Synthesis Collection

No. 1

THE NORTH-WESTERN SAHARA AQUIFER SYSTEM

CONCERTED MANAGEMENT OF A TRANSBOUNDARY WATER BASIN

OSS

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THE NORTH-WESTERN SAHARA AQUIFER SYSTEM

(ALGERIA, TUNISIA, LIBYA)

Concerted management of a transboundary water basin

Tunis, 2008

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No. 1 The North-Western Sahara Aquifer System: joint management of a trans-border water basin

No. 2 Iullemeden Aquifer System (Mali, Niger, Nigeria): concerted management of shared water resources of a sahelian transboundary aquifer

No. 3 Long-Term Environmental Monitoring in a Circum-Saharan Network: the Roselt/OSS experience

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Lamine Baba Sy, Charles Baubion, Ousmane S. Diallo, Djamel Latrech, and Ahmed Mamou have participated in this work, which is the outcome of their conjugated efforts.

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We hope that they find in this work the fruit of their candid collaboration.

CONTENT

INTRODUCTION

The North Western Sahara Aquifer System (NWSAS), shared by Algeria, Libya and Tunisia contains considerable water reserves, which are nevertheless lowly renewable and not fully exploitable. During the last thirty years, the exploitation of NWSAS waters by drilling increased from 0.6 à 2.5 billion m^3/an. Because of the non-concerted withdrawal multiplication, the resource is now confronting many risks such as water salinity, artesianism reduction, natural discharge depletion, piezometric level fall, or interferences between countries, thus seriously threatening the sustainability of socio-economic development in the entire zone.

In the face of such risks, a cooperation process between the three countries sharing the NWSAS water resources is crucial. This is the spirit of the NWSAS project facilitated and implemented by the Sahara and Sahel Observatory (OSS) in collaboration between the three countries. The joint work has focused its programme on the scientific stakes in the first place, enabling a significant knowledge improvement of the aquifer system, based on information exchange and a joint definition of working hypotheses among the three countries. The simulations by the mathematical model built within such framework have highlighted the most vulnerable areas in the medium and long terms. They have also enabled identifying new withdrawal zones that could increase the current exploitation while ensuring risk control through a reinforced consultation among the three countries. To this effect, the scientific cooperation is gradually leading to the establishment of a formal institutional framework for the management of shared water resources among the three countries, i.e. the Consultation Mechanism.

This publication presents the main obtained results from the implementation of the different components of the project: hydrogeological data collection, analysis, and synthesis; elaboration of a common database and an information system; development and exploitation of the NWSAS mathematical model and the regional sub-models; establishment of a consultation mechanism for the basin joint management; socio-economic study; and environmental study.

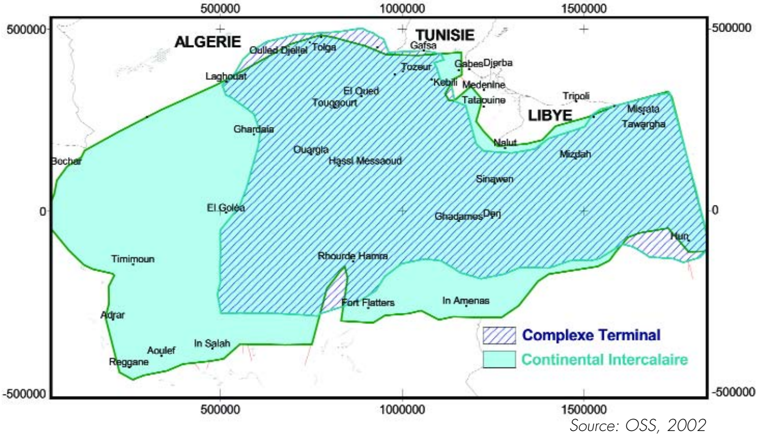
Figure 1: Location of the North Western Sahara Aquifer System

Source: ESA TIGER - AQUIFER Project, 2007

NWSAS, A COMPLEX SYSTEM TO MANAGE TOGETHER

1- The NWSAS issue

The North Western Sahara Aquifer System designates the superposition of two main deep aquifer layers: the Intercalary Continental (IC) and the Terminal Complex (TC). The system covers an area of over 1 million km^2 including 700,000 km^2 in Algeria, 80,000 km^2 in Tunisia and 250,000 km^2 in Libya (Figure 2).



Source: OSS, 2002

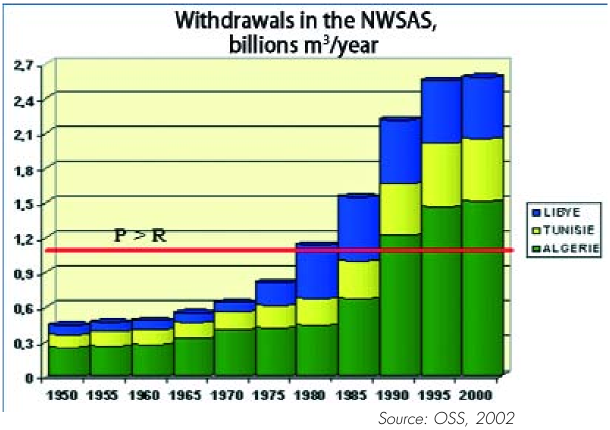
Figure 2: NWSAS formation extension

Given the arid-to-Saharan climate conditions, these formations are slightly recharged: the system recharge represents about 1 billion m^3/year, essentially percolating in the Saharan Atlas piedmont plains in Algeria, the Dahar in Tunisia and Djebel Nefoussa in Libya. However, the system extension and the layer thickness have facilitated the accumulation of considerable reserves over the past centuries.

How then to exploit the Saharan basin beyond the recharge rate by pumping in the accumulated reserves within a sustainable management perspective? How can we ensure maximum water withdrawals for the region's best development without irremediably degrading the resource? It is in these terms that we pose the question of the NWSAS water resource exploitation.

About 8,800 water points, drillings, and springs exploit the Saharan Aquifer System: 3,500 in the Intercalary Continental and 5,300 in the Terminal Complex. Per country water points are as follows: 6,500 in Algeria, 1,200 in Tunisia and 1,100 in Libya. Increasing drilling numbers and exploitation mode evolution indicate extremely strong withdrawal rates in the last twenty years (Figure 3): the exploitation has today reached 2.5 billion/year (i.e. 1.50 in Algeria, 0.55 in Tunisia and 0.45 in Libya) against 0.6 billion in 1970. If the trend observed in the countries continues, there will undoubtedly be serious reasons for concern for the future of Saharan regions where we have already recorded the first signs of water resource deterioration.

Figure 3: Total withdrawals in the Saharan aquifers in billions m³/year



Source: OSS, 2002

The intense withdrawal evolution in the NWSAS aquifers has profoundly modified the view that we can have from now on about this exploitation, which is confronting a number of major risks resulting from its development: strong interference between the countries, end of artesianism, natural discharge depletion, increased excessive drawdowns, water salinity… Therefore, the three countries concerned by the system's future have to jointly search for some form of an optimal and concerted Saharan basin management.

2- Improved knowledge for a joint management: NWSAS project

Well aware of the risks, the three countries' authorities have decided to undertake a major joint study programme. They entrusted OSS with its management and fund searching. In 1998, OSS obtained the support of Swiss Agency for Development and Cooperation (SDC), International Fund for Agricultural Development (IFAD) and Food and Agriculture Organisation (FAO) for a first three-year phase up to December 2002. During this phase, the NWSAS project objectives and activities comprised many components: hydrogeology, information system, overall mathematical model, and consultation mechanism.

The project then entered in a new phase up to 2006 with a view to pursuing the fruitful cooperation and concertedly identifying the technical tools leading to a standing consultation mechanism: an institution that can manage the NWSAS water resources. In partnership with the three countries, the financial support provided by the Global Environmental Facility (GEF/UNEP), the Swiss Agency for Development and Cooperation (SDC) and the French Global Environmental Facility (FGEF) has enabled OSS to implement the programme's second phase. In addition to continuing the work on hydrology, the information system, and the consultation mechanism, the project also addressed the environment and socio-economic issues relating to resource mobilization in the NWSAS basin.

The project third phase, starting in 2007, aims at improving knowledge of the socio-economic and environmental aspects, developing the use of innovating technologies such as remote sensing for estimating irrigation water consumptions, and sustaining the Consultation Mechanism, formally established in November 2007. The African Water Facility (AWF), the FGEF, and the GEF/UNEP jointly support the third phase.

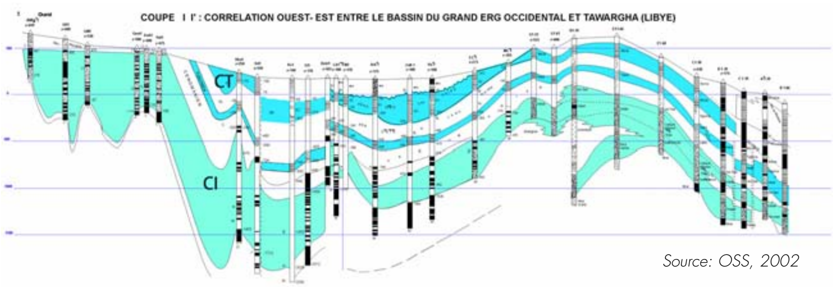
OBTAINED SCIENTIFIC RESULTS

During the various phases, the NWSAS project has made it possible to significantly improve the knowledge of NWSAS hydrological behaviour, the risks it faces, and the related socio-economic and environmental conditions. The three countries' built knowledge base represents a fundamental element in the system's joint management. Here follows a summary of the main research results.

