Chapter 2
Water Policy in Algeria

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Abstract Water scarcity is a reality in Algeria. However, this stark fact is sometimes misunderstood. High population growth coupled with industrialization calls for a sustainable water use pattern in industrial, agricultural, and domestic sectors. The problems caused by water scarcity imply important changes in the criteria and objectives of water policies. The major water issues in Algeria can be attributed to both policy implementation failure and a lack of on-the-ground application of regulations. For a better tomorrow, it is pressing to integrate policy frameworks with particular attention to efficient utilization, rationalization, and conservation. The proposed approach is illustrated in the paper by the case study of water policy analysis for Algeria.

Keywords Algeria · Water policies · Institutions · Pricing · Irrigation schemes

2.1 Introduction

Algeria is located in North Africa. Most of the country is covered by the Sahara Desert. Then it becomes evident that the country is a water-scarce nation. The Algerian population is expected to reach 45 million by 2020. Not only is the country affected by the severity of its climate and geography but also by the overexploitation of its water resources to an alarming extent. The quality of water management and

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service is one of the key priorities of the government as various forecasts predict that climate change could severely affect Algeria in the form of more frequent drought and flood cycles (CEDARE 2014; Drouiche et al. 2012; Hammouche 2011).

In Algeria, the coastal areas have a mild climate with hot summers and cool and rainy winters. In the highlands, summers are hot and dry. Winter rains in the highlands begin in October. However, most of the territory is occupied by the Sahara, which explains the distribution of population density. Ninety percent of the population is living along the coastlines (Agence du Bassin Hydrographique Constantinois-Seybousse-Mellegue 2009; Hammouche 2011).

Recent research shows that the water resources in Algeria are estimated at 17 billion m^3, with surface water estimated at 10 billion m^3; groundwater at 7 billion m^3 mainly in the Sahara. The aquifers situated in the north are exploited to 90%, with 1.9 billion m^3 per year with some aquifers being overexploited. In the Sahara region, the extracted volume of groundwater is around 1.7 billion m^3 per year (Drought management strategy in Algeria 2014).

The weather information services on water management are delivered through a National Agency for Water Resources via 220 hydrometric stations, 860 rainfall stations, 36 rain gauges, and 56 full weather stations (Drought management strategy in Algeria 2014). To support a growing and rapidly urbanizing population, Algiers hopes to employ technological solutions to maximize the country's water supplies. The emergency program dealing with the crisis and the disruption of water supply has highlighted the random nature of water resources and recommended to relying more heavily on nonconventional water resources such as seawater desalination and reuse of treated wastewater (Ministère des Ressources en Eau 2011), leading to the implementation of a new sector policy of water resources (Boye 2008; Drouiche et al. 2011; Mooij 2007).

2.2 Legal and Organizational Aspects of the Water Sector

The ministry of water resources (MRE) is the most important player in the Algerian water sector. Its mandate is given by Decree no 16-89 of 2016, having the responsibility of elaboration and implementation of policies and strategies in the context of water resources and environment protection. MRE controls both the water and environment sectors. Several public administrations and organizations are subordinated to it (CEDARE 2014; Kettab 2001; The World Bank Report No.: 36270 – DZ 2007). The Algerian water sector is characterized by few companies/utilities. Figure 2.1 lists the agencies and their prime responsibilities (Drouiche et al. 2012; Ministère des Ressources en Eau 2011).

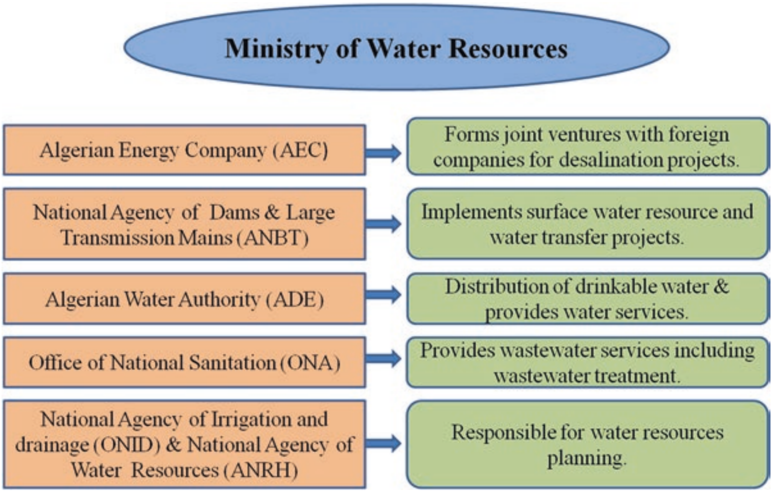

Fig. 2.1 Agencies of water sector and their roles

2.3 Agricultural Water

2.3.1 Surface Water

There are 17 major watersheds in Algeria. The country receives rainfall in an annual average of 89 mm, which allows a flow of 211 billion m^3. Rainfall is variable across the country with 350 mm average annual rainfall in the west and as much as 1000 mm in the north east. Rainfall decreases rapidly south of the Saharan Atlas range and toward the Sahara Desert. The surface water is 10 billion m^3 annually, distributed according to five watersheds, as shown in Fig. 2.2. Most of the surface water resources are concentrated in the North, along with the majority of the population (Groundwater Management in Algeria. Draft Synthesis Report 2009; Knoema 2014).

Only the rivers in the northern coastal region are perennial, flowing all year round. In the south, wadis (ephemeral rivers) drain to closed internal sinks—chotts or sebhkas—which are subject to high evaporation rates. In the drier area to the north of the Atlas, soils are generally suitable for agriculture, but water availability is a key constraint. Withdrawals for agriculture are estimated to be 3940 Mm^3/year, which means that some of these surface waters are being fully used mainly due to expansion of the irrigated land of agriculture irrigation (CEDARE 2014).

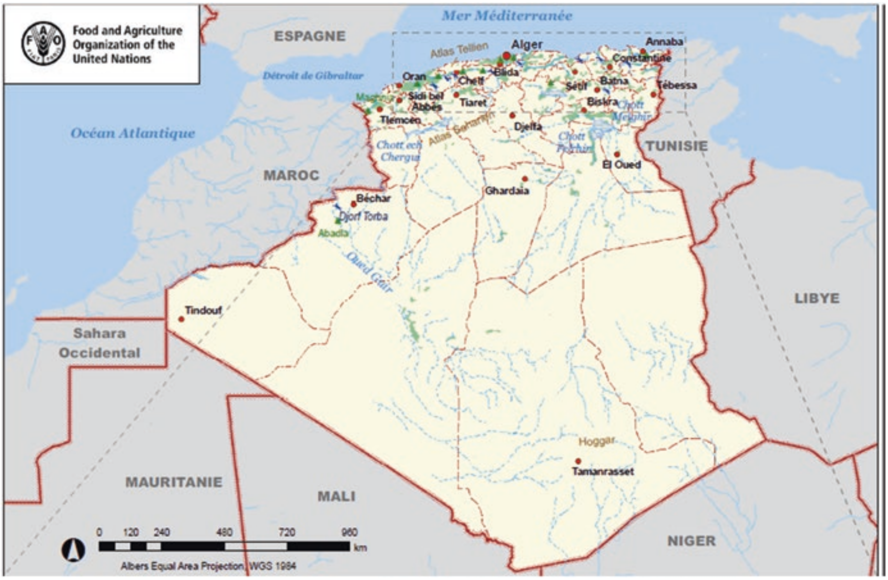

Fig. 2.2 Major Surface Water Features of Algeria. (Source: fao.org. 2015)

2.3.2 Groundwater

Groundwater is the major source of drinking water and its use for irrigation is forecasted to increase substantially to combat the growing food insecurity. Because of its geographical location, Algeria undergoes the influence of two climate types: the Mediterranean type in the north and the Saharan type in the south. Groundwater withdrawals are roughly double the annual recharge rate. The total available renewable potential is estimated at about 2.7 billion m^3/year in the northern Atlas region and 5 billion m^3 in the southern Saharan region. These aquifers are fed essentially by rainfall, whose distribution is irregular both in time and space. Agriculture is the country's primary user of total water, taking almost 4000 MCM/year and is the sector having the highest impact on aquifers, causing a threat for groundwater contamination (Ghodbane et al. 2016; The world bank Report No.: 36270 - DZ 2007).

