Chapter 5
Water Policy in Jordan

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Abstract Jordan's water resources are estimated at a long-term average value of 8191 MCM/year. Groundwater accounts for about 61% of water supply. Water scarcity threatens Jordan's development. About 93.5% of the country receives less than 200 mm of rainfall, and only 0.7% of the country has annual precipitation of more than 500 mm. Drought-occurrence periods are one of the most serious factors affecting water supply. The quality of treated effluent allowed to be discharged into Wadies follows Jordanian Standards. Exploitation of the aquifers increases the salinity level. One of the main weak institutional performances in Jordan's water sector is the overlapping responsibilities between the Ministry of Water and Irrigation (MWI), with Water Authority of Jordan (WAJ), and Jordan Rift Valley Authority (JRVA). Renewable water supply currently only meets about half of total water consumption. This is caused by unsustainable groundwater extraction, including thousands of illegal private wells. Despite the huge investments in the water sector programmed through the year 2025 the future food and water security is under threat unless the government strategy is fully implemented. The water deficit will grow from about 160 Mm^3 in 2015 to 490 Mm^3 by 2025. Without new water sources, only 90 m^3 per capita per year will be available by 2025. The Disi water conveyance project and the Red Sea-Dead Sea Canal will help increase the supply, but will not be sufficient to satisfy long-term demand. A combination of reduced demand and rationing distribution programs for domestic uses as well as the re-use of wastewater flows for irrigated agriculture will likely help bridge the gap.

Keywords Jordan · Water policy · Water resources · Water users

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5.1 Introduction

Jordan is an arid to semi-arid country with total population of 9.5 million; the number of Jordanians is around 6.6 million while the number of non-Jordanians who reside in the country is around 2.9 million, representing 30.6% of the overall population (Department of Statistics [DOS] 2017). The country has a total land area of 88,780 km^2; about one-third is dry land while the other two-thirds are irrigated land (World Bank 2016). Jordan is considered to be a water-poor country due to the water-supply shortage. Water scarcity threatens Jordan's development. Precipitation is very low, and it ranges from 30 to 600 mm annually. About 93.5% of the country has less than 200 mm of rainfall, and only 0.7% of the country has annual precipitation of more than 500 mm (UNESCO 2012). The variable and low rainfall with the high evaporation rate and droughts all contribute to low water-resource reliability and availability.

Jordan's water resources depend mainly on rainfall which is estimated at a long-term average value of 8191 MCM/year (MWI 2015a). Groundwater accounts for about 54% of Jordan's water supply; this water comes from 12 groundwater basins (Fig. 5.1). Jordan's groundwater is of two types, renewable and fossil. The latter constitutes 5% of the total groundwater storage. The safe-yield abstraction quantity from renewable groundwater is 275 MCM annually (MWI 2015a). For the fossil-water quantities, the safe-yield abstraction from groundwater for 50 years is about 143 MCM annually (MWI 2015a). The pumping for renewable groundwater was about 160 MCM in 2015 (MWI 2015a). The groundwater's quality varies from one aquifer to another; salinity ranges from 170 to 3000 ppm (Hussein et al. 2005).

Surface-water resources have two principal parts: base flow and flood flow. Base flow is derived from groundwater drainage through springs. Surface water is about 37% of the total water supply and develops through 15 water basins which are distributed across the country (Fig. 5.2). The main surface resource is the Yarmouk Basin in the north which contributes almost 50% of Jordan's base- and flood-flow waters (Al-Ansari et al 2014). In 2015, the actual supply of surface water was 730 MCM/year (MWI 2015a). Other water-supply sources are brackish water and treated wastewater. In 2015, the treated wastewater was 147 MCM/year (MWI 2015a).

The per-capita water availability dropped from 3600 m^3 in 1946 to 145 m^3 in 2008 (UNESCO 2012).

5.2 Administrative, Legal, and Institutional Aspects of the Water Sector

In terms of water governance, the Ministry of Water and Irrigation (MWI) is responsible for the overall strategic direction and planning; the MWI works with the Water Authority of Jordan (WAJ) and the Jordan Valley Authority (JVA) (Fig. 5.3). The

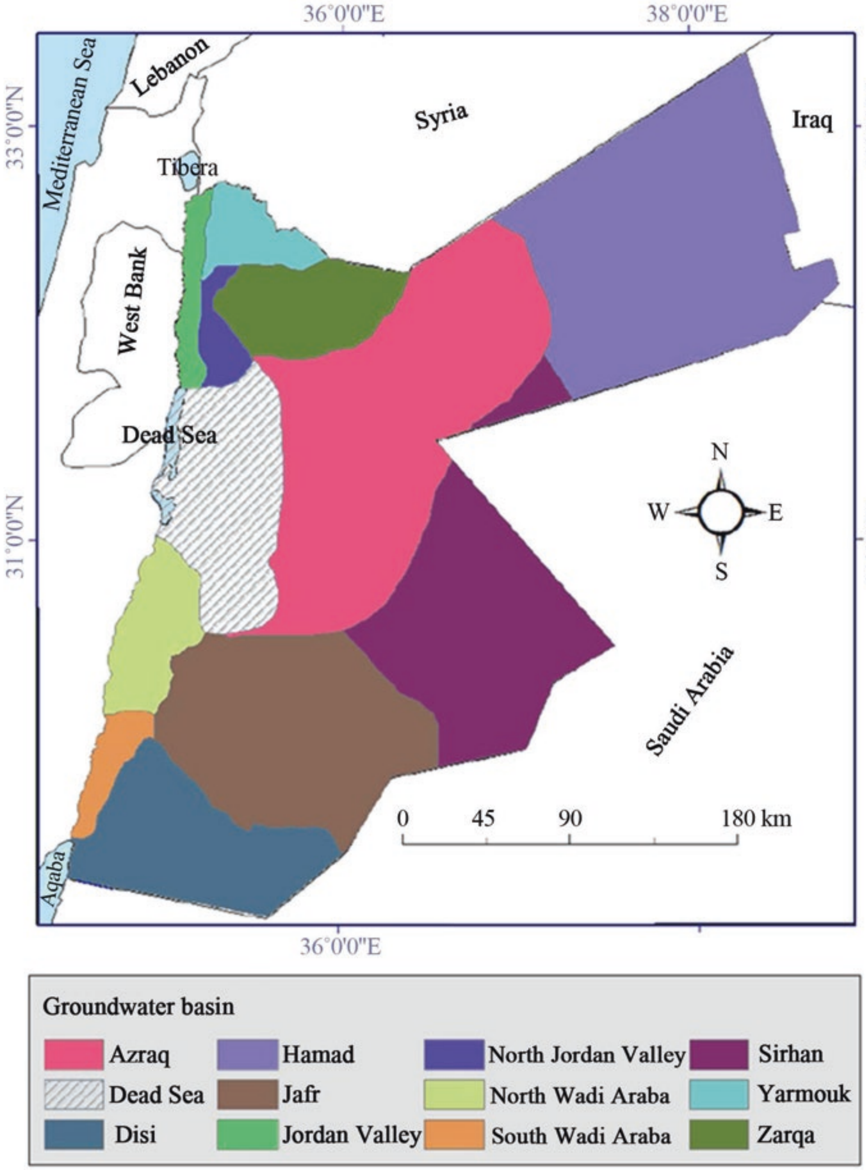

Fig. 5.1 Groundwater basins in Jordan. (Source: Al-Ansari et al. 2014)

