MINARET

NETWORKING FOR THE FUTURE

WATER BASELINE JORDAN

Sweden Sverige

FUTURE PIONEERS Empowering Communities

IUCN

NERC National Energy Research Center

Amman Jordan 1970 Royal Scientific Society

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List of Acronyms

BOT	Build Operate Transfer
IWRM	Integrated Water Resources Management
JVA	Jordan Valley Authority
MCM	Million Cubic Meters
MINARET Technologies	MENA Region Initiative as a model of NEXUS Approach and Renewable Energy
MoA	Ministry of Agriculture
MoEnv	Ministry of Environment
MoE	Ministry of Energy
MWI	Ministry of the Water and Irrigation
NA	Not Available

NGO	Non-Governmental organization
PMU	Program Management Unit
TDS	Total Dissolved Solids
USD	US Dollars
WAJ	Water Authority of Jordan
WB	World Bank
WWTP	Wastewater Treatment Plant
ha	hectare
km	kilometer
km^2	squared kilometer
$	US Dollars

1. INTRODUCTION

1.1. The MINARET project (MENA Region Initiative as a model of NEXUS Approach and Renewable Energy Technologies)

Many countries in the Middle-Eastern North Africa Region (MENA Region), including Jordan, Lebanon and Tunisia are facing several challenges, putting huge pressures on available energy, water and food resources. Existing water supplies can hardly meet the growing demand for irrigation and municipal water usage; and thus, the region must import most of its food.

To face these challenges and to tackle poverty, unemployment, and the growing demand for energy, water and food, these countries need to act quickly and respond to the different needs of their populations and economy. Improving energy efficiency, using renewable energy technologies and reducing water consumption for food production are the most cost-effective solutions that can be swiftly implemented. These solutions, which focus on the *nexus* of energy, water and food, have a great impact on the countries' economic growth and prosperity, while reducing poverty and improving livelihood opportunities of its people.

Based on case studies in three countries (Jordan, Lebanon, Tunisia), the MINARET project aims to identify such solutions that can support these countries' transition into affordable, sustainable and secure energy and water systems, while also leading to increased food security. The project aims to offer a framework for a coherent and inclusive regional strategy to support local authorities, municipalities, private sector and civil society in promoting renewable energy and energy efficiency, clean water accessibility and food security as well as executing relevant pilots.

The overall goal of the MINARET project is to strengthen regional cooperation within the MENA region through implementing the NEXUS approach integrating renewable energy technologies at the municipality's level to mitigate climate change impacts and combat poverty. More specific objectives include: building the municipalities' resilience to climate change; strengthening institutional capacities; promoting inter-municipal regional cooperation; reinforcing the role of women, youth, and marginalized groups; and developing a MENA dialogue knowledge platform.

The NEXUS approach is considered an effective and integrated approach that starts from the clear interactions that exist between water, food, and energy, to improve human well-being, reduce poverty and increase sustainable development. It aims to balance different uses of these ecosystem resources through identifying potential synergies between different sectors and/or related interest groups.

The first component of the MINARET project is set up to be a first step towards determining these synergies, through identifying baselines on energy and water consumption (related to agriculture), GHG emissions, and renewable energy use. This is done for a set of pilot areas in three countries (Jordan, Lebanon, Tunisia), presenting different socio-economic characteristics and reflecting the variety of challenges that the involved actors face. Given that agriculture accounts for 70 % of total global freshwater withdrawals, the water baseline data collection is merged with the collection of agricultural baseline data in one report.

The current report therefore, reflects the water/agriculture baseline for the Jordanian pilot area, and should as such be understood as one part of a tripartite first component of the MINARET project, which also includes similar baseline studies for Lebanon and Tunisia.

1.2. Scope of Baseline

The overall scope of the current report is to identify the baseline information on the water and agriculture situation at the municipality level in the pilot area. For the water sector, this includes analysis of: (1) the geographical, demographical, economic, social, and governance situation of the country and case study, (2) the policies and regulations for the water sector at municipal and national levels to identify the main water needs, (3) the institutional and governance structure of the water sector at municipal and national levels, (4) the water supply and demand profile and components at municipal and regional levels, (5) capacity assessment for the involved decision makers and stakeholders at local level.

For the agricultural sector, this entails analysis of: (1) the agricultural situation and practices at the municipal level and national/regional levels, (2) the institutional and governance structure of the agricultural sector at municipal and national levels, and (3) the suitability for implementation of new and modern agricultural technologies that consume less water and energy within the municipality.

The analyses are targeted to identify the main needs for both sectors to support municipalities in meeting development challenges in accordance with international standards (such as the Sustainable Development Goals). Based on this, potential interventions in the field of water governance and policy dialogue are identified for the pilot area as an outcome of this study.

For implementation of the MINARET project in Jordan, the greater Karak Municipality was selected. It is located in the south governorate of Karak. This selection was met using several criteria of the MINARET project which include; a fast-urban sprawl creating an increased stress on the infrastructure and natural resources in the area.

1.3. Structure

After this introduction, Chapter 2 describes the methodology that was used in general for this paper and the data collection methods to take stock of the water and agricultural situation in the case study area. Chapter 3 structures background information on Jordan including demographic, socio-economic and climatic situations, the existing policies related to the water and agriculture sectors, as well as the current water and agricultural situations. Chapter 4 presents the collected data for the case study area. Chapter 5 discusses the results and links them back to the objectives. Chapter 6 closes the report with conclusions and recommendations.

2. METHODOLOGY

2.1. Data Collection Tools, Protocols and Methods

The data collected for this study was mainly dependent on the review of available literature of reports, studies, scientific journals, and data banks from organizations working in the related sectors. The reviewed documents dealt with the water and agriculture sectors, geography, demography, climate, and socio- economy. National policies, laws and regulations governing the water and agriculture sectors were also reviewed. The reviewed literature was obtained from online sources, governmental institutions, international NGOs, and municipalities.

Two events were carried out in the study area.

1. The first event held on the 11th July 2017 included a site visit to the Ain al Samra spring, which is considered the main source of drinking water supply, the associated Waste Water Treatment Plant (WWTP) and two small farms around the water spring in that area. Information and observation during this site visit was collected and recorded.
2. The second visit held on the 17th July 2017 included a visit to Al Karak Municipality to meet with relevant stakeholders and collect information on the water, agriculture, and environmental sector in the study area. The visit included semi-structured meetings which included a short questionnaire focusing on their views regarding challenges facing the study area focusing on water, agriculture, environment and other related issues.

2.1. Data Categories

The data collected for this report included:

- Demographic data for Jordan and the study area
- Legislative data: covering policies, laws and regulations related to water and agriculture sectors
- Water sector: local and national demand and supply profiles, network, sources, quality, wastewater effluents, etc.
- Agriculture sector: local and national products, land use, irrigation methods, legislation, etc.
- Socio-Economic: including the national economy, as well as the main activities and income sources of residents, and income distribution
- Climatic and Geographic data related to Jordan
- Maps related to the above-mentioned categories

2.2. Data Quality

Data for this report was collected from available literature and verbal consultations with concerned authorities. It is important to recognize the following two important issues before going into the interpretation of the data and their significance. First, there are so many studies that are carried out by different entities and for different purposes, thus, there are some differences in the values obtained for the same parameter. However, these data sets are considered reliable because in many cases they are built on research methods and methodology for obtaining them. Second, surveys are also another tool

that provide reliable information since they allow obtaining expertise and experience of the stakeholders which are used in the analysis.

Data related to the water and agricultural sectors in Jordan, collected from literature are considered reliable, as they are based on scientifically based surveys and studies. As for the data on the Al Karak study area, only few reliable and comprehensive studies were available. Additionally, for the water sector for example, some private water sources and wells are not fully supervised and monitored by water authorities, thus making part of the information related to the water sector unavailable or sometimes inaccurate.

2.3. Limitation of the Collected Data

As mentioned earlier it is important to recognize the following two issues before interpreting data:

- There is an inherited discrepancy of information from different sources
- There are fewer studies on Al Karak area.

Discrepancies in information are resolved by relying on the newest information and/or by analyzing the credibility of source of the information.

3. BACKGROUND

3.1. Jordan's Context

3.1.1. Geography and Population

According to the world's bank data, Jordan's population amounted to seven million and 594 thousand people in 2015. In 2016, there was an increase to 9.5 million due to the Syrian crisis, with Syrian refugees contributing to the portion of non-Jordanians living in the kingdom (46%). The surface area of Jordan is 89,320 km² with population density of 85.5 and an annual growth rate of 2.4%. Population density is concentrated in the north and center of the country. Arabs make the majority of the population along with other ethnicities, and Islam is the official religion. **Figure 1** shows the location of Jordan in the region and its administrative divisions. **Figure 2** depicts the topographic map of Jordan.

