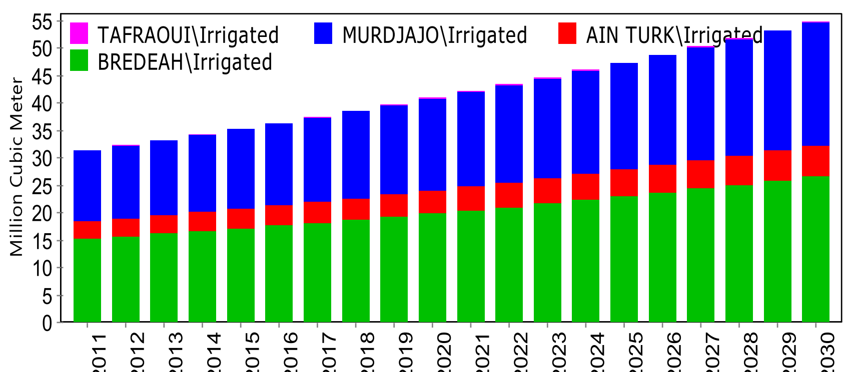

Fig. 6. Aquifer withdrawals requirement: baseline scenario.

more efficient irrigation modes induce a reduction in water withdrawals by reducing previous losses. When compared with the baseline scenario, the simulated reduction of water withdrawals will be 9.4 million m^3 in 2030.

Regarding water production, we introduce in this same scenario the hydraulic department project that consists of constructing many hillside dams in the region in order to increase the use of surface run-off for plants irrigation purpose [16]. In this context, we assume that the share of surface resources in Ain Turk will increase from the present level of 24 to 50% in 2030, and in Murdjadjo from 0 to 10%. These achievements will allow mobilizing a volume of 1.718 million m^3 per annum of water surface run-off, which will reduce the pressure on the groundwater in the concerned hydrologic units. Thus, in 2030, the rate of exploitation of Coastal Ain Turk groundwater will decrease from 86.2 to 69.5% and for Murdjadjo complex from 75.6 to 72.2%.

However, these volumes, regardless of their importance, are clearly inadequate as a solution to the agricultural irrigation issue in Oran region, especially since the model assumes a moderate growth in the

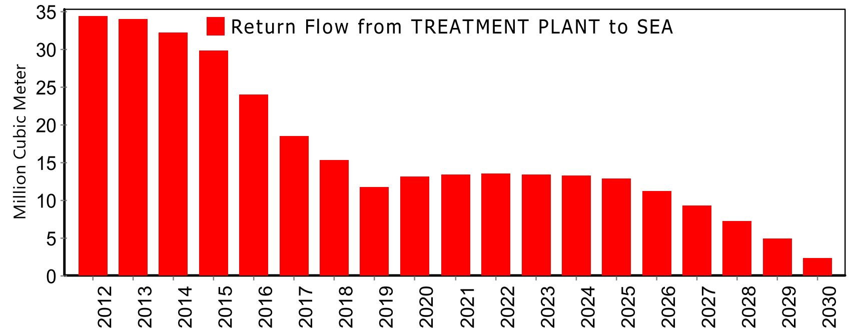

Fig. 7. Volume of the rejections of the WWTP towards the sea: alternative scenario.

agricultural sector. The low density of hydrographic network in Oran region, combined with insufficient rainfall, does not allow considering a long-term solution based solely on the mobilization of water from surface run-off.

5. An integrated system management: prospect for a larger integration of water system

By integrating the consumptive water sector and the irrigation sector, which are currently decoupled, we can attempt to address the irrigation issue in the region. In 2030, 65 million m^3 of water generated by households will be treated by the WWTPs but rejected in natural recipients, such as the Sebkha basin or the sea. The adequate medium- to long-term solution resides certainly, for irrigation purposes, in the recourse to the water treated by the WWTPs. This direction of water policy in Oran region will not only improve the water quality but also substitute the groundwater withdrawals by the resources from the WWTPs. As a result, the pressure on the aquifers, which are currently excessively exploited, will be greatly alleviated. In this new policy, the WWTP becomes the focal site, allowing integrating the agricultural sector with the remaining hydrological system of the region.

