Water Resources, State of Play, and Development Prospects in the Steppe Region of Naâma (Western Algeria)

Abdelkrim Benaradj, Hafidha Boucherit, and Touhami Merzougui

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A. Benaradj (✉) and H. Boucherit
Department of Nature and Life Sciences, Institute of Science and Technology, Salhi Ahmed University Center of Naâma (Algeria), Naâma, Algeria
e-mail: kbenaradj@yahoo.fr

T. Merzougui
Department of Hydroelectric, Faculty of Science and Technology, Tahri Mohamed University of Béchar (Algeria), Béchar, Algeria

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Abstract The Naâma region contains significant underground water potential that has been little exploited, especially in the steppe plains around the chotts (El Chergui and El Gharbi), in the Naâma syncline. It has relatively large water resources and indeed benefits from many natural assets: heavy rains, a mountain water tower with large infiltration areas and snow-capped peaks, perennial rivers, and large underground aquifers continental intercalary (Albien).

The water resources of the department are subject to constraints that affect the quantitative and qualitative potential of the waters.

This integrated water management approach will contribute to sound planning taking into account the various social, economic, and environmental interests. It emphasizes the participation of stakeholders at all levels in the development of legal texts and emphasizes good governance and effective institutional and regulatory arrangements to promote more equitable and sustainable decisions. The approach must be implemented using the economic, institutional, and technical tools to increase the efficiency of irrigation, improve the operation and maintenance of perimeters, improve drainage, and reduce soil salinity.

Integrated management of water resources must be learned from the perspective of sustainable development, to control its scarcity and excess; to ensure the supply of drinking water, agricultural, and industrial; and to preserve the quality of the environment.

Indeed, it should be noted that the water resources of the department are appreciable but require to be evaluated in a precise way to ensure their use in a rational and sustainable manner. Water, which is a resource that is both limited and vital, is increasingly sought after and raises problems of sharing between the different economic and social users: between the supply of drinking water and irrigation, between water and water and irrigation and industry, and between urban and rural populations.

Keywords Integrated management, Naâma, Threats, Use, Water resources

Acronyms

ADBADF	African Development Bank African Development Fund
DA	Algerian dinars
DE	Direction of the Environment
DPPM	Direction of Program Planning and Monitoring
DWR	Direction of Water Resources
DWS	Drinking water supply
IWRM	Integrated Water Resources Management Approach
MWR	Ministry of Water Resources
NAHR	National Agency of Hydraulic Resources

1 Introduction

The Naâma region is part of the arid territory of the South Mediterranean; it undergoes contrasting climatic influences where the rainfall is insufficient and irregular, the inter-annual and seasonal variations very marked, and the intense evaporation and the high temperatures with amplitude more or less contrast [1].

The issue of water resources is vital. It is at the center of a large number of interests: food security, agriculture, biological diversity, and desertification, land use planning, poverty, health, peace, conflict, etc. However, the risks of degradation of agro-ecological resources, including water resources, are still persistent, and levels of agricultural and pastoral production are still rather modest compared to the significant needs of a growing region [1].

The chapter presents a diagnosis of the current state of water resources and their challenges through the analysis of various natural, climatic, and anthropic constraints. According to OCOD [2]; and in the context of growing water scarcity exacerbated by rapid population growth and urbanization, misallocation of resources, environmental degradation, and mismanagement of water resources, this diagnosis requires the implementation of management strategies for available water resources, be it at the level of households, peasants, pastoralists, cities, companies, and developers. It is divided into two parts:

– The first part of the chapter is devoted to the characterization of the physical and natural environment of the department of Naâma, as well as to the analysis of its demographic characteristics.
– The second part presents the general state of the water resources of the department, their mode of exploitation, and the consequences that can result on the prospects for sustainable development and the environment.

2 Presentation of the Study Area

The department of Naâma extends over a vast territory of three million hectares. It is located between latitude 32°08′45″ and latitude 34°22′13″ North and longitude 0°36′45″ East at longitude 0°46′05″ West (Fig. 1).

It is located between the Tell Atlas and the Saharan Atlas in the western part of Algeria. It is limited:

- To the north by the departments of Tlemcen and Sidi-Bel-Abbes
- To the east by El Bayadh department
- To the south by the department of Bechar
- To the west by the Algerian-Moroccan border the Kingdom of Morocco

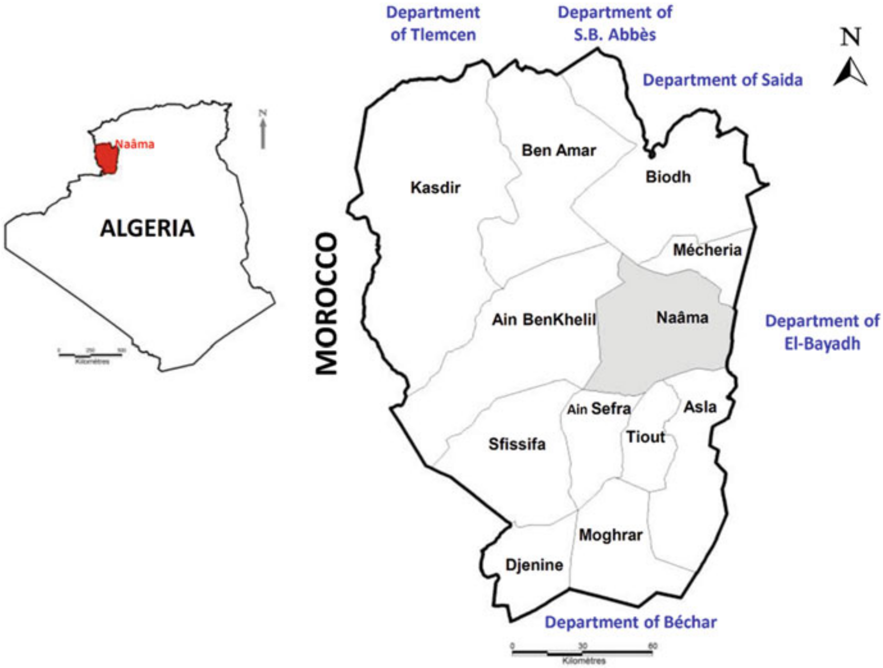

Fig. 1 Geographical location of the study area (department of Naâma-Algeria)

2.1 Physical Framework

Knowledge of the physical environment data in its different forms is essential in understanding the phenomena related to different aspects of the environment and its components. The analysis of the natural environment should enable us to identify and characterize the potentialities and physical constraints as well as their geographic interaction and variation. It will make it possible to appreciate the current use of the resources and the potentialities of the physical environment.

Geographically, the department of Naâma is a vast territory with stratified reliefs consists of three large geographical units [3, 4]:

– A steppe area with monotonous topography constituting most of the rangelands occupies about 74% of the total area.
– A mountainous part with a fairly massive aspect forming an integral part of nearly 12% of the Saharan Atlas chain, which is commonly referred to by the name of Ksour Mountains.
– A southern pre-Saharan zone, which extends over the remaining 14%, which is actually a subspace of the Ksour Mountains materialized by their southern piedmont. Indeed, it is the southern space bounded by the line of ridges going from the Djebel Bou Amoud stretching towards Djebel Bou Lefrhad.