National Water Strategy has been created to manage the water sector and to ensure optimal service levels. The National Water Strategy (2016–2025) is part of the MWI's plan which explores the need for more development of water legislation, including the need for a comprehensive water law and moving toward realizing humans' rights to water and sanitation while recognizing these rights and their

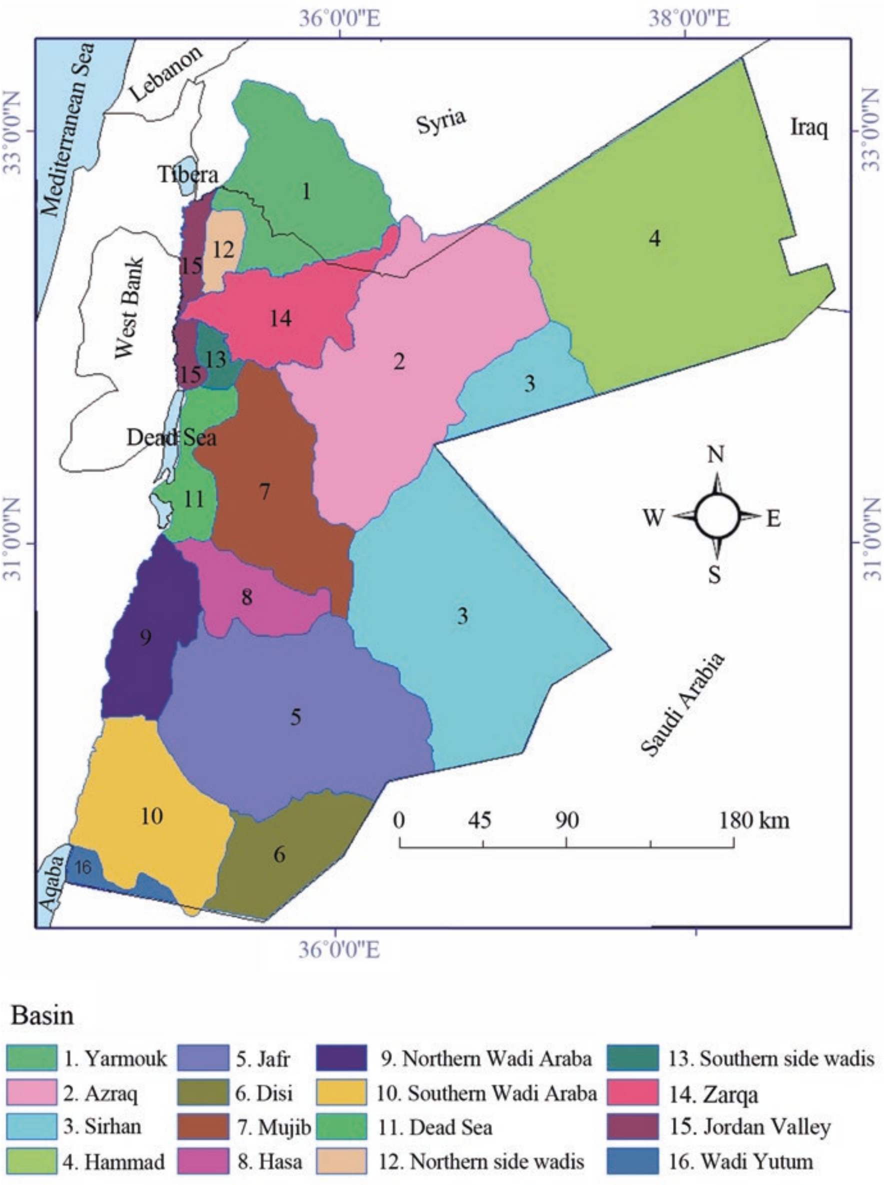

Fig. 5.2 Jordan's surface-water basins. (Source: Al-Ansari et al. 2014)

standard content for all. The strategy's key areas are as follows: (i) Integrated Water Resources Management (IWRM); (ii) water, sewage, and sanitation services; (iii) water for irrigation, energy, and other uses; (iv) institutional reform; and (v) sector information management and monitoring. The strategy also addresses the issues related to climate-change adaptation, transboundary/shared water resources, public/

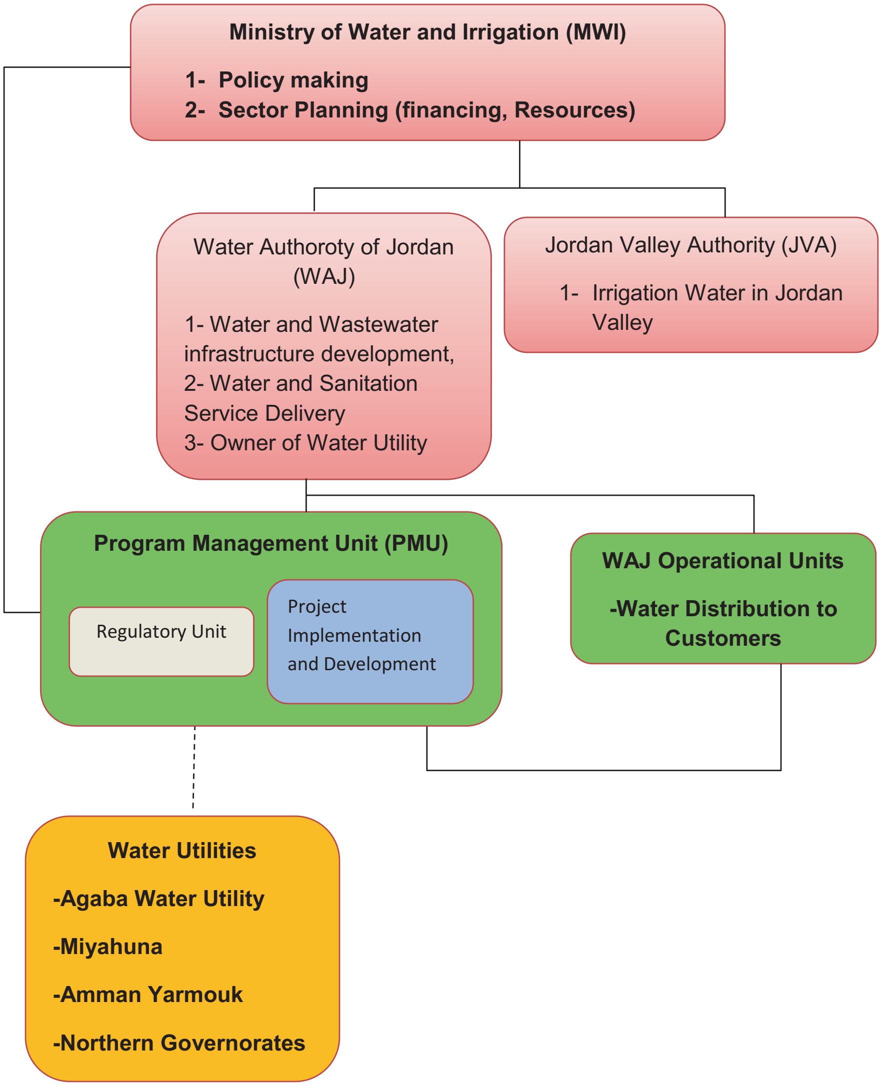

Fig. 5.3 The Different Institutions' interactions and hierarchy in water sector in Jordan. (Source: MWI 2016c)

private partnerships, and the water's economic dimensions. Within the timeframe for this strategy, the MWI aims to adopt a sector-wide, integrated water-resource planning and management approach; develop sector policies and legislation to enhance performance, equitable service provision, and optimization of available resources; initiate institutional reforms to restructure sector management; enhance fiscal discipline for cost recovery; improve internal efficiencies for sector coordination and management; and build technical capacity (MWI 2016a).