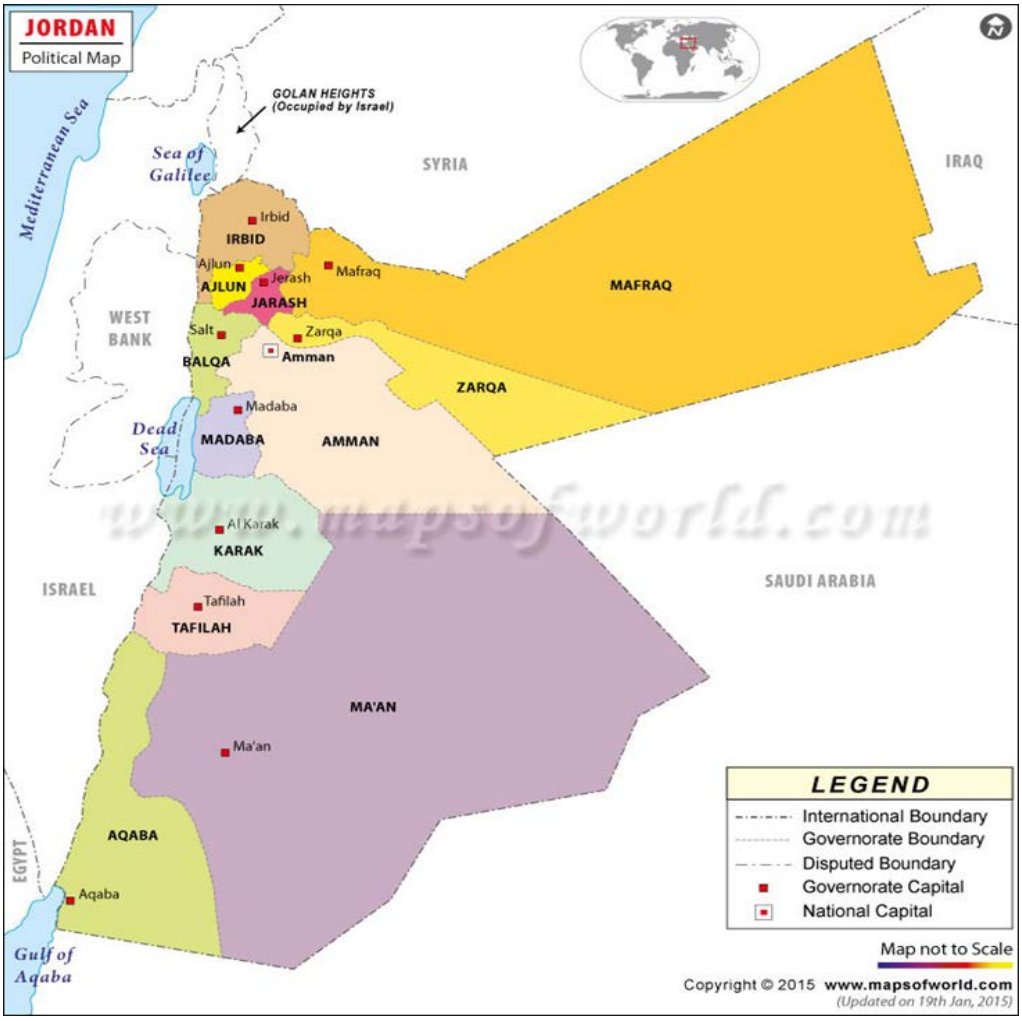


Figure 1 shows that Jordan is administratively divided into 12 governorates, Irbid, Mafraq, Ajloun, Jerash, Balqa, Amman, Zarqa, Madaba, Karak, Tafila, Maan, and Aqaba.

Jordan is divided into three main physiographic regions: the desert, the uplands east of the Jordan River, and the Jordan Valley from east to west. The desert is an extension of the Arabian desert comprising 75% of Jordan. It occupies the southern and eastern part of Jordan with elevations that vary between 600-900m above sea level. The highlands located east of the Jordan river, host most of Jordan's population in Amman, Karak, Zarqa and Irbid, and rise up to 1754m. They separate the Jordan valley

from the plains of the eastern desert. The Jordan valley extends through Syria and Lebanon to the Dead Sea, reaching 430m below sea level at its lowest point. The northern part of the valley is the most fertile region with a hot climate and relatively high rainfall during the winter making it the food basket for Jordan.

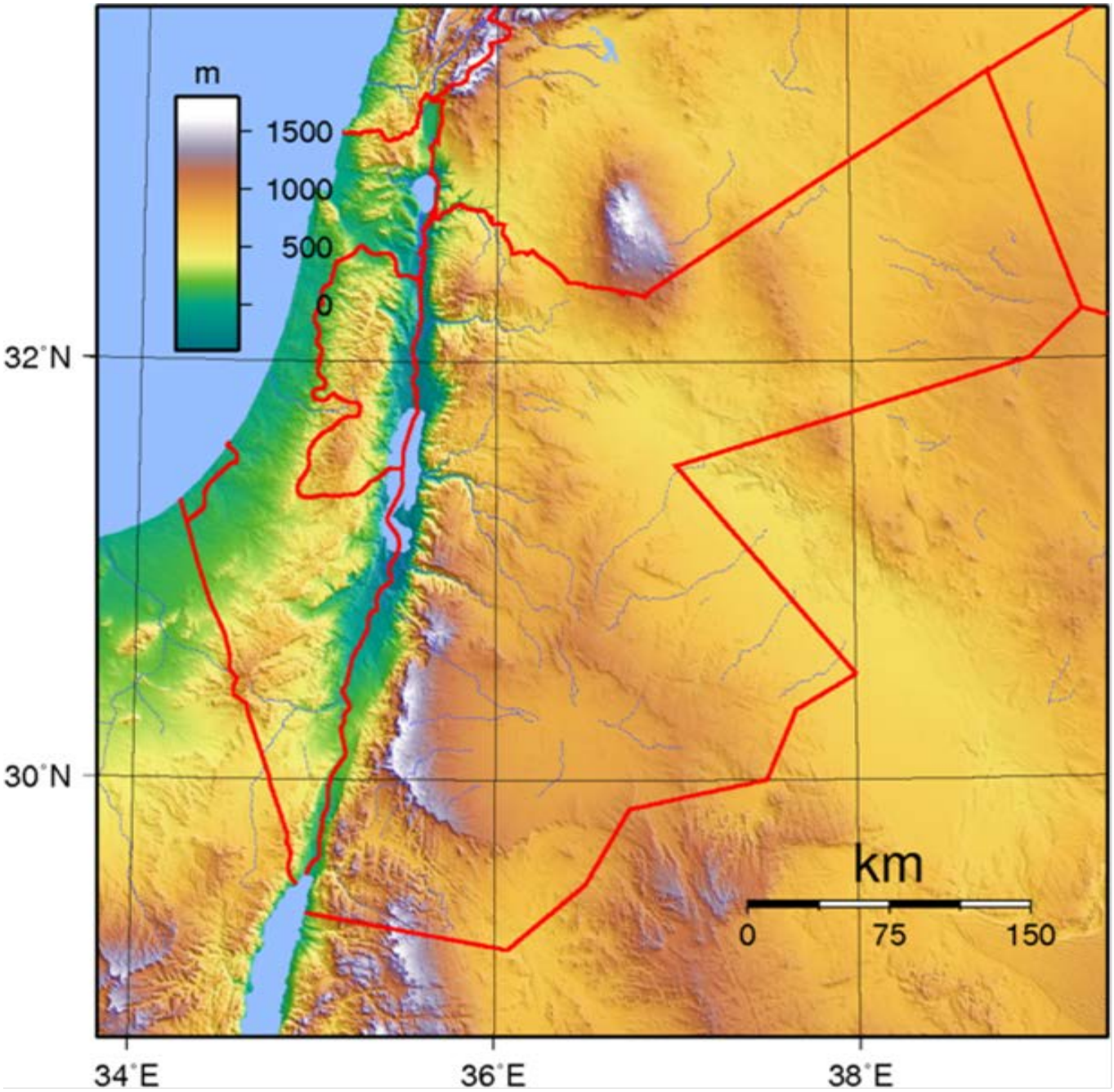


Figure 2 Topographic Map of Jordan (Wikipedia, 2017)

3.1.2. Climate

Jordan is located in the eastern Mediterranean climate zone with a Mediterranean climate in the west and desert climate in the east-south. The climate is generally hot and dry in the summer, and cold and wet in winter. Precipitation occurs during the winter in a decreasing amount from north to south. Precipitation in the northwest is estimated to be 400mm with average temperatures between 8-26 C° to less than 100mm with temperatures between 16-33 C° in the south. Occurrence of snow and frost is occasional in the uplands with rare occurrence in the rift valley. The climatic conditions not only have an impact on the amount and distribution of precipitation but also on the potential of evaporation, which is considered to be relatively high ranging from 1,600-4,000mm/year.

3.1.3. Economy

Jordan's economy is among the smallest in the Middle East (2015 GDP is about 38.5 Billion USD, Index mundi, 2017) with insufficient supplies of water, oil, and other natural resources, underlying the government's heavy reliance on foreign assistance. Other economic challenges for the government include chronic high rates of poverty, unemployment and underemployment, budget and current account deficits, and government debt.

During the first decade of the 2000s, Jordan implemented significant economic reforms, such as expanding foreign trade and privatizing state-owned companies which attracted foreign investment and contributed to average annual economic growth of 8% in the period 2004 through 2008. The global economic slowdown and regional turmoil contributed to slower growth from 2010 to 2016 - with growth averaging 2.8% per year - and hurt export-oriented sectors, construction, and tourism. Since the onset of the civil war in Syria and resulting refugee crisis, one of Jordan's most pressing socioeconomic challenges has been managing the influx of 650,000 UN-registered refugees, more than 80% of whom live in Jordan's urban areas. Jordan's own official census estimated the refugee number at 1.3 million as of early 2016.

Jordan is nearly completely dependent on imported energy—mostly natural gas— which consistently makes up 25-30 % of Jordan's import costs. To diversify its energy mix, Jordan has secured several contracts for liquefied natural gas and is currently exploring nuclear power generation, exploitation of abundant oil shale reserves and renewable technologies, as well as the import of Israeli offshore gas.

The GDP in 2015 reached 38.5 billion US dollars, distributed as follows:

- Agriculture: 4.2%
- Industry: 29.6%
- Services: 66.2%

Jordan's GDP by end use is composed as follows: (Index mundi, 2016)

- household consumption: 81.1%,
- government consumption: 19.8%,
- investment in fixed capital: 22.6%,
- inventory investment: 3.1%,
- exports of goods and services: 32.7%,
- imports of goods and services: -59.3%.

3.1.4. Resources

Jordan's natural resources are very limited and include phosphates, potash, and shale oil. The mining sector does not play a significant role in its economy.

In 2010, Jordan produced a significant amount of bromine and phosphate rock. It was ranked the sixth and seventh producer of phosphate rock and potash in the world, respectively.

Jordan also produced other mineral commodities in lesser quantities. These include cement, limestone, silica sand, fertilizer, clay, kaolin, pozzolanic material, refined petroleum products, steel, zeolitic tuff, and calcium carbonate (AZO Mining, 2012).

3.1.5. Challenges in Different Sectors

Energy Sector

The energy sector is considered to be the most burdensome sector on the national economy due to the high value of Jordan's energy import bill and its consequences on public finances, recently compounded by the continued disruptions of oil and gas flows from Iraq and Egypt. Therefore, this sector is currently considered a priority sector to be developed and is therefore receiving much attention from policy makers, private sector, and the international community.

Domestic energy sources in Jordan are scarce, where the country imports more than 96% of its energy needs. Table 1 reveals Jordan crude oil and natural gas production from 2008 till 2013.