Geologically, it is located on quaternary glacis belonging to the sub-sector of the atlas Saharan Oranian. The study area as a whole constitutes a transition zone of the geological formations of the Atlas Tellian and that of the Atlas Saharan. It is characterized by the juxtaposition of two sedimentary series, marine and continental, and this is according to the phases of regression and transgression of the sea. The base of the deposits is constituted by marine series of the Jurassic where the sandstones predominate and then the continental Cretaceous series consisting of sandstones and some dolomites and calcareous past in the late Cretaceous [1].

2.2 *Socioeconomic Framework*

2.2.1 Evolution of the Population

The department of Naâma is occupied by a population located along the road axis Oran-Bechar on a space of more than one million hectares or a third of the surface, which translates a bad occupation of the space.

According to the data of the Direction of Program Planning and Monitoring (DPPM) of the department of Naâma [3], the population has a significant increase in the last decades. The demographic development of the department passed 62,510 inhabitants in 1966 to 268,721 inhabitants in 2016 (a density of 9.01 inhabitants/ km^2) with a rate of increase of the department of 2.95%. This demographic change in number requires increasing water requirements.

The analysis in Table 1 shows a change in the population of the department of Naâma. The population has tripled in 30 years: the increase in the number of inhabitants affects the consumption of the inhabitants of the region. The department ranks 45th nationally and represents 0.7% of the total population of Algeria. This increase can be considered as a transition in the demographic behavior of the population.

Despite a decline in the population growth rate, growth is still very important. In fact, after registering an average annual growth rate of 3.40% between 1987 and 1998, the department recorded a demographic growth of around 2.5% per year over the period 2008–2016 compared with 1.72% at the national level.

The distribution of the population is mainly concentrated in the three main centers (Mecheria, Ain Sefra, Naâma) as well as other agglomerations located along the national road number 06 (Fig. 2). Nearly 58% of the total population resides in an area not exceeding 7% of the total area of the department.

2.2.2 Evolution of Agro-Pastoralism

The vocation of the department is essentially agro-pastoral traditional where cereal productions dominate. The morphological configuration of the department of Naâma

Table 1 Evolution of the population in the department of Naâma [3]

Years	1966	1977	1987	1998	2008	2010	2012	2014	2016
Number of inhabitants	62,510	82,555	113,700	165,578	209,470	225,530	239,522	253,934	268,721

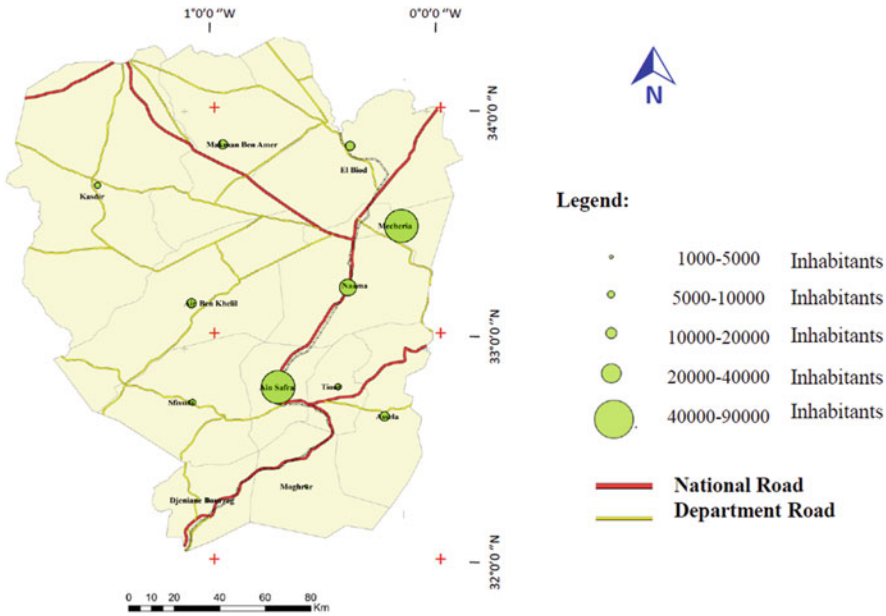

Fig. 2 Population map of the Naâma region [4]

Table 2 Evolution of agricultural land (Ha) in the department of Naâma [3, 4]

Years	2006	2008	2010	2012	2014	2016
Agricultural area	20,395	20,961	23,335	23,766	26,228	28,283
Irrigated agricultural area	6,539	95,305	11,160	13,571	15,374	15,405
Grazing and courses	2,183,005	2,182,439	2,180,065	2,179,634	2,177,172	2,176,117
Total	2,203,460	2,203,460	2,203,460	2,203,460	2,203,460	2,203,460

reveals several spaces for the development of agriculture, particularly in the southern region.

Agriculture

According to Table 2, land intended for agriculture requires water supply, which shows that a considerable amount is intended for these irrigated areas. In recent years, economic development, particularly in agriculture, has resulted, on the one hand, in increased water requirements and, on the other hand, has caused degradation of groundwater quality [5].

The increase in the useful agricultural area will be essentially at the expense of pastures and rangelands. This will support the thesis that agriculture is increasingly pushed back in unfavorable agro-climatic zones and requiring significant investments (drilling, access, electrification) for its practice, to the detriment of the previous use of these zones.

Pastoralism

The data in Table 3 highlight the importance of the sheep herding in the foreground. The numbers of ruminants vary from 1 year to the next mainly due to uncontrolled commercial transactions and the transhumance practiced by breeders.

This herd requires consumption of water like all living beings (Table 4). Livestock watering differs from one animal to another, depending on the environment and the practices of breeding, the season, the physiological state, the age, the quality of the feed, etc.

2.3 Climate Framework

The climate of the Naâma region is characterized by a low and irregular rainfall (100 and 300 mm/year) and a fairly long dry period of 6–7 months, characterized by low temperature that generally falls below −4°C (Fig. 3). This explains its membership in the arid bioclimatic stage. Irregular rainfall from year to year combined with prevailing dry winds causes a degradation of the vegetation cover and accelerates the phenomenon of aridization.

2.4 Hydrological Framework (Hydrography and Hydrogeology)

The hydrology of the department of Naâma strictly obeys the topography and the nature of the soil characterized by a strong dissymmetry between the north and south part of the department. The presence of water in the soil is related to the nature of lithological formations [8]. All formations of marine or continental cover are likely to store water bodies except clayey and marly facies. However, clays and marls there alter very frequently with sandy formations or sandstone aquifers. Only formations consisting of quartzites, shales, hard sandstones, and uncracked eruptive rocks do not contain a body of water [9].