1- Aquifer system operation and modelling

1.1- Aquifer system knowledge

The NWSAS project has firstly focused on the entire basin geology and hydro-geology. It is by combining a large number of geological cross-sections obtained thanks to recent geological boreholes (including 175 oil drillings) and new hydrogeological prospections that we have defined the NWSAS structure.



Source: OSS, 2002

Figure 4: NWSAS East-West simplified geological cross-section and drilings

a. Horizontal structure

The NWSAS general structure is broken down in three West to East sub-basins:

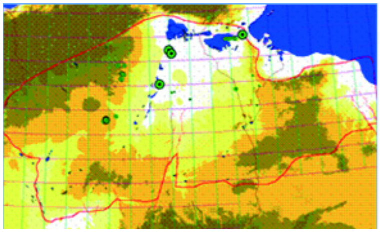
- The western basin includes the Foggaras sector to the South[1], and the Great Western Sand Sea (Grand Erg Occidental) and Saharan Atlas to the North.
- The central basin, the most extended in surface area and depth, represents the largest aquifer thickness. The three countries share its resources. It is limited to the West by the M'zab ridge and to the East by El Hmadah El Hamra table. The Great Western Sand Sea (Grand Erg Occidental) and the Algero-Tunisian Chotts dominate its morphology[2].
- El Hamada El Hamra table, the Hun Graben rockslide, and the accumulation of tertiary deposits characterize the oriental basin.

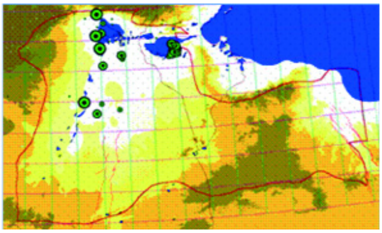
b. Vertical structure

The Saharan basin is a large multilayer deposit entity. The adoption of a simultaneous representation of these complete layers makes it possible to take stock of the hydraulic and chemical links and exchanges among each other and, consequently, the medium and long-term system behaviour. The hydro-geology has become clearer thanks to a 50-year hydrodynamic study (1950 - 2000) of the piezometry (water level), water salinity, and its exploitation. The result of this subtle geological and hydrogeological basin's analysis enabled schematizing the aquifers with a view to establishing a mathematical model of exchanges and water outflows within the aquifer system. Thus, the NWSAS multilayer will be simplified into three superposed aquifers, separated by or linked through semipermeable layers: the Intercalary Continental (IC) aquifer, the more local Turonian aquifer, and the Terminal Complex (TC) aquifer.

1.2- NWSAS database

Figure 5a: Drilling Withdrawals in NWSAS in 1970 (IC and TC)





Source: OSS, 2002

[1] The foggaras are traditional gravity catchment systems of the piedmont groundwater. They are very common in Algeria where they are used to irrigate palm groves in the Western Sahara basin.

[2] Permanent salty water stretches, with changing shores, situated in the arid and Saharan regions. The Chotts are discontinuously fed during the scarce rainfalls and usually by the deep water tables to which they serve as natural outlets. They undergo a strong evaporation accumulating salt on the silt surface, and are occasionally exploited.

The NWSAS project aims to elaborate a common database for integrating and streamlining all the surveyed information, in addition to new data collection, integration and updating. Such an objective requires that the national databases be adapted and homogenized. This implies homogenized data structures and codifications, a GIS interface and the elaboration of an access module with the digital model.

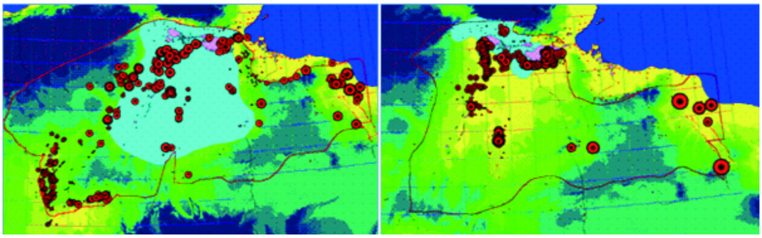


Figure 5b: Drilling withdrawals in NWSAS in 2000 (IC and TC)

Source: OSS, 2002

The Information System (IS) elaboration included the diagnosis, design and realization of a common database, with the objective of making IS accessible simultaneously in the project's headquarters and in each water administration of the three countries. The diversity and multiplicity of operations carried out on 9,000 inventoried water points appraise the amplitude of the task: collection, classification and identification system homogenization, criticism, aberrant data detection, correction, and validation. The obtained information system allows data updating and addition, statistical requests, graphs, and model connections. The system contains all the basic elements to establish the monitoring control panel and basin water exploitation. Now we have a very good quality management tool operating in each administration in the three countries.

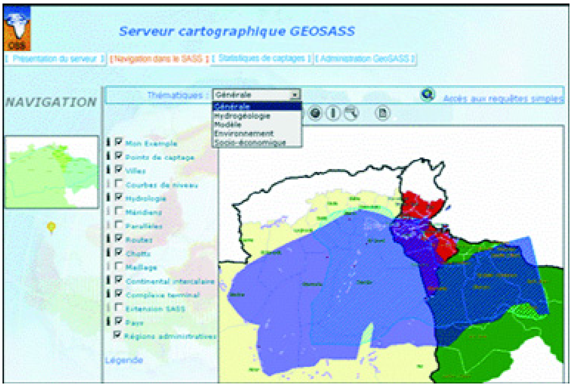


Figure 6: GEOSASS map server

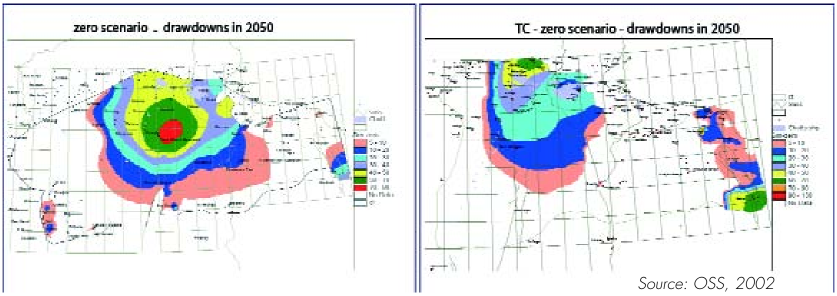
Source: OSS, 2005

At the same time, we have elaborated a specific NWSAS cartographic server to ensure a geo-referenced representation of the available information. This multilayer and thematic representation acts as a decision support tool for planners and makes it possible to go beyond the national framework to appreciate better the exploitation development impact. The server is available on the following Internet URL: http://www.geosass.oss.org.tn/geosass.

1.3- NWSAS model and results

Once the NWSAS geology and hydrogeology are better understood, its structure simplified, the data gathered, homogeneized and organised in the database and the GIS, the hydrodynamical model of the aquifer system could be built. The model has been calibrated and validated under the actual conditions. This has confirmed the hydrological behaviour of the system and allowed to identify more precisely the risk-prone areas. Then the model has been used under various prospective hypotheses, in order to assess future scenarios of withdrawal evolution as well as of water resources protection in the risk prone areas. The 1950-2000 data has been used for the calibration and validation of the model. Its exploitation to simulate future scenarios up to 2050 helped characterize the risks faced by the North Western Saharan Aquifers.

Figure 7: Evolution of drawdowns in 2050 according to the 'zero scenario'



Source: OSS, 2002

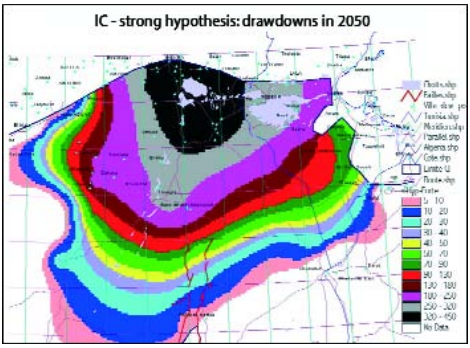


Figure 8: Evolution of drawdowns in 2050 (IC) according to the 'strong hypothesis' scenario

Source: OSS, 2002

Results of the exploratory simulations

Reference scenario

We defined a reference scenario as the zero scenario by keeping constant the overall withdrawals between 2000 and 2050 and calculating the system's corresponding evolution in the horizon of 2050.

For the IC: The zero scenario would lead to significant drawdowns over 40 meters in the Algerian Sahara lower part. In Tunisia, they would approximately reach 20 to 40 meters around Chott Fedjej. In Libya, the drawdowns would be about 25 meters.