Table 1: Jordan production of Crude Oil and Natural Gas (JIEW, 2015)

Year	Crude Oil Production (Thousand Tonnes)	Natural Gas Production (Billion Cubic Feet)	Share of Local Energy Production in Total Energy Consumption (%)
2008	1.7	7.2	3.2
2009	1.5	7.8	3.3
2010	1.2	6.5	2.8
2011	1	6.4	3
2012	1	5.8	2.4
2013	1	5.3	2.1

The growth of electricity consumption has been very significant over this period (2008 till 2013), with an average growth rate of 4.6%, mostly driven by household's consumption of energy (7.1% average growth). In fact, the household sector reaps the lion's share of electricity consumption consuming 43% of total energy, followed by 24% for the industrial sector and 14% for water sector.

Education

In Jordan, the education system is composed of elementary, preparatory, and secondary education during school years and moves on to diploma, bachelors, and higher degrees in adulthood. Technical & vocational education & training (TVET) is also closely related to the education sector, as it prepares an individual to

specialize in a specific vocation, and is considered to provide an alternative route to the traditional academic education.

Throughout its history, the education sector in Jordan has significantly contributed to the developmental shift of the Jordanian society from an agrarian nature to being service oriented with a modest industrialization process. Jordan's education sector (both at the public and private level) enjoys a very good reputation in the region, where a great number of the graduates are currently employed in higher income countries such as the Gulf Cooperation Council (GCC) countries.

The Jordanian adult population is considered to be well-educated relative to other countries in the Middle East and North Africa (MENA) region. In 2013, 6.8% of the adult population was illiterate, broken down into a 10% illiteracy rate for women and 3.5% for men. Although female illiteracy has decreased by a third over the past decade, women are still far more likely to be illiterate than men. Further progress is visible in the fact that 15% of the adult population held a bachelor degree or above in 2013, climbing from less than 10% a decade earlier. An exception to the positive educational trends is the proportion of adults who undertake vocational apprenticeships which fell from 0.8% in 2002 to 0.3% in 2013 in addition to the share of those holding the two years vocational community college diploma which fell from 8.3% to 7.8% in this same period. This suggests that the Jordanian society is not yet convinced of the value of vocational training & education and are rather opting to pursue an academic degree, mostly due to the high status of academic degrees as opposed to vocational education.

The reason for the emergence of the education sector as a main challenge to the economy is due to its inability to bring down the unemployment rate over the past decade or so. In other words, the sector is ineffective in providing the appropriate human capital for the various economic sectors in Jordan. The following chart illustrates the unemployment rate over the past decade.

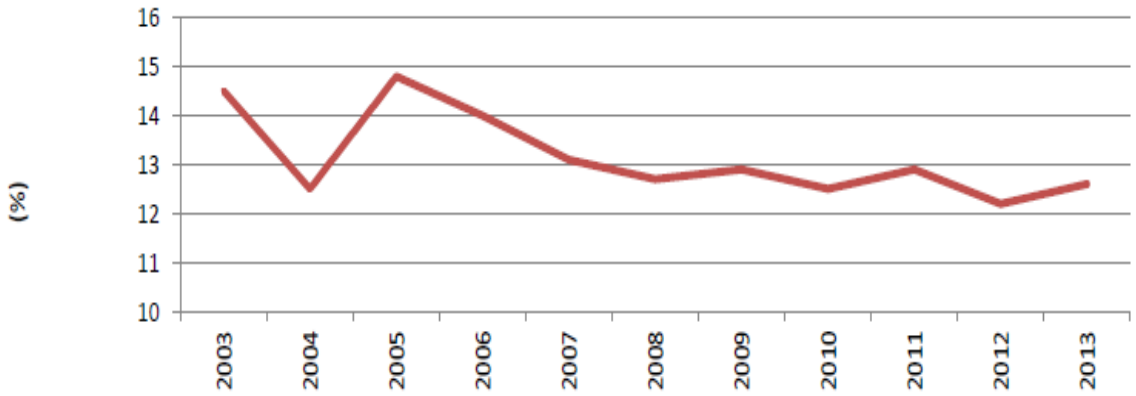


Figure 3: unemployment rate over the past decade

Despite the high education enrolment rates and a relatively well-educated workforce, the unemployment rate in Jordan remains persistently high, above the 12% mark, pointing towards a structural imbalance in the labour market. In other words, despite an increasing share of bachelor holders in the country, and an overall improvement in the education of the adult population, the unemployment rate did not reflect this development. This can be attributed to the overall weak economy and its ability to create new jobs for the new graduates. Other challenges to the education sector in Jordan include the lack of sufficient funding to the sector, poor infrastructure, inappropriate and poorly qualified human resources, outdated educational and teaching methods, and the influx of refugees. (JIEW, 2015)

3.2. Political and Legal Situation in Jordan

Jordan is a parliamentary democratic monarchy, headed by the king. Jordan's political system is based on the separation of executive, legislative and judicial powers (JIEW, 2015). Legislative power rests with the Parliament (lower house) elected directly by the people every four years; it consists of 150 deputies. The Parliament proposes and adopts laws, supervises Government policy. In addition, there is the upper house that consists of 75 members who are chosen by the government and serves as another layer of legislative power.

Executive power is entrusted to the Government (Council of Ministers), which determines and implements policies in all fields in accordance with the laws, appoints senior administrators and submits proposed legislation to the Parliament. Judicial power is fully vested with judicial courts of different degrees and levels of jurisdiction, and is autonomous.

Finally, the Constitution provides for the formation of a legislative bureau to rule on the constitutionality of laws and on challenges to the validity of presidential and parliamentary elections

3.3. Water Situation

Jordan is one of the most water-scarce countries in the world, as it suffers from very little groundwater resources and scant rainfall with a considerable variability from one region to another in the kingdom and from one year to the next. The region with most water is the north-west area around the Yarmouk and Jordan rivers. The major dams of unity, King Talal, and wadi Al Arab, are also situated in the same region, which receives the largest amounts of rainfall levels in the country. A recent study mapping water resources and needs in the kingdom based on Geographic Information Systems (GIS) revealed that Jordan's traditional interlinked water resources include rainfall, groundwater and surface waters, supplying Jordan with an estimated 780-850 million cubic meters (MCM) (Altz Smann, 2012).

3.3.1. Precipitation

Annual rainfall for the country is estimated at 266 millimeters (mm) per year but this does vary within different regions of the country. Some areas in the northwest area of Jordan can receive as much as 600 mm of rain per year, while sections of the southern and eastern desert areas receive only around 50 mm per year. 92% of the rainfall evaporates into the atmosphere (JVA, 2011), leaving the country with an even more meager share of rainfall. In **Figure 4**, average rainfall amounts per month are shown: rainfall is a seasonal affair, typically falling between the months of November and April, with the rest of the months witnessing almost no rain at all. Rainfall is the only source of recharge for the country's groundwater aquifers so its potential decline in the coming years due to climate change could pose a significant problem for Jordan (Altz-Stamm, 2012).

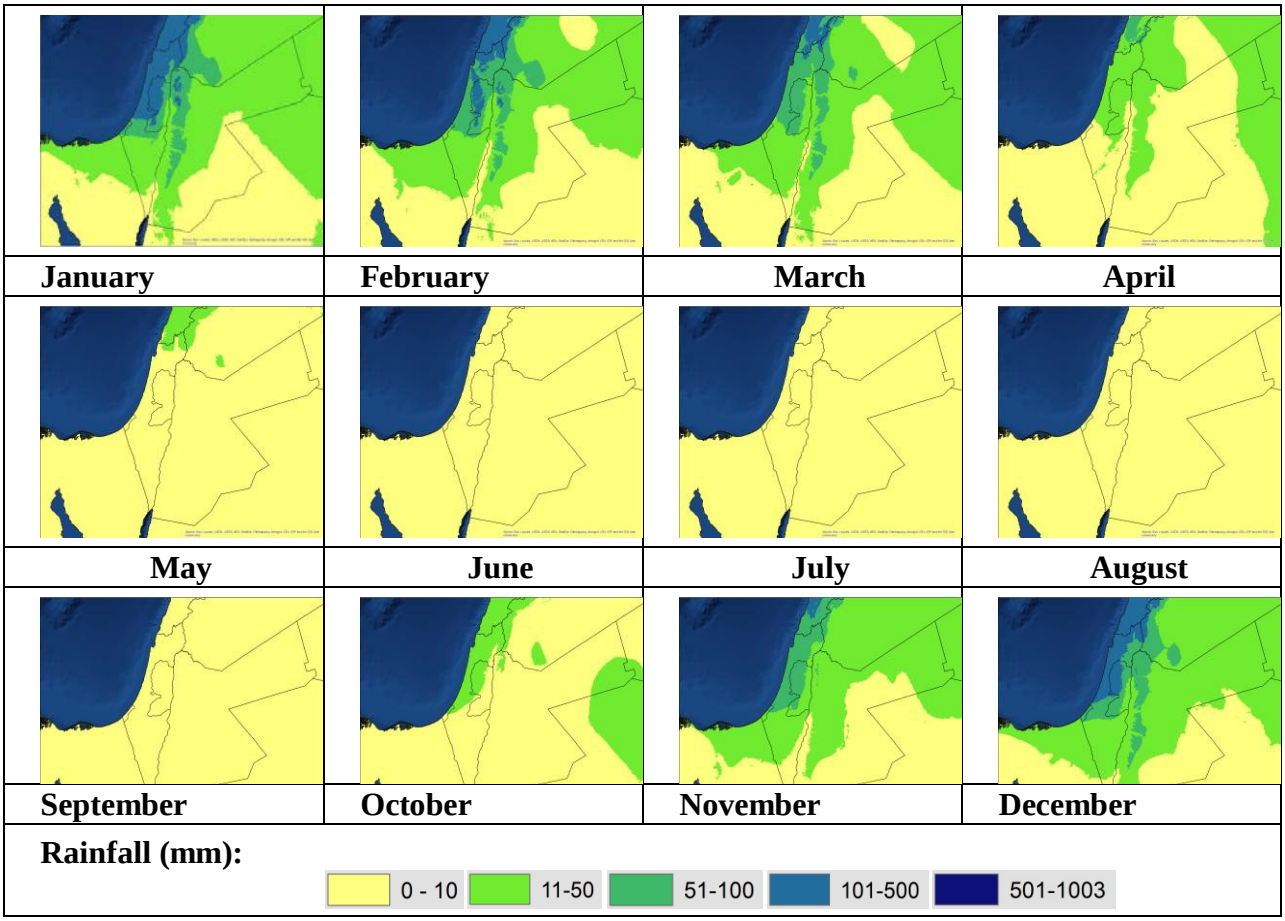


Figure 4: Average monthly rainfall in millimeters in Jordan(Altz-Stamm, 2012).