This final scenario of integrating the hydrological system of the region has three characteristics. First, we introduce a project, whereby a large irrigated perimeter supplied by the WWTP (with the 2030 capacity of 300,000 m^3/d, as previously noted) is established in Tafraoui region on an area of 7,000 hectares with an extension of 1,000 hectares toward Bredeah. Second, the entire production of the WWTP must, in an optimal situation, be used to irrigate new agricultural surfaces (here: Bredeah and Tafraoui sites) or supply the industry sector, instead of being rejected in natural receptacles. Thus, the volume of water rejected by the WWTP must be nil by 2030. Finally, we limit the withdrawals from the groundwater in order to not exceed their natural recharge. However, in doing so, the priority of supply will be given, within the limits of normal exploitation, to the groundwater as compared to the WWTP, since the production of non-conventional water is costly.

Thus, in this scenario, we determine the maximum rate of increase in the irrigated area surface, consistent with the constraints of supply priority, the sizing of the WWTP, and the final condition of non-rejecting

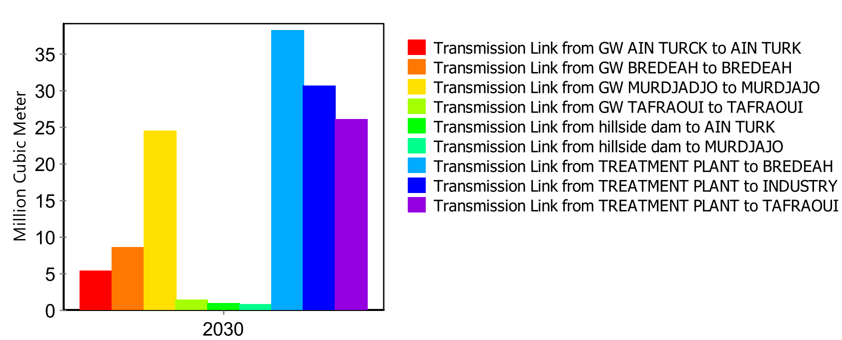

Fig. 8. Groundwaters withdrawals and WWTP outflows: alternative scenario.

water treated by the WWTP in 2030. The simulations performed by increasing, step by step, the reference rate of growth of irrigated agricultural areas, show that the sizing of the WWTP is consistent with the growth rate of the irrigated areas by 5.5% per annum over 2012–2030 period. Based on this rate, the amount of water rejected by the WWTPs to the sea will decrease, reaching zero by 2030 (Fig. 7). Moreover, the rate of groundwater exploitation will be equal to 100% in 2030 (Fig. 8 and Table 1) and an optimum recovery will be achieved at all demanding sites.

6. Conclusion

This study has explored, in a modeling framework, the long-term development of the hydrological system in Oran region. It has highlighted the importance of a prospective and integrated management of water resources of this region in order to predict the future constraints and develop capacities that can address the pressures resulting from the increase of demand from the different sectors.

The models used (whether those of the demand in consumption water or in irrigation water) allowed us not only to estimate the future water demand for all user sectors in the region (households, pubic services, industry, and agriculture) but also to highlight the vulnerability of the region due to the very limited current resource capacity. The simulated scenarios allowed us to identify management measures and capacity expansion needed to ensure that the mobilizable water resources converge toward the long-term needs in the region and to reduce—even without eliminating—the region's dependency on the external resources which currently supply more than half of the drinking water in the region.

Nonetheless, a water policy in the Oran province can be sustainable only if it remedies the main issue of the region, which is the current segmentation of its hydrologic system where the disconnection of the agricultural sector from the water system leads to overexploitation of certain aquifers. The implementation of a WWTP allowing the treatment of households and utilities wastewater for irrigation purposes is thus the recommended route for the recovery of an integrated nature of the region's water system.

This work provided an accurate presentation of this prospect and the findings reported here demonstrated that the recommended measures not only help preserve the groundwater resources, but also contribute to the economic development of the region through the growth transmitted to the agricultural sector by the extension of its irrigated areas.

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