Water as parameter of cooperation between Morocco and Algeria: the case of transboundary stressed aquifers of Bounaïm-Tafna basin

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Abstract: The hydrological basin of Bounaim-Taffna shared between Morocco and Algeria is an example of the politics of silence and non-cooperation. The basin is situated in the north of the Morocco-Algerian administrative border. It is formed by two aquifers (confined and unconfined), which symbolise a major asset for the region's socioeconomic development.

On both sides of the border, a remarkable decrease of piezometric level has been recorded with a drying up of some wells, adding to this, the presence of contaminants (nitrate) on the plain. These impacts are felt on both sides of the border, but no action has so far been undertaken because of the bilateral problems. This work is an action reflecting an unofficial cooperation that will evolve to real cooperation by establishing a confidence between the local actors of the two countries. Thereafter, the identification of the objectives and actions will be tacked.

Keywords: transboundary aquifers, Bounaïm Basin, stressed aquifers, Morocco, Algeria, Cooperation

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Riassunto: *Il bacino idrologico di Bounaim-Taffna condiviso dal Marocco e dall'Algeria è un esempio della politica del silenzio e della non cooperazione. Il bacino è situato nel Nord del confine amministrativo tra Marocco e Algeria. E' formato da due acquiferi (confinato e libero) che simboleggiano una risorsa importante per lo sviluppo socio-economico regionale. Da entrambe le parti del confine una notevole diminuzione del livello piezometrico è stata registrata dal il prosciugamento di alcuni pozzi, aggiungendo a questo la presenza di contaminanti (nitrati) nella pianura. Questi effetti si fanno sentire su entrambi i lati della frontiera, ma nessuna azione è stata finora intrapresa a causa dei problemi bilaterali. Questo lavoro è una azione che riflette una collaborazione non ufficiale che evolverà in una reale cooperazione creando un clima di fiducia tra gli attori locali dei due paesi e poi nell'identificazione degli obbiettivi e delle azioni che verranno intraprese.*

Introduction

Despite the engagements achieved in Johannesburg (World bank, 2007) regarding the famous "millennium development goals", the situation has not yet improved in many countries. On the contrary, it seems to have deteriorated. In Morocco and Algeria, fast economic development, demographic growth, and climate change has contributed to both a strong mobilization of available water resources on one hand, but also the pollution of the groundwater on the other. The alarming report of the World Bank (April 2007) on the water situation in the MENA region calls the governments of this entire region to undertake deep political reforms in order to avoid the consequences of serious shortages of water in the future. A better governance of water in the MENA region is an emergency requirement.

This alert highlights some elementary truths and should attract the attention of the political leaders to their short-term responsibility. Water is a precious commodity in Maghreb region, as everywhere else where the water demand exceeds the water supplies. Morocco and Algeria must mobilize efforts to preserve the resource in order to rationalize its management in a more efficient manner, mainly in the agricultural sector (taking into account that 88% of water withdrawal is allocated to irrigation). In 2025, the expected water availability for Algeria is 300 m^3/person/year and for Morocco is 500 m^3/person/year.

Dams and unconventional water will provide new means of mobilizing additional water resources. The estimated total dam storage capacity of Morocco is 16.1 km^3, an achievement which, since 1967, has been a priority in water strategy. Algeria, the other large country of the Maghreb region facing this problem, is currently investing in alternative water resources through a program of construction of desalination plants of sea water (42 units with a combined total capacity of 59 Million m^3/year in 2004 and 28 new units planned for 2009). The two neighbours, Morocco and Algeria, could participate in the setting up of water geopolitics and work together to mobilize their energies and expertises.

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It is in this context that Morocco and Algeria need to promote mutual cooperation and politics of good transboundary water governance, in order to safeguard this "blue gold". Morocco and Algeria can learn from both their own experience as well as the success of their neighbours, and other regions could learn from them.