3.3.2. Rivers

Surface waters in Jordan supply roughly 37% of the total water supply. **Figure 5** shows the flow accumulation lines in blue against a backdrop of the elevation map of Jordan. Because rainfall is concentrated in the northwest of the country, and due to the flow of much of Jordan's surface water originating in Syria, the actual surface flow accumulation is solely within the northwest of the country, as shown with the area surrounded by a red box.

The major suppliers of surface water in Jordan are the Yarmouk, Jordan and Zarqa Rivers, as well as what is accumulated in side wadis, or valleys, within seasonal streams. **Figure 6** shows these waterways, with rivers in dark blue and seasonal streams in light blue.

The Yarmouk River originates in Syria, flows along the Syria-Jordan border, and then dumps into the Lower Jordan River. Its historic flow at the beginning of the 20th century was estimated at 480 MCM per year but now it is only 171 MCM per year. As for the Lower Jordan River, its waters come from the Upper Jordan River, whose tributaries come from the Golan Heights and Lebanon and then run through Jordan. Its historic flow at the beginning of the 20th century was around 1300 MCM per year and has sadly dropped 98% to 20-30 MCM per year today due to the consumption of the majority of its natural flow from its upstream tributaries (Altz-Stamm, 2012). Both the Jordan and Yarmouk Rivers are international waterways shared with Israel and Syria and are thus vulnerable to the diversions and dams that those two countries have constructed along their flows. Despite international treaties with regard to the use of these waters, Jordan, as the downstream riparian, is still constrained in its ability to acquire more of their flows.

The Zarqa River is mainly the product of seasonal rainfall as well as treated wastewater. Due to its proximity to the major population centers in and around Amman, it suffers from severe pollution. In addition to these rivers, as mentioned above, rainfall is also collected in side valleys that create seasonal streams running into the Jordan Valley.

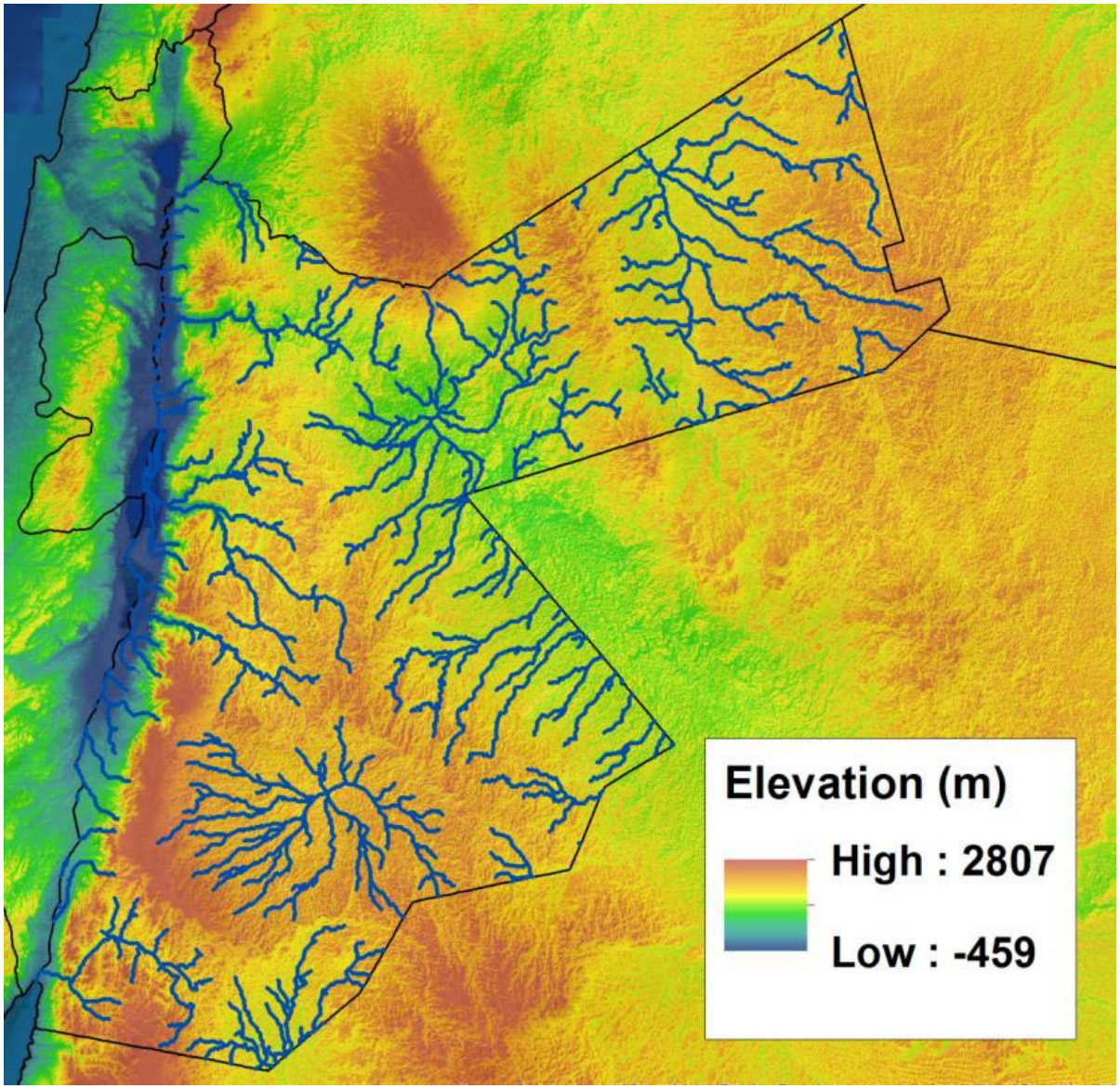


Figure 5 Flow accumulation lines on a raster map of Jordan showing elevation (Altz-Stamm, 2012)

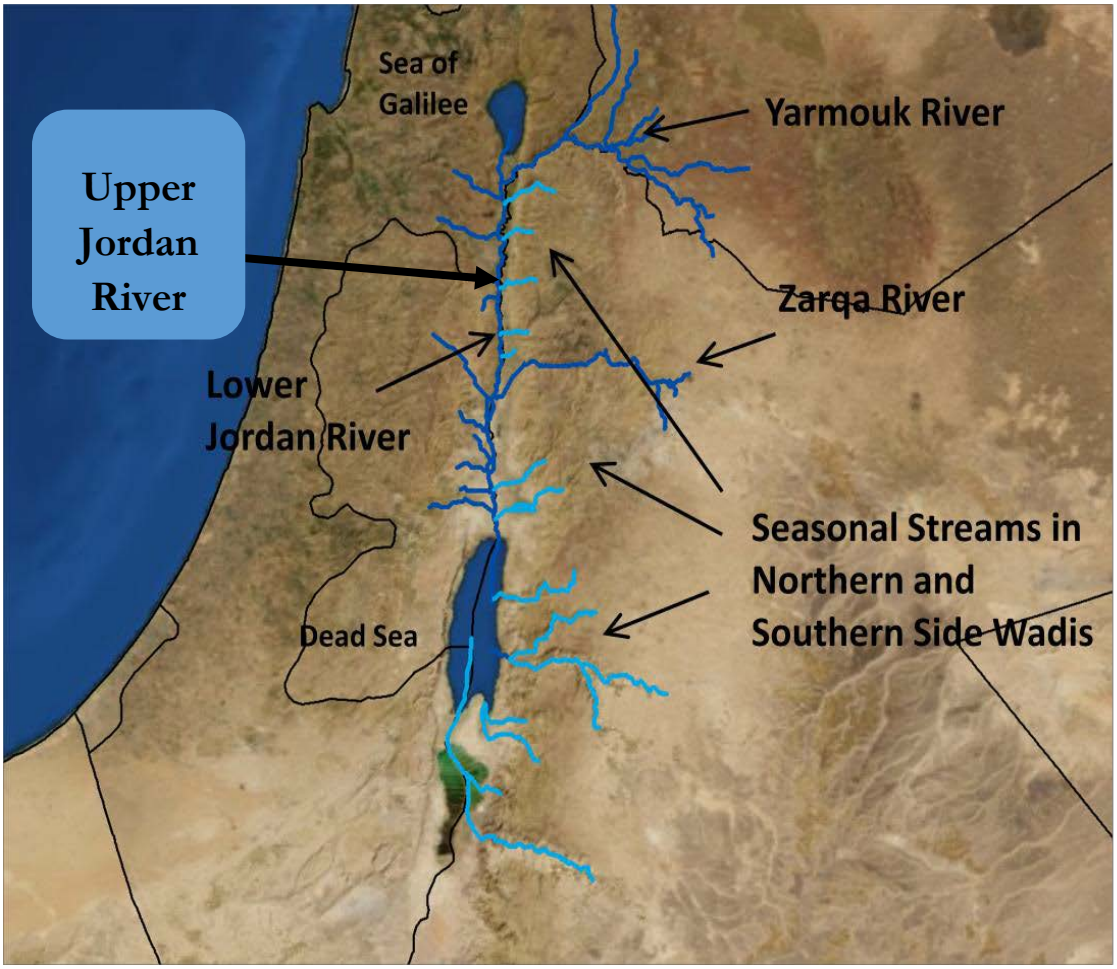


Figure 6 Jordan's surface waters as present in rivers and streams. (Altz-Stamm, 2012)

3.3.3. Springs

Jordan's geological characteristics, namely its highly fractured geological rocks, and the inter-bed rock formations of different permeability have led to the formation of hundreds of springs. Many of these springs are hot and usually used for medical tourism. There is no accurate number of the volumes of water provided by these springs. The volumes are very much dependent on the amounts of rainfall and the subsequent groundwater recharge to the aquifers. Most of the Springs are located in Ajlun, Jerash, Al Hemma in the North, Tafila, Shoubak, and Ma'een

3.3.4. Groundwater

Jordan's groundwater resources account for roughly 54% of the total water supply in the country. There are 12 major basins as seen in **Figure 7**, along with each basin's annual safe yield in MCM. The total safe yield of all of the basins is estimated at 275 MCM per year, whereas yearly abstraction can be above 473 MCM. This over-abstraction is due to the lax enforcement of well drilling regulations and the lack of control on licensed abstraction rates. In turn, this over-abstraction has lowered the water table a significant amount and has increased pumping costs (MWI; Al-Halasah and Ammary, 2006). Moreover, the quality of the water in these basins has declined a significant amount due to the overuse of pesticides and insecticides in

agriculture, improper disposal of industrial waste, leakage from landfills and septic tanks, and the general pollution that comes from an increasing population with incomplete wastewater systems (MWI).