2.3.2.1 Fossil Water vs Renewable Groundwater

Water is usually a renewable resource, but in some cases, it can be fossil. The fossil water requires careful exploitation and usage, as it is a nonrenewable resource. The largest fossil groundwater volumes are found in the large sedimentary aquifers in the Sahara where the climate is harsh desert with little or no rainfall.

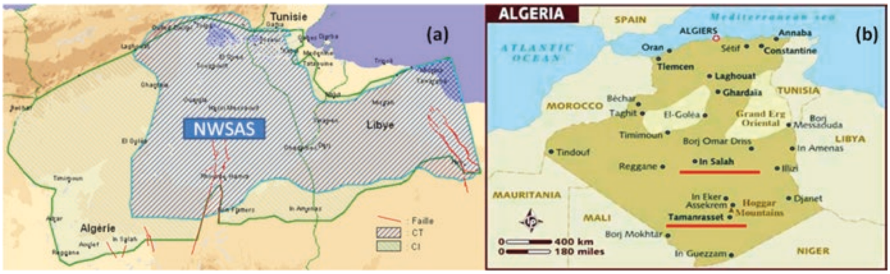

Fig. 2.3 (**a**) Hydrogeological sketch map of the North-West Sahara Aquifer System (Foster and Loucks 2006). (**b**) Map showing position of Tamanrasset

Table 2.1 Projections of the irrigated surfaces evolution in the NWSAS region

Country name	Surface (ha) in 2000	Surface (ha) in 2020	Surface (ha) in 2050
Projections of the irrigated surfaces evolution in the NWSAS region			
Algeria	170,000	300,000	340,000
Demographic Projections (number of capita of the NWSAS region)			
Algeria	2,600,000	3,700,000	4,800,000

Algeria manages and shares its deep fossil groundwater (i.e., The Continental Interlayer fossil aquifers) with Libya and Tunisia as a member of the North-Western Sahara Aquifer System (NWSAS). The agreement is subjected to an international cooperation setup in 2008 between the three countries to sustainably manage the groundwater resource. The latter involves the sharing of two major confined fossil aquifers—the Continental Interlayer sandstone aquifer and the shallower sandstone aquifer known as the Terminal Complex. This system, as shown in Fig. 2.3a, covers an area of more than 1 million km^2, 69% of which is in Algeria, almost 8% in Tunisia, and 23% in Libya. The projections of the increasing pressure on NWSAS water resources for the few coming decades are alarming and are presented in Table 2.1.

This resource is largely nonrenewable, not fully exploitable but confronted to risks due to exploitation, including water salinity and falling water table level, which seriously threaten the sustainability of the economic development in the region.

Algeria started pumping fossil water reserves through a large-scale transfer project to transfer water from Ain Salah to Tamanrasset, over a distance of 750 km, completed in 2011. This project supplies potable water to the city of Tamanrasset to balance the demand. The Ain Salah-Tamanrasset water transfer canal has a conveyance capacity of 100,000 m^3/day. This attitude toward abstraction is prevalent across the entire region (CEDARE 2014; Edmunds et al. 2003; Foster and Loucks 2006; Groundwater Management in the Near East Region Synthesis Report 2011; Sekkoum et al. 2012).

2.3.2.2 Aquifer Depletion

In a semiarid region like Algeria, where groundwater is a primary source of water, intensive irrigation may threaten future water security. In addition, with anticipated shifts in precipitation patterns induced by climate change, groundwater's value as a strategic reserve is increasing in the country. While farmers in Algeria have significantly improved their livelihoods and household food security, aquifer depletion and groundwater pollution are also a direct result of this intensive use of groundwater for irrigation purposes. In the North-Western Sahara, where people are dependent on the North-Western Sahara Aquifer System, depletion of aquifer reserves is taking place with a high dependency on irrigation for agriculture. During the last 30 years, 0.6–2.5 billion m^3/year of water has been abstracted from this system. Algeria is planning to increase the extraction as a response to climate change.

In the Sahara, the *foggara* has played a leading role in the field of abstraction of groundwater distribution and sharing through formal and strict rules. Foggaras are tilted underground tunnels draining water from the water reserve to the field of irrigation. The water flows downstream owing to gravity. It consists of a series of wells 3–12 m apart and a tunnel 50–80 cm wide and 90–150 cm high. Fogarras are still functional and are used to irrigate oases like Touat and Tidikelt group and Gourara oases.

In the northern part of the country, groundwater resources are still available, either in the form of springs or shallow wells. Although significant progress has been made in groundwater governance, the overexploitation due to irrigation over the past two decades has particularly affected the northern areas of the country. Local estimates suggest that by 2025 groundwater supplies could be fully exploited and in some places, they will be overexploited as they are already in parts of the north (Maliva and Missimer 2012; Remini and Achour 2013; Good Practices in Agricultural Water Management Case Studies from Farmers Worldwide 2005).

2.3.3 Property Rights

Algeria has adopted a participatory process to review its legislation and policies and improve its legal and policy framework. Under the 2005 Article 3 of the Water Law, the right to access to water and sanitation to satisfy the basic needs of the population, respecting equity is recognized (Export.gov 2019; Investment Climate Statement – Algeria 2015; Righttowater.info 2019).

Water rights are private in some parts of the country. Thus, in some regions of Algeria partnership agreements exist between the owners of unirrigated land and the owners of water quotas. The share of water received by each recipient is determined based on the size or level of investment contribution. "Association sharing" exists in a region of Southern Algeria between owners of unirrigated land and owners of water quotas for the production of palm dates. In such an agreement the owner of the land transfers half of his property rights to the owner of the water quota. After few years, when the tree bears fruits, the “association” comes to an end and the land owner gets permanent ownership of the water on his land. Both participants benefit through such association as each gets half the ownership of palm groves (Benmehaia and Brabez 2016; Benmehiaia and Brabez 2016; Laoubi and Yamao 2008).

2.3.4 Reuse of Treated Wastewater

During the last three decades, Algeria has suffered from recurrent progression of periods of drought (Intergovernmental Panel on Climate Change (IPCC) 2007). A decrease in annual rainfall of between 10% and 20% was observed in the western region of the country (Meddi and Meddi 2007). The use of groundwater in the northern region has already reached its limits leading to higher pumping rates that have affected the groundwater levels in this region. Significant rise in the population, agricultural irrigation, and economic development have exerted further strain on the water resources. Climate change has also intensified the water scarcity issue. Therefore, reuse of wastewater has become a necessity as properly treated wastewater has been successfully employed to meet nonpotable water needs.

Wastewater reuse alternatives can be generally listed as agricultural reuse, urban and landscape reuse, industrial reuse, domestic reuse, and groundwater recharge. The possibility of reusing treated wastewater for the above-mentioned alternatives depends upon several factors, which include water quality requirement of each user, location of user, probable health risks, government regulations, and cost requirement. Owing to the growing population, water requirement by the agricultural and industrial sector is increasing. As a result, wastewater reuse contributes toward the sustainable management of water resources. The volume of sewage water in Algeria is estimated to be 600 million m^3/year. This number is expected to reach 1.2 billion m^3 in the year 2020 (ONA), 2011, http://www.ona-dz.org/ (accessed 06.06.12).]. Currently, the number of wastewater treatment plants in Algeria exceeds 60, with a total treated volume of 1 Mm^3/day approximately. The Government investments in this subsector over the last 30 years amounted to USD 15 billion (Drouiche et al. 2012). A list of treatment plants is shown in Table 2.2.

Table 2.2 List of major treatment plants, their capacity and volume they treat

Name	Wilaya	Year of service	Capacity (m^3/day)	Treated volume
BBA	BBA	2008	2500	30,000
Ibn Ziad	Constantine	2009	5000	69,120
Ain Hout	Tlemcen	2009	9300	30,000
Ghriss	Mascara	2012	1000	3,700
Baraki	Alger	2013	76712	150,000
Annaba	Annaba	2013	83620	116,000

2.3.5 Food Safety/Vegetables/Heavy Metals

The agriculture sector in Algeria uses 70% of the water resources and is most exposed to weather and therefore most sensitive to drought. In Algeria, treated wastewater is used for unrestricted irrigation, industrial use, and restricted agricultural use according to the degree of treatment. Treated wastewater contains significant amounts of nutrients (nitrogen, phosphorus, and potassium) ranging from 20 to 60 mg/L nitrogen, 6–15 mg/L phosphorus, and 10 to 40 mg/L for potassium (da Fonseca et al. 2005). These nutrients are essential to crops for high yields and undesirable for environmentalists in aquatic compartments, whose excess presence is detrimental to the environment and public health (Mohammad and Mazahreh 2003). Although much progress has been made on laws and standards for wastewater reuse, the critical water scenario suggests the need for further development of wastewater reuse standards and related laws (Intergovernmental Panel on Climate Change (IPCC) 2007; Hamdy and Lacirignola 2005; Meddi and Meddi 2007).