Institutional reform is set for greater efficiency and effectiveness, and improve inter-sectoral linkages to generate greater synergy and impact on the health and economic wellbeing of all Jordanians, where each operating agency/unit that is part of MWI would have a clear purpose and incentives to perform effectively and efficiently; these actions are aimed to restructure sector management, enhance fiscal discipline in cost recovery, improve internal efficiencies in sector coordination and management, and build technical capacity.

5.3 Agricultural Water

Agriculture is currently the largest water user. While farmers irrigate less than 10% of the total agriculture land, the agricultural water is estimated to be 700 MCM (Fig. 5.4). The agricultural sector contributed about 3–4% to the gross domestic product (GDP) in 2013 (MWI 2016a, b). The Jordan 2025 vision calls for an increased agriculture GDP share. Although agriculture comprises a relatively small share of the GDP, it provides most of the agricultural production and offers the high percentage of direct agricultural jobs. Cropping patterns, water-reallocation policies, and different irrigation technologies will be adopted by 2025, resulting in yield gains and water savings. Figure 5.4 provides an overview of the agricultural sector's water use in Jordan.

In 2015, there were 52 private desalination plants operated by farmers to desalinate brackish water for irrigation purposes and desalinate about 10 MCM annually.

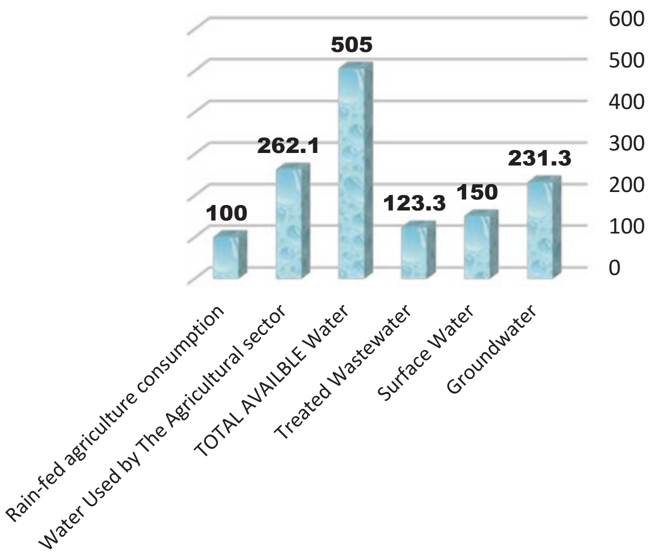

Fig. 5.4 Water use for the Agricultural Sector (2015b). (Source: Adapted from the Ministry of Water and Irrigation MWI 2015b)

Brackish water with salinity between 2000 and 8000 ppm is pumped from wells at depths between 100 and 150 m. The facilities are generally in operation 24 h/d in summer and 8 h/d in winter. The only energy source used to run the plants is electric power.

The surface, groundwater, and wastewater are located in this section because the discussion covers only their use in agriculture, since agriculture is main user of available water in Jordan.

5.3.1 Surface Water

Surface water provides about 27.2% of Jordan total water supply. Jordan developed surface-water resources where they produced about 259 MCM in 2014 and are projected to be about 329 MCM by 2025 mainly through water harvesting by building small dams on the Wadies (MWI 2016a, b). The Jordan and Yarmouk Rivers, major sources of surface water, now provide less than 25% of the shared water that flows in the Yarmouk River Basin, amounting to about one-third of the proposed share to distribute water among the riparian countries (MWI 2016a, b). Rainfall is seasonal, localized, and unpredictable. High evapotranspiration rates diminish the available water's value.

5.3.2 Groundwater

Groundwater contributes about 59.6% of the total water supply. Out of the 12 major groundwater basins, 6 are over-extracted; 4 are at capacity; and 2 are underexploited (MWI 2016a, b). Increasing the overall water extraction to meet national needs carries a high cost; Jordan is now accessing nonrenewable water resources from fossilized deep-water aquifers. Groundwater from the nonrenewable Disi Aquifer (about 100 MCM/in year 2015) contributes to Jordan's water supply for domestic and agricultural needs (MWI 2016a, b).

Jordan's groundwater is in renewable and nonrenewable forms in 12 distinct basins. The installed pumps are capable of extracting more water than the safe yield for each basin. There are 11 renewable groundwater reservoirs in the country. Their sustainable yields vary from one aquifer to another, and their combined yield is 275 MCM per year. The average annual abstraction from all basins exceeds the renewable recharge average and currently stands at 159% of that average (MWI 2016a, b). Decisions were made to treat the situation. These measures include: (1) The agricultural sector's share of groundwater resources shall be capped in favor of other sectors with higher economic return per cubic meter. (2) Treated wastewater of quality meeting national standards and complying with public health requirements shall be increasingly used to replace fresh water resources. (3) The government could close the wells in owned lands after compensating their owners' water rights or land value in a buy-back scheme. (4) Legislations pertaining to groundwater management are enforced equally on all well-owners. Strict measures that deter future violations shall be designed and enforced. (5) Groundwater management action plans developed for Azraq Basin and Yarmouk Basin, with the participation of the local community and water users, as well as the one in the Jordan Valley, shall be implemented.

There are extensive nonrenewable reservoirs in the sandstone formations. These reservoirs' water quality varies and is known to be fresh in the Disi-Mudawwara area. Using fresh fossil water from the nonrenewable reservoir in Disi-Mudawwara started in the early 1980s for municipal and industrial purposes in the city of Aqaba. This was followed by utilizing the same aquifer (Disi) for agricultural purposes. Future use of this aquifer is earmarked for the city of Amman's municipal purposes, and pumping for agricultural purposes is being reduced (MWI 2016a, b).

5.3.3 Treated Wastewater

Treated wastewater generated in Amman and Zarqa is a main water resource in the Jordan Valley. It is treated at As Samra Wastewater Treatment Plant (WWTP) in Zarqa governorate and discharged to Zarqa River, which ends in KTD. The flow from the As Samra WWTP to Zarqa River increased from about 61 MCM in 2007 to about 106 MCM in 2015 (MWI 2016a, b). The treated wastewater constituted about 13.2% of water supplied in Jordan in 2015.

The Water authority of Jordan (WAJ) operates 31 wastewater facilities, serving about 6.7 million people. The highest coverage of the wastewater stations is in Amman governorate (about 84% of the population), Aqaba (about 72%), and Jerash (about 69%), while the lowest covering rates are Tafilah (about 31% of its population), Karak (about 20%), and Mafraq (about 8%) (International Resources Group (IRG) 2013). Most of the WWTPs are applying the activated sludge system as standard treatment process. There are some challenges regarding operation and maintenance (O&M) of wastewater treatment plants; they include lack of professional expertise in WWTP process control, inadequate O&M budgets, and lack of performance-based bonus/malus schemes and at the end an effective monitoring system to control and steer the WWTP operations in real-time mode (MWI 2016c).

5.3.3.1 Aquifer Depletion

Modern technology to access groundwater was introduced to Jordan in the late 1950s; legislation to regulate the exploitation of groundwater resources and to have it supervised by the government was introduced in 2002. The difference between the amount of renewable water and the amount extracted slowly led to depletion and salinization of the country's groundwater resources (El-Naqa and Al-Shayeb 2009). The depletion of groundwater aquifers was declared by the MWI's 1998 National

Groundwater Management Policy as the major problem facing Jordan's water sector. The MWI established a law that prohibited drilling new wells in most parts of the country where aquifers are afflicted by depletion and quality degradation.