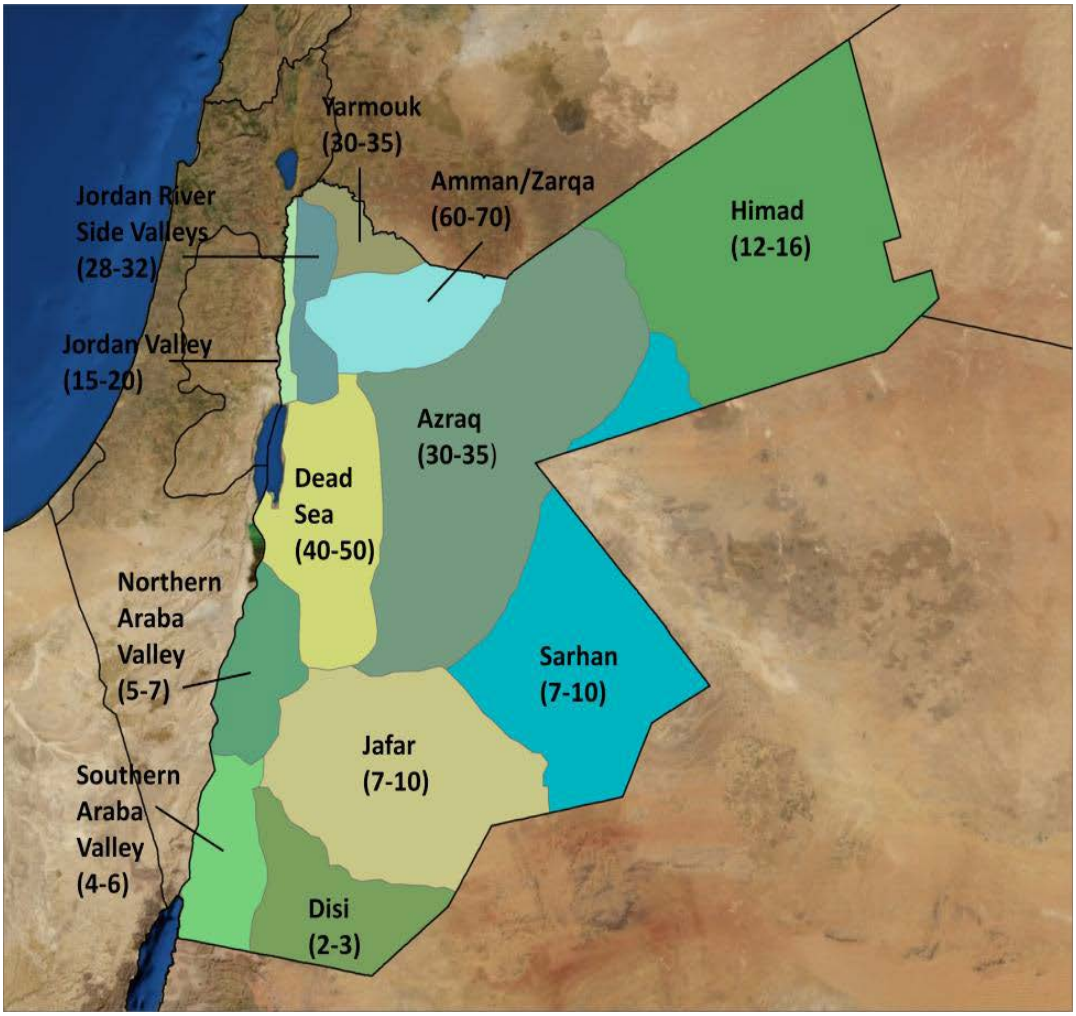


Figure 7 Groundwater Basins in Jordan and their annual safe yield in million cubic meters (Altz-stamm, 2012)

3.3.5. Water Demand and Supply

Water demand in Jordan is estimated to be around 955 MCM per year. The gap between supply and demand is estimated to be around 105-175 MCM per year. Water is consumed by four main sectors with the largest user being the agriculture sector, consuming around 64% of the total supply, while contributing only 3% to GDP. The second largest user of water is the Municipal sector (i.e. households & businesses) which consumes around 30% of Jordan's total water supply whereas 5% of the water supply is used for Jordan's domestic industries and 1% for tourism (Altz Stamm, 2012).

Water demand has been high in Jordan over the years due to the influx of multiple waves of refugees in Jordan, exacerbating the water shortage in the country. The most recent influx of refugees taking place over the past decade has pushed water demand further, above natural levels. According to the Ministry of Water and Irrigation, the water of one Syrian refugee costs Jordan JOD400/year. Nevertheless, despite the shortage in supply, 98% of Jordan's population have access to water through the country's national water network.

Table 2 illustrates the past/projected evolution of the gap between the total water and the total demand for the period 2015-2025. Future numbers are estimated based on the inclusion of all planned future water resources projects such as the Red Sea-Dead Sea water conveyance canal (about 870 MCM in the final stage), the Aqaba desalination plant (about 50 MCM), etc.

Table 2 Gap between water Supply and Demand in Jordan (Ali Subah, 2017)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Groundwater Safe yield	275	275	275	275	275	275	275	275	275	275	275
Non-renewable groundwater	144	145	145	147	178	189	174	240	241	242	243
Groundwater Over Abstraction	160	156	156	148	144	140	136	131	127	122	118
Surface water (Local + Tiberius Lake)	274	276	278	280	283	286	290	293	306	311	329
Treated wastewater	147	151	155	177	182	188	191	196	202	208	235
Additional Resources (Desalination + SWAP)	10	11	11	18	19	20	85	86	87	88	233
Total Resources	1010	1014	1020	1045	1081	1098	1151	1221	1238	1246	1433
Sustainable Resources	832	836	836	886	920	942	1030	1106	1125	1131	1341
Municipal, Industrial, Tourist demands	701	703	703	717	723	730	737	746	755	766	778
Irrigation demand	700	700	700	700	700	700	700	700	700	700	700
Oil shale and Nuclear power demand				25	25	25	48	48	48	70	70
Total demand without irrigations	701	703	703	742	748	755	785	793	803	836	848
Total Demand	1401	1403	1412	1442	1448	1455	1485	1493	1503	1536	1548
Deficit in MCM/a (with over abstraction)	391	389	392	397	367	357	334	272	265	290	115

(SWAP = Water amount swap with Israel in accordance with the peace treaty).

Public water is supplied to connected households on a subscription basis, with a predetermined tariff that is categorized into slices. The price per cubic meter increases with increasing water use. This would usually discourage wasting water by the consumers and is considered as a water saving measure.

Although the water network coverage in Jordan is high (99%), the continuity of supply is low. In fact, All Jordanian (except for the residents of Aqaba) receive water on an intermittent supplies basis of 24 to 36 hours per week.

The inability of water authorities to cover the need all over the week has led to the development of the private water market. The reliance on private suppliers increases the financial burden, especially on low-income families, as the water bill consists of:

- Public network fee,
- Other sources of service water (private wells, tankers)
- Other sources of drinking water (bottled water and water gallons)

Combined water and sewer bills amount, on average, to less than 0.5% of total household expenditures and are thus quite affordable. In 2007 it was estimated that an average poor household with 6 members in the Middle Governorates (Amman, Zarqa, and Madaba) spends 31-39 JOD per year on its water and sewer bill at a consumption of 70 liter/capita/day, corresponding to only 0.4% of household expenditures. In summary, the cost of the water bill is thus only a fraction of actual water expenditures, and household water expenditures could be lowered significantly if a sufficient quantity of good quality water was supplied on a reliable basis (JIEW, 2015)

Tariff structure and level

Water and sewer tariffs in Jordan are differentiated by geographic area, type of use and volume of use. In areas served by public companies - the governorates of Amman, Aqaba, Irbid, Jerash, Ajloun and Mafraq - tariffs are higher than in the rest of the country where services are provided by WAJ. Residential water and sewer tariffs use an increasing-block system, under which users pay a higher tariff per m3 if they consume more water. The first block, corresponding to a consumption of 18m3 per quarter, is a minimum charge independent of the amount of water consumed. Water and sewer tariffs for non-residential use (commercial and industrial users) are about ten to twenty times higher respectively than residential water and sewer tariffs in the lowest consumption block.

In areas served by public companies, as of 2015, the residential minimum charge was JOD 5.22/quarter of a year for water and sewerage. This corresponds to an average water tariff of JOD 0.14/m3 and a sewer tariff of JOD0.04/m3 for 18m3 per quarter. For a consumption level of 36m3 per quarter the average water and sewer tariff was JOD0.24/m3 and JOD 0.14/m3 respectively. The tariff for each next m3 increases until it reaches JOD 1.92/m3 and JOD 1.11/m3 respectively for water and sewerage at a consumption of more than 122 m3/quarter. Tariffs for non-residential customers were JOD 1.30/m3 and 0,87 m3 respectively above a consumption of 6 m3/quarter, independently of the level of consumption. There is also a sewerage tax that is set at 3% of the assessed property value, which is charged in addition to the sewer tariff. Despite rising property values the sewerage tax revenue has remained constant for many years at JOD15m per year, representing less than 10% of water revenues (JIEW, 2015).

3.3.6. Waste Water

Another unconventional source of water is treated wastewater; which supply is currently limited due to the low capacity in most of the 27 wastewater treatment plants. Most of this treated wastewater is coming from Al Samra WWTP which serves Amman, Zarqa, Rusaifeh, and Hashmia with an amount of about 90 MCM annually. It is used for irrigation, after being mixed with surface water in the King Talal reservoir and later with water from the Yarmouk and Jordan rivers.