Methodology

Most of the published literature on transboundary water addresses transboundary rivers. However, transboundary groundwater is also a significant issue. None of the transboundary aquifers in the region are managed or exploited under a multicountry cooperative framework.

The hydrological basin of Bounaïm-Tafna contains two reservoirs: the Angad-Maghnia unconfined aquifer and the Jbel-Hamra confined aquifer. These aquifers constitute a large freshwater reservoir shared between two riparian countries (Morocco and Algeria). They symbolise a major asset for regional socioeconomic development. To date, mismanagement due mainly to groundwater overexploitation has had ominous repercussions on both sides of the border. Currently, a remarkable decrease of piezometric levels has been recorded with a drying up of some wells, and the presence of contaminants (nitrate) on the Angad-Maghnia plain. The groundwater resources in Morocco and Algeria are vulnerable in terms of both quantity and quality.The methodology adopted in this work is shown in Figures1 and 2. For a first "unofficial" cooperation in order to establish confidence between the local actors of the two countries, the choice of the aquifer proposed here has been based on the quantitative importance of the groundwater resources and their contribution to the economic development on both sides of the border. In this case, the extension of the aquifer is limited to the south of the zone (Hauts-Plateaux aquifer). The second criteria is the quantity and quality of the data that allow us to analyze, diagnose and identify the effects, the main problem, and the reasons and constraints (Fig. 1). The diagnoses will make it possible to identify the objectives and actions needed, in order to move from non-cooperation to cooperation.

In the setting of this working paper, the motivation and the scientific curiosity of the stakeholders, rather than the decision-makers, from the two sides, are two components that can promote cooperation through the sharing and processing of data (Fig. 2). On the other hand, at the national level and outside an official bilateral cooperation, a small part of the stakeholders feature an elevated degree of engagement.

In addition, this survey will identify the vulnerable zones and propose actions that could be the precursors of a potential official bilateral cooperation and therefore the utilisation of sustainable shared groundwater in this aquifer.