Table 3 Livestock evolution in the department of Naâma [3]

Years	2000	2002	2004	2006	2008	2010	2012	2014	2016
Sheep	565,368	817,570	831,570	842,140	864,000	1,116,500	1,150,249	1,200,000	1,400,000
Goats	56,949	36,000	36,360	56,625	57,500	63,440	68,619	37,605	82,986
Cattle	21,334	32,820	33,148	37,200	37,500	37,500	37,560	37,560	73,167
Camels	500	755	784	799	812	953	1,004	1,015	1,048
Total	644,151	887,145	901,862	936,764	959,812	1,218,393	1,219,872	1,276,180	1,557,201

Table 4 Daily water consumption by sheep, cattle, and camels

	Average water consumption	Authors
Sheep	4.4–10.4 L/day	
Cattle	9–115 L/jour	[6]
Camels	200 L/min/for 14 days	[7]

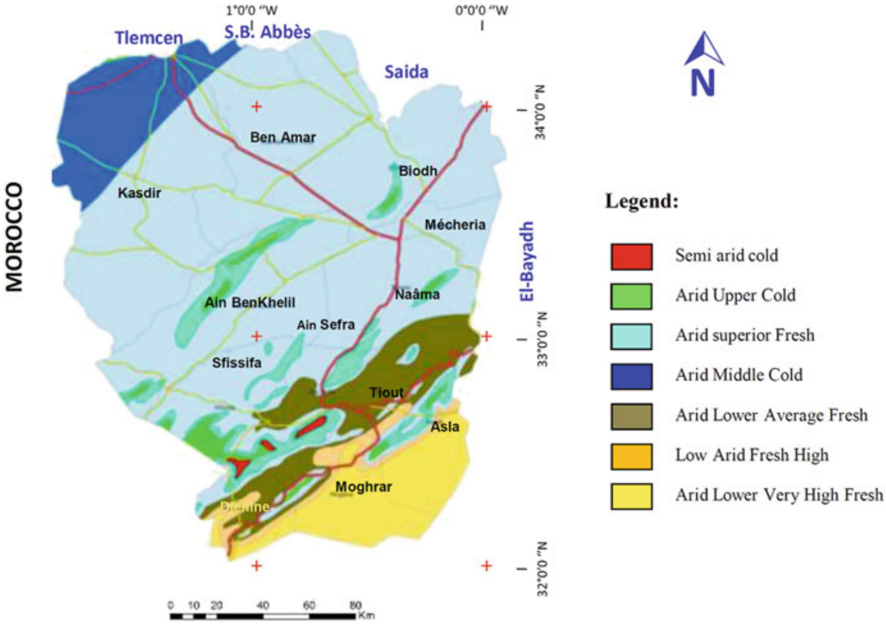

Fig. 3 Bioclimatic map of Naâma [2]

2.4.1 Hydrogeology

The groundwater resources of the department of Naâma come from several aquifer systems whose formation is favored by the geological context.

In general, the work of the National Agency of Hydraulic Resources (NAHR) [9, 10] reports four main aquifers:

– The Chott El-Chergui aquifer, exploited for the benefit of four departments: Naâma, El Bayadh, Saïda, and Tiaret
– The tablecloth of Chott El-Gharbi
– The tablecloth of the syncline of Naâma
– The tablecloth of the syncline of Ain Sefra

Potential groundwater aquifers fall into two types, deep aquifers, mainly exploited by boreholes and aquifers and mainly exploited by springs. Also, the excessive depth of the boreholes in the department testifies to the presence of deep aquifers in the Cretaceous (Albian) formations.

Overall, the region covering the extension field of the Naâma syncline contains formations that may be aquifers that are as follows:

- Tertiary infill formations: 20 and 120 m deep, favorable intrinsic properties of the development of small aquifer horizons.
- The sandstone of the Upper Jurassic, e.g., Callo-Oxfordian, Kimmeridgian contains important aquifer levels located at depths between 50 and 450 m.
- The dolomitic limestone fractures of the Middle Jurassic (Bajo-Bathonian) whose stratigraphic position within the synclines places them very deeply. A second synclinal (south limit of the Naâma syncline) with a NNE/SSW direction takes over and is none other than Tirkount.
- The Mio-Pliocene and Mesozoic formations of this synclinal contain a cylindrical sheet with a parabolic profile whose general flow takes place from NE to SW.
- This Mio-Pliocene aquifer is fed from Jurassic and Cretaceous formations of the NW flank of the Djebel Aissa and the NE flank of the Djebel Morghad.
- South of the Tirkount depression. Another layer of lesser importance is contained in the alluvial deposits of the Breidj valley: it is developed in a scene of sandy-clay alluvial deposits about 10 m thick exploited by wells and whose general flow at SSE/NNW management [1].

2.4.2 Hydrographic

The hydrographic network is poorly developed in the north, while in the south, it is denser with an important inferoflux crossing the Saharan Atlas [11]. The northern part of the High Steppe Plains had an undeveloped hydrographic network characterized by relatively flat topography and dotted with depressions, which is at the origin of the endorheic nature of these valleys. The surface waters are temporary; they flow in the direction of three closed basins: Chott El-Gharbi to the West, Chott Ech Chergui to the North-East, and sebkha to Naâma to the South-East [1].

In the south, the existence of reliefs gives rise to a more dense flow and a more hierarchical hydrographic network, thus forming some valleys whose flow takes a direction parallel to the structures. Valley of El Breidj has a south-west/north-easterly flow, while valleys of Ed-Douis and El Rhouiba have a north-east-southwest flow.

The lithostratigraphic and structural context prevailing in the Naâma department space has favored the formation of aquifer units or systems from various horizons captured by drilling. However, if these aquifer systems exist, their identifications and knowledge remain uncertain. Currently, the only data available relates to information provided by drilling and shallow wells. Most of these drill holes are exploited from Upper Jurassic formations, particularly the Callovo-Oxfordian, which appears to contain significant aquifer horizons with depths ranging from 50 to 450 m [12].

In the synclinal structures of the region of Ain Sefra and Tiout, the Cretaceous (Albian) formations offer appreciable potentialities in groundwater at depths of 150–200 m with flow rates varying from 10 to 84 l/s. For shallow and medium depths, the more or less coarse levels of the tertiary base may contain small aquifer horizons.

Also, fractured Bajo-Bathonian formations may be able to accumulate groundwater [1].

3 Potentiality of Water Resources

The region of Naâma has a significant wealth of surface water resources and above all underground, which however is very little exploited.

Potentialities in groundwater are poorly known because of the lack of detailed and recent hydrogeological studies, but they can be considered significant given the number of boreholes in operation and flows achieved [1].

3.1 Surface Water

A rather dense flow, hierarchical, originating on the slopes of the massifs of the Saharan atlas and directed entirely towards the south towards the great western erg crossing thus the whole of the mountainous barrier. This is the case of the waters of the valley of Breidj, which supports the drainage waters of the valley of Tirkount and Sfissifa, crossing the entire Ain sefra depression and then heading south through a low point located between the mountain Cheracher and Djara and then moving towards the West and finally to the south while changing names (Oued Rhouiba and then Oued Namous) to finish in the great Western erg. The 8,492 km^2 Ksour watershed receives on average 190 mm of precipitation per year, generating an average inflow of 30–36 Hm^3/year. A diffuse intermittent flow network that is poorly developed in this region, is located mainly in the north of the Saharan Atlas, and ending in the most cases on depressions (dayas, sebkhas, and chotts).

This is the case of all superficial flows draining the plains located north-west and north of the mountainous ridge extending from Djebel Oust to Djebel Hafid. Indeed, the streams that come from slopes of these ridges and plains are ending on the depression of Chott El-Gharbi when liquid flows are sufficient.