2.3.6 Pricing

2.3.6.1 Cost Recovery/Maintenance of the Irrigation Schemes

Water pricing and cost recovery of irrigation investments, operation, and maintenance have been contentious issues for many decades. In Alegria, water pricing is considered as a significant economic tool in the reform process of water demand management. Over the two last decades, the country invested in irrigation to secure and increase water supply in order to develop the economic sector, improve food security, and target populations in less favored rural areas. In this regard, reforms in water resources management have been established to improve the performance of irrigation schemes, such as the national plan of agricultural development (PNDA) in 2000 and the water pricing policy of 2005. Other steps taken to improve cost recovery include improved irrigation services and more transparent decisionmaking. The success of these steps relies on government policies as well as institutional arrangements, including the basic legal system. The agricultural price policies have a negative impact on farmer's incomes, which affect policies of water pricing or need complementary policies addressing the issue of acceptance to the farmers. Electricity pricing in the agriculture sector is expected to be the most efficient way to begin managing and regulating the use of groundwater by farmers (Algeria MWR et al. (2014) (Table 2.3).

Table 2.3 Electricity consumption by agriculture (2012) in ktoe [33]

Sector	In ton of oil equivalent (TEP)	In %
Agriculture	1,069,935	3

2.3.6.2 Irrigation Organizations and Farmers' Participation

The National Office of Irrigation and Drainage (ONID) allocates volumes of water to the irrigation schemes according to the needs expressed by farmers. The process begins at the starting of irrigation season. The user submits his water demand to the agency, by specifying the number of hectares, the crop type, and volume of water desired. The ONID forwards the volume requested to the DHA Directorate before the start of the irrigation season. The request is subsequently processed in the Sub-directorate of the Operation and Regulation of Agricultural Water Management (SDERHA) (Laoubi and Yamao 2008). The final decision on allocations is determined according to the available storage in the dams, after subtracting the volume of water allocated to urban use. The MADR informs the DSA (Directorate of Agricultural Utilities of the Provinces), which, in turn, informs farmers (Chamber of Agriculture) of quota availability. Farmers contact the ONID and organize themselves for the water release.

Crop irrigation accounts for approximately 70% of the total water consumption and covers an area of 865,286 ha (i.e., 2% of the agricultural area), with a predominance of medium and small-scale schemes (88% of the area). These systems were partially or entirely created by farmers using shallow wells, deep tube wells, small reservoirs, wadis (spate irrigation systems), springs, and ghotts (small oases in the South).

In Algeria, there is little research on farmers' cooperatives and organizations. The main studies showed that farmers' cooperation behavior relies on their perception of professional cooperatives and that the educational level is an important factor critical to farmers' participation in cooperatives and associations. They concluded that the government should increase its efforts in promoting and publicizing the benefits of cooperation in more effective ways (Benmehaia and Brabez 2016; Benmehiaia and Brabez 2016).

2.3.7 Irrigation Efficiency

2.3.7.1 Technology Adoption/Subsidy and Other Policies

Many challenges that re already confronting irrigation development in Algeria and that will become steadily more acute as population grows and climate change adds stresses on the available freshwater resources. Careful management of scarce water resources is thus essential to improve food security (Dinar and Mody 2004). Since the 1980s, the government of Algeria began development of the National Irrigation Policy, which is designed to fully address the challenges that the irrigation sector faces and promote effective irrigation development. The concept of integrated water resources management was introduced by the Algerian water policymakers. It aims at providing a vision and step-wise prioritization of irrigation development in the country. Several reforms have been tried since, including water conservation, good irrigation development and management practices and use, improving water use efficiency, and the sustainability of irrigation schemes. The principle of cost recovery has been established, and the irrigation water prices increased in 1998 and 2005. A number of innovative technologies (drip, sprinkler) are financed through water sales and state subsidies have been tested and adopted in Algeria (Dinar and Mody 2004; Easter and Liu 2005; Ghazouani et al. 2012). Over the last decades there has been a major change in the irrigation technology used in Algeria. There has been a general move from traditional flood irrigation to application of more efficient irrigation technologies such as central pivots, drip, and microsprinklers.

2.3.7.2 State-of-the-Art Technology/Smart Irrigation & Innovations

Facing severe water shortages, Algeria is trying hard to save irrigation water by investing in water saving technologies and changing cropping patterns toward less-water-demanding crops. Cereal crops such as wheat and barley are grown along coastal areas and in some of the mountain valleys where rainfall is plentiful. Potato is also grown. However, only around 3% of Algeria's land is suitable for arable farming. The slopes of Algeria's northern mountains and plateaus are used for pastoral farming, mainly sheep, cattle, and goats. Further south and across the desert regions, date palms are common in oases. Poor irrigation management has often resulted in several sites to soil salinization and groundwater contamination and pollution. New irrigation technologies and decision support tools are continually being innovated in Algeria and worldwide. Water use efficiency and energy use efficiency are the main focuses of these innovations. Fortunately, efficiency is linked to better quality production and improved profitability.

2.4 Research

New technologies, mainly seawater desalination and water reuse processes, which address the emerging challenges, are easily embraced by the water sector to increase water availability. Some cooperation agreements exist between the ADE and ONA and research institutes for water-related issues. Algeria and the European Union (EU) signed the Prima agreement on scientific cooperation to increase research in the key sectors of water and agriculture. The PRIMA initiative (2018–2028) aims to develop new solutions for sustainable water management and food production (PRIMA; https://www.euneighbours.eu/en).

FAWIRA project is launched in Algeria with the objective of strengthening the cooperation capacities of Algeria's "National Institute of Agronomic Research"—INRAA in the context of the European Research Area and development to the Food, Agriculture and Water center of excellence. This is in turn facilitates its participation in European and regional collaborative research initiatives. To ensure adequate coverage of research areas, INRAA deploys an intensive cooperation both nationally and internationally. The international project portfolio consists of several projects dedicated to the improvement of wheat, building research capacity, renewable energy, the fight against desertification and rural development in fragile ecosystems (mountains, plains, and Sahara areas), food security, the application of nuclear techniques to agricultural areas (Pathology and Animal Health, irrigation, crop breeding, bioclimatology), mobilization of water resources, and soil conservation.

The Centre for Development of Renewable Energies (CDER) was established as a research center specialized in renewable energies, resulting from the restructuring of the Algerian High Commission for Research. The center is responsible for developing and implementing programs of research and development in the field of science and technology, energy systems exploiting solar energy, wind, geothermal, and biomass.

2.5 Food Security Versus Virtual Water/Food Imports

By importing food and agricultural goods, Algeria copes with the heterogeneous global water distribution and often relies on water resources available globally. The marked decrease of import observed in Algeria is likely due to the expansion of the irrigated areas in the last two decades. However, at the country level, there is an extreme variability in terms of total renewable water resources (TRWR), the TRWR per capita is less than 600 m^3/capita/year, the threshold that corresponds to the water scarcity levels proposed by Falkenmark (1986). As a result, the country imports most of its basic foods and all of its livestock feed, one-half of the public expenditure in the budget of the Ministry of Agriculture is allocated to financing the price support program for wheat.

Cereals represent 38% of Algeria's total food import bill (2015) and also the top food import. Algeria imported 6–7 MMT per annum of total wheat over the past 5 years of which bread wheat always represents 75–83% of the wheat imports. Algeria imported an average of 222,000 MT of pulses per year over the past 5 years mostly from Canada, China, Mexico, Argentina, and Turkey. Barley imports increased following an average crop production in 2013/2014, and as the production was revised downward in 2014/2015, more barley was imported to meet the demand for animal feed.

2.6 Water Salinity/Other Pollution Problems

Algeria faces severe water scarcity and hence resorts to groundwater to cover water demand. Overexploitation of groundwater, however, often causes intrusion of seawater into coastal fresh water aquifers, and as a result there is fresh water shortage. Often, emergency measures are being imposed to counter fresh water shortages. Water scarcity is further complicated by lack of sewage control and pollutants from the oil industry and other industrial effluents.