The policy set specific objectives and principles for groundwater use and management. The groundwater management policy addressed the management of groundwater resources, covering development, protection, and reducing abstraction from each renewable aquifer to sustainable rates. Other measures included continuous enhancement of the groundwater quantity and quality monitoring networks, substitution of fresh groundwater with marginal water in agriculture (brackish, treated wastewater), and adopting strategies for the reduction of groundwater abstractions, to reach the safe-yield levels of 275 MCM/year by the year 2020 within the scope of Water Master Planning, which is the authorized source for data on water monitoring, management, and planning for external users like research institutions or international donors.

Table 5.1 summarizes the measures of groundwater management in Jordan under four levels: reducing groundwater consumption, promoting recharge and retaining groundwater, and regulating groundwater development.

5.3.3.2 Property Rights

The following rules were set by the groundwater policy implemented by MWI to institutionalize the priorities of water allocation: (1) Priority of allocation of groundwater shall be given to municipal and industrial uses, to educational institutes and to tourism. These purposes are deemed to have the higher returns in economic and social terms. (2) Priority shall also be given to the sustainability of existing irrigated agriculture where high capital investment had been made. In particular, plantations irrigated from groundwater shall continue to receive an amount sufficient for their sustainability with the use of advanced irrigation methods. (3) Expropriation of use rights arising from legal use of groundwater or of water rights established on springs rising from groundwater reservoirs shall not be made without clear higher priority need and against fair compensation. (4) Priority shall be given to the use in irrigated agriculture of the reservoirs whose water quality does not qualify them for use in municipal and industrial purposes. (5) Priority for use in agriculture shall also be given to the cases where supplementary irrigation from the groundwater reservoir is possible. (6) A contingency plan shall be made and updated for the purpose of allocating the water from privately operated wells for use in the municipal networks (MWI 2017).

In the Jordan Basin, the magnitude and frequency of conflict increase during periods of drought. During the drought of 1998–99, Israeli and Jordanian members of the JWC brokered a temporary arrangement to modify allocations to reflect water availability, thus resolving the conflict. While the absence of a drought provision in the Treaty of 1994 left Jordan and Israel vulnerable to conflict, the treaty did establish the Jordan Water Committee to resolve conflicts without making permanent amendments to the original agreement (Odom and Wolf 2011).

Table 5.1 Measures of groundwater management in Jordan

Level	Features
Reducing groundwater consumption	Promoting higher water productivity in agriculture:
	Changing cropping pattern, varieties, and agronomic practices
	Micro-irrigation and root-zone irrigation
	Improved water conveyance
	Increasing water-holding capacity of soil
	Reducing waste in processing and marketing
	Reducing urban groundwater use
	Leakage detection
	Reducing domestic water loss and use
	Urban landscaping
	Use of economic incentives
	User fees
	Pricing of energy supplies
	Redirecting subsidies from water-intensive crops
	Water-efficiency incentives
	Smart-card-controlled abstraction and quotas
Promoting recharge and retention of groundwater	Interception and retaining surface runoff and floods
	Field bunding and terracing
	Contour buds and gullis
	Seepage wells and maintaining natural pits
	Injection wells
	Water harvesting from roads
	Recharge bonds, dams, and sand dams
	Flood water retention
	Improved infiltration capacity of land surface
	Permeable urban surface
	Penetration of day Layers
	Increasing infiltration by burrowing action of animals
	Sand dams
	Retaining surface flows
	Gully plugging of drainage canals
	Subsurface dams
	Conjunctive management of surface water and groundwater
	Adjusting surface water delivery to recharge and reuse potential
	Storage of seasonal excess water

(continued)

Table 5.1 (continued)

Level	Features
Regulating groundwater development	Promoting self-regulation
	Enabling laws
	Developing and applying local rules
	Participatory monitoring and assessment
	Joint crop planning
	Local investment in recharge
	Well licensing and well regulation
	Geographic bans
	Licensing of drilling rigs
	Tracking of drilling rigs

Source: Smith et al. (2016)

5.3.4 Reuse of Treated Wastewater

5.3.4.1 Food Safety/Vegetables/Heavy Metals

When using treated wastewater, food safety is considered an important issue in Jordan because it affects the fruits-and-vegetables export sector. In 1990, the Gulf Cooperative Council States (GCC) stopped importing fruits and vegetables because the crops were irrigated by blended fresh water with treated wastewater (Albakkar 2014). Wastewater in Jordan is considered as a main source of irrigation. Crops irrigated with wastewater or blended water are monitored in Jordan. Water quality monitoring in Jordan is covered by the following intuitions: Royal Scientific society, Water authority of Jordan, Jordan Valley Authority, Ministry of Water and Irrigation, Ministry of Environment, Ministry of Health, Meyahouna, Aqaba Water Authority, and North Governorates water Agency (Saidam 2009). The monitoring is conducted through continuous, automated, on-site sampling and analysis, data acquisition, storage and dissemination in one system in real time. As for fruits and vegetables ready for export, they are inspected for chemical residues in specialized laboratory in the Ministry of Agriculture.

The government role in this sector is regulatory and supervisory while encouraging the private operation and maintenance of utilities. The wastewater-treatment plant owners' responsibility is to consider the conformity of the standards with the end user. Jordan follows ISO and GlobalGap standards to monitor use of treated wastewater for fresh fruits and vegetables (Seder and Abdel-Jabbar 2011). In contrast, toxic-material discharge to sewers and sludge use are regulated in Jordan by MWI. The successful utilization of recycled water within Jordan has been made possible by the development and evolution of a sound legislative and legal foundation. There are several sets of standards that have paved the way Jordanian Standards

JS893/95, JS202/91, JS 1145/96, WAJ's regulations for the quality of industrial wastewater to be connected to the collection system, and WAJ's specifications for sewerage works, have been, thus far, the benchmarks against which plans and specifications of treatment plants and wastewater reuse were evaluated. They were established to bring about relative uniformity throughout the country. However, there is a risk in using industrial wastewater which comes from inadequate industrial and municipal wastewater-treatment capacities, and the industrial plants are built near or immediately upstream from potable water supplies (Haddadin and Tarawneh 2007).

5.3.5 Pricing

Appropriate water pricing can be used for optimizing cropping patterns and water distribution, which can also substantially increase production and yields (Table 5.1).

5.4 Agricultural Production

5.4.1 Cost Recovery/Maintenance of the Irrigation Schemes

Jordan's water subsidy is considered to be high because the irrigation water price level is much lower than the total cost recovery which covers the direct and financing costs (USAID 2012). Analyzing the cost of Jordan's irrigation water shows the need for significant price increases to strengthen its financial sustainability. Depending on the level of cost recovery, the minimum price increase that is required for irrigation water could be very large. If the government wants to pursue its objective, as stated in the Government of Jordan's Water Strategy (2009b), that depreciation should also be covered, the irrigation-water price would have to be increased to between JD 0.132 and JD 0.215 per cubic meter, depending on whether billing and collection inefficiencies improve (Van Den Berg et al. 2016). In 2012, the Cabinet of Ministers approved a new pricing policy on irrigation water – even on amounts already granted in existing licenses – with a block price system, where charges increase in relation to the amounts of water extracted (Table 5.2).