It is the same for other flows that end their journey in small closed depressions that serve as their base level: this is the case of the water of the valley El Adjedar that ends in the Mekmen-Abiod, where the water runoff from the northwestern side of Djebel el Mellah is ending in the sebkha of Naâma (Fig. 4).

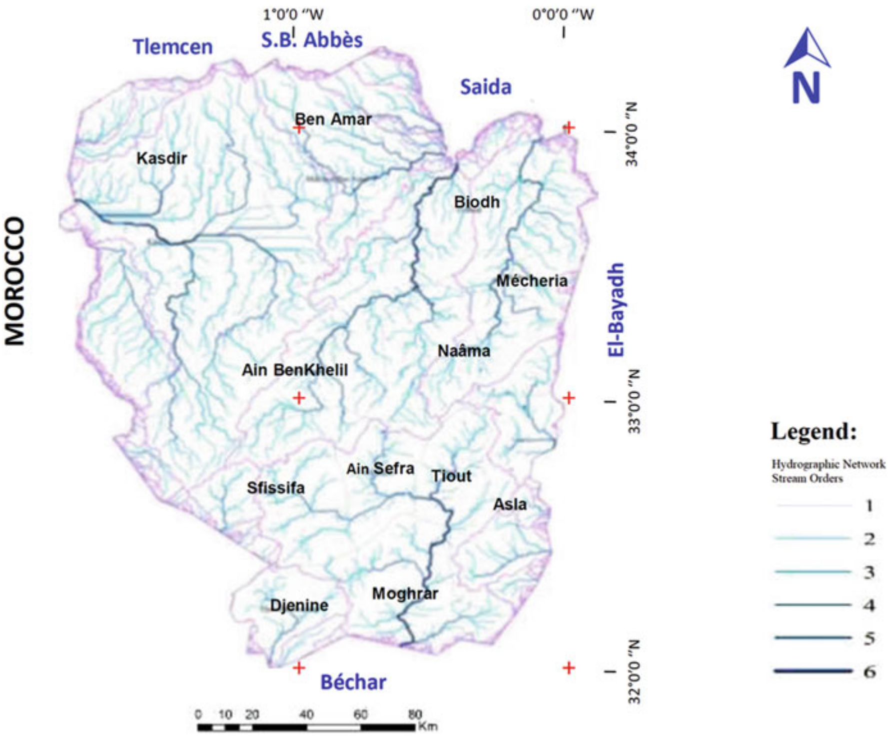

Fig. 4 Hydrographic map of the department of Naâma

3.2 Groundwater

Groundwater is an important part of the water resource. They have the advantage of their regularity, their low mobilization costs, and their good spatial distribution. It is also a resource less vulnerable to climate hazards and pollution. This resource is unique, which gives it an exceptional value.

The implantation of the boreholes indicates that the aquifer potential is particularly concentrated around the chotts (El-Chergui and El-Gharbi), in the syncline of Naâma, and the valley of Ain Sefra-Tiout (Table 5).

However, the estimation of these potentialities, by the various sources of information consulted, reveals an appreciable potential. The main aquifers that exist throughout the department of Naâma are essentially the aquifer of the Albian, Barremo-Aptian, Kimmeridgian, and Turonian [12].

Table 5 Assessment of groundwater resources [10]

Aquifer	Exploitable resource (Hm^3)	Operated volume (Hm^3)
Chott Chergui	46	31.6
Chott Gharbi	40	–
Synclinal of Naâma	15	15
Synclinal of Ain Sefra	11	11

3.2.1 The Aquifer Field of the Syncline of Naâma

It contains interesting potentialities thanks to its geological layers favorable to the formation of aquifers:

– Tertiary formations located between 20 and 120 m deep
– Upper Jurassic sandstones, located at depths between 50 and 450 m
– The fractured dolomitic limestones of the Middle Jurassic, located at great depths

3.2.2 The Aquifer Field of the Tirkount Syncline

This Mio-Pliocene aquifer is fed from the Jurassic and Cretaceous formations of the northwestern flank of Djebel Aissa and the northeastern flank of Djebel Morghad.

3.2.3 The Alluvial Aquifer of the Valley Breidj

Limited to the northeast by the city of Ain Sefra, to the south by the Djebel Mekter, and to the northwest by the valley Breidj, this layer, developed in a series of sandy-clay alluvial deposits of about 10 m thickness, is exploited by wells.

Although the department of Naâma is close to the large sheets of the Saharan Atlas (see Fig. 5), it has significant underground water potential, especially around the aquifers of the chotts (El-Chergui and El-Gharbi), as well as the aquifers of the synclinal of Naâma and in the valley of Ain Sefra-Tiout, the exploitation of the ignorance of the intrinsic characteristics and the geometry of the different aquifers.

3.3 Potentialities in Water and Their Mobilization

The semiarid climate and the lack of surface water mobilization structures mean that the department of Naâma is essentially supplied with groundwater.

Mobilizations in surface water are insignificant; they amount to 0.092 Hm^3, captured by two hill reservoirs intended for irrigation:

– A capacity of 0.062 Hm^3, located in the commune of Naâma
– A capacity of 0.030 Hm^3, located in the municipality of Tiout

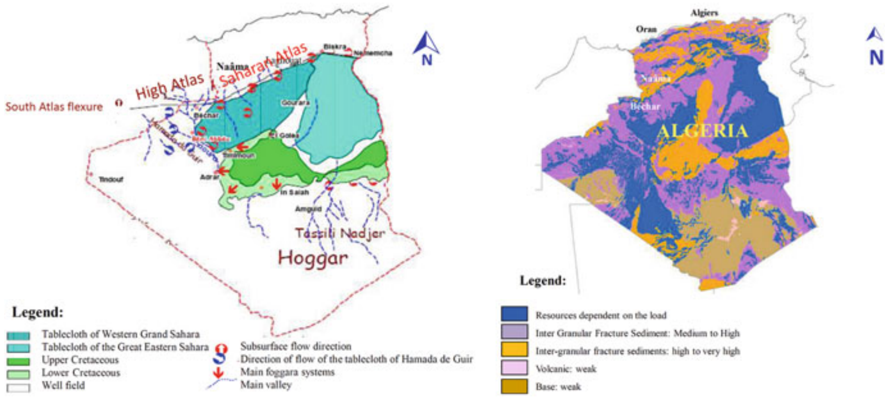

Fig. 5 The great water potential of southern Algeria [10, 13]

The overall situation with regard to water mobilization and their assignments is shown in the following table (Table 6):

The analysis in Table 6 and the data from the DPPM show very clearly:

- The data presented in the table provide very significant indications.
- The balance of mobilizations by type of works (drilling, wells, sources, and Collin Dams), number of structures, and their flows.
- Groundwater resources are very significant, especially for deep aquifers.
- In terms of water mobilization, boreholes and water points have all been positive. The flows achieved vary between 5 and 80 l/s.
- The department has 89 storage facilities with a total capacity of 39,200 m^3.
- Mobilization by 1,163 boreholes across the territory with a cumulative flow of 5,131 l/s.
- Mobilization by 905 wells throughout the territory with a cumulative flow of 464 l/s.
- The wells collect shallow water; these shallow groundwater mainly for irrigation are appreciable (in the perimeters of the region of Ain Ben Khellil).
- Mobilization by five sources across the territory with a cumulative flow of 5.3 l/s per unit is located in the municipalities of Ain Sefra and Asla.
- The mobilization of surface water through three hilly reservoirs across the territory of the department is generally intended for irrigation (Table 7 and Fig. 6).
- The problems of exploitation related to the networks of drinking water supply (DWS) result notably from the defects of the study of conception and realization, as well as from the dilapidated networks in some cities (Mecheria, Ain Sefra and Asla). Also, the pumping of water from the boreholes is conditioned by the electrical energy; the power cuts sometimes cause disturbances in the drinking water supply.