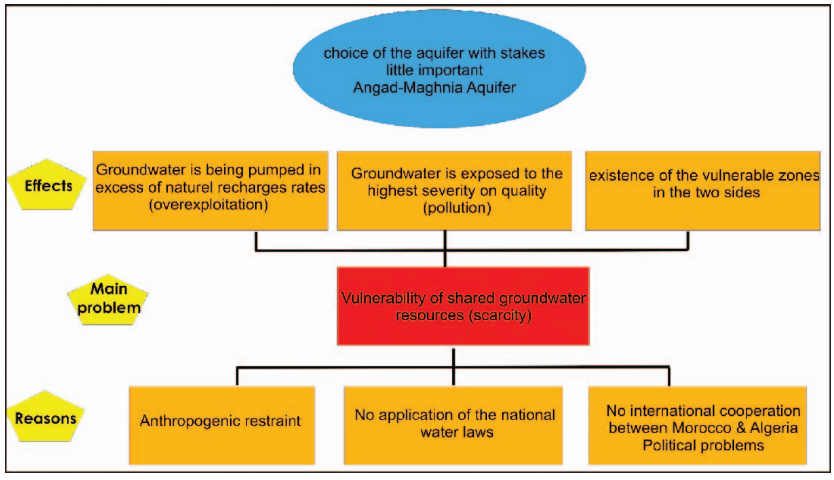

Fig. 1: *Analysis, diagnosis and identification of the problem.*

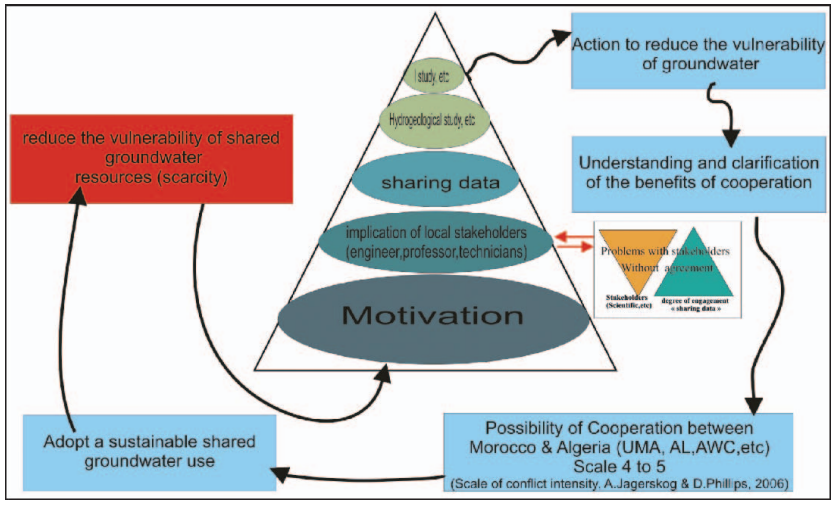

Fig. 2: *Assets and actions.*

Political issues and general context

The geopolitical problems marking the diplomatic relationships between these two countries prior to the signing of the Union of Arab Maghreb Agreement in 1989 cannot be ignored:

- 1963: the War of the Sands
- 1975: 45,000 Moroccan families expelled from Algeria following the start of the conflict of the Sahara.
- 1994: the closing of the borders until now: the border remains a military zone.
- Today: the war of words continues

In this conflict situation, the questions that we can propose are:

- Is water a priority of cooperation in this geopolitical context? And if yes:
- What is the best way to stimulate cooperation over this transboundary groundwater?

Located in the North-Eastern part of Morocco and North-Western part of Algeria, Bounaim-Tafna basin covers 2650 km² (approximately 70 percent of which is located in Morocco) (Fig. 3).

The current population of the Basin is estimated at 615,000 habitants: 114,000 habitants in the plain of Maghnia (Algeria) and over 500,000 habitants at the plain of Angad (Morocco). The largest city in the basin is Oujda (Morocco), with nearly 430,000 inhabitants and a growth rate of 1.2 percent.

The region has suffered both economically and socially because of the conflict between Morocco and Algeria. In this area, the water of the aquifer is used mainly for agriculture (80%) with little economic return. No control of water abstraction is carried out, and the crops produced in this region have only a minor positive impact on the quality of life of the population. The water use in this region is without added value, as long as poverty and illiteracy remain a major handicap. The unconfined aquifer is polluted heavily by nitrate (Boughriba et al., 2010), and in the some places the population uses untreated groundwater for drinking, risking adverse health impacts, especially to children. The unconfined aquifer is overexploited and the water is used for drinking water in Morocco and for agricultural activity and drinking water in Algeria

The hydrological basin of Bounaim-Taffna and the aquifers shared between Morocco and Algeria are extensively stressed and impacted not only by the aridity of the climate, but also by anthropogenic activities (overexploitation and pollution). These impacts are felt in both sides the border, but no action has so far been undertaken, although at the national level both countries have passed water laws (04 September 2005, newspaper official N°60, for Algeria and January 1995, for Morocco) and have adopted the principle of Integrated Water Resource Management.

The hydrological basins of BouNaïm-Tafna and the aquifers (Figures 4 and 5) are located in the north of the Morocco-Algerian administrative border. These two basins represent examples of the politics of silence and non-cooperation. In this region, mutual accusations have been recorded in relation to wastewater disposal and its adverse effects (Fig. 4). This is a hydro-geo-politically vulnerable zone, and should be the subject of an assessment and periodical surveillance, to ensure sustainable and equitable management.