For the TC: In Algeria and Tunisia, the drawdowns would exceed 30 meters around the Chotts. In Libya, they would reach 60 meters. There is also the disappearance of artesianism in the Algero-Tunisian Chott region, with the significant risk of water intrusion from the Chott recharge into the TC's aquifer and salt contamination. From this perspective, the continuation of the current pace represents a major potential danger to the region.

"Strong hypothesis" scenario

The "strong hypothesis" scenario predicts a withdrawal increase of 101 m^3/s in Algeria from 42 m^3/s to 143 m^3/s between 2000 and 2030, while maintaining the current withdrawals in Tunisia (the additional demand being met by irrigation efficiency improvement).

For the IC: Drawdowns are 300 to 400 meters in the Algerian Sahara lower part, with the complete disappearance of artesianism. This scenario does not affect Libya. In Tunisia, drawdowns are from 200 to 300 meters, with the significant disappearance of artesianism and Tunisian outlet flow recession[3].

For the TC: This scenario does not affect Libya. There are important drawdowns in Algeria. The Chotts can re-supply, with the risk of water table salinisation.

"Weak hypothesis" scenario

The "weak hypothesis" scenario predicts a withdrawal increase of 62 m^3/s in Algeria from 42 m^3/s to 104 m^3/s between 2000 and 2030, while maintaining the same unchanged withdrawals in Tunisia. The effects in Algeria as well as in Tunisia are very strong and as such unacceptable for the IC and the TC.

Libyan GMRP scenarios[4]

The exploratory simulations deal with two Great Man-made River Project (GMRP) programmes: The Ghadames-Derj pumping field, with an additional flow of 90 Mm^3/year, equivalent to 2.85m^3/s, and the Djebel Hassaounah collecting field. In Ghadames, the drawdowns in the IC are 100 meters in the collecting field, with an additional drawdown impact of around 50 meters in the Tunisian deep south and Debdeb in Algeria. The IC impact of Djebel Hassaounah collecting field remains negligible.

[3] Communication zone between the Saharan basin IC and the Djeffara aquifer of the Tuniso-Libyan coastal plain. The underground transiting flow represents the major part of this coastal aquifer's feed.

[4] Great Man-Made River Project: The Libyan project consists in mobilising and transferring the fossil aquifer water of Nubia and Murzuk sandstone basins, contiguous to NWSAS, to the coastal zones.

These exploratory simulations have highlighted the harmful effects and risks threatening the basin water resources. To continue IC and TC aquifer exploitation, we have to alleviate and manage the following risks:

1. Disappearance of artesianism;
2. increasing excessive pumping depth;
3. Tunisian outlet recession;
4. Foggaras drying;
5. drawdown interference in the countries;
6. Potential TC recharging by the Chott salty waters.

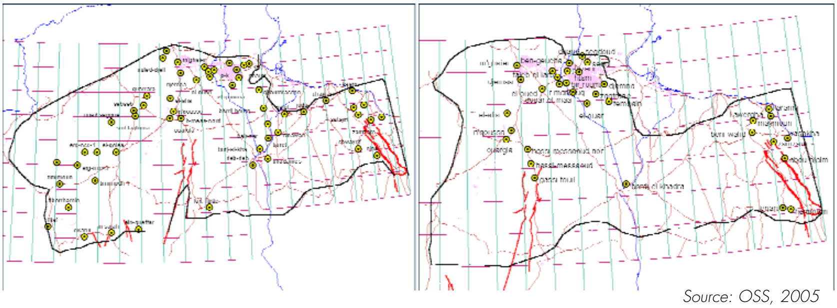
1.4- Towards searching for solutions: NWSAS micro-model

a. Numerical model significance

The first simulation results have highlighted the limitations of the "pure simulation" approach in defining an NWSAS development strategy. In fact, the various defined scenarios with a "strong hypothesis" and a "weak hypothesis", which first seemed to be appropriate for guiding the decision-makers and the conceivable solutions, appeared, in view of the results, to have serious consequences on the future of NWSAS water resources.

For this reason, we decided to search for a new approach to the common definition of acceptable solutions based on a numerical model. The adopted principle was to dismiss development scenarios solely based on water demand predictions in the three countries and search for building 'hydraulic'-based scenarios, which would take the NWSAS output capacity as an input, and minimize the identified risks. The first stage in such a process consisted in listing potential pumping sites in each country. We have singled out the closest sites to the areas where a current or future demand would probably be the strongest. However, we did not refrain from prospecting potential sectors that could be distant from the potential demand sites but suitable for export.

Figure 9: Potential pumping sites in IC and TC (left) and TC (right)



Source: OSS, 2005

How can we ensure maximum water withdrawals for the best regional development without risking degrading the resource as such? Moreover, how can we formulate the "best" exploitation pattern in the same sense? To this end, we designed the NWSAS numerical micro-model. We first need to make a list of all the incurred risks and identify the constraints that we need to observe to minimize these risks. This requires quantifying the risks, i.e. knowing how to model them. The NWSAS Numerical Model precisely fulfils this function.

b. Western Basin exploitation potential

The numerical model application has made it possible to check whether there is an opportunity to increase the NWSAS drilling exploitation, estimated at 2.5 billion m^3 in 2000, to 7.8 billion m^3/year in the horizon of 2050, while respecting the risk constraint of resource degradation. We can achieve such a resource development level only at the cost of completely breaking away from the traditional intensive exploitation regions. In fact, 80% of the additional withdrawals will have to be done in "new" distant regions, essentially in the unconfined part of the aquifers: 3.5 billion in the IC Western Basin and 0.6 billion on the Algerian CT borders. This drilling exploitation would represent 6.1 billion m^3/y in Algeria, 0.72 billion m^3/y in Tunisia, and 0.95 billion m^3/y in Libya. Such a possibility would increase the NWSAS exploitation regime to a level representing 8 times its renewable resources. Such an option is only attainable through an important pumping of the system reserves. However, we must underscore the need for confirming some obtained results: in spite of the achieved progress by the NWSAS project, some uncertainty subsists about the system knowledge, and further investigations are required.

1.5- Development of more refined local modelling

This huge work has made it possible to clarify the main NWSAS exploitation risks and stakes. An independent scientific evaluation committee[5] has underscored the modelling quality and its contribution to improving knowledge on the system as a whole. It has also recommended further modelling refining in three main sectors: the Western Basin, the northern Chott region (Biskra) as well as the Djeffara Tuniso-Libyan plain. We have thus built the three NWSAS hydrological sub-models to refine water assessment and aquifer exchanges in these zones during the second NWSAS project phase.

[5] de MARSILY G., KINZELBACH W., MARGAT J., PALLAS P., PIZZI G., Observatoire du Sahara et du Sahel, Système Aquifère du Sahara Septentrional (SASS), Avis du Comité d'Evaluation sur le modèle du SASS, janvier 2002.

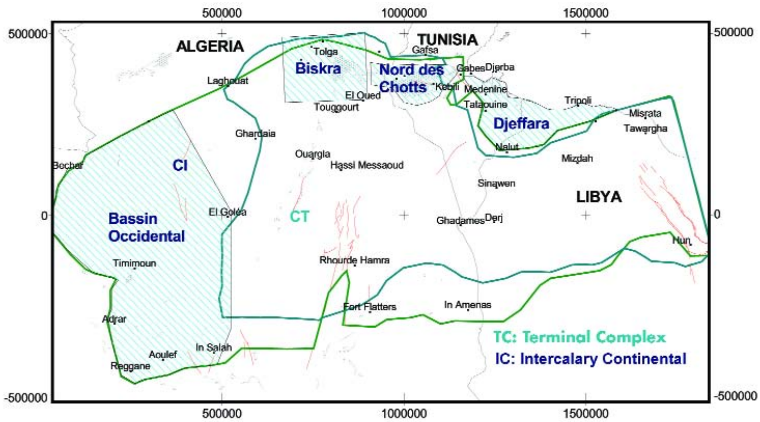
a. Confirmation of the Western Basin exploitation potential

This NWSAS part is the only one that offers a significant potential, with its recharge from the Atlas, its free water table, and its gravitary exploitation by the Foggaras. Here a variable-mesh model has made it possible to represent more precisely the exploitation of the Foggaras areas (Gourara, Touat, Tidikelt), and to evaluate the predictable influences of the initiated or programmed drilling exploitation. The model has confirmed the important aforementioned transfer potential. It has also clarified the gradual recession of the Foggaras flows.

b. Risk location in the Northern Chott region (Biskra)

The NWSAS model has shown that the Algero-Tunisian Chotts area in the Terminal Complex (TC) is the most exposed. Here, the water table is most vulnerable. This is the area where we find the strongest population density and where the pressure on the resource will be the strongest. The model calculation output has clearly shown that the simple continuation of the current withdrawals would lead, in the horizon of 2050, to additional drawdowns of 30 to 50 meters in each of the two water tables and the entire zone. Such a situation would be unacceptable for the Terminal Complex: the risk of the Chott salty water percolation to the water table would be fatal for the latter because of salinity.