Table 6 The situation of mobilized resources (DPPM of Naâma [3, 14–16])

Topics	2010	2012	2014	2016
Drilling				
Number	1,074	1,151	1,129	1,163
Flow (L/S)	3,706	5,999	5,054	5,131
Destination (L/S): – Drinking water supply (DWS) – Irrigation – Other	 1,386 1,990 330	 1,381 4,288 330	 1,381 3,673 219	 1,267 3,864 244
Well				
Number	1,006	1,011	901	905
Flow (L/S)	2,035	516	466.00	464.00
Destination (L/S): – Drinking water supply (DWS) – Irrigation – Other	 24 1,992 19	 13 503 19	 13 453 0	 11 453 0
Sources				
Number	5	3	5	5
Flow (L/S)	9	5.80	5.80	5.30
Destination (L/S): – Drinking water supply (DWS) – Irrigation – Other	 4 5 0	 4 2 –	 4 2 –	 3,8 2 –
Hill dams				
Number	5		3	3
Storage capacity (Hm^3)	11.45	11.421	10.719	10.719
Destination (L/S): – Drinking water supply (DWS) – Irrigation – Other	 0 0.09 11.36	 0 0.0165 8.33	 0 0 3.60	 0 3.60 0
Underground resources mobilized (flow: L/s)				
Daily water allocation (L/D/H)	480.09	475.00	482.10	439
Number of tanks and water towers	83	86	86	89
Production and consumption of drinking water (m^3)	36,550	38,550	38,550	39,200
Drinking water roduction and consumption				
– Mobilized volume (m^3/day) – Volume produced (m^3/day) – Distributed volume (m^3/day)	119,750.4 32,529.4 30,902.93	119,318.4 38,565.1 36,535.20	119,318.4 44,929.8 42,302.50	109,468.8 43,604.0 42,066.00

Table 7 Probable availabilities from hill dams and small dams in Horizon 2030 [2]

2006 (Hm^3/an)	2010 (Hm^3/an)	2020 (Hm^3/an)	2025 (Hm^3/an)	2030 (Hm^3/an)
10.10	10.6	11.7	12.2	12.8

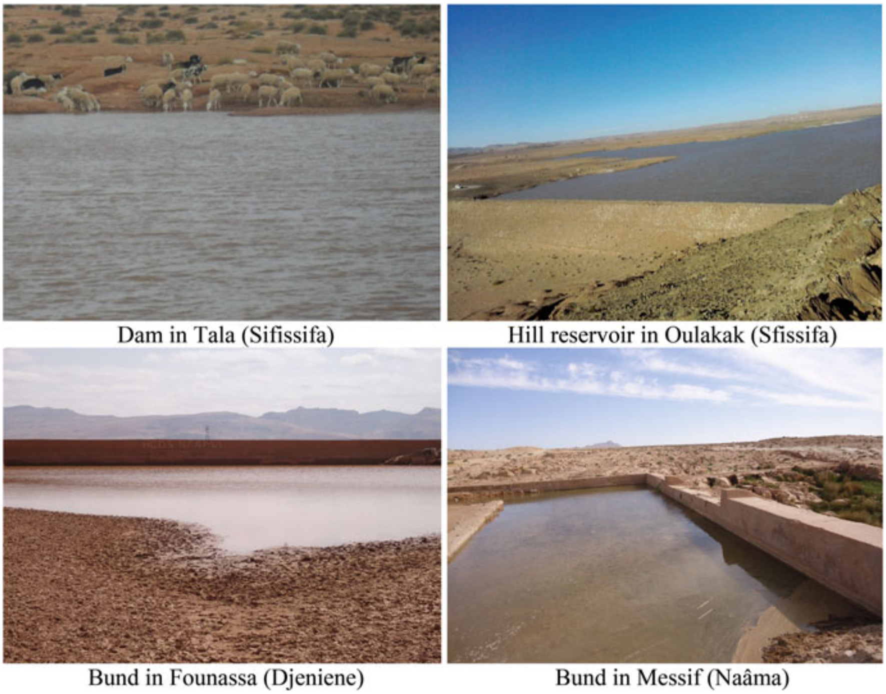

Fig. 6 Hydraulic water storage structures in the area of Naâma

- The rational mobilization of this resource requires capital importance in the development of this region in the agro-sylvo-pastoral field.
- Regarding the projections of the use of recycled wastewater, through the construction of wastewater treatment plants in the main cities of the department (Naâma, Mecheria and Ain Sefra), with a resource capacity of nearly 02 Hm^3.
- The theoretical daily average water allocation, at the scale of the department, assessed through the volumes of water distributed to the agglomerated population recorded in 2016, reaches 439 l/d/ inhabitants. This level, compared to the national standard (150 l/d/inhabitant), remains appreciable. Per capita water availability has deteriorated significantly since independence. By 2020, per capita water availability in Algeria is estimated at 473 m^3/inhabitant/year. The scarcity threshold set by the World Bank is 1,000 m^3/inhabitant/year [17].

4 Threats and Environmental Challenges of Water Resources in the Naâma Region

The problem of water is certainly seen from new dimensions such as delegated management, profession of water, rigor, and economy. However, face to this situation, the rationalization of daily consumption of water of users becomes a necessity to keep the durability of water resources in this region. Leaks are still present, and as important as before, the dissatisfaction of the users is still visible; the changes made in the management were not the taste of the workers of the sector, etc. For that, a diagnosis, even summary, of the situation will enlighten us on the subject.

The water resources of the department are subject to several threats (climatic, socioeconomic, and ecological), which affect the quantitative and qualitative potential of the water [18].

4.1 Climate Threats

The most cited causes are climate changes, which are marked by a decrease in rainfall and an increase in evaporation. These phenomena could notably be reflected in the frequency of droughts or floods.