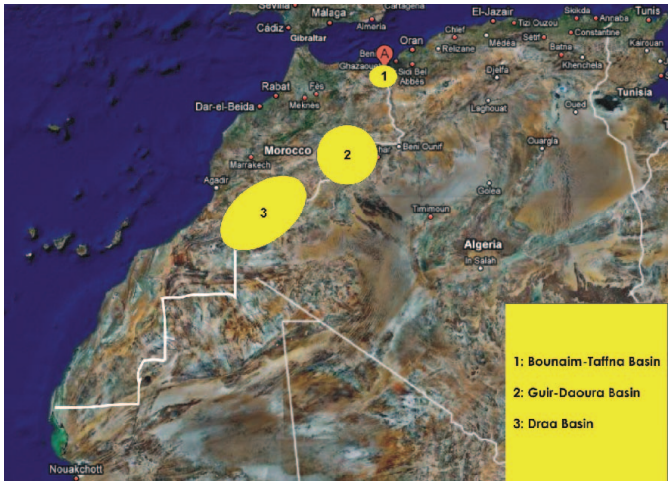

Fig. 3: *Transboundary basins shared between Morocco and Algeria.*

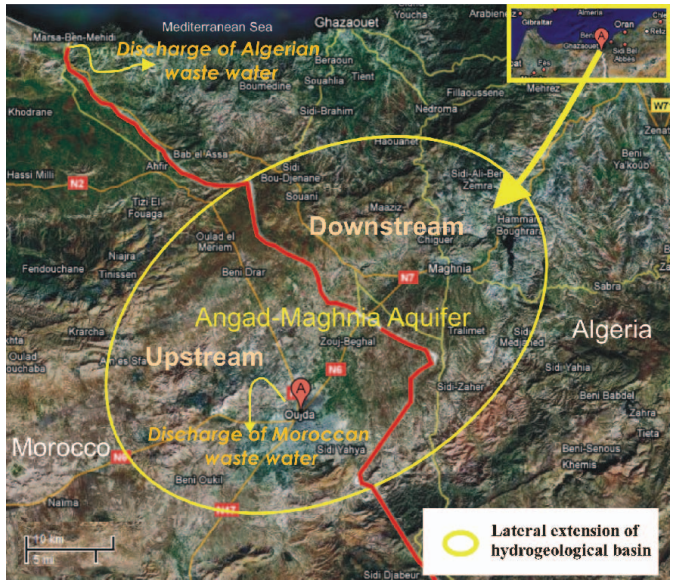

Fig. 4: *The localisation of the Angad-Maghnia aquifer.*

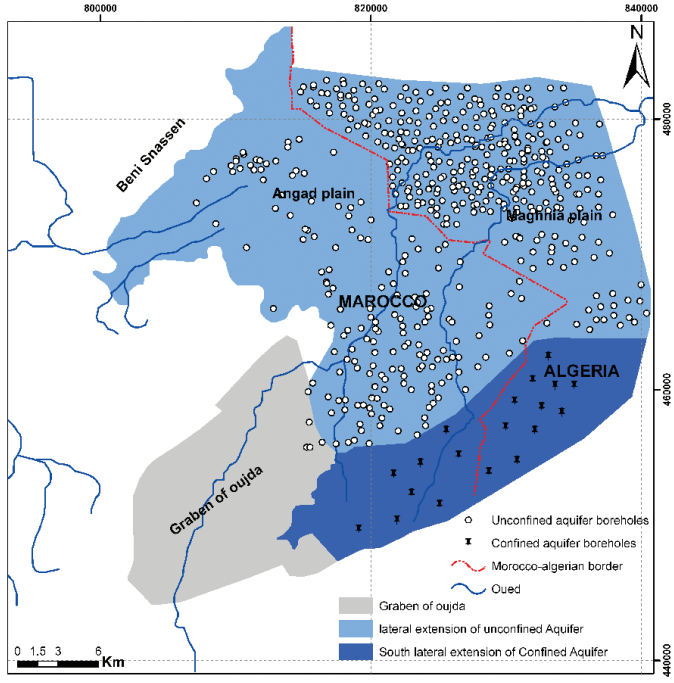

Fig. 5: *Transboundary Aquifers (confined and unconfined).*

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Hydrogeological context

Unconfined aquifer: Angad-Maghnia aquifer:

The region has an arid climate, with large temperature and rainfall variations. Average annual temperature and rainfall are about 18°C and 230 mm respectively, and the region is characterized by a high evaporation rate.