Nitrates are a key ingredient of manures used in Algeria as they serve as a nitrogen source for plants. Part of these manures is absorbed by plants while the rest is collected in surface water bodies such as the Dam of Beni Haroun in Algeria or in the groundwater (Cheurfi et al. 2009). Nitrate pollution is hazardous as it is toxic for humans if ingested in too large quantities. Also, it participates in eutrophication along with phosphates.

2.7 Urban Water

2.7.1 Sources of Supply

Algeria undertook over the last decades a vast program of rehabilitation and extension of the city networks of drinking water distribution and treatment. The reform also touched on the capacity building of management of the water public service. The rate of connection of the population to the public network of urban water went from 78% in 1999 to 94% in 2011, with an average consumption of 170 L/capita/day. In Algiers, since 2006, urban water supply is managed by a public company called SEAAL in cooperation with a private partner, SUEZ environment. The company provides drinking water services to approximately 3 million people. In 2011, the Algerian authorities renewed and extended the contract with SUEZ for 5 years to help modernize the water and wastewater management services for Algiers. The contract covers the provinces of Algiers and Tipaza and serves 3.8 million citizens approximately.

In Oran, the water utility "Société de l'Eau et de l'Assanissement d'Oran" (SEOR) was established in 2008. It is a 100% state-owned company, with sufficient funding (a 15 billion Euro investment over 5 years) and operated by a private company, Agbar, through which the company provides drinking water to over 1.6 million people. The access to water 24 h a day has increased from 10% to 99.3% in just over 5 years.

In June 2008, the Société des Eaux de Marseille (SEM) of France, a subsidiary of Suez and Veolia, was awarded a Euro 28 million and 5.5-year management contract for Constantine. The objectives of the management contract are to provide good quality water on a continuous basis, to improve bathing water quality on the beaches, to rehabilitate infrastructure, and to improve customer satisfaction. The operator began its work in 2008. The contractual partner is the water and sanitation utility for Constantine, SEACO.

Other cities in Algeria rely on the state-owned company Algerienne des eaux, which continues to provide water and sanitation services without partnerships with the private sector. Eighty percent of water distribution systems in Algeria are under its responsibility. Since 2008, desalinated water has been a non-negligible part of the water supply in the Northern part of the country. Algeria has 15 seawater desalination plants along its coast in 2011 with a capacity of 2.3 million m^3/day. Growing desalination capacity has helped increase water supply in the coastal cities by about 30%. The Magtaa plant, which began operations in 2014, has a capacity of 0.5 million m^3/day, provides 5 million people with drinking water for the eastern population. There are plans to expand desalination capacity for seawater and brackish groundwater in the near future. Besides these sources of water supply and management, the authorities launched a series of major projects to ensure water supply. Among these measures, the 2015–2019 five-year plan plans to spend 262 billion USD in developing new basic infrastructure and completion of ongoing projects.

2.7.2 Regulations, Priority, and Allocation

In the year 2000, the Ministry of Water Resources was created under Executive Decree no. 2000–324. All directorates related to irrigation were transferred from the Ministry of Agriculture to the Ministry of Water Resources. The latter launched broad institutional reforms. Five public agencies have been established that are in charge of developing infrastructure and managing water services, sanitation, and irrigation (Drouiche et al. 2012).

In the year 2005, a new water law was set up (Law No. 05-12, 2005) that aims to establish the principles and rules for use, management, and sustainable development of water resources as an asset of the national community. It stressed upon the rational use of water. Executive Decree no. 07-149 of 20 May 2007 established detailed rules for the use of treated wastewater for irrigation as well as standard specifications relating thereto. Executive Decree no. 07-270 of 11 September 2007 established the conditions and procedures for establishing a pricing system for water for irrigation. Executive Decree no. 07-399 of 23 December 2007 relates to the qualitative protection of water resources. Executive Decree no. 07-69 of 19 February 2007 established the conditions and procedures for authorizing the grant of use of thermal waters (Ministère des Ressources en Eau 2011).

2.7.3 Drought Management

Algeria has been experiencing more frequent drought events over the last two decades. Droughts that hit most of the regions of North Algeria in the early 1980s and the early 1990s had substantial negative effects on agricultural production, natural resources, and socioeconomic aspects. Review of literature on drought in Algeria indicates that drought occurs especially in the dry south Oran region (Hirche et al. 2011). In Algeria, average annual rainfall has decreased by over 30% in recent decades. The 2001 drought in Algeria was caused by a low precipitation rate in all the territory. The annual average precipitation has been lower than the minimum measured in the historical series from 1991 to 2015. This extreme reduction of rainfall resulted in significant impacts on water stored in reservoirs, potable water availability, and water quality. This situation called for the implementation of special emergency plans and eventual drought, implementing management measures such as irrigation restrictions and setting emergency measures. Grain production in Algeria fell by 11% to 3.3 million tons in 2016–2017 from 4 million tons in 2015–2016.

2.7.4 Water Transfers and Water Markets

The water transfer process was a top priority for the Algerian Government not only for immediate drought response, but also as part of a comprehensive, long-term water management policy, as outlined in the national water strategy. Improvements to the water transfer process and creation of water markets would play an important role in implementing a comprehensive long-term water management policy. Achieving this goal requires the use of large transfers, and to rely on nonconventional resources, especially seawater desalination and reuse of treated wastewater, and water saving.

The Taksebt Dam supplies drinking water to a population of 4 million people. Mostaganem–Arzew–Oran (MAO) project transfers an annual volume of 155 million m^3 of water in the east of the country. The Setif-Hodna-El Eulma transfer project is comprised of west and east system transfers. The west system enables the transfer of an annual volume of 122 million m^3 of water to the 550,000 inhabitants of Setif and the irrigation of 13,000 ha of plains in Setif. The east system allows the transfer of an annual volume of 190 million m^3 of water to the 700,000 inhabitants of El Eulma city and the irrigation of 30,000 ha of land (Ministère des Ressources en Eau 2011). Beni Haroun dam is intended to transfer the water through pumps to six provinces, namely, Batna, Khenchela, Mila, Oum El Bouaghi, Constantine, and Jijel–Mila region (Fig. 2.4).

2.7.5 Water Quality

In Algeria, the quality of water is affected by various forms of pollution. Water quality, neglected for a long time, has now become the focus of attention. Data indicate that most water resources are polluted, and major pollution sources are municipal wastewater discharge, industrial effluents, and agricultural activities. The estimated volume of wastewater generated from urban areas is around 1 billion m^3/year (Karrou et al. 2011). Despite major efforts during the last decade to build wastewater facilities, the overall quality of water remains at risk and could worsen from industrial, domestic, and irrigation expansion. Salinity is also a major constraint. Salinity levels of surface water vary between 0.8 and 1.5 g/L with the majority of resources having a salinity of less than 1 g/L. The majority of groundwater resources are of poor quality due to high salinity; in the north, most groundwater is nonsaline

Fig. 2.4 Map of Beni Haroun transfer

with less than 1 g/L salinity. In the south, the salinity levels are variable and some sources have high salinity levels of up to 8 g/L. Although most of the domestic wastewater collected is treated, untreated sewage is still being discharged into natural water bodies. Industries discharge untreated effluents into natural water bodies in violation of government regulations. About 200 million m^3/year of untreated industrial wastewater is discharged into the environment. Uncontrolled and improperly monitored leaching practices and agricultural drainage that includes nitrates and phosphorus from fertilizers pollute water. Pesticide residues can also be detected in some surface water. Leaching from improperly discharged and untreated solid waste also pollutes water. Agricultural drains also receive domestic pollution.