Table 5.2 Volumetric prices of water abstracted from replacement wells

Water quantity, (m^3)/a	Water price, JD/ (m^3)	Water price, US$ /(m^3)
1. 0–75 thousand	Free	Free
2. 75–200 thousand	10 Fils/m^3	0.0141
3. > 200 thousand	100 Fils/m^3	0.141

Source: Al-Karablieh and Salman (2016)

5.4.2 Institution Setting of Irrigation Organizations and Farmers' Participation

Recognizing the difficulty of managing farm-level irrigation in Jordan, the government started forming water user associations (WUAs) since 2001 (USAID 2013). Most WUAs are legally registered as independent cooperatives, and they work under government control.

WUAs in the Jordan Valley are classified into three progressive levels in terms of their status: (1) Water councils: They are based on the traditional mechanism of problem solving. Water councils are recognized by the JVA. Each council would have 15–20 elected farmers chosen through prior informal discussion with the concerned farmers. The government is represented through the sub-governor (Al Mutassarif) in the water council. Thus, the council has an executive power. Al Mutassarif may even chair the council. (2) Water user committees: They are also based on or similar to the traditional form of farmers' management that existed before the formation of JVA. A water user associations committee is a group of representatives of farmers elected by the farmers in a general assembly after several informal meetings. Although the associations have no legal status as such, they are recognized by JVA; normally, a letter is issued by the JVA secretary general in this respect. (3) Water user cooperatives: They are the type of associations that have a legal status. Cooperatives follow the Cooperation Law No. 18/1997 and thus they are affiliated to the Jordan Cooperative Corporation (JCC). Cooperatives have their internal regulatory system that specifies the objectives, capital, membership procedure, and financial and administrative issues.

Farmers' participation resulted in direct savings of water resources. A good example is given in Al Kafrein area, where the community was able to optimize the irrigation scheme, reduce leakages and illegal connections to the network, and thus reduce the water released from the dam to the network from 12,000 to 6000 m^3/day. This was achieved only in 2 months after handing over the water distribution task to the WUA. The WUA of Al Kafrein also pointed that the proper management of water enabled them to withstand and manage their farms even with less amount of water in the dry seasons.

5.4.3 Irrigation Efficiency

5.4.3.1 Technology Adoption/Subsidy and Other Policies

Irrigation-water efficiency in the Jordan Rift Valley is around 65% while on-farm irrigation efficiency in the highland where drip irrigation from groundwater is utilized is around 85%. The center-pivot system's performance is between 76% and 84% (Shatnawi et al. 2005). Irrigation efficiency in the Al'Azraq area is around 75% for sprinkler and 85% for drip irrigation (Abu-Awwad and Blair 2013).

5.4.3.2 State-of-the-Art Technology/Smart Irrigation and Innovations

In 2010, the SMART II project was initiated in the Lower Jordan Valley for three countries: Jordan, Palestine, and Israel. The project aimed to develop the Integrated Water Resource Management (IWRM) concept to ensure optimized and sustainable use for all the region's water resources in addition to achieving socioeconomic conditions that satisfy the demands of society's diverging groups. The overall goal of IWRM is to ensure that national water-resource management is based on the principles of sustainable use, economic efficiency, social equity, and environmental and ecological sustainabilities.

There are several methods that farmers use to irrigate their lands in the Jordan Valley. Farmers' choices of irrigation technique depend on the kind of crops they grow, their financial reality, and the information they have access to. In the Jordan Valley, 68% of the farmers use drip irrigation, 30% use surface irrigation, and 2% use sprinklers. It is estimated that water savings through optimization of irrigation could reach almost 40 MCM/year by the year 2020 at a cost of 0.5 US$/m^3 (Klinger et al. 2012).

5.4.3.3 Research

A large amount of research covering different aspects of the water demand was conducted for Jordan's water sector (Al-Ansari et al. 2014; Hjazi 2010; Arabiyat 2005). The Water Demand Management Program ensures further reduction in water use, reduces water losses through the distribution supply net, and prevents pollution. In addition, it helps minimize water disposal in nature, makes efficient use of available water resources, plans for future new water resources prudently, and finally imposes a real cost for water supply that would be acceptable. In addition to the above, public awareness program is to be put in action. Such a program should be used in schools as well as the media. The public is to be aware of the problem and how they can assist with overcoming the water shortage crisis (Al-Ansari et al. 2014).

Another study found that there are a variety of water-use efficiency programs that can be implemented. However, the cost of these programs is usually the major factor that influences the implementation. Past and ongoing experience on WDM programs indicates that strong emphasis should be devoted to retrofitting programs such as aerators and showerheads. The analysis shows that they are most cost effective in the residential sector, government buildings, mosques, and schools. A WDM Code for new buildings should be in place and enforced (Hjazi 2010).

Field studies using groundwater for irrigation showed that water-pricing policies based on volumetric charges could have little impact on water consumption as water demand is inelastic. Irrigation water consumption has decreased significantly only when water prices have exceeded the 0.5 US$/m^3 (Arabiyat 2005).

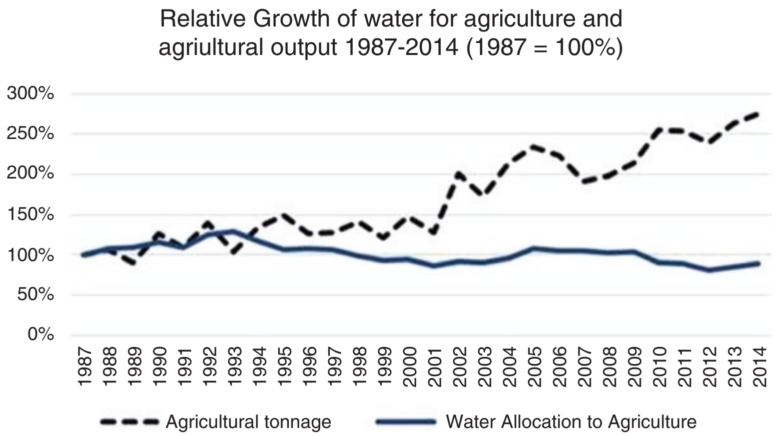

Fig. 5.5 Relative growth of water for agriculture and agricultural output in Jordan during 1987–2014. (Source: Namrouqa 2017a, b)

The Jordan Water Authorities are in the process of increasing the water supply by implementing the Red-Dead Sea canal which will provide desalinized water for agriculture and drinking water. A feasibility study found that this project is financially viable (Blogger 2012).

5.4.4 Food Security vs Virtual Water/Food Imports

The agricultural sector's water use constitutes about 64% of the water demand in Jordan; thus, food security and water are strongly linked (Fig. 5.5).

From Fig. 5.5 it is noticed that agricultural output had increased during 2005–2014, while the water allocation to agriculture had decreased. This was due to the water conservation policies implemented during the same period.

Jordan has established trade and economic agreements both at regional and bilateral levels with around 86 countries from all over the world (specifically, 19 agreements are with Arab countries and 67 with non-Arab countries). To mention are hereby the Greater Arab Free Trade Agreement (GAFTA); the Agadir Agreement, which is creating a free trade area between Jordan, Egypt, Tunisia, and Morocco; the Jordan-United States Free Trade Agreement, which entered into force in 2001; the Euro-Jordanian Association Agreement of 2002; and the FTAs with Singapore, Canada, and Turkey.

Jordan's agricultural and food exports are mainly focused on neighboring countries. Jordan's major agricultural exports are fresh fruits and vegetables, processed meat, food preparations, and live sheep (Tables 5.3 and 5.4).