3.3.7. Challenges

Water deficit

As pointed out above, there is a significant gap between water supply and water demand in the country. This water deficit has a considerable impact on Jordan's domestic economy on different levels as access to clean water is key to economic prosperity and welfare. One of the main effects is limiting the share of land that can be utilized for agricultural purposes, thereby limiting the extent to which agriculture can contribute to the development of the national economy. Another serious effect can be observed on public finances; since the shortage of supply results in a high equilibrium price of water, the government provides a general water subsidy estimated to have reached a total of JOD335.2 million in 2013. Other than the issue of water subsidies, public finances are also adversely affected by the water shortage due to high energy costs of pumping groundwater resources above ground, especially to highlands (JIEW, 2015)

Furthermore, Jordan's shortage of water adversely affects the trade balance of the economy, as the gap between demand and supply will have to be imported from outside the country to meet domestic needs, thereby putting pressures on available foreign currency reserves. Water scarcity also has an effect on the energy sector, limiting the viability of generating power from some energy sources, mainly nuclear energy, since it requires a significant amount of water for cooling and other functions.

Ultimately, the major and most threatening impact of water scarcity is on the long-term sustainability of economic activities across all different sectors. Industry and businesses, especially those dependent on water resources, may choose to relocate if faced with more severe water shortages. Similarly, water supply shortages limit the attractiveness of investments in Jordan, especially those requiring considerable amounts of water.

Climate Change

Recent studies (SNC 2007, TNC 2015, MoEnv, 2013) have reported that Jordan has been witnessing a decrease in annual rainfall in many regions especially those in the wet north-east. Additionally, the studies showed an increased occurrence of consecutive dry years.

According to the Jordan's Second National Communication to the UNFCCC, climate change is expected to cause the average rainfall in the country to decrease from present values by 10-20% by 2050 (MoEnv, 2007).

Moreover, the Intergovernmental Panel on Climate Change (IPCC) assessment report of 2013 states that the frequency and intensity of drought in the Mediterranean region (which Jordan is part of) will likely increase into the early and late 21st century. Additionally, the report predicts that change in average precipitation in the eastern Mediterranean for the period 1986-2005 to 2081-2100 will likely decrease between 20% and 30% coupled with an increase in temperature of 2°C to 3°C.

Furthermore, for the period 1961 to 1990, an increase in average air temperature in Jordan of 1.3 to 1.8 °C has been reported by IPCC-DCC (1999). By the same trend, it is believed that further increase in temperature will be witnessed in Jordan in the following four decades.

Water quality

Several agencies including the Jordan Valley Authority, the Ministry of Environment, the Ministry of Health, the Ministry of Water and Irrigation, the Royal Scientific Society and the Water Authority of Jordan monitor water quality and effluent discharge countrywide. Reports (JIEW, 2015) indicate that:

- 73 percent of spring water has biological contamination.
- Surface water shows high fecal coliform counts from non-point pollution sources including wastewater treatment plants operating over capacity.
- Water resources have a high level of toxicity.
- Industrial discharge is improperly treated or untreated.
- Intermittent operation of municipal water supplies allows for recontamination of treated water.
- Over-abstraction of groundwater for irrigation has reduced the water table by 5 meters in some areas (Dhuleil-Hallabat area of the Amman -Zarqa basin) and tripled salinity.
- Unregulated fertilizer and pesticide application has increased nitrates and phosphorus in water supplies.

3.3.8. Water Governance

Jordan has developed water policies and strategies (see below) to enhance development, management, and use of scarce water resources. These policies included various measures related to creating enabling environment, defining institutional roles and establishing management tools which are the three main pillars required for the successful implementation of Integrated Water Resources Management (IWRM). For

example, Jordan has followed a participatory approach in developing its national water plans with active involvement of governmental agencies, ministries, civil society, water user organizations and others through meetings, workshops, and national conferences. Moreover, Jordan has achieved progress in developing investment and implementation plans of the National Water Resources Plans, including the total investment required by the government and through loans and grants from donors and other financial institutions. Economic instruments such as cost recovery, taxes, incentives and fines measures were investigated and initiated to make more fund available to improve operation and maintenance costs of water resources infrastructure and, therefore, to increase water use efficiency (MOPIC, 2017)

Also, Jordan has assessed its current and future water resources and demands and the available management tools that could be utilized for IWRM implementation. For instance, with respect to water demand management, a package of measures has been proposed in Jordan to increase water tariff, introduce new modern irrigation techniques, and develop new codes for water use that stress on water savings aspects and assist in enhancing public awareness.

Water Administrative Structure in Jordan

Water resources were managed and regulated by WAJ, JVA, Ministry of Agriculture and Ministry of Health until 1988 when the Ministry of Water and Irrigation (MWI) was established. The major objective of establishing the MWI was to centralize water sector activities in an endeavor to improve its management. This made MWI the official institute in charge of water sector activities that include planning, setting of strategies and policy and research and development.

The MWI is the official body responsible for the overall monitoring of the water sector, water supply (production, transmission, and distribution) and wastewater system. It embraces the two most important entities dealing with water in Jordan: The Water Authority of Jordan (WAJ), in charge of water & sewerage systems for the country, and The Jordan Valley Authority (JVA), responsible for the socio-economic development of the Jordan Rift Valley, including water development and distribution of irrigation. There are three Secretary Generals within MWI, one for MWI itself, one for WAJ and another for JVA. They are required to report to the Minister. MWI contains eight directorates. Namely, Legal Affairs, Water Resources Development, Deep wells and Drilling, Water Resources Planning, Environment, Public Information Affairs and Awareness, Financial and General Affairs and Project Directorate.

The Water Authority of Jordan (WAJ) was established as an autonomous corporate body, with financial and administrative independence linked with the Minister of Water and Irrigation. WAJ is responsible for planning, implementing and operating public water and wastewater projects and all water supply and wastewater facilities in Jordan. WAJ explores existing water resources, and maintains and operates water and wastewater networks throughout the Kingdom (WAJ 2009). WAJ's Project Management Unit (PMU) regulates water and wastewater utilities under private management (MWI 2009).

According to the Ministries and Public Institutions and Departments Linked Organization By-Law No.16 of 1988 WAJ and JVA are linked with the Minister of Water and Irrigation. Nonetheless, WAJ is an autonomous corporate body, with financial and administrative independence. WAJ Secretary General has five assistants; for Technical Support, Planning and Investment, Maintenance and Workshop, Financial Affairs and Administrative Sectors. WAJ has been undergoing reform according to an improvement plan.

Established in 1977, Jordan Valley Authority (JVA) has been entrusted with the social and economic development of the Jordan Rift Valley from the Yarmouk River in the north to Aqaba in the south, Jordan's major agriculture region. It has also been delegated the responsibility of developing, maintaining and

protecting water resources. In addition to the 110 km King Abdullah Canal, JVA is also responsible for all dams and reservoirs in the country. It has a Secretary General who has six assistants; for Planning and Environment, Southern Ghors and Wadi Araba, Lands and Urban Development, Administration, Finance and Tenders, Northern and Middle Ghors, and Studies and Projects. JVA creates partnerships with the private sector where appropriate, and also implement projects stemming from regional agreements on water and development on behalf of the Jordanian government (JVA 2009).

MWI embarked on an ambitious restructuring programme in order to increase efficiency in Water Sector. Decentralization has been at the center of such efforts. This has been epitomized by delegating management responsibilities from WAJ to regional units operating on commercial basis with Private Sector Participation (PSP). This is in line with overall government policy directed at the promotion of private sector participation in various governmental sectors. A Project Management Unit (PMU) has been established within WAJ since 1996 to regulate water and wastewater utilities under private management, e.g. the Greater Amman water supply management contract which has been introduced in 1999. The PMU is mandated to initiate and follow-up privatization contracts. It is managing the transition period with support from an international aid agency. Management contracts and Build Operate Transfer (BOT) systems have been set up for the construction of water conveyance and water supply projects and wastewater treatment plants. An example is the Northern Governorates Water Administration (NGWA) which was founded in 2001. NAGWA is comprised of the 4 Northern governorates of Irbid, Jerash, Ajloun and Mafraq (including North Badia). It started operation in January 2002, and provides water supply and wastewater disposal services to more than 1.4 million people living in a predominantly rural service area.

The establishment of public water companies (Yarmouk for the Northern governorates, Meyahuna for the middle governorates, and Aqaba for the southern governorates) is another emerging form managing the water sector. Such a company has its own board of directors with representatives from MWI, concerned ministries and authorities.

The water sector is known to increase government debt problems. This is attributed to the annual subsidies paid to WAJ and JVA. About 25% is known to go for interest payments on external loans contracted for investments in hydraulic infrastructure. WAJ consumes seventy-five percent of this amount. On the other hand, indirect energy subsidies are given out to farmers. Only half of the water sector expenditures are recovered though levies and associated charges. It is worth mentioning that the total water quantities billed by WAJ amount to about fifty percent of the water quantity produced. This has been attributed to "technical and financial losses" caused by the unaccounted for quantities of water. While this is for municipal water, water for irrigation in the Jordan Valley is sold by JVA at 11-12 Fils/m3 (JOD is 1000 Fils, One JOD equals 1.41 USD) which is considered rather low as farmers in the highlands put up with a 50 Fils/m3. The low water tariffs are seen somehow justifiable because JVA's main mission is to promote social and economic development in the Jordan Valley. Nonetheless, full cost recovery is targeted for 2020. It is estimated that 30% of the "cost recovery gap" can be achieved through improvements in operational efficiency and a further 30% by the institution of better integrated investment planning.

Regulatory Framework of the Water sector (MoEnv, 2013)

Currently there are six major laws governing the management and use of water in the country:

- The Water Authority Law (no. 18 for 1988)

This law created the Water Authority in Jordan in 1988, and is still the most comprehensive legislation dealing with water issues. It sets the responsibilities of the WAJ as full control of the monitoring and

management of water resources. The law gives WAJ the authority to direct, regulate and license the construction of private wells. The law considers all water resources in the country to be state-owned property. Any person who attempts to use water resources without a license from the WAJ can be fined, according to the law.

- The Jordan Valley Authority Law (no. 30 for 2001)

This law controls the use of water resources in the Jordan Valley, the main center of agricultural activities in the country. It also sets guidelines on land ownership and farming activities in the Jordan Valley. It has full authority over water resources, and the right to settle any disputes in water allocation. The law gives JVA the mandate to manage any project in the region in a commercial way, with the exception of water resources development and irrigation projects.