To continue with the existing situation, at least in the Terminal Complex (TC), would be utterly unacceptable for the Chott region. For such reasons, we have developed a sub-model for this NWSAS part to establish if we have to take into account the flow inversion risk between the Chotts and the aquifers, with the consequence of increased salinity. Thus, the undertaken forecast simulations have shown that the calculated drawdowns for 2050 are excessively high, especially in the Mio-Pliocene table on the entire oriental part of the plain: 100 m to 200 m of counted drawdowns compared to the situation in 2000, which had already been difficult to accept in terms of its sustainability. The high salinisation risk in the region's entire system is therefore real. The realization of the Biskra sub-model has made it possible to assess the risks and establish a monitoring network. It has enabled a thorough study of the NWSAS project and has raised the hope for solidarity among the users in confronting the risks.



Source: OSS, 2005

Figure 10: Location of NWSAS sub-models

c. Modelling of the Djeffara coastal aquifer system, the NWSAS natural outlet

The Djeffara aquifer system does not intrinsically belong to NWSAS. However, it is closely related to it because its water supply essentially emanates from the Intercalary Continental (IC) via the NWSAS Tunisian outlet. In addition, the resource exploitation in the Tuniso-Libyan plain has witnessed an intensive development over the last thirty years. Improving NWSAS knowledge has therefore emerged as an interesting opportunity to propose a homogenous and coordinated vision of the Djeffara aquifer system. The aim is to meet the need for defining the exploitation policies of water resource, predicting the short-term and long-term impacts, clarifying and helping with the risk management, and evaluating the consequences of such impacts.

Based on the collected and analyzed information with the help of specialists from both countries, we have designed and elaborated a hydrodynamic model to simulate the aquifer system's behaviour and predict its medium-term behaviour (50 years). It gives an assessment of the system output based on 594 Mm^3 in 1950, including 52 Mm^3 of pumped water, and 1365 Mm^3 in 2000, including 1039 Mm^3 of pumped water. Such assessment highlights the net imbalance that the system has undergone in the meantime. The evaluation underscores the importance of infiltration (330 Mm^3/year) and the value that must be given to a natural recharge study as well as to the estimation of ground lateral contributions from the North Western Sahara Aquifer System (260 Mm^3/year in 1950 versus 200 Mm^3/year in 2000). Finally, another element that is likely to become important in the assessment is “seawater entry”, which is becoming noticeable in the Tripoli region (34 Mm^3/year) and represents a major risk for water quality. At the end of the simulations, we proposed the following conclusions and recommendations to the two countries, while keeping in mind that any intervention in any country – as long as it is even slightly distant from the border areas – will not generate noticeable consequences on the other country:

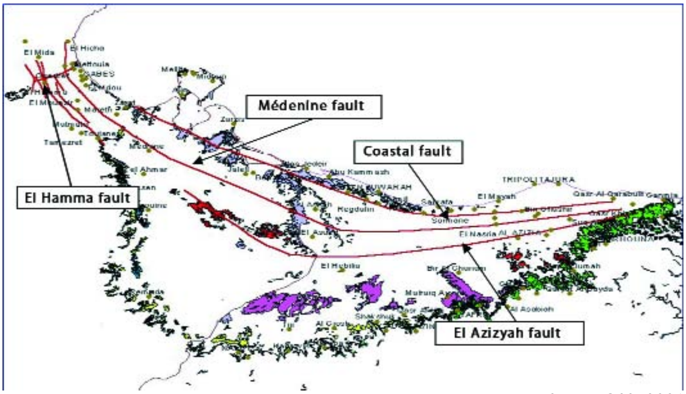
Djeffara modelling: conclusions and recommendations

For Tunisia:

- Pursuing the current withdrawals up to 2050 will not lead to significant repercussions on water table behaviour.
- A localized increase (Weak hypothesis: additional total withdrawals: 1.8 m^3/s) seems acceptable according to the model results.
- A more important increase (Strong hypothesis: additional total withdrawals: 3.4 m^3/s) will have to be gradually and carefully implemented.
- The development of non-conventional resources as alternative solutions must be strongly encouraged.
- The policy aimed at promoting an extensive irrigation type over small-irrigated perimeters in rainfall-dependent crop areas seems adapted to exploitable resource distribution.

For Libya:

- Continuation of the current withdrawals up to 2050 leads to important drawdowns and a continued marine intrusion progression around Tripoli.
- An additional withdrawal increase in the Djeffara already-exploited areas is inconceivable.
- The hypothesis of a significant withdrawal reduction, which is politically difficult to put in place, would have significant positive results on the resource future but without completely eradicating marine intrusion.
- The water contribution of the Great Man-Made River to farms in the central area will have a positive impact on water table withdrawals and could slow down, but not dismiss, water level decrease and marine intrusion progression.
- We have to take into account the withdrawals in the Trias water table of Western Djeffara after testing the real water table quality. This scenario may constitute a precious addition to water supply in the Libyan western coastal towns.



Source: OSS, 2006

Figure 11: Djeffara Plain, a natural NWSAS continuation

2- Beyond hydrology: socio-economic and environmental aspects

NWSAS knowledge improvement and the different hydrological models have identified the risks facing resources and uses, as well as the NWSAS potential for developing such uses. Beyond hydrology, and in the perspective of providing decision-makers with a complete NWSAS picture, we agreed to extend the system knowledge by first focusing on water use through a socio-economic study and the state of the environment in the entire NWSAS zone, which is very strongly correlated with water resource availability and its uses.

2.1- Socio-economic aspects

a. Supply-based management and demand-based management

The initial NWSAS project work has mainly focused on water supply. In an arid environment where water resources, which are quasi-exclusively limited to groundwater, are increasingly precious, and where the water supply management policies can no longer face an ever-increasing demand, the water demand-based management, placed within a regional framework of competitiveness, must become the norm and lead to a more rational use of each water drop. Thus, we must confront water supply with demand. The objectives of the socio-economic aspects of the NWSAS Phase II are set as follows:

- Delimit the current and future water demand contours.
- Establish a diagnosis of farming practices in each country.
- Define the sustainable development themes by taking into account the countries' planned orientations.

Within the framework of this component's implementation, we have carried out national studies of the available socio-economic data. Elaborated independently of each other, these studies[6] shed light on the different socio-economic aspects of the respective countries. They have highlighted the following issues. Shared between the three traditional water uses in terms of domestic, industrial, and agricultural uses, water demand in the North Western Sahara basin is difficult to determine. In fact, it seems that the information on water use in the NWSAS basin strongly varies from one country to another and is mostly fragmentary. Consequently, it is very difficult to access relevant information everywhere. However, it is possible to underline some features.

b. Evolution of domestic water demand

With regards to domestic use, the demographic surveys undertaken in 1998 in Algeria, in 1994 in Tunisia and in 1995 in Libya, coupled with other national statistical data, have made it possible to feed the demographic models and forecast demographic growth in the NWSAS zone up to 2030. As shown in Table 1, we should expect a quasi-doubling of the NWSAS population in the period 2000-2030, with the highest rates in Algeria and Libya. We note that in Algeria a strong urban sprawl at the rates of 63% in 2015 and 73% in 2030 would accompany such growth. This population forecast corresponds to a variable domestic water demand by country:

- **Algeria** has reached the rate of 80% of the NWSAS area population connected to drinking water supply networks in 1998 and the rate has strongly increased since then. Water consumption estimates in the Algerian NWSAS zone vary by district from 62 to 295 litres/day/inhabitant with an average 155 litres. Public planners in the zone estimate 110 litres for urban domestic demand and 80 litres for the rural one, whereas the estimate for the tourism sector is 150 litres per day per tourist. In light of these hypotheses and the retained demographic hypothesis, the net drinking water demand varies from 166 to 260 million m^3 in 2025, which corresponds to the required production of 171 to 313 million m^3 per year in that horizon, taking into account a 20% loss in the networks.
- In **Tunisia**, SONEDE[7] counted a consumption of 65 litres per day and per inhabitant in the NWSAS zone in 2003. If such value holds for the years to come, the domestic water consumption would increase to 27 million m^3 in 2004, 39 million m^3 in 2016 to reach 59 million m^3 in 2030. In the perspective of the zone's socio-economic development, another scenario forecasts a domestic demand increase to 200 litres/day/inhabitant. Therefore, the demand would

[6] Données agronomiques et socio économiques sur la zone SASS en Algérie ; L'agriculture et les différents usages de l'eau dans la zone SASS en Tunisie, Analyse socio-économique ; Les systèmes de culture et d'élevage de la zone du SASS du Sud tunisien ; Aspect socio économique de Hamada El Hamra, Libye

[7] Société nationale d'exploitation des eaux : National water company.

increase from 44 million m^3 in 2004 to 95 million m^3 in 2015 and 108 million m^3 in 2030. In addition, we note the Tunisian forecast for drinking water demand in tourism, based on a daily consumption of 700 litres per day/hotelbed and the zone's hotel capacity development. The study evaluates the hotel sector demand at 10 million m^3 in 2003 and 27 million m^3 in 2030.

- In **Libya**, the current domestic demand estimate is 157 litres/day/inhabitant. It is admitted that future demand would increase to 200 litres per day in 2010 and remain at that level. Thus, domestic demand would increase from 57 million m^3 per year now to 170 million m^3 in 2030.