Table 5.3 Virtual water import (VWI) per major trade partner (Million m^3/year) 1996–2005

County	Green VWI	Blue VWI	Gray VWI	Total VWI	Major products
USA	697	88	123	908	Wheat – 66%, maize – 16%, rice – 8%
Syria	626	92	122	840	Barley – 78%, animal products – 4%
Argentina	641	11	31	683	Wheat – 25%, maize – 38%, soybean – 35%
India	434	35	29	498	Animal products – 40%, soybean – 34%, coffee – 7%, wheat – 6%, cotton – 4%
Iraq	172	222	156	550	Barley – 69%, industrial products – 29%
Malaysia	319	0.5	14	333	Oil palm – 97%
Indonesia	238	0.1	17	255	Oil palm – 88%
China	133	22	83	239	Cotton – 71%, industrial products – 14%, animal products – 6%
Turkey	172	21	25	218	Wheat – 41%, barley – 29%, chickpeas – 13%, cotton – 7%
Ukraine	173	4	30	208	Barley – 60%, sunflower seed – 16%, industrial products – 14%, wheat – 9%
Australia	93	41	3	138	Animal products – 53%, rice – 32%, barley – 12%
Total	3698	536.6	633	4870	

Source: Hoekstra and Mekonnen (2012)

Table 5.4 Value of main exports during 1995–2013 (1000 US$)

	Year				
Product	1995	2000	2005	2011	2013
Total merchandise trade	1,772,340	1,899,000	4,301,419	8,006,449	7,910,716
Fruit + vegetables	99,847	105,544	273,247	590,955	724,703
Oranges + tang + clem	9016	3995	6737	12,304	50,393
Oranges	3728	1891	2859	5337	6674
Grapes fresh	1196	1161	2521	1988	1702
Olives	0	10	4500	5200	15,038
Olives preserved	493	372	2071	5555	6770
Lettuce and chicory	1987	4426	7340	7154	11,447
Potatoes	5596	2413	7200	3943	9180
Tomatoes	24,745	34,262	105,707	224,847	316,321
Poultry meat	5383	448	5622	30,178	41,815
Eggs in the shell	3095	5761	4369	10,172	5954

Source: FAOSTAT (2017)

5.4.5 *Water Salinity and Other Pollution Problems (Nutrients and Manure)*

Over-pumping the underground reservoirs increases the salinity level, such as in the North Badia and Jordan Valleys. Over-drafting the surface reservoirs, such as in the Azraq Oasis, and dumping wastewater from the Khirbit Al-Samra treatment plant polluted the Amman-Zarqa Basin. Saline and brackish water resources are available in many places in the country, especially in the South Jordan Valley (Permaculture Research Institute 2005).

5.5 Urban Water

Investments in municipal networks in Jordan remain inadequate. Although the level of services in the water supply in Jordan is fairly high, with service to 97% of the population in the urban areas and 83% in the rural areas, distribution systems are still far from optimal and efficiencies are still low. The unaccounted-for water in the municipal networks was estimated to be 55% of the quantity supplied in 1995. In 2004, over 50% of the water entering the city's distribution system was effectively unaccounted for, with half of this being lost by leakage and the rest due to poor administration and inadequate billing. Although the losses in the urban water supply networks have become a growing concern, water companies have budgetary and other constraints that hinder addressing the problem. According to Trojan and Morais (2012), problems encountered in the maintenance and management of the water-supply systems are indicated by the lack of decision support models that give a manager an overview of the system.

Households pay progressive drinking water and wastewater tariffs. Households are charged for water utility services based on an increasing block tariff, which provides incentives to save water. The polluter pays principle is enforced via sewage charges added to the water bill. Since the sewage charge increases the total water and wastewater bill, it also functions as an incentive to reduce water consumption (MWI 2016b) (Table 5.5).

Table 5.5 Urban water price in Amman in 2016

	Consumption per month in US$/m^3		
Water quantity, (m^3)/month	15 m^3	50 m^3	100 m^3
Price	0.78	2.98	3.06
Fixed charge	0.45	1.13	0.57
Variable charge	0.22	1.44	2.07
Other charges			
VAT	0.11	0.41	0.42
Total	1.56	5.96	6.12

Source: WAJ Amman, Jordan, 2016

The level and design of water and wastewater tariffs paid by households could not be further improved to approach cost-recovery levels and provide additional incentives to save water. Since households receive an intermittent water supply, their consumption is already limited by the capacity of residential water-storage tanks. The current progressive tariffs were linked to consumption per person. There would be an opportunity to introduce a tariff structure with more targeted incentives to save water. A prerequisite for such a measure is the availability (or development) of good household records on the number of inhabitants/family. There is also an economic barrier related to the affordability of more expensive water. Any change in tariff levels should therefore be gradual and should respect the economic status of households.

Most policymakers in Jordan agree that water for human consumption, including drinking, cooking, bathing, and cleaning, should be given priority over other uses (Qtaishat 2013).

About 48% of the total water resources are used in the industrial and domestic sectors: 4% and 44%, respectively (MWI 2016a, b). Water-reallocation strategies, such as changing the cropping patterns and moving away from crops where the product value per unit of water is relatively low, could improve the overall economy. Water reallocation could have a substantial effect on the municipal and industrial sectors and might lead to an increased GDP for the region, creating jobs in the industrial sector (Qtaishat 2013). A small water reallocation (5%) from agriculture could dramatically increase the water available for other sectors, particularly the municipal sector. Reallocation will be based on the following conditions (MWI 2016a, b): Each governorate shall retain its available water for its sole needs, unless there is severe shortage in other governorates; in this case, it will be transferred to the geographically nearest governorate and to the governorate of highest need, with due consideration to sustainability, long-term feasibility, availability of infrastructure. Shared water resources shall be allocated to the governorate of the highest need and geographically closest, and which can technically receive the water. Supplied water shall be increased to achieve the target shares by the reduction ratios in Non-Renewable Water (NRW). Availability of water infrastructure shall be insured during the reallocation process. Plans shall be made for infrastructures to meet the long-term needs and/or the structure life time.

Among the options for water-supply augmentation are desalinating saline groundwater, brackish drainage water, and seawater. In Jordan, desalination is receiving considerable attention from scientists, resource planners, policymakers, and other stakeholders. In 2010, desalination provided 30 MCM of water in Jordan, and by 2030, desalination is projected to provide about 170 MCM of water (Al-Mutaz 2005; El-Sadek 2010; World Bank 2007; United Nations 2010). Several brackish springs have been identified in various parts of the country. Estimates of stored volumes of brackish groundwater for the major aquifers suggest immense resources, but not all of these quantities will be feasible for utilization.

Currently, there are 44 public desalination plants and an additional 10 under construction that desalinate about 80 MCM annually. All these plants are run or will be run by WAJ to treat saline water for drinking water supply (Al-Karablieh and Salman 2016). Currently, desalination is primarily used for the industrial and tourism sectors because of the high cost of seawater desalination. Utilizing desalination for other purposes (agriculture and municipal) will depend on technological improvements that result in reduced overall and marginal costs (Qtaishat 2012).

The desalination process that will be implemented for the Dead-Red Sea canal is hydropower generation and reverse osmosis desalination facility with a capacity of 850 MCM/year. The estimated cost for desalinization in this process was at US$ 0.46, out of which US$ 0.23 was for electricity, US$ 0.03 for membranes, US$ 0.10 for labor, US$ 0.07 for chemicals, and US$ 0.03 for parts (Ornwipa and Rodriguez 2008). On the other hand, the desalination cost for brackish water was estimated at US$ 0.33 for large plants and US$0.48 for small plants (Qtaishat et al. 2016).