2.7.6 Desalination

Over the two last decades, Algeria has experienced a dramatic demographic shift as large numbers of rural dwellers have moved to cities. To alleviate the water shortage, Algiers needed to find a sustainable, long-term water supply that could meet the expanding urban water demand. Investment in secure sources of water like seawater desalination enabled rapid and affordable solutions without adverse environmental impact. Such supplies are always available in times of drought and scarcity and ensure response to demand growth, climate change, and increasing weather volatility (Drouiche et al. 2011). To this end, the Algerian government had embarked on a

Table 2.4 Seawater desalination capacity in Algeria

Project	Capacity (m^3/h)	Commissioning	Partners
Kahrama	86.880	Since 2006	J. Burrow Ltd:50%
Hamma	200.000	Since 2008	GE Ionics "Etas-Unis":70%
Skikda	100.000	Since 2009	Geida (Befesa/Sadyt) "Espagne": 51%
Beni Saf	200.000	Since 2010	Obra/Espagne: 51%
Souk Tlata	200.000	Since 2011	TDIC (Hyflux/Malakoff) "Singapour:51%
Fouka	120.000	Since 2011	AWI (Snc Lavalin/Acciona): 51%
Mostaganem	200.000	Since 2011	Inima/Aqualia "Espagne" :51%
Honaine	200.000	Since 2012	Geida (Befesa/Sadyt) "Espagne" :51%
Cap Djinet	100.000	Since 2014	Inima/Aqualia "Espagne" :51%
Tenes	200.000	Since 2015	Befesa "Espagne" :51%
Magtaa	500.000	November 2015	Hyflux "Singapour": 47% ADE, 10%

major and large-scale program of investment in seawater desalination to meet the demand. Oran was the first major city to use desalinated water for drinking water supply through Kahrama project, which is an independent water and power project (IWPP). The facility produces a net power output of 300 MW coupled with an average annual water production of 80,000 m^3/day, and by 2008 Algiers was the second city to rely on desalinated seawater. Nine other large-scale SWRO plants are in operation at several locations for the purpose of supplying drinking water (Algerian Energy Company (AEC) 2011; Bessenasse et al. 2010; Ghaffour 2009; Kettab 2001; Water Desalination Report 2011; Terra 2011). Desalination plants in Algeria have a cumulative capacity of about 2 million m^3/day (see Table 2.4). They are in the form of public and private partnership. The public partner is the Algerian Energy Company that is a consortium between the National Oil Company (sonatrach) and the National Company of Electricity, Sonelgaz.

Seawater desalination in Algeria is becoming a practical technology even though the prices are still higher than conventional water. This is a result of water scarcity as a result of climate change and concentration of population in coastal cities.

2.7.7 Wastewater Treatment

The average production of wastewater per capita per day is estimated at around 140 L/day. The actual total volume of sewage discharged in Algeria is estimated at about 731 hm^3/year. Sixty-three cities are served by 61 large wastewater treatment plants. The treatment provided is mainly secondary (56%) and primary treatment (44%). Disposal of treated (510,000 m^3/day) as well as untreated sewage (290,000 m^3/day) is discharged into the rivers or to the sea. A limited quantity of treated sewage (4.5%) is reused to irrigate about 7500 hectares.

Municipal sanitary services are carried out by a set of authorities affiliated to the ministry of water resources (MRE). Under MRE, the national office of Sanitation

(ONA) manages 68 wastewater treatment plants (WWTP) and 41,000 km network. ONA is responsible for operating municipal wastewater treatment plants and sewage collection systems throughout Algeria. The ONA has embarked on an approach to environmental management according to ISO international standard 14,001 with 2004 version. With the achievement of approximately 1500 km of collectors per year, the national total sanitation network is expected to reach 54,000 km by 2020. Sewage collection systems are delegated by a management contract established between ONA and ADE on one side and foreign private operators (SUEZ environment in Algiers, Eaux de Marseille in Constantine, Agbar in Oran) on the other side under the oath of the Ministry of Water Resources to improve sewerage collection and to connect urban households to sewers (Cheurfi et al. 2009; Kettab 2001; Office Nationale de l'Assainissement (ONA) 2011; Terra 2011).

Overall, the National Park of sewage treatment plants has 134 sewage treatment plants, 61 sewage treatment plants (activated sludge), and 73 lagoons (stabilization pond, aerated lagoon, sand filter, reed bed sewage treatment, garden filter) with a total capacity of 800 million m^3/year in 2010 for sewage only. The WWTP and lagoons have laboratories for daily control of water quality at the inlet and outlet works and the quality of sludge (DB05, COD, TSS). These laboratories are backed by the central laboratory of the ONA, which provides more analysis of heavy metals on water and sludge treatment plants. In addition, a project to implement a Geographic Information System on a national scale is currently being developed (Kettab 2001; Office Nationale de l'Assainissement (ONA) 2011; Terra 2011).

The program for 2016–2020, it is projected the achievement of 50WWTP, which would make reach the treatment capacity in 2020 to 1.2 billion m^3.

2.7.8 Wastewater Reuse in the Urban Sector

To combat the water scarcity the treated wastewater is reused for different purposes, namely: in the preservation of the environment and water resources, industrial use, including the cooling of industrial installations, and artificial recharge of aquifers.

2.7.9 Urban Water Pricing

Responsibility for drinking and wastewater operations in the major cities of Algeria was transferred through contracts involving multinational corporations. These corporations became increasingly involved in the provision of urban water infrastructure, in investment, management, and sewerage services. Algeria Water Company (ADE), a public utility, is responsible for the management of these services in the remaining cities. Price rates are often determined by considerations of political acceptance and are therefore subsidized. All households connected to the water network in Algeria benefit from subsidies for their water consumption. The authorities

Table 2.5 Water prices and subsidies in Algeria 2005

	Price in Algerian Dinars	Price in USD	Percentage of subsidies
Average	31	0.30	57
Block 1 0–25 m^3	28.3	0.27	60
Block 2 26–55 m^3	24.9	0.24	65
Block 3 56–82 m^3	31.6	0.30	56
Block 4 ˃ 83 m^3	46.7	0.44	35

that set prices for drinking water must steer a course between political acceptability and the need to cover cash deficits. The water price is stipulated by Law no. 05-12 of 4 August 2005. The prices are volumetric with four blocks. Billing is quarterly. The average price is \$0.30/m^3. The first block price is \$0.27/m^3 and the highest is \$0.40/m^3. As shown in Table 2.5, the average subsidy is about 57%. Observe that all domestic users benefit from subsidy. Fifty-three percent passing from 26.2 DA/m^3 (0, 37\$) to 40 DA/m^3 (0, 40\$). For domestic use, the increase is about 40% (22.2–31 DA/m^3) (see Table 2.3).This indicates that the water in Algeria is priced far below its cost (Drouiche et al. 2012).

2.7.10 Public–Private Sector Partnership and Water Utility Management

Suez Environment was awarded a water management contract for Algiers in November 2005 for 5.5 years. Its objective was to distribute water for several purposes and improve customer satisfaction. As a result of good services in 2009, the reliability of supply increased from 16% to 80%, seven beaches were opened to the public, and extensive training has been conducted (Suez Environment/SEAAL 2009). In 2011, reliability reached 99% and the contract was renewed for 5 more years.

Magtaa reverse osmosis desalination plant is constructed on a DBOOT (design-build-own-operate-transfer) basis. Under the Hyflux agreement, the project company supplies 500,000 m^3 a day of desalinated water to L'Algerienne Des Eaux (ADE), a state-owned national public water entity in Algeria. HWD or "Hamma Water Desalination Plant" is also a desalination plant on BOO (build-own-operate) basis. It is a joint venture between GE and Algerian Energy company (AEC) which supplies 200,000 m^3/day of water to Algeria (Drouiche et al. 2011).

2.8 Water and the Environment

Effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems. Ecosystems of the earth are related and maintained by water. Water drives growth of plants and provides a permanent habitat for many species (Young et al. 2004).

2.8.1 Water and Ecosystems

Water plays a vital role in ecosystems across the earth. Although many other substances are necessary for life and for ecosystems to survive, without water nothing else would function to sustain life. The dry climate of Algeria is indicative of the exploitation and reduced recharge of groundwater. Ecosystem management is one of the main principles of water management for people and the environment as suggested by Acreman (1998). Fig. 2.4 demonstrates the implications of using water for humans in an indirect way, by supporting ecosystem processes and using it directly for humans. The upper part of Fig. 2.4 shows a positive impact of utilizing water for natural ecosystems that provide valuable goods, services, and tourist value. It suggests that every form of life is unique in its own way and all should be taken care of to maintain the essential ecological processes to receive benefit from the nature. The lower part of Fig. 2.4 shows the effect of direct use of water for the welfare of society, which has benefited society but at times is also a cause of pollution. Therefore, a tradeoff is to be maintained to decide direct water use by people for domestic use, agriculture, and industry and indirect water use by people to maintain ecosystems, which are responsible for providing environmental goods and elemental services.