Country	2000	2020	2030
Algeria	2,600,000	3,700,000	4,800,000
Tunisia	1,200,000	1,500,000	1,700,000
Libya	1,000,000	1,800,000	2,300,000
NWSAS total	4,800,000	7,000,000	8,800,000

Source: OSS, 2005

Table 1: Demographic projections (NWSAS inhabitants per country)

In spite of the uncertainties and the different used methodologies in each of the three countries, we may initially estimate that the NWSAS domestic water demand would reach 400 to 600 million m^3 per year in 2030, pending the different development trajectories that the countries will take.

c. Water use in the industrial sector

Water demand data in industry are scarce:

- According to the Algerian National Water Resources Agency (ANRH) list established in 2000, the oil industry would have withdrawn 146 million m^3 from 177 drillings during that year. Intensified exploitation could lead to a demand increase up to 262 million m^3 in 2025. In addition, planners estimate that the non-oil industrial use is 35% of drinking water demand.
- In Tunisia, the current level of industrial consumption, established in 2002 by DGRE, amounts to 19.6 million m^3. The development of industrial activity in Gabes and Gafsa as envisaged up to 2030 would see the total industrial water demand in the NWSAS Tunisian zone reach 35 million m^3 in 2015 and 51 million m^3 in 2030.
- In Libya, the National Committee for water resources estimated water consumption for industrial use at 5 million m^3/year in 2002.

Thus, the industrial water demand would increase from 180 million m^3 in 2000 to 325 million m^3 in 2030.

c. Evolution of farming water demand

The farming sector is by far the main water consumer and activity supplier in the NWSAS zone. However, it is also a sector where the evaluation of current and future water demand is the hardest. The diagnosis of farming practices in the NWSAS zone has addressed crop systems, irrigation techniques and the economic aspects of water prices. We first need to characterize farming practices in the NWSAS zone with specific reference to crop systems to evaluate water needs in the sector and its socio-economic significance in the region.

Apart from rainfall farming, the farming systems in the three regions are similar, with major oasis farming. A typology of oasis crops in Algeria and Tunisia has enabled addressing farm complexity and diversity. First, an important number of small farms characterize the farming sector. For example, in Algeria, about 600,000 individuals farm about 170,000 ha. The systems are therefore highly labor intensive. The surface area of an average farm is very small. However, in Tunisia, there are large single-crop date palm farms extending over dozens of hectares, established by private companies for export. The oasis crop systems in the two countries are based on palm tree plantations, with or without other crops in the traditional three-layer system, or animal husbandry, which is an important agricultural activity in the region. For instance, Tunisia considered about 3 million hectares, i.e. 40% of the NWSAS Tunisian surface area, as grazing land in 1995. In the NWSAS Libyan part, the establishment of farms is relatively recent, with an agricultural development that flourished in the 1970s and the 1980s. We estimate that 40,000 ha of farming land are irrigated today. One third of the farms have a public exploitation system. The main crops in the region are palm trees, olive trees, cereals, fodder, fruit trees, and vegetables.

Country	Algeria	Libya	Tunisia	NWSAS
NWSAS farming water demand (m^3/year)	1,700,000	630,000	540,000	2,870,000

Source: OSS, 2005

Table 2: Evaluating NWSAS farming water demand in 2000

More specifically on farming water demand, the study evaluates in the first stage the irrigated surface areas in the NWSAS countries at 170,000 ha in Algeria, 40,000 ha for each of the two remaining countries, Libya and Tunisia. These lands are primarily dedicated to arboriculture (palm trees, date palms and fruit trees). Irrigation modes are variable, but the traditional gravitory irrigation technique is predominant. Submersion irrigation is also used, as well as sprinkling or centre-pivot irrigation for cereal crops. Localized irrigation and the drop irrigation system, especially in greenhouses, have been recently introduced and are the most water-saving irrigation types. We can envisage estimating farming water consumption, which highly varies by farm type, crop type, irrigation mode, and irrigation management. Based on both farmer surveys and the farming references given to farmers by the public technical centre, an average of 10,000 m^3/ha/year in Algeria has been established. Tunisia suggests a water allocation per hectare at a continuous flow between 0.7l/s and 1l/s, but the 0.5 value seems more realistic as it gives an average of 15,000 m^3/ha/year. Finally, the Libyan estimate is 12,275 m^3/ha/year.

Projections for the horizon of 2030 have been established (Table 3). Used water estimates by crop type and irrigation method have been carried out on the basis of farmer surveys and data supplied by the national institutions. While envisaging improved irrigation efficiency, the expected irrigated land increase would lead to a farming water increase from 3 billion m^3/year currently to a projected 5 billion m^3/year in 2030.

To conclude on demand evaluations, we underscore the lack of the statistical and established standard reliability in the three countries. The current demand evaluation at 3 billion m^3/year runs counter to the total NWSAS withdrawal evaluation carried out based on water points in the hydraulic part. As for the economic aspects, the extreme water price variability is underscored in the three countries. Water prices appear in the Tunisian report only. As for water valorisation, the reports contain output and producer price data. Products and revenues relating to tourism and industrial activity are not provided.

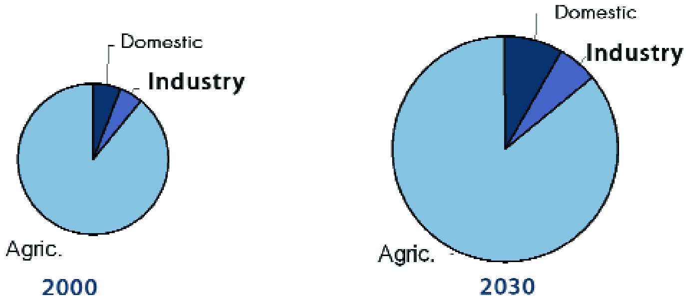
Country	2000	2020	2030
Algeria	170,000	300,000	340,000
Tunisia	40,000	55,000	70,000
Libya	40,000	77,000	103,000
NWSAS total	250,000	400,000	500,0000

Source: OSS, 2005

Table 3: Irrigated land in hectares

To conclude, if the current demand for domestic, industrial, and especially farming water in the three countries continues, we will witness a worrisome divergence, with the fragile supply of a resource that is low-renewable and threatened by irreversible degradation. In fact, with population doubling in the horizon of 2030, the pressure on a resource that is highly solicited because of the current exploitation pace can only be stronger. Agriculture as a major water consumer with a low efficient irrigation is also witnessing the doubling of its surface area. This compels thinking about the adopted development options in these regions.

Figure 12: Water demand in 2000 and 2030 by sector



Recommendations for a sustainable NWSAS water management

The review of water use has made it possible to define, in consultation with the three countries, the main recommendations for a sustainable NWSAS water management, especially irrigation. The recommendations are summed up as follows:

- Promote the more efficient use of the already mobilized water, continue support for adopting new water-saving techniques, and support scientific and technological research in the water domain to carry out an efficient water allocation.
- Conduct a redefinition of the current irrigation strategy in the zones threatened with the resource irreversible degradations by putting in place, for instance, mechanisms for discouraging the low valorising products such as cereal crops, and ensure a sustainable and integrated management of greenhouse crops in the areas that currently have recognized comparative advantages.
- Diversify regional economic activity by encouraging the sectors that valorise best the resource, thus promoting non-agricultural job creation.
- Ensure an urban development that explicitly integrates resource scarcity and mainly guarantees its sustainability.
- Conduct a serious economic investigation of water transfer from the production zones (Western Sahara and El Hamada El Hamra) to high demand exploitation zones.
- Valorise non conventional water resources (treated used water and drainage water)

It is noteworthy that the implementation of such recommendations by the three countries requires the elaboration of appropriate programmes that analyse the political feasibility of such recommendations and enlighten the decision-makers about the need for the recommended changes and the benefits of resource preservation.

d. Towards elaborating a sustainable development strategy in the NWSAS zone

In light of the first joint work on the entire NWSAS basin, the elaboration of a sustainable development strategy for the basin, based on the NWSAS water resources, requires thorough knowledge of the following aspects:

- **Comparative cost/benefit study of different water uses**

  The quantitative cost/benefit study of all activities resorting to intensive use of the NWSAS water resources in each of the three countries is necessary for enlightening development options. To this end, it is essential to consolidate the current socio-economic data by more complete information on tourism and industry, which offer promising development perspectives in an area where classical farming is reconsidered.

- **Real-cost oriented pricing**

  Resorting to a pricing that explicitly integrates the real cost of water resource mobilisation and use would also make it possible to limit pressure on the resource. We should engage a serious evaluation of the various costs beforehand. A gradual incentive tariff system for real resource preservation should integrate at once:

  - direct operating cost;
  - investment cost;
  - indirect cost, especially environment degradation cost;
  - water scarcity cost. It is a flagrant error to consider that groundwater in its natural site does not have a price.

- **Demand control**

  A real demand control, requiring the appropriate reallocation of the water monopolized by uses that are not very valorising, goes through incentive mechanisms, which would be inclusive and operated at a decentralized level. In fact, there are today instruments that enable a reallocation towards highly valorised uses and ensure participant adhesion (water market, bids, user association).