In Jordan, water reuse is an existing tool to manage scarce water resources. Over time, wastewater reuse has changed from simply irrigating field crops with untreated wastewater to a sophisticated reclamation process for agricultural, industrial, and domestic reuse (Durham et al. 2005). The most practical solution for water scarcity is reusing domestic wastewater for some non-potable municipal purposes, such as flushing toilets, irrigating green spaces, and agriculture. Reusing wastewater is cheaper than developing new water supplies and protects existing sources of valuable fresh water from overexploitation (Faruqui 2002). The As-Samra plant is the largest wastewater treatment plant in Jordan, and it can treat about 75% of the 267,000 m^3/day (Ammary 2007). The government buys water from the As-Samra plant for approximately $1.10/$m^3$ for irrigation in the Jordan Valley farms (Al-Zu'bi 2007). It should be noticed that this cost is higher than desalinization of brackish water. The effluent Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), and Total suspended solids (TSS) from As-Samra WWTP complies with Jordanian standards for reclaimed wastewater discharge to streams, groundwater recharge, irrigation parks, reuse for irrigation of cocked vegetables, fruits, and trees, and for reclaimed wastewater reuse for fodder crops (Myszograj and Qteishat 2011).

The investment and operation costs for wastewater treatment and reuse are high. However, treated wastewater is increasingly being used for agricultural irrigation. Many efforts, such as increasing awareness and information campaigns, are needed to encourage participatory approaches by the farmers.

5.6 Water and Ecosystems

There are two components of ecosystems: (a) biotic components: plants, animals, fish, and parasites and (b) abiotic components: water resources, soil, and climate. Ecosystem regulations, maintenance, and provision are directly affected by the habitat quality and the water quality. A study showed the existence of high pressure on natural habitats in the northern region of the Jordan Valley. In this area, agriculture and industry are the main activities (El-Habbab 2013).

Jordan established several groundwater protection zones, out of which was Wadi Shuaib ecosystem. An economic evaluation of the Wadi Shuaib ecosystem found that it is important to implement groundwater protection zones; the main benefits from these practices are to protect drinking water and the ecosystem as well as to

Table 5.6 Tariff structure for wastewater in Amman in 2016

Wastewater quantity (m^3)	Consumption per month in US$/$m^3$		
	15 m^3	50 m^3	100 m^3
Price	0.15	0.99	1.40
Fixed charge	0.02	0.01	0.00
Variable charge	0.11	0.85	1.20
Other charges			
VAT	0.02	0.14	0.19
Total	0.3	1.99	2.79

Source: Tariff reference date: 1 Jan 2016, WAJ Amman, Jordan, 2016

Table 5.7 Zoning scheme for groundwater protection zones

Zone	Size	Land-use restrictions
Zone I	Springs: 50 m upstream, 15 m lateral, 10 m downstream	Fenced off; access only for personnel of water works and management and control agency (government purchases property)
	Wells: 25 m upstream, 15 m lateral and downstream	
Zone II	50-day line; but: maximum of 2 km in upstream and 50–150 m in downstream directions in karst areas: areas classified as highly and very highly vulnerable (groundwater vulnerability map); but: maximum of 2 km in upstream and 50–150 m in downstream directions	Existing settlements and organic permitted; new development only with permission granted by licensing committee; existing land uses which generate waste and sewage water that may negatively affect the environment have to apply rules of best management practice (BMP), which will be issued by the government; construction of wastewater collection and treatment systems in this zone will be given priority
Zone III	Entire contribution zone	All types of land use are permitted if they are conducted in accordance with the rules of best management practice

Source: El-Naqa and Al-Shayeb (2009)

prevent water-quality-related health problems. Some costs are the implementation and operational costs of the groundwater-protection zones (Zones 1, 2, and 3) while the main costs are for rehabilitating the existing sewer system and/or connecting the unconnected houses in Zones 2 and 3 (Tables 5.6 and 5.7) (El-Habbab 2013).

5.6.1 Brine Disposal

The Red-Dead Sea project will be applied through three phases: (a) water transfer from the Red Sea to the Dead Sea, (b) hydropower generation and a reverse-osmosis desalination facility (capacity of 850 MCM/year), in addition to 30 MCM of desalinized water in other project, and (c) freshwater transmission system.

The quantity of brine and seawater from this project will be about 110–220 MCM/year. The water will be discharged to the Dead Sea through a pipeline of 56-km length (Rabadi 2015). On the other hand, there are considerable quantities of brackish groundwater in some basins, mainly in the central Jordan Valley and the Zarqa Aquifer in the Hisban and Kafrein areas.

5.7 Water–Energy Nexus

As a result of scarce surface-water resources, hydropower is limited through the King Talal Dam, which has a capacity of 5 MW, and the Aqaba thermal power station, which also has a capacity of 5 MW.

Electrical power generation in Jordan relies predominantly on fossil fuels with significant impact on the environment through harmful greenhouse gases (GHG) such as CO_2 and NO_x. Today, photovoltaic technology can produce solar power at a fixed rate of 0.05–0.08 JOD/kWh calculated for a 20-year project. This rate is lower than the cost of power produced with conventional methods. Photovoltaic power supply system represents an opportunity for the water sector to significantly decrease operational expenses and to mitigate the effects of energy price volatility, which largely depend on fluctuating fossil fuel prices. The water sector involves an energy-extensive operation by deploying large water pumping, boosting, treatment, and distribution facilities. The power requirements only for water pumping in 2014 amounted to about 15% of the total power production of Jordan with a total amount of 1592 GWh. The specific energy consumption for the same year was 7.51 kWh/m^3 (billed) for the Water Authority of Jordan (WAJ), mainly for municipal water supply and wastewater, and 0.274 kWh/m^3 (billed) for the Jordan Valley Authority (JVA), mainly for irrigation and industrial use in the Jordan Valley. The weighted average consumption for the public-sector water facilities is 4.31 kWh/m^3 (MWI 2016a, b).

The water sector, among all other power-consuming sectors in the country, will directly benefit from the implementation of the national energy strategy, which states that renewable energy shall contribute with a rate of 7% to the overall energy mix by 2015 and 10% by 2020. The introduction of renewable energy technologies into the water sector shall lead to the following results: (ibid)

- Supply of power at stable and low rates leading to reducing energy prices volatility
- Reduction of the sector dependence on fossil fuels
- Reduction of water-pumping costs
- Enabling long-term planning of water supply
- Reducing CO_2 emissions making it a high ecological value option, too.

5.8 Special Issues

Many water resources are transboundary and, as such, especially in semi-arid regions such as Jordan, are a basis for conflict. Wolf (1996) showed that most past attempts – from the early 1950s to 1991 – to resolve water issues in the Nile, Tigris-Euphrates, and Jordan Basins without considering socio-political implications failed. Political and water-scarcity issues cannot be addressed in isolation.

Many policymakers consider water shortages to be an intractable problem with multi-dimensional conflicts between countries on Jordan's borders. Many actions, such as water-management treaties, are taken to resolve the conflicts about using water from major rivers in the area.