– Belonging from the Naâma region to the arid and semiarid bioclimatic level.
– Climatic aridity and climatic changes recorded during the last decades (climatic fluctuations).
– Drought is one of the most common natural hazards in Algeria with negative effects on agriculture and water resources.
– Annual rainfall weakness: Like the other departments of High Plains, precipitation is, on the physical and natural levels, the first constraint for the department. Indeed, the rainfall regime is characterized by very low annual rainfall (between 100 and 300 mm on average), often of a stormy nature and presenting a great inter-monthly and inter-annual variability; their height decreases from north to south. This climatic characteristic, combined with other environmental factors (relief and lithological formations), implies many handicaps and threats:

  (a) Insufficient rainfall, which is a limiting factor for rain fed agriculture and groundwater recharge, as well as a major factor in the degradation of steppe vegetation cover and the desertification process.
  (b) The irregularity of the precipitations and their seasonal and annual variations, which makes any production in random dryness.
  (c) The intensity of the rains which is generally reflected by strong floods and the flooding of inhabited areas (Ksour Mountains and mainly the city of Ain Sefra). Floods are among the most common and unpredictable natural disasters. Regarding the department of Naâma, the threat to floods is mainly seen in the Ksour Mountains, where the stormy character of the rains, combined

with the declivity of the relief and a hydrographic network with banks undermined, gives rise to significant floods that flow on inhabited areas. The most convincing case for the illustration of this phenomenon is the city of Ain Sefra, which saw its former European village ravaged by the great flood of 21-10-1904. In the urban areas of the plain, like Mecheria, the problem of flooding in low-income neighborhoods is mainly due to the absence or insufficiency of rainwater drainage networks [19].

(d) Effect of evaporation on the water balance. It is itself based on several factors including wind, sunstroke, and temperature. The longer the dry season, the greater the importance of evaporation. Precipitation largely absorbed by intense evapotranspiration [20].

4.2 Socioeconomic Threats

4.2.1 Demographic Pressure

Given the single problem of meeting the need for drinking water, demographic factors and urbanization are very heavy constraints in terms of water resources, notwithstanding the economic aspects and the pace of investments that characterize the water supply [21]. With a significant demographic growth, even if today the slowdown is significant, Algeria is confronted with the problem of the adequacy between its population and the physical limits of water availability. These can only increase over time as demand for water steadily increases under the combined effects of population growth and increased domestic, industrial, and agricultural needs related to economic development and rising standards of living. Today, the demand for water is important because of the economic and social changes recorded by the country: the increase in irrigated areas and urban growth.

4.2.2 An Accelerated Urbanization Process

The accelerated urbanization experienced by Algeria since its independence is the result of a historical fact, a spectacular demographic growth, and migratory movements which were no less so, especially during the first three decades. The impact is doubly negative. In addition to the removal of agricultural land, urbanization has a more insidious effect on the agricultural sector because of water consumption, both superficial and underground. It follows a lowering of the water tables and a drying of the wells, requiring either a deeper sinking or a sinking of new boreholes.

4.2.3 The Overexploitation of Groundwater and the Development of Interregional Transfers

The two aquifers of the Naâma syncline and the Ain Sefra syncline are exploited to 100% of their capacities, whereas the usual practices recommend, for a preservation of groundwater, a farm must not exceed 70–80% of their capacity [1]. The exploitation volume exceeds the tolerated level for the aquifers of the Naâma syncline and the Ain Sefra syncline [22]. Overexploitation of groundwater can cause a lowering of the piezometric level [23].

4.2.4 The Wastewater

The wastewater does not only concern the agricultural sector. In cities, pipes are often old and poorly maintained. The losses of network water are still impressive, up to 50%, whereas in a modern system, they must not exceed 10% [24].

4.2.5 Leaks

It is clear that the problem of leaks is not recent, and we can affirm that from a quantitative point of view, losses, especially in the form of leakage networks that only rational use and a more efficient operation can reduce, are one of the main causes of the deterioration of the rate of satisfaction of domestic needs. The result is that the leaks are at a still high level; however, improvements are reported. Experts agree that reducing losses by as much as 30% saves 1.5 billion cubic meters per year and therefore meets the needs of around 4 million consumers. Leaks in individuals are also quite important. Just imagine what a leak of 0.1 l/s (split between flush and different faucets in a dwelling) to measure the wasted volume. According to Touati [24], the water loss per day is estimated to 8640 l, which give an annual quantity of 3,153,600 l, that leads to an important financial loss around to 20,000,000 Algerian Dinars (the price of one cubic meter is 6 AD excluding taxes). Total losses in irrigation systems are estimated globally at 40% of abstractions; they would exceed 50% in the cities.

4.2.6 Extension of Agricultural Irrigation in Algeria

The development of irrigation is a mandatory step to ensure food security of the country. Irrigation is poorly developed in Algeria. However, it has evolved in recent years with a doubling of irrigated areas. The importance of water for life and as a component of the global ecosystem is well established. This resource, which meets the basic needs of man, is a key element of development, but even more, agricultural water appears as one of the major levers of development. The dramatic increase in demand and the consequences of climate change have made water the most valuable resource on our planet. The water deficit is one of the most important factors limiting crop production in the world [25].

4.2.7 Energy Pressure

Increased energy demand will also weigh in the future on water resources. Hydroelectric generation is expected to grow by around 60% by 2030 [26].

4.2.8 Geopolitical Problem

Water in relation to society is represented as a fundamental problem related to the management of conflicts, sources of income, etc.

4.3 Ecological Threats

4.3.1 Mining and Shale Gas

One of the most harmful impacts of shale gas exploitation is the risk of groundwater pollution and methane pollution of drinking water.

4.3.2 Risk of Pollution of Surface Water and Aquifers

Agriculture, industry, and urbanization have exploded the consumption of water causing discharges of astronomical quantities of wastewater which eventually make this precious resource unsuitable for the consumption. This pollution of surface water and groundwater is a process caused by the rejection, in the valley, of urban wastewater (domestic or industrial) without prior treatment. This phenomenon affects the majority of valley located near settlements, to more or less severe degrees. Groundwater is increasingly subject to voluntary discharges of polluting effluent, wastewater, or storm water runoff into urbanized areas [27, 28].

4.3.3 Salinization of the Waters

The risks of salinization of the waters of the water tables of the department are because of two main reasons: the presence of the two depressions with salty waters, Chott El-Chergui and Chott El-Gharbi, and the presence of north and south flexures Atlas, which favor the ascents of the triad.

5 Prospects for the Development of Water Resources in the Department of Naâma

The region of Naâma has relatively large water resources and indeed benefits from many natural assets: fairly heavy rainfall (rain, snow), a mountain water tower, valleys, and large underground aquifers. The concern to save and exploit the environment rationally involves acquiring the basic data needed to understand how ecosystems function and to evaluate their potential.

Groundwater is an important part of the water resource. They have the advantage of their regularity, their low mobilization costs, and their good spatial distribution. It is also a resource less vulnerable to climate hazards and pollution. This resource is unique, which gives it an exceptional value.

Because of their economic, social, and environmental importance, water resources are the cornerstone of sustainable development. The growth of drinking water needs is due to the population growth, the development of cities, and the growth of water-consuming economic activities such as agriculture, industry, and tourism.

This growth imposes large-scale challenges and requires solidarity sometimes going beyond the limits of departments or even regions, just as the satisfaction of these needs requires the use of new techniques and methods of mobilization and exploitation of resources in water [1].

The phase of development of the territory of the department of Naâma "allowed delivering an inventory of fixtures and an analysis of the current situation of the department." This examination related at the same time on the water resources and the assets of the department, its constraints, as well as on its general level of equipment and development. The development of all these resources and potentialities, within the framework of thoughtful and coordinated actions of promotion of the investment and in respect of the principles and orientations in the matter of preservation of the environment, may allow the department to initiate a dynamic of growth and sustainable development.