2.8.2 Brine Disposal

Seawater desalination is growing rapidly, with many plants in operation, which affect coastal water quality. This is mainly due to the highly saline brine that is released into the sea, which may be increased in containing residual chemicals from pretreatment process, cleaning agents, and heavy metals from corrosion. The desalination concentrates from desalination plants vary widely, with multiple effects on water, biotic community, sediment, and marine organisms. It, therefore, threatens the quality of marine resources.

There are few actual regulations, standards, or guidelines for brine discharges around the world. In Algeria, brine disposal is dealt with in two different methods, in seawater plants, submerged disposal, by means of pipe that transports brine far into the sea to minimize concentration and facilitates faster and greater dilution, and evaporation ponds in case of brackish water. Both methods intend reducing its environmental impact (Mooij 2007; ICWE 1992). Diffusers are used in the pipelines to dilute the brine. The desalination plants at Beni Saf and Mostaganem in Algeria demonstrate the use of such diffusers (Mooij 2007; Algerian law No. 83–17; Decree No. 93–160).

2.9 Energy–Water Nexus

The water–energy nexus is the relationship between water used to generate and transmit energy and the energy required to collect, clean, move, store, and dispose water. A pictorial representation of energy–water nexus is shown in Figs. 2.5 and 2.6

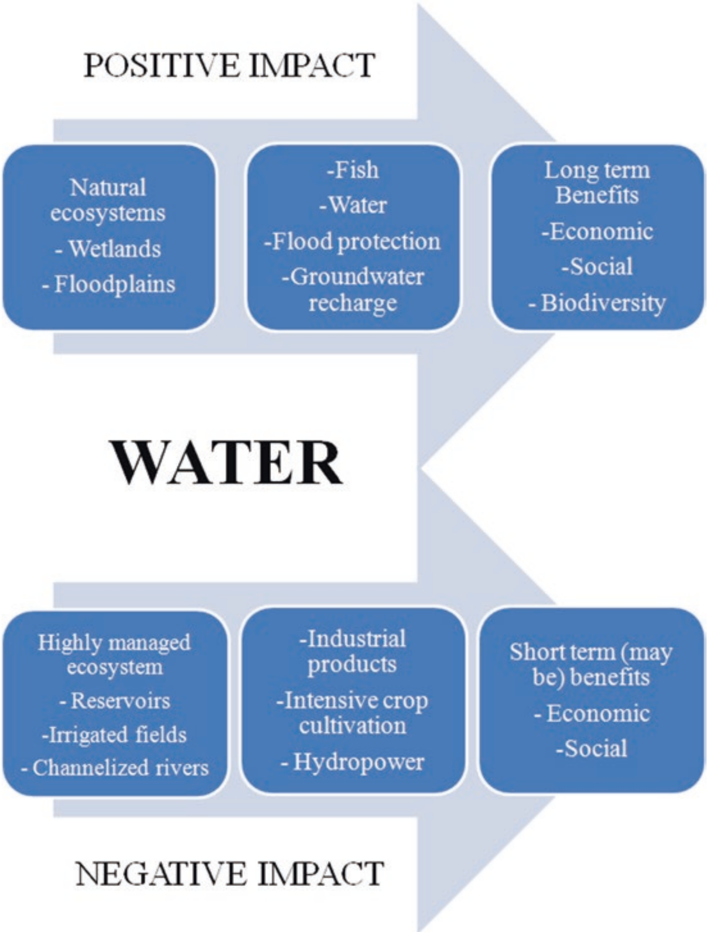

Fig. 2.5 Natural and highly managed ecosystem benefits. (Source: Acreman 1998)

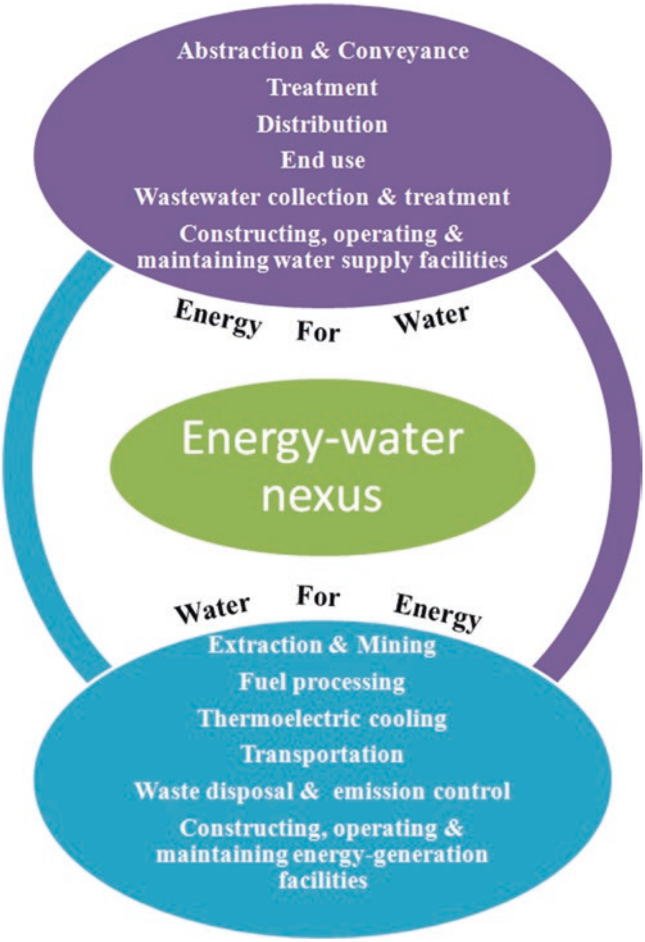

Fig. 2.6 Pictorial representation of energy water nexus. (Source: IRENA 2015)

Predictions regarding climate change indicate that rainfall might decrease by more than 20% by 2050, resulting in the worsening of water shortages in different parts of Algeria. The development of nonconventional water resources to meet the demand has increased the energy consumption of the water sector. In Algeria, the water sector in 2011 consumed around 4983 GWh and is set to raise to 16,090 GWh by 2030, more than treble (Hamiche et al. 2015). This predicted increase is attributed mainly to seawater desalination, water transfer projects, supply of water through pipes, and wastewater treatment facilities. As of 2014, Algeria's energy mix is mainly based on natural gas (more than 90%) in terms of power generation. Natural gas reserves are expected to last for 30 more years, that is, until 2030 (Hamiche et al. 2015). By 2030 it is expected that 30–40% of the electricity produced for domestic consumption will be from solar energy.

While there are many impediments and challenges toward NEXUS approach, these can be overcome by comprehensive planning, risk assessment, and policy implementation. Undoubtedly, the holistic Nexus approach in Algeria will empower a hub for knowledge and technology exchange and for innovating, adding value to economy by providing employment opportunities, reducing environmental impacts, and adapting and benchmarking solutions (Drouiche and Aoudj 2015). As energy production is based on fossil fuels, a finite source, it is obvious that promoting renewable energies to power desalination plants is needed. To further avoid water scarcity a coordination is required between the water and energy sectors. The use of renewable energy (most important is solar) must be promoted, which will help save fossil fuels, share water needs in a sustainable manner, and also be the reason of technical advancement.

2.10 Special Issues

2.10.1 International Water

2.10.1.1 Groundwater/Surface Water

Algeria has access to two main shared water basins: The North Western Sahara Aquifer System (NWSA), shared between Algeria, Libya, and Tunisia, and the hydrological basin of Bounaim-Taffna, shared between Morocco and Algeria.

The hydrological basin of Bounaïm-Tafna shared between Morocco and Algeria has two reservoirs: the Angad-Maghnia unconfined aquifer and the Jbel-Hamra confined aquifer. Due to overexploitation of groundwater, both countries suffer from quality and quantity of water resources. The unconfined aquifer has nitrate contamination (Boughriba et al. 2010), and in some places people use the untreated groundwater for drinking, which causes adverse health impacts. The water situation is stressed due to scanty rainfall and anthropogenic interferences.

The Medjerda river basin covers 23,700 km^2 and is shared between Tunisia and Algeria. The Medjerda River, which encompasses 22 reservoirs, represents 37% of the surface water of Tunisia and receives about 15,069 m^3/day of effluents. The sources of pollution are mainly used waters (95%); agriculture (0.14%); chemical industries such as plastic, automotive, textile, oil, and paper (0.44%), and food processing industries. Water quality is threatened by point source pollution, including municipal sewage discharges, industrial wastewater loads, and nonpoint source pollution from agriculture (Etteieb et al. 2017). An agreement was established between the Algerian and Tunisian governments to assure the management and access to the water resource and a joint technical commission for the Water Resources Planning and Management was formed for the exchange of information and data.