- The Ministry of Water and Irrigation bylaw (no 54 for 1992)

This bylaw created the MWI in 1988. It provides the Ministry with full responsibility for water and public sewage in the Kingdom. The bylaw established a special directorate in the Ministry called the Citizen Service Directorate which assumes the functions of conducting studies, designing enlightened strategies of education and information provision, which aim at the minimization of water consumption in houses, factories and agriculture.

- The groundwater bylaw (no. 85 of 2002)

This important bylaw was established in 2002 to meet the urgent need for conserving the country's scarce and depleting groundwater resources. In this bylaw the ownership of the groundwater wells was maintained to lie with the state. Even land ownership does not mean ownership of groundwater resources. The WAJ will issue a license to use water within limits of extraction rates. As per the bylaw, the MWI determines the maximum quantity of underground water permitted to be extracted annually from each ground water basin, within the limits of safe yield. The strict clauses of the bylaw clearly reflect the severity of the groundwater situation in the country, and the uncompromised authority of the state in controlling this resource and preventing its over-exploitation.

- Environmental protection law (no 6 of 2017)

This new law is the updated version of the 2006 law. The new law outlines the Ministry of Environment's mandates and responsibilities. The law specifically stresses the sustainability principles and the protection of all natural resources including, water, soil, biodiversity, marine environment, and air. The law came as a response to the new commitments of the government of Jordan to many international and regional conventions and multilateral agreements, such as climate change, biodiversity, desertification, etc.

- Drinking Water Standards

The drinking water standard in Jordan (No. 286:2001) is based on the WHO drinking water standards. The standards were raised in 2001, after a major drinking water pollution outbreak occurred in Amman in the summer of 1998 due to a malfunction of the capital's major drinking water treatment plant. The standard includes specific measures to be undertaken in case of the occurrence of pollution in drinking water samples, and the frequency of testing samples that is directly correlated to the number of people served by the water supply.

- The National Water Strategy

In accordance with Article 5 of the Water Authority Law No.18 of 1988 and pursuant to the Council of Ministers approval, the basic strategy and policies for the water sector of Jordan have been formulated and published by the Ministry of Water and Irrigation.

In 2016, a new National Water Strategy 2016 – 2025 was issued based on vision-driven change effort. This Water Strategy for Jordan identifies plans for future actions that will be taken to ensure that water is available for people, business and nature. It sets the vision of what we want to have by 2025. It looks at all aspects of the water cycle from rainfall to collection, treatment and discharge. The practical steps needed to take include an effective Water Demand Management, an efficient Water Supply Operations and a well-developed institutional reform.

The strategy stresses on the need for improved resources management with particular emphasis on sustainability of present and future uses, water protection against pollution, depletion of water resources, achieving the highest practical efficiency in the conveyance, distribution, application and use of water resources. The strategy takes into account both supply and demand management. The strategy ensures that the rightful shares of the Kingdom's shared water resources will be achieved through bilateral and multilateral negotiations and agreements. Jordan's water strategy provided the foundation and initiative to develop policies addressing specific issues facing Jordan's water sector.

The Strategy stresses that the full potential of surface water and groundwater shall be tapped to the extent permissible by economic feasibility, and by social and environmental impacts and that the use of ground and surface water with different qualities shall be considered. The strategy also considers that wastewater should not be managed as waste; wastewater is to be collected and treated for reuse in unrestricted agriculture and other non-domestic purposes, including groundwater recharge. Similarly, also brackish water and desalinated sea water shall support irrigated agriculture and produce additional water for municipal, industrial and commercial uses. "Priority criterion for project implementation, and for additional water allocation, shall be based on economic, social and environmental considerations. A 'critical path' shall be established for the allocation of each new source of water. Consideration shall be given to the sustainability of the allocation in the light of the national water balance situation and the economic, social and environmental opportunity cost of forgone alternative uses of water. First priority will be given to allocation of the basic human needs; as such, first priority is given to allocation of a modest share of 100 liters per capita per day to domestic water supplies. Expensive additional water has municipal purposes as a first priority in allocation, followed by tourism and industrial purposes" (MWI 2009).

Water policies, investments programs, and action plan as part of the National Water Strategy

There are many water management challenges in Jordan due to severe water shortage, the rapid population growth and increase in industrial development. The gap between water demand and supply is increasing and is compensated by over-exploitation of available groundwater resources. Water scarcity is expected to increase in the future and may result in a decrease of water use for agricultural purposes.

Below is a list of the policies, investment programs, and action plan stemming from the water strategy for Jordan:

Policies

- Water Demand Management Policy.
- Energy Efficiency and Renewable Energy in the water sector Policy.
- Water Substitution and Re-Use Policy.
- Water Reallocation Policy.
- Surface Water Utilization Policy.
- Groundwater Sustainability Policy.
- Climate Change Policy for a Resilient Water Sector.
- Decentralized Wastewater Management Policy.

Investment program

Water Sector Capital Investment Program (2016-2025).

Action Plan

Action Plan to Reduce Water Sector Losses (Structural Benchmark).

The strategy and policies were formulated with an obvious target of promoting sustainable utilization of the already scarce natural water resources. Improvement in the quality of life for the Jordanian citizen has been the ultimate development goal and thus dictated the prevailing approach of implementation.

By international standards, the marginal cost of water is considered high and is on the rise. Water networks have been in need of rehabilitation and yet present another formidable technical and financial challenge. Additional water resources that can be mobilized are modest.

In view of the aforementioned status and anticipated trends in the water sector, the Water Strategy was adopted by the Government of Jordan. Policy documents mentioned above were issued with an aim of detailing Government's policy and intentions pertaining to water sector and respective sub-sectors, including Resource Development, Resource Management, Legislation and Institutional Set-Up, Shared Water Resources, Public Awareness, Performance, Health Standards, Private Sector Participation, Financing and Research & Development.

3.4. Agriculture

3.4.1. General Figures

Jordan's surface area is about 89.300 km2, 90% of which receives rain fall of 200 mm or less. The topography of the land can be classified as follows:

- Jordan Valley to the west; which accounts for 2.25% of the total country area.
- Central Highlands; which accounts for 19.94% of the total country area.
- The Badia to the east; which accounts for 77.37% of the total country area.

The arable land is estimated at 8.9 million Dunums for the whole country. Out of this, only 3.6 million are utilized (about 40.5%) which accounts for 4% of the total area of the country.

Agriculture is considered, in all countries, a basic pillar of economic and social development. During the past three decades, agriculture has also started globally to play a major role in the protection of the

environment, including the protection of biodiversity and ensuring an environmental balance that would secure sustainable use of resources and preserve them for future generations.

These principles have been globally used as a basis for agricultural strategies for many countries. Strategies no longer focus on the economic dimension of development alone, but emphasize the social and environmental dimensions as well.

In Jordan, despite of the sector's moderate contribution to GDP (about 3%), it is still considered the base for integrated rural development, a source of income and employment for rural and Badiya (semi- desert) people and a generator of activities in the other economic sub-sectors, especially the industrial and services sub-sectors. It also plays a central role in food security and trade balance improvement.

The above considerations should not overshadow the need for economic efficiency in utilizing agricultural resources. Efforts must aim at building the agricultural economy on the basis of comparative advantage and competitiveness in price and quality.

Land use in Jordan is a complex mixture of rural and urban activities that reflect both climate and socioeconomic characteristics. According to the Department of Statistics (2003), land use shows that 93% of the country is dominated by non-cultivated areas, classified as rangeland, due to limitations of climate, water availability, soil suitability and surface cover of stones. Although the eastern and western arid lands and deserts are used as open rangelands, irrigation is practiced in these hot areas. Cultivated areas form 2.7% of the total area of Jordan. Intersecting land use/cover and agro-climatological maps show that 90% of rain-fed agriculture is taking place in the northern and western highlands. Irrigation is taking place in Jordan Valley (JV), highlands and desert areas (see **Figure 8**).

The map of land use/cover **Figure 9** includes 5 main categories of land use/cover (following CORINE classification system) including 14 classes. Areas with rainfed cereals are concentrated in the northern Central highlands. Irrigated areas are concentrated in the northern part of the Jordan Valley and further scattered in the Jordan Valley and Central Highlands. Open rangelands mainly appear in the Central highlands and the most eastern part of the Badia.