For its water needs, the department of Naâma has water resources, especially underground, which allow it to envisage favorable projections of demand satisfaction (all uses combined), according to the forecasts by 2030, elaborated by the Ministry of Water Resources. Although they are not sufficiently known, the underground water resources of the department are considered appreciable; however, they must be rationally exploited and protected against the risk of pollution. Projections of the demand and availability of water resources by 2030, developed in the framework of the national water plan, presented in the following table, show that the overall balance sheet (all uses combined) remains largely positive for the Naâma department, whether short, medium, or long term [1, 23].

Prospects are still worrying because of the contamination of available water resources by the intensification of human activities. Many of the efforts to manage available water resources are to realize the need, to protect groundwater quality, and to limit impacts on groundwater quality. Among the possible actions of development of the water resources in the department of Naâma:

1. Assessment and mapping of water resources
2. Integrated Water Resources Management Approach
3. Sustainable Development of Water Resources Approach

5.1 Studies and Mapping of Water Resources

The development of a mapping of the vulnerability of groundwater makes it possible to optimize the use of the territory to minimize the risks of the appearance of contaminations. Also, the delimitation of catchment protection perimeters is a measure to help prevent contamination during the supply. Thus, undertake the necessary studies to determine with precision: the real water potential of the department, its location, its degree of exploitation, and its economic cost.

5.1.1 Improving and Securing the Situation of the Drinking Water Supply

- Improvement of the living environment of the populations
- Protection of water resources against all forms of pollution
- Protection of works and human settlements
- In-depth knowledge of water resources in quantitative and qualitative terms
- Mobilization and strengthening of the drinking water supply
- Extension, rehabilitation, and construction of networks for water supply and sanitation
- Equipment coming within the framework of local development and responding to a collective need
- Establishment of a comprehensive inventory of water points (boreholes, wells, springs, etc.)
- Priority to the mobilization of the surface water resource from structures adapted to the region (diversion hillside dams, flood spreading works) which also allow groundwater recharge
- Construction of works and devices for the purification of wastewater and reuse of these treated waters for agriculture and industry

5.1.2 Fight Against the Flood Problem

To fight against the flood problem, the measures to be considered to stem this phenomenon will have to relate to:

– The development of storm water drainage networks at the level of agglomerations and their permanent maintenance
– The cleaning of valley
– Biological treatment of watersheds and riverbanks

5.1.3 Fight Against Waste and Leaks

To fight against waste, it is necessary that the water professionals carry out campaigns of sensitization and descend until the consumers (schools, mosques, public or private establishments, farmers), by the implementation of an effective policy, regular and sustained information, training, and extension. Education courses should be done from the primary level of the economy and the good management of water. The water policy will involve civil society (community movement), local authorities, and, of course, watershed management representatives, and in this context, funding must be defined [24]. Thus, implement measures to minimize losses on networks (supply, storage, and distribution).

5.1.4 Preservation and Valorization of the Water Resource

Because of their economic, social, and environmental importance, water resources are the cornerstone of sustainable development. These resources are in high demand due to growing needs, water supply and irrigation, as well as industrial, service, and other activities.

The semiarid climate and the lack of surface water mobilization structures mean that the department of Naâma is essentially supplied with groundwater. Potentialities in groundwater are considered appreciable given the number of boreholes in operation and flows achieved;

however, they are poorly known because of the lack of detailed and recent hydrogeological studies. The Program of Action that is defined in this area relates to the knowledge, the preservation, and the greater exploitation of the water resource [1, 29].

5.1.5 Flood Control

The department of Naâma is highly exposed to floods. These are the result of meteorological situations, characterized by intense precipitation over a very short period, combined with unfavorable topography. They mainly affect the Ksour Mountains area, where people, communication infrastructure, and agricultural land often suffer serious damage.

The recommended action plan recommends, firstly, the establishment of an inventory of the flood zones and then a set of actions of protection (improvement and regular maintenance of the sewerage networks, cleaning, calibration and maintenance of wadis in agglomerated zones, construction of protective works, and regulation of building zones) [1].

5.1.6 Pollution Control

The fight against pollution to the environment and water resources involves the completion of wastewater treatment in the large agglomerations (Mecheria and Ain Sefra) and lagoon stations near other agglomerations [1].

5.1.7 Saving and Rationalizing the Consumption of Drinking Water

To better control the demand for water, it is necessary to review the current pricing of drinking water (pay the actual cost) and the implementation of a policy that generally guides consumer decisions to achieve a collective economic optimization and reduce the excessive exploitation of this resource. The many opportunities are to reduce the water consumption in agriculture and industry. The technologies provide significant water savings in irrigated agriculture. Thus, the drip system saves up to 50% of the water normally used for irrigation. In industry, with the modern techniques, it is possible to reduce up to 90% [30] of the quantity necessary for cooking, cleaning, etc.

5.1.8 Hydraulic Awareness

According to Touati [24], the hydraulic consciousness induces a real saving of water. It is obvious that no policy can succeed without the massive and convinced adhesion of all users. At the same time, the latter will only become involved the day they feel that, together with the water economy, the State's water policy aims to substantially improve their own standard of living individual and collective by limiting or even eradicating all leaks. On the other hand, the limitation of the consumption passes by:

- A choice of plant species adapted to the climatic conditions of the region
- The implementation of modern irrigation technologies (drip) to achieve real water savings
- Training farmers in modern irrigation practices
- Improvement of the conditions of management and maintenance of treatment plants, to encourage irrigation by wastewater
- Improvement of distribution networks and the fight against leaks and waste
- The introduction of water-saving technologies (closed circuit cooling, pressure washing, automatic shutdown of pumps, pressurized taps, etc.)
- Recycling in the process
- Awareness and information of the staff on the water economy and the protection of the environment

5.1.9 Adaptations and Practices on Water Demand By

- The mobilization of conventional water resources and the creation of new hydraulic dams for surface waters
- The creation of new boreholes for the mobilization of deep aquifers
- The mobilization of unconventional water resources: by the purification of wastewater and the protection of resources against pollution

5.1.10 Adaptation of the Water Demand Climate Change

We must keep a system adaptable to the hazards and structurally reduce the demand by implementing a system of supply which will have to be more flexible and flexible so as not to be too vulnerable to climatic hazards, as soon as possible when we manage the balance between resource and demand on the edge of the razor.

5.2 Integrated Water Resources Management Approach "IWRM"

Integrated water management is an approach that has been the subject of a large number of documents for various purposes; whole websites are devoted to it. It has been widely developed since the international conferences on water and the environment held in Dublin and Rio de Janeiro in 1992, until that of Kyoto in 2003. It encourages the development and management of the environmental water, to maximizing the resulting economic and social well-being in a fair way, without compromising the sustainability of the vital pastoral ecosystem. It aims at all the actions to be carried out to guarantee optimal use of the water resource qualitatively and quantitatively for the benefit of the populations and their need of the economic activities.