2.10.1.2 Conflicts, Negotiations, and Agreements

The South of Algeria, dominated by the Saharan platform, has large aquifers that cover hundreds of thousands of km^2. Algeria shares with Tunisia and Libya these immense reserves, which are only partially usable and weakly renewable. Due to the increased abstraction that caused a decline of the aquifer artesian pressure and groundwater salinization, an aquifer management organization was established to coordinate the plans and management. The three countries reached an agreement in 2002 to establish a Consultation Mechanism for the North-West Sahara Aquifer System (NWSAS). Under the umbrella of the Observatory of the Sahara and the Sahel (OSS), the three countries have initiated joint studies to assess the risks facing the Saharan Basin and to establish a consultation mechanism that is responsible for supporting the countries in implementing the main technical activities aimed at facilitating consultation, especially data collection, identifying transboundary water resources challenges, ensuring information dissemination, and organizing discussion at the level of decision makers for the NWSAS. The Consultation Mechanism was implemented in the form of a steering committee and was elaborated into a permanent structure in 2006 (Edmunds et al. 2003; Intergovernmental Panel on Climate Change (IPCC) 2007; Algeria et al. 2014).

2.11 Social, Equity, Institutional Performance, and Other Issues

Algeria has made good progress in extending water supply and sanitation coverage during the past two decades, under clear legislation and policies to three complementary sets of targets: the Economic Development, Millennium Development Goals (2015), and Strategy 2020**.** The institutional framework has been reinforced by the recently updated National Policy and the Water Law (2005), addressing all four subsectors. The Ministry of Water Resources leads coordination of stakeholders in the water supply subsectors, sharing this role with the Ministry of Health in the case of sanitation. However, there are outstanding challenges regarding planning and budgeting, monitoring and evaluation, as well as capacity building at the lower levels of the government following decentralization.

According to statistics supplied by ADE, indicators on network connection reached 98% nationally, the consumption exceeds 200 L/day/capita in 27 wilayas (state), with a national average of 180 L/day/capita. The same utility indicates that 73% of Algerians receive water daily. However, in addition to the disparity between regions, there is the problem of the intermittent water distribution in 62% of the Algerian households. This phenomenon, which affects households as well as administrations and companies, results in additional expenditure on water storage equipment and electricity bills that are not always easy to bear.

However, since water is poorly distributed, dissatisfaction is often expressed in several regions. According to the Ministry of Water Resources, Algeria has storage capacity of 8 billion m^3 from the existing 75 dams, to which nine new dams will be added, by 2018, with additional capacity of 500 million m^3. Also, the desalination stations provide 2.1 million m^3/day (Maghreb Emergent 2011).

2.12 Conclusions

Algeria relies on scarce water resources unevenly distributed. Due to scanty rainfall and drought persistent situations, the level of reservoirs and dams is fluctuating, thereby causing a negative impact on social and economic activities in the country. On the contrary, population growth and development in the country have increased the demand of water for drinking, industrial, and agricultural purposes. In recent years, Algeria invested heavily to address water scarcity. The main actions performed consisted of reducing water losses, building new dams, rationalization of aquifer use, popularizing the use of treated wastewater, and desalination of seawater. Algeria is faced by several challenges in the water sector such as the climate change and lower rain fall, leakages in the old water supply system, water pollution due to increased urbanization, unauthorized drilling of wells and boreholes, and poor water quality in the Sahara region.

Owing to the driving demand of water in Algeria, the country will have to depend upon nonconventional water since renewable water resources are overexploited. Other options to bridge the water gap are the rationalization of virtual water trade and use of renewable energy for desalination. The quality of rivers is deteriorated by various forms of pollution. Water resources have become increasingly limited, difficult to exploit, and often are exposed to significant amounts of wastewater.

Government efforts alone cannot improve the efficiency of Algeria's water supply. Private investments are necessary to address the country's water challenges. Public–private partnerships in the water sector are partly responsible for the recent surge in desalination capacity. In addition, private organizations are responsible for water management in some of the country's largest cities.

The water policy reforms show progress and address the challenges of water scarcity through an investment strategy, institutional strengthening, and legislative and regulatory reforms. But due to the increasing water demand for various purposes, there is still a need for efficient use, management of water resources, and public awareness of the importance of water conservation. It is imperative for the authorities to implement the principles of sustainable and integrated resource management.

Researchers contribute to Algeria's water knowledge base by tackling fundamental water research, growing scientific capacity, and disseminating knowledge to important stakeholders. Research-funded projects directly address the country's water challenges by investigating new technologies and methods to enhance water and sanitation supply, supporting policy and legislation, and providing much-needed guidance to decisionmakers. The research topics cover all aspects of the water cycle, including water resource management, aquatic ecosystems, desalination, water use, waste management, and the use of water in agriculture. They also consider climate change that will affect the water resources in the future.

Several agreements to strengthen bilateral cooperation in water field with countries facing the same challenges (i.e., droughts, flooding, and other events exacerbated by climate change) were signed aiming at facilitating the inflow of relevant results from research projects to the water sector and promote collaboration. Moreover, The European Union and Algeria are strengthening their scientific collaboration under several research and innovation programs in order to better tackle issues related to water research and innovation.

References

Acreman, M. (1998). Principles of water management for people and the environment. In A. de Shirbinin & V. Dompka (Eds.), *Water and population dynamics* (321 pp). Washington, DC: American Association for the Advancement of Science.

Agence du Bassin Hydrographique Constantinois-Seybousse-Mellegue. (2009). *Institutional framework and decision-making practices for water management in Algeria*. Towards the development of a strategy for water pollution prevention and control in the Seybousse River Basin.

Algeria MWR, CEDARE, Denmark, A. (2014). Algeria 2012 state of the water report, Monitoring & Evaluation for Water in North Africa (MEWINA) project, Ministry of Water Resources, Algeria – MWR, Water Resources Management Program – CEDARE.

Algerian Energy Company (AEC). (2011). Website: www.aec.dz

Algerian law No. 83-17 — relating to the water code.

Benmehaia, M. A., & Brabez, F. (2016). The propensity to cooperate among peasant farmers in Algeria: An analysis from bivariate approach. *International Journal of Food and Agricultural Economics (IJFAEC), 4*, 79.

Benmehiaia, M., & Brabez, F. (2016). Determinants of on-farm diversification among rural households: Empirical evidence from Northern Algeria. *International Journal of Food and Agricultural Economics, 4*(2), 87 99.

Bessenasse, M., Kettab, A., & Moulla, A. S. (2010). Seawater desalination: Study of three coastal stations in Algiers region. *Desalination, 250*, 423–427.

Boughriba, M., Barkaoui, A.-E., Zarhloule, Y., Lahmer, Z., El Houadi, B., & Verdoya, M. (2010). Groundwater vulnerability and risk mapping of the Angad transboundary aquifer using DRASTIC index method in GIS environment. *Arabian Journal of Geosciences, 3*, 207–220.

Boye, H. (2008). *Water, energy, desalination and climate change in the Mediterranean*. Sophia Antipolis: Plan Bleu.

CEDARE. (2014). Algeria Water Sector M&E Rapid Assessment Report. Monitoring & Evaluation for Water in North Africa (MEWINA) project, Water Resources Management Program, CEDARE.

Cheurfi, W., Bougherara, H., Bentabet, O., Batouche, K., & Kebabi, B. (2009). Fighting against nitrate pollution of the dam-retained waters through biological treatment. *Scientific Study & Research-Chemistry and Chemical Engineering, Biotechnology, Food Industry*, 285–294.

da Fonseca, A. F., Melfi, A. J., & Montes, C. R. (2005). Maize growth and changes in soil fertility after irrigation with treated sewage effluent. I. Plant dry matter yield and soil nitrogen and phosphorus availability. *Communications in Soil Science and Plant Analysis, 36*, 1965–1981.