The important aquifer (780 Km^2) shared between Morocco "upstream" and Algeria "downstream" is located in the Plio-Quaternary layer system (Figures 5 and 6), which is constituted by heterogeneous rock (sand, grava, basalt and silty clay, etc.). The thickness of the aquifer varies between 20 m and 120 m. The water table varies in depth between 10 m and 80 m. The aquifer is intercepted by more than 4000 wells at both sides of the border (Fig. 5).

Groundwater recharge is assured by a direct infiltration of received surface water on the Angad-Maghnia plain, and also water flow from the Moroccan part to Algerian area (34 Mm^3/year, Lahrach, 1999).

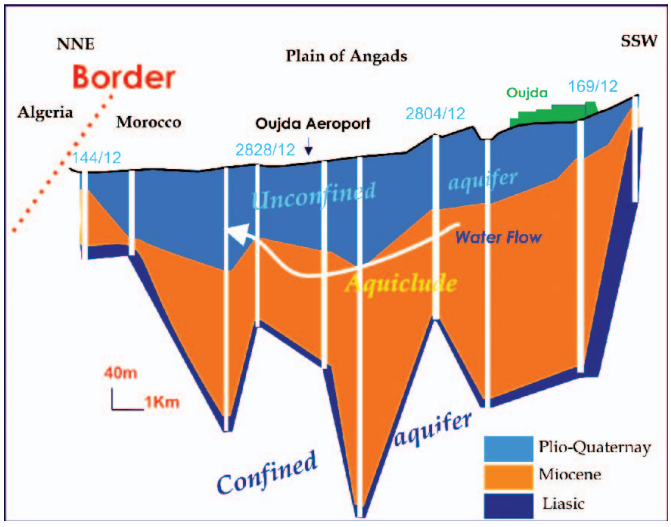

Fig. 6: *Hydrogeological cross section.*

Groundwater deterioration in the Moroccan side

Quantitatively, the piezometric map (June 2007) shows the fall of the Angad water table with the onset of depression in some areas south and north of the Angad plain (Fig. 7). In qualitative terms, the measured salinization reflects the progressive growth of this parameter. Not only are we assisting a decrease in the number groundwater resources, but we are also contributing to a qualitative deterioration (Boughriba et al., 2010).

Vulnerability assessment

Vulnerability is a construct designed to help planners protect aquifers as an economic resource. There has not yet been a general agreement on what the strict definition of vulnerability should be (Vrba and Zoporozec, 1994), and the term vulnerability has come to mean different things in different contexts. It generally refers to the sensitivity of groundwater to contamination. This concept is based on the assumption that the physical environment may provide some degree of protection to groundwater against human activities.

The modified DASTIC model was used in this case to identify the vulnerable area in the Moroccan side. DRASTIC is an acronym for the most important hydrogeological features which control groundwater pollution: Depth to water, Net Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone media, and hydraulic Conductivity of the aquifer. The seven parameters cut, in a schematic way, a local hydrogeological unity into its main components, which, in varying degrees, affect the processes of transport and attenuation of contaminants in soil and their transit time. Each of the hydrogeological factors is assigned a rating from one to ten based on a range of values. The ratings are then multiplied by a relative weight ranging from one to five. The most significant factors have a weight of five; the least significant have a weight of one. A Geographic Information System (GIS) is used to compile the geospatial data, to compute the DRASTIC indices, and to generate the final vulnerability map. The equation for determining the DRASTIC index is:

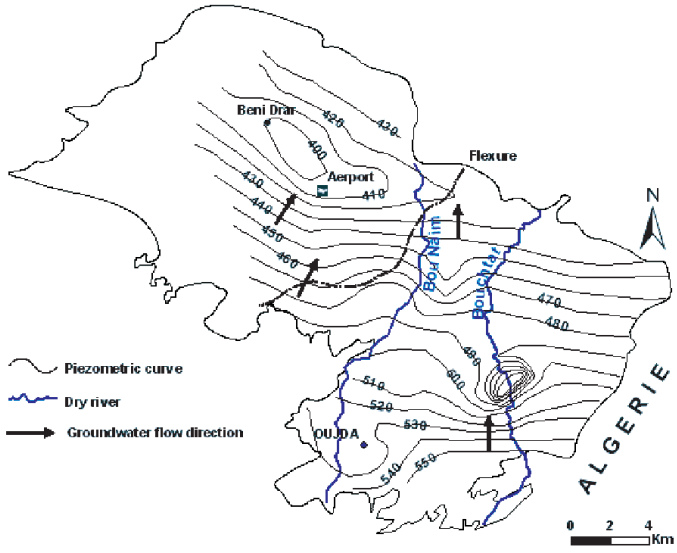

Fig. 7: *Piezometric map.*

$$ID = Dr\,Dw + Rr\,Rw + Ar\,Aw + Sr\,Sw + Tr\,Tw + Ir\,Iw + Cr\,Cw$$

Where D, R, A, S, T, I, C represent the seven hydrogeologic factors, r designates the rating, and w the weight.

The resulting DRASTIC index represents a relative measure of groundwater vulnerability. The higher the DRASTIC index, the greater is the vulnerability of the aquifer to contamination.

In this study, the DRASTIC method was modified in response to certain characteristics of the Angad plain; indeed, depth to water alone does not provide a protection for groundwater against the contaminants infiltration. It is possible that the pollutant easily taints the aquifer with the presence of fractures even if the aquifer is deep (Lee S. R and al., 1998). Following this logic, the Modified DRASTIC system is sum of DRASTIC system and Fractures density, which is obtained by using aerial photographs and geological maps. Higher fractures density values may represent more potential to groundwater contamination.

Modified DRASTIC index =
DRASTIC index + (Distribution density rating x 5)

The modified DRASTIC map shows three degrees of vulnerability: Moderate, High and Low (Fig.8).

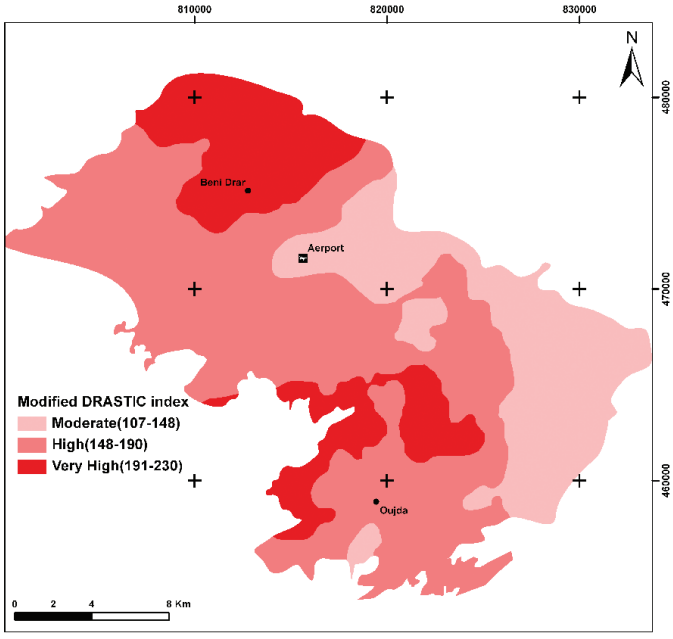

Fig. 8: *Vulnerability map of the unconfined aquifer (Moroccan side).*

Confined aquifer: Jbel Hamra aquifer

Jebel Hamra is an asymmetrical anticline whose axis is oriented roughly east-west. Its heart is made up of Paleozoic and Triassic formations and its flanks by dolomitic limestones and dolomites of the Lower and Middle Lias. These levels are overlain by calcareous marly formations of Upper Lias age. In the north, the foundations of Jebel Hamra continues under the Angad plain.