Jordan has concluded two bilateral water agreements with Israel and Syria to manage shared water resources in the Jordan basin. Jordan has not benefited much from either. This is in part due to its weak strategic position against more powerful interlocutors and Jordan's little success in implementing many of the provisions of the agreements. The Peace Treaty of 1994 between Jordan and Israel calls for desalination projects on the Lower Jordan River but these have yet to be built. Further, diversion of 60 MCM from winter floodwaters of the Yarmouk River to Lake Tiberias for use by Jordan has not materialized either (Haddadin 2006). Jordan also claims that it has been able to access less than half of its share of flow from that river (Haddadin 2006). The Agreement of 1987 focuses on establishing the Al-Wehdah (Unity) Dam on the Yarmouk River. The latter has an annual gross flow of 110 MCM and a capacity to generate 18,800 kWh of power (MWI 2009a). However, because of excessive depletion of the Yarmouk's surface and groundwater, the water retained in the dam has been well below its 110 MCM capacity, sitting at little more than 18 MCM since its construction in 2006 (Namrouqa 2010). Even after the 1987 Agreement, the Syrians increased damming of the four recharge springs of the Yarmouk and have increased groundwater drilling in the river basin (Al-Kloub and Shemmeri 1996; Haddadin 2006; MWI 2007), leading to significant reductions in base flow along the Jordanian/Syrian border (Haddadin 2006; MWI 2007). Base flow is estimated to have dropped to 2 cubic meters per second in 2000, and to 0.9 cubic meter per second in 2008, compared to 5–7 cubic meters per second in the 1950s (Haddadin 2006; Ministry of Water and Irrigation, Jordan 2007; Namrouqa 2010).

The Jordan River Basin is one of the main sources of conflict in the Middle East region. It is shared by three countries: Jordan, Palestine, and Israel. One suggested solution for the conflict is to trade water according to market mechanism, but this procedure has serious problems because property rights are weakly defined and because of distrust between the parties leads to inefficient and environmentally damaging outcomes. To solve this problem, water-use rules are suggested to prevent over-extraction by some partners (Luterbacher and Wiegandt 2002).

5.8.1 Regional and International Water Issues

The Jordan River system and associated aquifers are important sources for Jordan and Israel. The Upper Jordan River is fed by three sources – the Dan, the Hasbani, and the Banias, which empty their water in the Sea of Galilee. Yarmoouk River, which has its source from Syria, is considered one of the boundaries between Jordan Israel and Syria; it empties its water in Jordan Valley near north (Adasyah Black 2010).

The majority of water resources in Jordan, such as the Disi aquifer and major rivers, are shared, originating outside the Kingdom. Transboundary water cooperation on the Jordan River Basin between Jordan and Israel scored 56.67 under the Water Cooperation Quotient (WCQ) 2017 that quantifies the quality of cooperation within transboundary river basins on a global basis, which means that the two countries have a relatively peaceful and stable relationship with each other in this respect. But in the case of the Yarmouk River Basin, the WCQ 2017 explained that since 2011, Syria has been unable to attend to its transboundary water relations due to the protracted armed conflict, indicating that any two countries not engaged in active water cooperation "do not necessarily go to war" (Namrouqa 2017a, b).

5.9 Other Issues

Social, Equity, and Institutional Performance One of the main, weak institutional performances in Jordan's water sector is the overlapping responsibilities for the Ministry of Water and Irrigation (MWI) as well as the government-owned Water Authority of Jordan (WAJ) and Jordan Valley Authority (JVA). The MWI has no responsibility for the water supply while the WAJ has both supply and retail roles which hinder water management in the country. The JVA is responsible for carrying out the socioeconomic development for Jordan's side of the Jordan Valley and is responsible for land distribution in the Jordan Valley. Another institutional problem for Jordan's water sector is the lack of agreement about using multiple data sources and over-staffed institutions (Yorke 2016).

In this respect, it is recommended to achieve the following activities (USAID 2017):

Strengthening and consolidating authority for water planning and management to address the over-extraction of groundwater improve sector planning and ensure better quality of data used in decision making. Solutions include capacity building, policy reform, process improvements, legal reforms, and institutional restructuring;

Reorganizing WAJ to focus on its core mandate (sector investment and bulk water source development/supply) to improve operational efficiency and better plan for future water supply and wastewater service needs;

Focusing on capacity to manage new national water supplies and removing institutional conflicts of interest between bulk water supply, utility oversight, and retail service delivery;

Strengthening utility management to support service improvement, further corporatization, and management/fiscal/operational independence; Improving water utility regulation to enhance the monitoring of utilities' financial and technical performance;

Strengthening water-user associations and the Jordan Valley Authority to further separate bulk and retail water management to improve irrigation water management and services across the Jordan Valley;

Conducting technical studies to provide analysis for better policy and water management decision making.

The National Water Strategy 2016–2025 was established to revise the institutional and legal frameworks in order to enhance the workable management activities for Jordan's water sector. Moreover, the strategy's main actions are: (a) including provisions for climate change; (b) focusing on water economics and financing; (c) ensuring the sustainability of overexploited groundwater resources; (d) adopting new technologies and available techniques, such as decentralized wastewater management; and (e) reusing treated wastewater (MWI 2016a, b).

The Millennium Challenge Corporation (MCC) was established in Jordan to increase the supply of fresh water for homes and businesses in the Zarqa Governorate, aiming to improve economic growth and the quality of life through three interrelated projects: (a) modernizing the water-supply infrastructure to improve the freshwater delivery efficiency in the city, (b) developing the sewerage in the project area to increase the wastewater-collection volume, and (c) enhancing the As-Samra wastewater treatment plant's capacity to provide treated wastewater to farms (Millennium Challenge Corporation 2010).

5.10 Conclusions

Jordan's water resources, both surface water and groundwater, mainly depend on rainfall. Groundwater from 12 groundwater basins accounts for about 54% of Jordan's water supply. Surface-water resources in Jordan have two principal parts: base flow and flood flow. Base flow is derived from groundwater drainage through springs. Surface water forms about 37% of the total water supply which is developed through 15 water basins that are distributed across the country.

Jordan is a water-poor country. Water scarcity threatens Jordan's development. Only 0.7% of the country has annual precipitation of more than 500 mm. The variable and low rainfall amounts with the high evaporation rate and droughts all contribute to low water-resource reliability and availability.

On the supply side, Jordan should improve water-supply and wastewater treatment infrastructure. Introduce affordable technologies for utilities, communities, and households to reduce water losses, private sector participation in infrastructure investments, reduce water losses, strengthen water sector institutions and policies, and encourage best commercial practices in water utilities. The Red Sea-Dead Sea (RSDS) Phase II project, which will be implemented in the near future, is conceived to address the challenges associated with the Dead Sea's declining water level and Jordan's ongoing water crisis.

On the demand side, MWI is encouraging the installation of Water Saving Devices (WSD) through the introduction and enforcement of a revised building code for new buildings. Retrofitting of existing buildings has been piloted in two areas through sponsorships.

A great deal of research covering different aspects of water demand was conducted for Jordan's water sector. On the supply side, because Jordan is characterized by limited water resources, Jordan has to emphasize water-resource management to meet the increased demand.

Jordan's current water policy requires a strong redirection toward water demand management. Actual implementation of the plans in the national water strategy (against existing oppositions) would be a first step. However, more attention should be paid to reducing water demand by changing the consumption pattern of Jordanian consumers. Moreover, unsustainable exploitation of the fossil Disi aquifer should soon be halted and planned desalination projects require careful consideration regarding the sustainability of their energy supply. Moreover, water policy encourages water harvesting, conserving, and protecting resources, while the water substitution and reuse policy proposes the reuse of treated wastewater in irrigation in order to enable the freeing of fresh water for municipal uses.

In irrigation it is recommended to consider water-saving technologies, replacement of groundwater with treated wastewater for farms located not far away from the existing or planned wastewater plants.

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