Decree No. 93-160 — Regulating discharges of industrial liquid effluents.
Dinar, A., & Mody, J. (2004). Irrigation water management policies: Allocation and pricing principles and implementation experience. In *Natural resources forum*, vol 2. Wiley Online Library, pp. 112–122.
Drought management strategy in Algeria. (2014). Regional workshop for the Near East and North Africa.
Drouiche, N., & Aoudj, S. (2015). Water-energy-food nexus approach: Motivations, challenges and opportunities in Algeria. *International Journal of Thermal and Environmental Engineering, 10*, 11–15.
Drouiche, N., Ghaffour, N., Naceur, M. W., Mahmoudi, H., & Ouslimane, T. (2011). Reasons for the fast growing seawater desalination capacity in Algeria. *Water Resources Management, 25*, 2743–2754.
Drouiche, N., Ghaffour, N., Naceur, M. W., Lounici, H., & Drouiche, M. (2012). Towards sustainable water management in Algeria. *Desalination and Water Treatment, 50*, 272–284.
Easter, K. W., & Liu, Y. (2005). *Cost recovery and water pricing for irrigation and drainage projects agriculture and rural development* (Discussion paper 26).
Edmunds, W., Guendouz, A., Mamou, A., Moulla, A., Shand, P., & Zouari, K. (2003). Groundwater evolution in the Continental Intercalaire aquifer of southern Algeria and Tunisia: Trace element and isotopic indicators. *Applied Geochemistry, 18*, 805–822.
Etteieb, S., Cherif, S., & Tarhouni, J. (2017). Hydrochemical assessment of water quality for irrigation: A case study of the Medjerda River in Tunisia. *Applied Water Science, 7*, 469–480.
Export.gov. (2019). *Algeria – public works, infrastructure development, and water resources | export.gov*. [online] Available at: https://www.export.gov/article?id=Algeria-Public-Works-Infrastructure-Development-and-Water-Resources. Accessed 6 Mar 2019.
Falkenmark, M. (1986). Fresh water: Time for a modified approach. *Ambio, 15*, 192–200.
fao.org. (2015). *FAO AQUASTAT*. [online] Available at: http://www.fao.org/nr/water/aquastat/countries_regions/DZA/DZA-map_detailed.pdf
Foster, S., & Loucks, D. (2006). *Non-renewable groundwater resources*. Paris: UNESCO.
Ghaffour, N. (2009). The challenge of capacity-building strategies and perspectives for desalination for sustainable water use in MENA. *Desalination and Water Treatment, 5*, 48–53.
Ghazouani, W., Molle, F., & Rap, E. (2012). Water users associations in the NEN region: IFAD interventions and overall dynamics International Fund for Agricultural Development and International Water Management Institute, [Draft].
Ghodbane, M., Boudoukha, A., & Benaabidate, L. (2016). Hydrochemical and statistical characterization of groundwater in the Chemora area, Northeastern Algeria. *Desalination and Water Treatment, 57*, 14858–14868.
Good Practices in Agricultural Water Management Case Studies from Farmers Worldwide. (2005, April 11–22). *Commission on sustainable development thirteen session*. New York.
Groundwater Management in Algeria. Draft Synthesis Report. (2009). Food and Agriculture Organization of the United Nations Rome.
Groundwater Management in the Near East Region Synthesis Report. (2011). Food and Agriculture Organization of the United Nations Rome.
Hamdy, A., & Lacirignola, C. (2005). *Coping with water scarcity in the Mediterranean: What, why and how*. CIHEAM Mediterranean Agronomic Institute Bari Italy, pp. 277–326.
Hamiche, A. M., Stambouli, A. B., & Flazi, S. (2015). A review on the water and energy sectors in Algeria: Current forecasts, scenario and sustainability issues. *Renewable and Sustainable Energy Reviews, 41*, 261–276.
Hammouche, H. (2011). *Algeria report country experts consultation on wastewater management in the Arab world*. Dubai: The Arab Water Council.
Hirche, A., Salamani, M., Abdellaoui, A., Benhouhou, S., & Valderrama, J. M. (2011). Landscape changes of desertification in arid areas: The case of south-West Algeria. *Environmental Monitoring and Assessment, 179*, 403–420.

ICWE. (1992). *The Dublin statement and record of the conference. International conference on water and the environment*. Geneva: World Meteorological Organization.

Intergovernmental Panel on Climate Change (IPCC). (2007). *IPCC fourth assessment report: Climate change 2007 (AR4)*. Available from: http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

Investment Climate Statement – Algeria. (2015). *Bureau of economic and business affairs.* [online] Available at: https://www.state.gov/e/eb/rls/othr/ics/2015/241455.htm

IRENA. (2015). *Renewable energy in the water, energy and food nexus.* [online] Available at: https://www.irena.org/documentdownloads/publications/irena_water_energy_food_nexus_2015.pdf

Karrou, M., Oweis, T., & Bahri, A. (2011). *Improving water and land productivities in rainfed systems. Community-based optimization of the management of scarce water resources in agriculture in CWANA*. Report.

Kettab, A. (2001). Les ressources en eau en Algérie: stratégies, enjeux et vision. *Desalination, 136*, 25–33.

Knoema. (2014). *Algérie renewable surface water.* [online] Available at: https://knoema.fr/atlas/Alg%C3%A9rie/topics/Eau/Ressources-totaux-deau-renouvelables/Renewable-surface-water. Accessed 6 Mar 2019.

Laoubi, K., & Yamao, M. (2008). Algerian irrigation in transition; effects on irrigation profitability in irrigation schemes: The case of the East Mitidja scheme World Academy of Science. *Engineering and Technology, 48*, 293–297.

Maghreb Emergent. (2011). *Accueil > Maghreb Emergent.* [online] Available at: http://www.maghrebemergent.com/actualite/maghrebine/76492-62-des-algeriens-n-ont-pas-d-eau-24-heures-sur-24-ade.html. Accessed 6 Mar 2019.

Maliva, R., & Missimer, T. (2012). *Arid lands water evaluation and management*. Berlin: Springer.

Meddi, H., & Meddi, M. (2007). Spatial and temporal variability of rainfall in north west of Algeria Geographia. *Tech, 2*, 49–55.

Millennium Development Goals. (2015). *The Millennium Development Goals Report 2015*. United Nations 2015, ISBN 978-92-1-101320-7.

Ministère des Ressources en Eau. (2011). [online] Available at: http://www.mre.gov.dz/. Accessed 6 Mar 2018.

Mohammad, M. J., & Mazahreh, N. (2003). Changes in soil fertility parameters in response to irrigation of forage crops with secondary treated wastewater. *Communications in Soil Science and Plant Analysis, 34*, 1281–1294.

Mooij, C. (2007). Hamma water desalination plant: Planning and funding. *Desalination, 203*, 107–118.

National Policy and the water Law. (2005). *Loi relative à l'eau N° 2005-12 du 28 Joumada Ethania 1426 correspondant au 4 août 2005*. p. 3.

Office Nationale de l'Assainissement (ONA). (2011). [online] Available at http://www.ona-dz.org/

Remini, B., & Achour, B. (2013). The foggaras of in Salah (Algeria): The forgotten heritage. *LARHYSS Journal*. ISSN 1112-3680.

Righttowater.info. (2019). *Righttowater.info*. [online] Available at: http://www.righttowater.info/progress-so-far/national-legislation-on-the-right-to-water/#AL

Sekkoum, K., Talhi, M. F., Cheriti, A., Bourmita, Y., Belboukhari, N., Boulenouar, N., & Taleb, S. (2012). Water in Algerian Sahara: Environmental and health impact. In *Advancing desalination*. London: IntechOpen.

Suez Environnement/SEAAL. (2009). *An innovative public-private partnership in the environment sector: The Management Contract Of Societe Des Eaux Et De L'assainissement D'Alger (PDF)*. World Bank Water Week. Retrieved September 28, 2011.

Terra, M. (2011). *Algerian water policy: The potable water problem*. The first international seminar on water, energy and environment, ISWEE 11 Algiers, Algeria.

The world bank Report No. : 36270 – DZ. (2007). *People's democratic Republic of Algeria a public expenditure review.* [online] Social and Economic Development Group Middle East and North Africa Region. Available at: http://siteresources.worldbank.org/INTALGERIA/Resources/ALGERIAPER_ENG_Volume_I.pdf

Water Desalination Report. (2011). www.waterdesalreport.com

Young, G. J., Dooge, J. C., & Rodda, J. C. (2004). *Global water resource issues*. Cambridge: Cambridge University Press.

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