These formations constitute the reservoir of Jebel Hamra. The impermeable Triassic deposits adjusted and the faults bounding the horst form the lateral limits of the aquifer. The bedrock is formed by marls and Triassic basalts and the roof is composed by Miocene marls at the plain.

The depth of the aquifer is variable. Its thickness is 250m. The static level of the water is between 40 and 110 m for the ground in the Moroccan territory and about 25-145 m in Algeria. The boreholes are deep: 100-400 m from the Moroccan side and 320 to 650 in Algeria.

The aquifer is characterized by good hydrodynamic parameters. The transmissivity is particularly high; it is about 1.10-1 m^2/s. The storage coefficient is around 10^{-3}.

Groundwater quality and chemical facies

In the confined aquifer, the salinity varies between 0.5 to 1.2 g/l in Morocco and from 1.1 to 2.8 g/l in Algeria. The temperature is from 21 to 52 °C. From a chemical point of view, three facies are represented: bicarnonate, chloride and sulfate.

The high levels of sodium, chloride and sulphate were probably acquired by a localized leaching (in space or deep) of gypsiferous deposits and salt-bearing Triassic; such is the case in Algeria with the boreholes MOH1 et SAL (depth > 600 m) and the boreholes 253/12, 2916/12 and 159/12 in Morocco.

Recharge of the aquifer

The recharge of the aquifer is estimated at 9.5 Mm^3/an, realised by a direct infiltration of rainfall through an impluvium 15 km^2 and by downward seepage from a pool of 300 km^2.

A further contribution is provided through hydraulic connections with the adjacent basins, and this is to allow the infiltration of flood-waters around the neck of Metsila (Oued Sedra) and the Guenfouda Gully (wadi Isly).

Exploitation of the aquifer

The Jebel Hamra aquifer was initially used exclusively to supply drinking water to the city of Oujda. Initially, the operation was limited to the catchment of Sidi Yahia source, with 300 l/s. Then, since the 1960s, the samples have started to rise by the addition of a battery of wells, reaching over 750 l/s in 1982. The operation was reduced thereafter to around 600 l/s through a dozen holes.

Since 2004, eleven other holes were drilled on the Algerian side to meet drinking water needs of the Algerian population in the Bounaim Basin. The boreholes are operated with ten to 60 l/s. There are seven reservoirs built in the Zouia area (Algeria) with radii of 5-35 m and heights of three m). Unfortunately, exact data about the mobilized volumes in this sector are not available at present, and even the number of reservoirs and their dimensions are undefined, they were determined from the satellite image (seven reservoirs of capacity estimated between 150 and 1200 m^3 depending on size) (Fig.9).

Fig. 9: *Reservoir in the Morocco-Algerian boundary (Algerian side).*

Climate change and groundwater stress

The Basin is characterized by irregular rainfall, brutal and usually torrential, causing an important run-off, but at the disadvantage of the natural recharge of aquifers.

The treatment of rainfall data (Fig.10) shows that rainfall shows a downward trend in the three weather stations at Oujda (Morocco), Beni Maghnia, and Ouassini (both Algeria). Also, the overexploitations as-

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sociated with climate change have caused a decrease of groundwater level of 2 to 3 m/year since 1982 (Fig. 11). After the commissioning of wells in Algeria (Bensouala and Adjim, 2006), a decrease of 6 to 7 m/year was recorded between late 2004 and late 2006 (7 m/year for 2005).