- **The alternative of resorting to virtual water**

  A significant water stress characterises the three NWSAS countries. It is therefore perfectly reasonable to opt for a development based on the maximum valorisation of this precious and scarce resource as a priority in highly profitable activities. To overcome the food deficit, foodstuffs imports amount to virtually importing the water of the producing regions. More explicitly, as water is scarce, we should allocate it to activities that valorise it best and not freeze it in those activities whose yield per allocated cubic meter of water is lower than the total mobilisation cost. It is clear that agriculture in all the Sahara regions is generally characterised by a low valorisation but it plays a socio-economic role that cannot be overlooked. One of the imaginable scenarios would be to reduce farming to activities for which the region has obvious natural predispositions (early fruit and vegetables, dates) and reallocate water resources to highly valorising sectors.

2.2- Environmental aspects

Beyond the precise and concrete threats hovering over the NWSAS water resources, as highlighted by the aforementioned studies, and which are directly due to NWSAS withdrawals increase from 0.6 billion m^3/year in 1970 to 2.5 billion in 2000, other negative impacts on natural resources and the environment are recorded at different levels. Essentially linked to irrigation, environment degradation in the NWSAS zone jeopardises farming sustainability and consequently threatens the future of local populations, given the activity's socio-economic significance. Work on the environment component has focused on analysing the irrigation impact on natural resources, as well as diagnosing highly vulnerable wetlands. Based on the elaborated national reports, we describe the current state of affairs and formulate recommendations to establish a protection strategy.

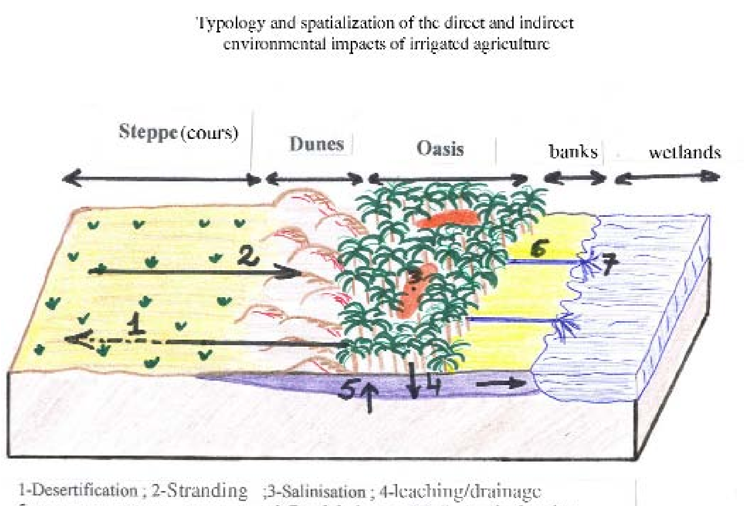
a. Impacts of irrigation on NWSAS environment

The environment pressure factors directly result from irrigated land increase from 60,000 ha in 1970 to 250,000 ha in 2000, thus multiplying water points and increasing withdrawals from 0.6 billion m^3 per year to more than 2.5 billion per year. These are loaded with considerable soluble salt quantities estimated at 1.2 to 4.4 million tons, respectively, with an average water salinity of 2g/L. Irrigation has various environmental impacts affecting, in a more or less direct manner, the quasi-totality of natural resources, and particularly irrigated land and soils. Those impacts can be divided into:

- **Direct impacts** on irrigated land integrity, hydraulic and saline functioning of the soils and soils fertility reduce farming output and used water productivity. Examples of direct impacts include :
  - Irrigated land salinity because of a non-rational irrigation management and salt accumulation in the soil from irrigation water;

- groundwater upwelling following many causes of irrigated land drainage deficiency;
- irrigated land fertility degradation following the abandonment of oasis crop systems and traditional techniques relating to integrated land fertility management.

- **Indirect impacts** resulting from the overexploitation of other natural resources in the irrigated perimeter surroundings:
  - genetic erosion and biodiversity impoverishment in the classical oases, which are considered as a rich deposit of species and crops, adapted to hydraulic stress and climate variability;
  - wetland hydrological dysfunction and pollution by various domestic and industrial waste effluents;
  - desertification and landscape quality degradation in the irrigated zone surroundings.



Source: OSS, 2005

Figure 13: Diagram of environmental impacts related to NWSAS water management

b. Severe land degradation

Regarding soil quality, work has focussed on salty soil inventories, salinisation impact evaluation, protection strategies for adoption, indicator development, and economic impact quantification. To illustrate the importance of salinisation, in addition to the land ecological quality damage it causes, salinisation lead to a considerable soil resource loss, estimated at 4,300 ha/year over a surface area of 170,000 ha in Algeria and at 300 ha/year over a surface area of 40,000 ha in Tunisia. The income loss caused by such detriments is added to the generalised weak irrigation efficiency in terms of cubic meter productivity, i.e.:

- 0.32 Kg of dates/m^3 for the date palm, whereas it can exceed 0.5.
- 0.02 Kg of wheat grain/m^3 for pivot irrigated wheat, whereas it can exceed 1.2.
- 2.5 Kg of tomatoes/m^3 for open-air tomato growing whereas it can exceed six.

Generally, precise data on these land degradation phenomena are limited. They are summed up in the following table:

Threatened resources	Impact nature	Algeria	Tunisia	Libya
Soil	Salinisation	75% of lands are salinised	42% of lands are salinised	Undocumented
	Non-efficient drainage	Important Not monitored	Important Estimated at 10,000 ha	Undocumented
	Fertility loss	Important, not monitored	Important, not monitored	Important, not monitored
Oasis	Dysfunction Loss of biodiversity	Heavy tendency Loss of local species	Heavy tendency Loss of local cultivars	Heavy tendency Loss of local cultivars
Steppe rangeland	Desertification	Serious, irreversible in some areas	Serious, irreversible in some areas	Serious, irreversible in some areas
Wetland	Drying-up pollution	Long-term risk	Long-term risk	Long-term risk
Landscapes	Sand silting Salinisation	Serious	Serious	Serious

Source : OSS, 2005

Table 4: Environment impacts of NWSAS water exploitation and use

c. Many wetlands, but very vulnerable

NWSAS water resources are essentially groundwater. However, there are also surface waters, scarce and irregular, generally localized in the lakes, permanent or seasonal, artificial or natural, and oases that we commonly call wetlands. These zones are fed by groundwater upwelling and may act as outlets for urban and industrial wastewater. In addition, water here usually has a high salinisation level and is sometimes much polluted because of the waste nature and/or frequency. Wetlands are vulnerable ecosystems. They are living environements with a microclimate favourable to biodiversity in an arid and xeric Sahara. They are an important habitat for the avifauna migrating from the Mediterranean to the

Sahara, especially in wintertime. We differentiate many wetland types by hydraulic regime and salinity, on the one hand, and ecosystems, on the other.

These wetlands have very recently been subject to intensive care, and even restoration attempts, to preserve (or recreate) these complex systems, whose biological productivity is high, and which are safe havens for many fauna and flora species. The ecosystems are fragile and sensitive to water shortage. They are also sensitive to the fight against floods, which they need to function, and polluting waste (eutriphication, chemical contamination).

The Saharan wetlands are extremely vulnerable and fragile. They are submitted to direct threats endangering their sustainability. Their survival depends on oued outflows, which sometimes bring in waste and pollutants, on the drainage water of palm groves or groundwater upwelling near the soil or the water table drainage. Some zones are used to extract salt. Others are used as rubbish and untreated wastewater dumps. Some others are untreated, abandoned, and left for warblers and algae to grow. In such conditions, the major risks threatening wetland lasting quality are:

- Overexploitation and irrational use of available waters.
- Wastewater pollution loaded with organic elements.
- Pollution by solid waste, metal, and rubble.
- Silting and lake and dam degradation because of lack of maintenance.

NWSAS wetlands

The **sebkhas**, which are not very deep depressions with salty water, dry up only in scorching heat. The sebkhas act like partial outlets for draining table water and flooding oueds.

The **Chotts**: As localised depressions at the bottom of endorheic basins, their depth never exceeds few meters in wintertime and strongly decreases in the dry period. Their surface area may reach several hundred hectares, situated at altitudes lower than the sea level. The water is salty and comes from palm grove irrigation water drainage as well as aquifers whose waters swell up to the surface. The Chotts are ecologically very important because of their surface water sustainability and area stretch. They are an unavoidable stopover for migrating birds, some of which are threatened with extinction (flamingos and ruddy shelduck). Mammals are not very numerous but fauna studies must be carried out in further detail. We note the presence of the fennec (vulpes zerda), a species threatened with extinction and protected. Flora is diverse and depends on water lasting quality and salinisation. The Chotts are an environment favourable to endemic species - 14 species have been inventoried in Chott Melghir in Algeria. The Chotts are exploited to produce table salt, but the most harmful impact is wastewater, which affects and pollutes the ecosystems.