The integrated water management approach is widely developed following the national water policy by various international and national laws on water and the environment to give guidelines through integrated and sustainable management instruments resources. The two laws (83–17 and 05–12) relating to water, give all the actions to be carried out in order to guarantee an optimal use of water resources qualitatively and quantitatively for the benefit of the citizens and their need for different activities. It promotes the development and management of water, with a view to maximizing the resulting economic and social well-being equitably, without compromising the sustainability of the vital pastoral ecosystem. It aims at all the actions to be carried out to guarantee optimal use of the water resource qualitatively and quantitatively for the benefit of the populations and their need of the economic activities.

The concept of integrated management aims to improve the current management of water by promoting a better harmonization between the various needs and interests of human communities and those of aquatic ecosystems. It integrates the protection of public health, the security of populations and their property (floods), the protection of wildlife, and the restoration of habitats [31].

To this end, the rational management of water resources has become a necessity today, even an obligation, to ensure a harmonious and sustainable development that requires for its success a combination of technical, economic, and financial solutions, moreover institutional to meet growing needs.

Integrated management of water resources must be learned in a perspective of sustainable development, to control its scarcity and excess; to ensure the supply of drinking water, agricultural and industrial; and to preserve the quality of the environment [32].

To this end, the rational management of water resources has become a necessity today, even an obligation, to ensure a harmonious and sustainable development that requires for its success a combination of technical, economic, and financial solutions and institutional. However, it will be necessary to launch programs of economy and progress in the efficiency of use, to revise certain allocations of resources, and to answer the increasing needs. Future choices are therefore likely to be critical.

This approach has contributed to rational management by taking into account the various social, economic, and environmental interests. It emphasizes the participation of stakeholders at all levels in the development of legal texts and emphasizes good governance and effective institutional and regulatory arrangements to promote more equitable and sustainable decisions. Therefore, the development and implementation of these approaches will need to use economic, institutional, and technical tools to increase the efficiency of irrigation, improve the operation and maintenance of perimeters, and improve drainage and the reduction of soil salinity [33].

5.3 Approach to Sustainable Development of Water Resources

Achieving sustainable development requires equating social, economic, and environmental concerns with the essential factor and limiting water. Available resources could, however, be used much more effectively by reducing reservoir contamination and evaporation, recycling, maintaining networks, reducing waste, and growing less water-intensive varieties or more and salt tolerant. Efficient, sustainable, and equitable management of water will provide a solid foundation for the recovery, preservation, conservation, and protection of water resources.

Alternative water resources management should involve political, scientific, technological, economic, and technical cooperation. It is a strategy based on:

– Water resource governance with a water policy oriented towards supply management by improving access to drinking water and food security for the population.

- Rationalization of agricultural water.
- Better knowledge of water resources through ongoing and systematic data and information collection programs, analyses, syntheses, and research on the range of water issues.
- Valorization of water and management of water scarcity by technical measures by the development of water conservation structures such as dams to allow the storage of a larger volume of water to use during periods of drought and water transfer facilities to allow water to be transferred from surplus areas to deficit areas.
- Flood mitigation measures such as watershed conservation, storage facilities to mitigate extreme events, stream regulation and regulation, and floodplain management.
- Water conservation through the creation of storage and the replenishment of the water table are measures to be considered for periods of drought.
- Integrate the relationship between solid waste management and integrated water resources management into their national integrated water resources management policies and include appropriate measures in national environmental action plans.
- Wastewater treatment to protect surface water and groundwater against the harmful effects of waste. Garbage dumps must be located and controlled in such a way as to eliminate any risk to human health.
- Awareness and information of all stakeholders in water management, and first of all users, are a paramount condition for the effective application of regulatory, technical, or financial instruments.
- The establishment of an effective and concerted groundwater management policy to mitigate the depletion and degradation of this strategic resource.
- Environmental education is necessary to awaken everyone's awareness of their responsibility for the protection of water resources, their rational management, and a fight against their pollution.

All of these measures can be planned and implemented as part of the integrated water resources management policy [34]. The human factor is primarily responsible for the protection, treatment, and management of this precious natural resource by its preponderant place in any preservation strategy and its sustainable development because it is a strategic and essential matter for the development of the society.

6 Conclusions

The department of Naâma is a region with a pastoral and agro-pastoral vocation which has considerable pastoral and underground water resources. With an arid climate and the absence of structures for mobilizing surface water, the department of Naâma is mainly supplied with groundwater.

The water resources of the department are appreciable but require to be evaluated in a precise way to ensure their use in a rational and sustainable way. Water, which is a resource that is both limited and vital, is increasingly sought after and raises problems of sharing between different economic and social users: between drinking water supply and irrigation and between the potable water of urban and rural populations, water irrigation, and industry.

It should be noted that the water resources of the department are appreciable but require to be evaluated in a precise way to ensure their use in a rational and sustainable manner. So the availability of water of good quality is essential for the well-being of the man.

The department of Naâma is a worrying situation where water must be at the center of the concerns of local authorities, management bodies, users, and all citizens. Faced with this situation, and in order to avoid potential conflicts, we must involve all those involved in water, where individual practices must become more aware and more respectful.

The major concern for the sustainable safeguarding of the water resource in these arid regions is to implement a strategy of safeguarding and exploitation rationally by resorting to plan based on short-, medium-, and long-term forecasting models for detecting trends, future patterns of water use, socioeconomic development, and population growth.

7 Recommendations

The rational, optimal, participatory, and sustainable management of water resources represents a forward-looking approach involving the mobilization, exploitation, and protection of this resource in an efficient and competent manner.

The recommendations to be considered at the end of this study should focus on the following areas:

– Undertake the necessary studies (hydrogeological, hydrological, bacteriological analyses) to determine with precision the real water potential across the department, its location, its degree of exploitation, and its economic cost, by estimating the volumes stored and not yet exploited, notably the synclines of Naâma and Ain Sefra, the Ksour Mountains, as well as the Chott-Gharbi and the northeast of Mecheria.
– Learning how to manage the water resource in a perspective of sustainable development is learning to control its scarcity but also its excesses, to ensure the supply of drinking water, agricultural and industrial, to use it for its energy potential, and to preserve the quality of the environment.
– Water development and management should be based on a participatory approach, involving users (users), managers, planners, and policymakers at all levels.
– Quantitative and qualitative assessment of water resources and the planning of the development of hydraulic infrastructures.

- Implement measures to minimize network losses (supply, storage, and distribution) by modernizing and expanding infrastructure.
- Rehabilitation and optimization of infrastructure by better management of pumping stations with a policy of preservation and effective and continuous maintenance of the equipment of dewatering are supervised by qualified personnel and able to provide for any failure.
- Improve the water economy by adapting agricultural practices to local climatic conditions and by using new irrigation techniques.
- Promote water purification technologies, which aim to find the mechanisms for the extension of the rational exploitation of water, the recycling of wastewater (treatment and purification of wastewater), and their exploitation in the agricultural or industrial fields.
- A policy of rational pricing of water is necessary, in particular the implementation of the progressive scale for the large consumers of water.
- Integrating climate change into water resource management strategies.
- Adoption of a strategy to increase the storage of water by the construction of hydraulic structures (dams, dikes and hill dams, etc.).
- Adaptation of the legal and institutional framework of water.
- Develop and improve public information and specialized education and training for integrated and sustainable water management.

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