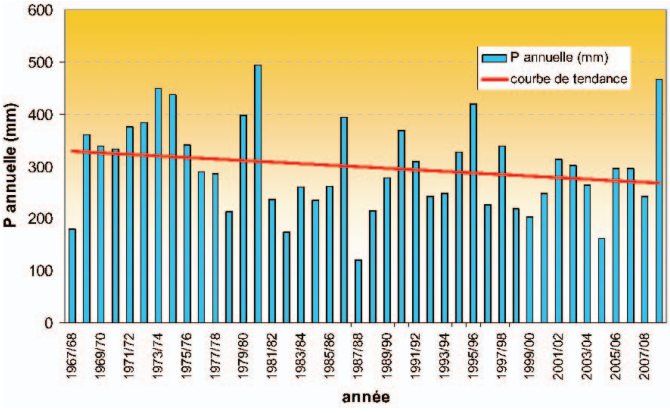

Fig. 10: *Evolution of rain-off in the basin.*

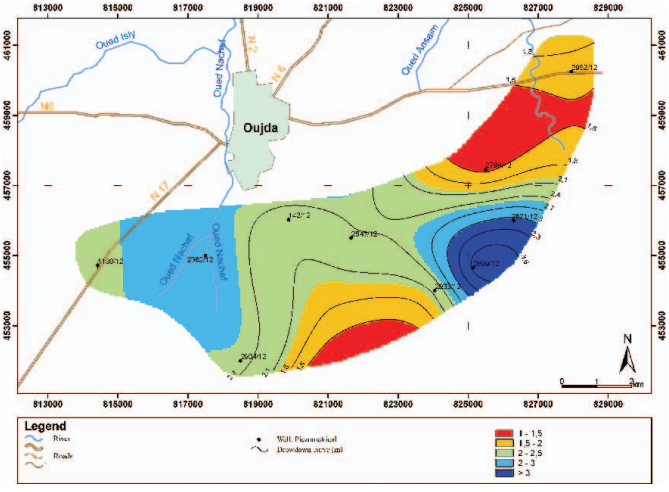

Fig. 11: *Drawdown of the confined aquifer (Moroccan side) (ABMH, 2004).*

Conclusion and discussion

Transboundary groundwater is more vulnerable than surface waters, and the present study reveals adverse anthropogenic impacts on the Angad-Maghnia aquifer, both in relation to quantity and quality of the aquifer. These affect both the Moroccan and Algerian use of the aquifer.

To better understand the Angad-Maghnia aquifer, and to assure its improved protection, a first step of merit would involve technical cooperation between the scientific communities of Morocco and Algeria. This could be promoted through the creation of a Maghreb Scientific Association, through which data exchange and technical discussions could occur. During the course of the present study, Algerian colleagues assisted in the provision of data and in discussions.

Action needed in the short and medium term:

The current exploitation of the aquifers in the basin exceeds its potential, and in transboundary context, the management of the resource cannot be unilateral; such management would be ineffective if no similar action were taken by other users. On the other hand, a credible and indisputable management should integrate all the basin resources as well as oversee opportunities for development. In this logic, some actions are proposed in this study for an adequate and plausible IWRM of the Bounaim-Tafna basin:

- Sharing data
- Make a joint committee-board for the reflection and monitoring of the water resources states of the Bounaim-Tafan basin, in view of preparing the start of negotiations on the management of transboundary water resources
- Consider the confined aquifer as a strategic resource
- Reduce withdrawals from the unconfined aquifer
- Reuse treated wastewater for irrigation in the Agnad plain (Moroccan side) and the transfer of surface water to the Maghnia plain for agricultural purposes (Algerian side).

Constraints to cooperation

Transboundary cooperation relating to groundwater is more complex in time and space than that needed for surface waters because:

- groundwater moves in 3 dimensions;
- the groundwater recharge and discharge rates vary in various timescales, from within a few hours to thousands of years;
- groundwater basin boundaries are not as obvious as those of river basins, and can change with the rates of groundwater abstraction;
- unconfined aquifers are more vulnerable than confined aquifers; and agreements should integrate all the stakeholders (farmers, domestic users, etc.), making cooperation more challenging.

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