Bodies of water: Located in the closed basins and generally fed by the drainage water of palm groves, extracted from the deep water table. Water quality is fresh and not very salty. Fauna and flora are less important but these areas are avifauna transit areas.

Seasonal salty lakes: They are located in the depressions whose feeding depends on irrigation water and water table drainage. The water can reach 1-m depth in winter and dries up in summer. They can have a surface area of 1,000 hectares such Chott Ain Beida, which is much polluted with total nitrogen and phosphorous in wastewaters, and the accumulation of metal, rubble, and solid waste.

Oases: These are areas of high pastoral and farming activity, linked to the traditional use of groundwater emanating from deep water tables, and which is equitably shared among the local communities thanks to a network of underground galleries dug in a gentle slope known as Foggara. The oasis ecosystem is of prime importance for the local inhabitants of these areas where rainfall is generally less than 10mm/year. Many important pastoral and medicinal plant species have been censed, in addition to the main species and resource: the date palm. Fauna is more numerous and varied with the presence of species threatened with extinction such as the fennec, the gazelle and the desert varanus lizard. These wetlands are used for wintering and nest building by an important part of the avifauna.

Biological diversity is characterized by the existence of many flora and fauna species threatened with extinction and protected. Wetlands are a significant stopover for many birds migrating from Western Europe to Africa. The undertaken biodiversity surveys to date do not certainly reflect reality. Flora and fauna are still under-estimated. An exhaustive species list seems necessary to obtain precise information on Saharan fauna and flora.

d. Perspectives and recommendations

The risks for amplifying all these degradations are obvious and very high. The expected production increase resulting from irrigated land extension is not easily achievable given the faced environmental challenges. The current situation of natural resources in these zones is worrying. It has attained irreversible thresholds in some cases; and the sustainability of the agricultural development process, launched about twenty years ago, is not always guaranteed. However, major valorisation potentials for the specificities of this agriculture are exploitable if some conditions of a reasoned scarce resource management are met. It is therefore urgent to underline that if the reasoned management of NWSAS withdrawals is a condition for prolonging the resource exploitation, only a better use of irrigation water in return for the improved performance of production techniques is likely to guarantee both the development objective and the preservation of natural resources from all forms of degradation. Without attaining these two objectives, the costly restoration of the incurred environmental impacts will take a heavy toll of the concerned countries.

To face this vital challenge, an action plan aimed at alleviating the negative and already established impacts, on the one hand, and the prevention of very high potential risks, should be designed and carried out as soon as possible in each of the involved countries. This can be achieved with OSS assistance within the framework of a total regional programme, which the consultation mechanism should be able to design and steer in line with farming and natural resource exploitation policies in these countries. The following recommendations can help elaborate this action plan.

In addition to the appropriate recommendations on water management as formulated in the hydraulic and socio-economic studies, this environmental synthesis recommends strong actions on degraded soil restoration, and especially the establishment of an environment tool to monitor and evaluate natural resources under the impact of exploitation or restoration by the appropriate techniques. Currently, very large areas, formerly exploited in an extensive manner because of the absence of water resources, are now very solicited by various socio-economic sectors. Thus, they are gradually but surely loosing their renewal capacity. It is highly useful and even urgent to put in place the monitoring/evaluation mechanisms for the exploitation of the threatened resources and the resulting environmental impact.

All this scientific and technical work has thus highlighted the zones where NWSAS water resources are most vulnerable. Between Algeria, Libya and Tunisia, the Terminal Complex today, the Intercalary Continental tomorrow, are in such a state of exploitation that one day one will have to think about controlling together, if not reducing, the pumping flows. How can we control such flows within the framework of the States' will to contribute mutually to ensuring the future of the region, especially through a concerted preservation policy of water resources?

NWSAS JOINT MANAGEMENT THROUGH THE CONSULTATION MECHANISM

The scientific work has enabled researchers and administrations of the three NWSAS countries to exchange and build together a common knowledge on which they can build a concerted management. They have gradually defined the forms and mechanisms of such common management, culminating in the formal creation of the Mechanism and its Secretariat hosted at OSS in November 2007.

1- Beginning consultation between the three countries

Prior to the concerted arrangements among the three countries and NWSAS project implementation by OSS, other scientific studies to characterize NWSAS have been developed. UNESCO (ERESS Project 1968-1971) carried out the first study with the participation of Algeria and Tunisia. In 1982-83, an updating of the models was carried out with the support of UNDP, still without considering the basin part located in Libya, and new withdrawal hypotheses were simulated to support the agricultural development plans envisaged by Algeria and Tunisia. Libya on its side carried out two models of the basin part located in its territory[8]. In 1981, Algeria established another model within its territorial limits[9]. But these studies have not made it possible to agree upon common objectives by the three countries to jointly manage the NWSAS water resources. However, at the same

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[8] Idrotecneco, 1982, Hydrogeological study of the Central Wadi zone & Golf of Sirt, groundwater resources GEOMATH, 1994, Western Jamahiria system hydrogeological modelling of aquifers and wheel fields.

[9] BRL, 1999, *Etude du plan directeur général de développement des régions sahariennes.*

time,the importance accorded by Algeria, Libya, and Tunisia to consultation in the area of shared water management has led to the creation of mechanisms such as:

- The Algero-Tunisian technical committee on water and the environment, created in the 1980s within the "grand committee" dealing with the questions of shared water resource evaluation, the fight against pollution, information exchange on water development programmes, follow-up of NWSAS studies, and the consolidation of bilateral cooperation in water management.
- The working groups within the Algero-Libyan "grand committee", established during the 1990s, on shared water between Algeria and Libya. The two countries have decided to create a "common technical committee on water resources".
- The Tuniso-Libyan sectoral committee on agriculture, established at the beginning of the 1990s within the framework of the "Tuniso-Libyan grand committee", dedicated to experience exchange, groundwater protection, water and soil conservation (WSC), identification of studies on shared groundwater, and follow-up of NWSAS studies.

Top officials from the ministries in charge of water resources participate in the deliberations of committees and working groups. Although the aforementioned institutional mechanisms have turned out to be efficient in the sense that they promoted the discussion of important themes in the area of shared water management, they are bipartite with wider objectives that are not necessarily consistent with the NWSAS concerns. In addition, these bipartite committees do not have the sufficient technical elements or assessment of the identified risks based on common in-depth investigations of the basin's resources.

2- Institutional cooperation since project inception

Since the beginning of the NWSAS project design, the three countries, OSS and cooperation partners have been primarily concerned with continuing cooperation beyond the project. Aware of the need for a strong technical cooperation and solidarity for an efficient management taking into account the various potential risks, reflexions on a standing technical NWSAS management structure were initiated in 1999. In the framework of this new vision, there have been sustainable data collection and analysis, making it possible to grasp knowledge to better target the potential mediation in water resource distribution. For such reason, the NWSAS project, from the outset, aimed at two objectives:

- The first objective is technical, aimed at producing reliable technical elements (data, simulations…), putting in place the dialogue tools, and rendering risks more visible.
- The second objective is institutional, aimed at perpetuating consultation, first at the technical level, and its ownership at the political level by establishing a standing structure for harmonising development planning.

3- Defining NWSAS consultation structure

First of all, the practice of partnership within the NWSAS project has gradually fostered mutual trust between the technical teams, the conviction that common actions increase solution efficiency, and the certainty that information exchange, the foundation of all solidarity, has become during the project not only a possible activity but a necessary one. Once the NWSAS model and the operational databases in each of the three countries have been established, a form of efficient consultation first consisted in ensuring the maintenance, development, and constant updating of the two tools (database and simulation models) within the framework of a technical structure. The establishment of the technical structure was the subject of three national workshops respectively held in Tripoli, Tunis and Algiers in November 2002. A number of convergence and consensus points have transpired from the three workshops on:

- Continuing the work within the NWSAS project on improving system knowledge and operation.
- Establishing a consultation mechanism at the technical level and its institutional anchoring, in the first phase, within an independant organisation, i.e. OSS.
- The gradual and evolving character of the mechanism from an efficient and light technical structure to a more elaborate entity endowed with more important attributions in the end.

These options were approved during the regional synthesis workshop held in Rome at the FAO headquarters in December 2002 and officially confirmed to OSS by the three countries. During the same workshop, the diagram of the technical structure and its attributions was adopted at the level of the Directors-General of the three institutions in charge of water in each of the three countries.

Composition of NWSAS technical consultation structure

- a Steering Committee comprising the national structures in charge of water resources, acting as national focal points;
- a Coordination Committee managed by and housed at OSS;
- an Ad hoc Scientific Committee for scientific evaluation and orientation.

4- Towards an enduring consultation mechanism

After approval of the technical consultation structure in 2002, OSS devoted itself, in close cooperation with the three countries, to establishing a standing consultation structure, which beyond the technical level, can be appropriated at the political level in the three countries. The establishment of such standing structure has required the following steps:

- Organisation of three workshops, one in each country where national steering committees have recommended upscaling from the technical level to the decision-making or even political level.
- Organisation of the meeting of the three national steering committees in Algiers in March 2005 where the ministerial declaration on the adoption of the consultation mechanism encouraged OSS to define the effective attributions of the nascent structure.
- Meeting of OSS Board of Directors in Tunis in April 2005, where the ministerial declaration was approved for signing by the three countries.
- Algiers meeting of 10-11 June 2007 where the mechanism configuration, operation and funding have been defined.

In November 2007, the structure coordinator was appointed to OSS for one year on a revolving basis. The funding is equally shared by the three countries.

Missions of NWSAS Coordination Unit

- support the countries in implementing the main technical activities aimed at facilitating consultation, especially data collection by establishing joint networks and updating common databases and models;
- dynamize the institutional process by identifying transborder hydraulic problems, formulating solution proposals, and formalising consensus and consent;
- ensure, on the one hand, information dissemination and debate organisation at the level of decision-makers on programmes and development options in the basins, and promote participatory management through real communication work, on the other.

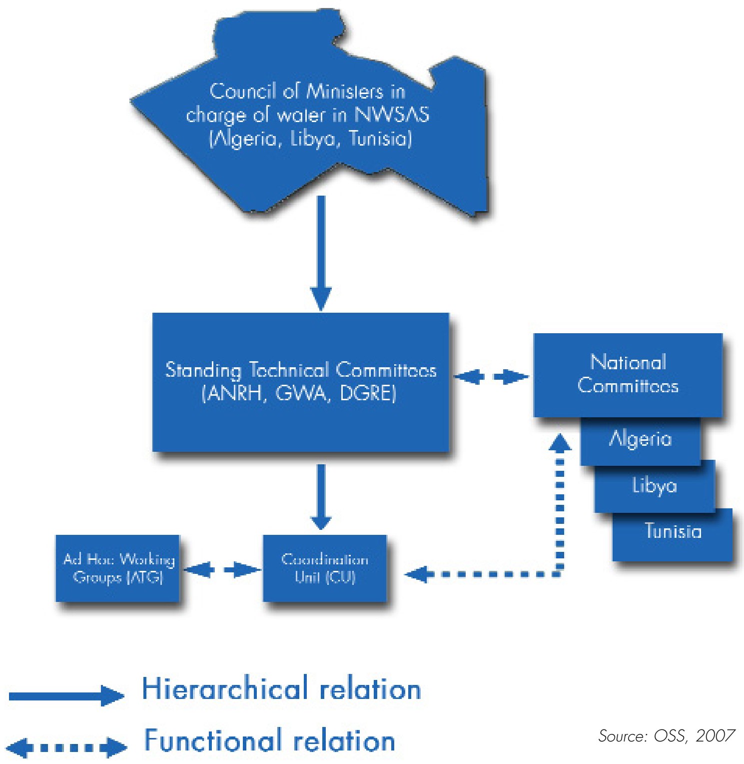

Figure 14: Diagram of Consultation Mechanism structure

Source: OSS, 2007

CONCLUSION

In Algeria, Tunisia and Libya, the Terminal Complex today, the Intercalary Continental tomorrow, are exploited in such a manner that we need to think about how to jointly control, if not reduce, water withdrawals. Among the objective reasons pushing for consultation, the management of the risks threatening NWSAS water resources and the environment in the entire NWSAS zone, as highlighted by this investigation, represent one major reason.

The similar views among the three countries and the finalised agreement on the consultation mechanism make it possible from now on to envisage more serenely the future of NWSAS populations and development. The most fulfilling outcome in this long scientific, technical, and political process would be the establishment of a sustainable development plan in the transborder aquifer basin based on the NWSAS water potential, operation risk minimisation, agricultural improvement at the technical, economic, and environmental levels, and economic diversification - all discussed within the Consultation Mechanism.

Today, the project is moving towards its third phase, aimed at continuously improving the technical tools by using remote sensing for a precise irrigated land cartography and pursuing the socio-economic and environmental investigations. These elements will undoubtedly constitute an additional step to achieving the overall objective of the OSS recommended approach aimed at developing an awareness of the basin towards a sustainable development of the arid and semi-arid zones.

Thus, we underline the exemplarity of this process, which could not have attained such results without the full adhesion of Algeria, Libya, and Tunisia, from now aware of sharing a common destiny through the sustainable development of the NWSAS zone. The project confirms the OSS partnership and facilitation approach to shared resources among the member countries. It has produced a wealth of experience, which OSS can use in other aquifer basins such as the Iullemeden aquifer shared by Mali, Niger, and Nigeria, and for which the NWSAS example is extremely instructive.

BIBLIOGRAPHY

OSS (2002), NWSASS Activity report, Volume 1, a basin awareness

OSS (2002), Hydrogeology, NWSASS Activity report, a basin awareness

OSS (2002), Data Base and SIG, NWSASS Activity report, a basin awareness

OSS (2002), Mathematical Model, NWSASS Activity report, a basin awareness

OSS, De MARSILY G., KINZELBACH W., MARGAT J., PALLAS P., PIZZI G, Avis du Comité d'Evaluation sur le modèle du SASS

OSS (2005), Mathematical model study of the Biskra - North of chotts aquifer - Final report - may 05 - 124 p

OSS (2005) Study of the recharge of the North Western Sahara Aquifer System - Final report - dec. 05 - 35 p

OSS (2005) North western sahara aquifer system - phase II - attempted socio economic summary - sept 05 - 30 p

OSS (2005), Current and Potential Environmental impacts related to the abstraction and use of NWSAS water in Algeria, Tunisia and Libya.

OSS (2005), Wetland of the North Western Sahara Aquifer Sytem (Algeria, Tunisia and Libya) - dec 05 - 16 p

OSS (2005), Implementation of the NWSAS piezometric network - june 05 - 51 p

OSS (2005), Design of the quality network

OSS (2006), Modelling of the Aquifer System of the Western Basin of the North-Western Sahara - Final report - hydrogeology & conceptual model

OSS (2006), Modelling of the Aquifer System of the Western Basin of the North-Western Sahara - Final report - Calibration and model results

OSS (2006) Hydrogeological study of Tunisian Libyan Djefara Aquifer System

ACRONYMS

ANRH	Water resources Authority of Algeria *Agence nationale des ressources hydrauliques d'Algérie*
AWF	African Water Facility
DGRE	Department of Water Resources of Tunisia *Direction générale des ressources en eau*
DWS	Drinking Water Supply
FAO	Food and Agriculture Organisation
FGEF	French Global Environmental Facility
GEF	Global Environmental Facility
GIS	Geographic Information System
GMRP	Great Man-Made River Project
GWA	General Water Authority of Libya
IC	Intercalary Continental
IFAD	International Fund for Agricultural Development
IS	Information System
NWSAS	North Western Sahara Aquifer System
OSS	Sahara and Sahel Observatory
SDC	Swiss Agency for Development and Cooperation SDC
SONEDE	*Société nationale d'exploitation et de distribution de l'eau* Tunisian Water Board
SWRNWS	Study of Water Resources in the North Western Sahara
SWS	Soil and Water Conservation
TC	Terminal Complex

UNDP	United Nations Development Programme
UNESCO	United Nations Education Science and Culture Organisation

NWSAS PARTNERS

National partners

Agence nationale des ressources hydrauliques (Algérie)

Direction générale des ressources en eau (Tunisie)

General Water Authority (Libye)

Financial and Scientific partners

FAO FGEF GEF GTZ

IFAD SDC UNESCO WAF

NORTH-WESTERN SAHARA AQUIFER SYSTEM

The North Western Sahara Aquifer System (NWSAS), shared by Algeria, Libya and Tunisia, contains considerable water reserves which are, however, mostly non-renewable and not fully exploitable. The NWSAS covers an area of over 1 million Km² and includes two main deep aquifer layers: the Intercalary Continental and the Terminal Complex. During the last thirty years, withdrawals from NWSAS grew apace from 0.6 to 2.5 billion m³/an. Due to the non-concerted withdrawal multiplication, the resource is currently confronting many risks such as water salinity, declining artesianism, natural discharge depletion, piezometric level drawdown, or interferences between the countries... The simulations generated by the NWSAS mathematical model have pinpointed the most vulnerable areas and allowed us to map the various risks. The three countries sharing the NWSAS have had to tackle these risks together by finding a way to manage the basin in a collective manner. A landmark development took place in 2007 when Africa's first basin institution on shared groundwater resources saw the light of day: The NWSAS institutional consultation mechanism was formally established.

This document aims to provide an overview of the main results obtained from the implementation of the different NWSAS project components: hydrogeological data collection, analysis, and synthesis; elaboration of a common database and an information system; development and exploitation of the NWSAS mathematical model and the regional sub-models; establishment of a consultation mechanism; socio-economic and environmental study.

OSS, though its dynamic and multidisciplinary approach on circum-Saharan transboundary groundwater resources has acted as a facilitator and has given impetus to the implementation of this project, which is mainly underpinned by national institutions in the three countries sharing the NWSAS water resources. The important results obtained in this project vindicate the OSS approach consisting in promoting basin awareness on shared water – particularly groundwater resources – in Africa.

NWSAS PARTNERS

Algeria	FAO	GTZ	UNESCO
Tunisia	FGEF	IFAD	WAF
Libya	GEF	SDC	

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