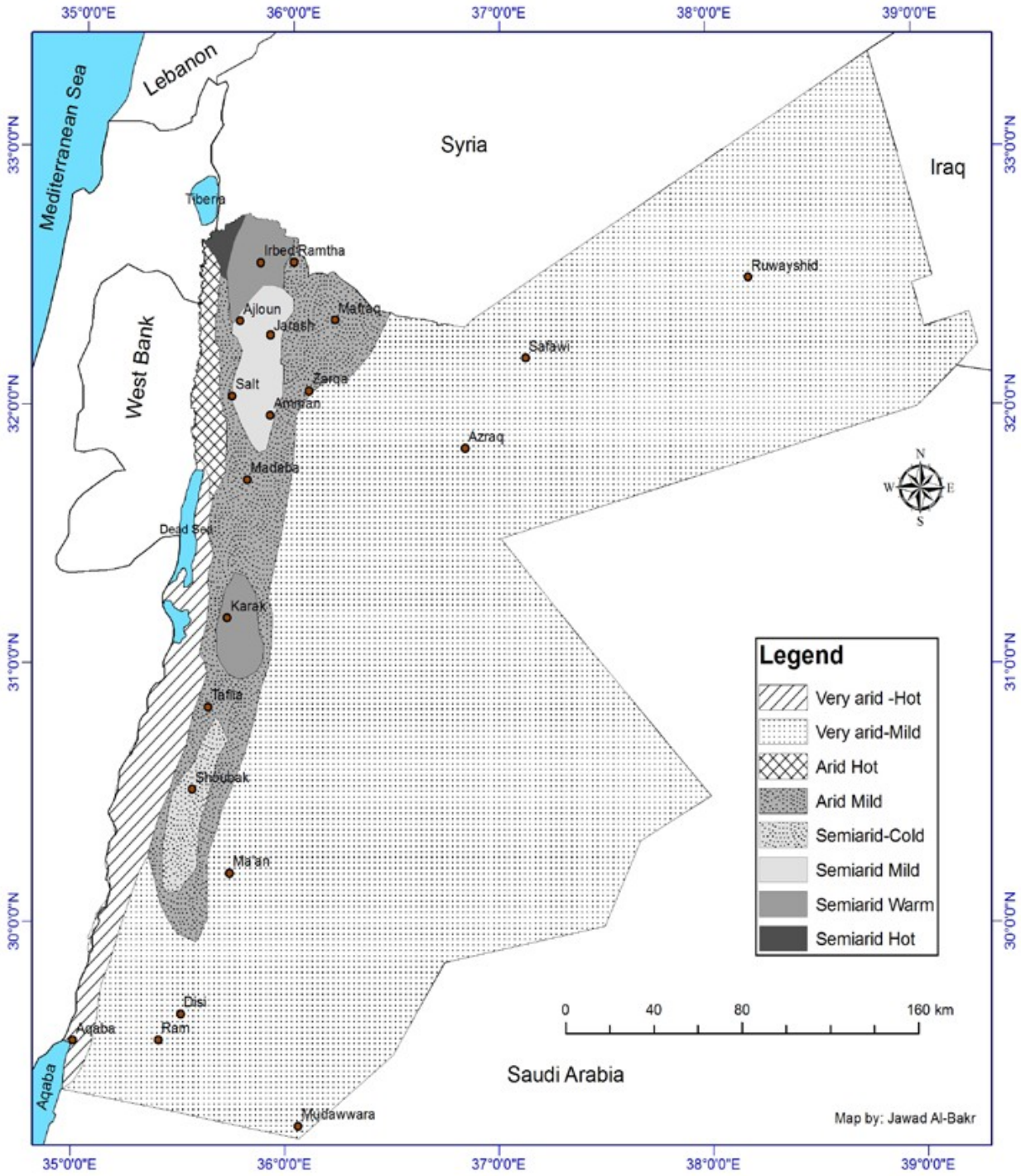


Figure 8 Aridity Index (Emberger Classification) in Jordan (Source: JNGC, 1984)

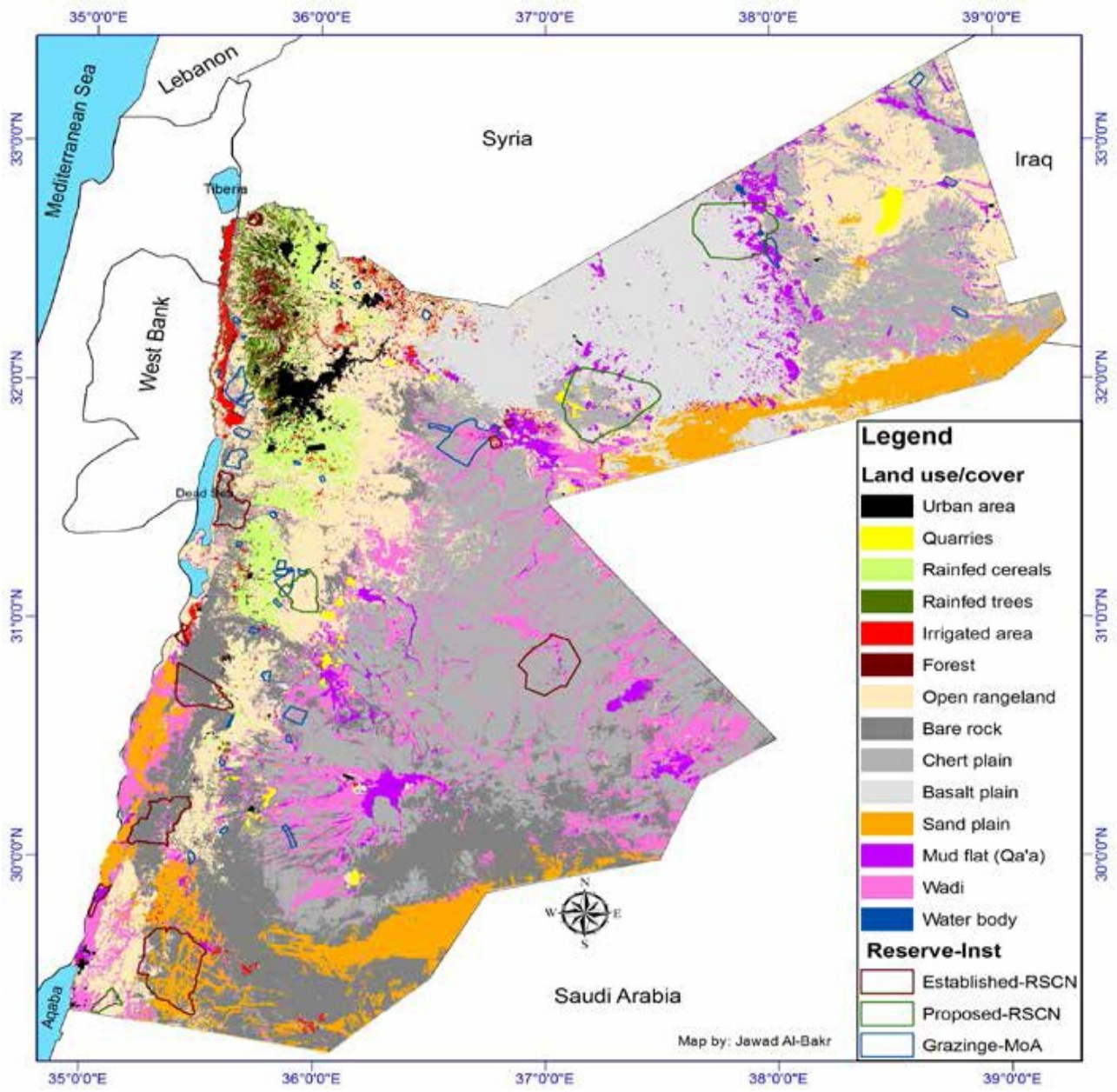


Figure 9 Existing land use/cover of Jordan. (Al-Bakri et al., 2010)

3.4.2. Agricultural Production

Agricultural products in Jordan consist of the following types:

- Field crops; wheat, barley, lentils, chick-peas, maize, clover trefoil, vetch-common vech, and others.
- Vegetables; tomatoes, squash, eggplants, cucumber, potatoes, cabbage, cauliflower, hot pepper, sweet pepper, broad beans, string beans, peas, Jews mallow, water melon, onion dry, and others.
- Bearing trees; citrus fruits, olives, grapes, fig, almonds, peach, apple, date palm, bananas and others.
- Livestock; sheep, goats, cattle, and poultry.

Table 3 The areas of cultivated land in Jordan according to the type of crops from 2009-2012 (in one thousand Dunums) (JIEW, 2015)

Area	2009	2010	2011	2012
Total cultivated land	2243.0	2593	2408	2437
Field crops cultivated land	1008.0	1286	1129	1155
Fruit trees cultivated land	823.0	827	850	859
Vegetables cultivated land	412.0	480	429	423
Irrigated land	948.2	1024.7	964.5	931
Non-irrigated land	1293.7	1568.8	1443.2	1506

The total cultivated land increased between 2009 and 2012, whereas the area of irrigated land slightly decreased. Most of the area is cultivated with field crops (47%) and fruit trees (35%), whereas vegetables occupy 17% of the cultivated area.

Table 4 Cultivated area and production of vegetables (summer and winter) per location in 2011 (GOPA, 2014)

Location	Total	
	Production (Ton)	Area (Dunum)
High Lands	1,052,164	244,956
Jordan Valley	876,139	183,672
Total	1,928,303	428,628

As for vegetables, the Highlands account for 57% of the cultivated area, yielding 55% of the total vegetable production, whereas the Jordan Valley accounts for 43% of the cultivated area, yielding 45% of the total vegetable production.

3.4.3. Irrigation Types

The types of irrigation used for agriculture are:

- Surface irrigation
- Sprinklers
- Drip irrigation

Table 5 Cultivated areas according to irrigation type in the different locations in 2011 (JIEW, 2015)

Location	Total area Dunum	Non-irrigated area	Irrigated area		
			Surface	Sprinklers	Others
High Land	1,107,723	1,040,458	23,801	29,613	13,852
Jordan Valley	21,317	1,033	11,756	652	7,877
Total	1,129,040	1,041,491	35,557	30,265	21,729

Most of the cultivated land with field crops is non-irrigated (rain-fed). Irrigated field crops are mostly cultivated in the High Lands.

Table 6 Cultivated area with winter vegetables by type of plantation and irrigation in Jordan, 2011 (Area in Donum) (JIEW, 2015)

Irrigated								Non-irrigated	Total Area
Location	Plastic houses		Plastic tunnels		Open field				
	Drip	Surface	Drip	Surface	Sprinkles	Drip	Surface		
High lands	5,221	0	242	0	18,188	56,623	4,797	12,073	97,144
Jordan Valley	30,805	2	3,433	10	0	108,420	1,433	42	144,144
Total	36,026	2	3,675	10	18,188	165,043	6,230	12,115	241,288

Winter vegetables are cultivated in plastic houses, plastic tunnels, and open field, with the latter being the dominant type of plantation. Of the 241,288 Dunums that are cultivated with winter vegetables, only 12,115 Dunums are non-irrigated.

Table 7 Cultivated area with summer vegetables by type of plantation and irrigation in Jordan, 2011 (Area in Donum) (GOPA, 2014)

Irrigated								Non-irrigated	Total Area
Location	Plastic houses		Plastic tunnels		Open field				
	Drip	Surface	Drip	Surface	Sprinkles	Drip	Surface		
Up lands	8,624	0	9,876	0	21,725	94,919	3,355	9,314	147,812
Ghore	1,282	53	6,451	17	0	30,373	1,354	3	39,529
Total	9,906	53	16,327	17	21,725	125,292	4,709	9,317	187,341

Summer vegetables are cultivated in plastic houses, plastic tunnels, and open field, with the latter being the dominant type of plantation. Types of irrigation used in open field are sprinkles, drip, and surface. The non-irrigated area is very small compared to the irrigated area.

3.4.4. Import and Export

Table 8 The contribution of agriculture to GDP at constant basic price in 2010-2012 (JIEW, 2015)

Contribution of Agricultural sector to GDP at constant basic prices			
year	2010	2011	2012
Agriculture, Hunting, Forestry, & Fishing	4.4	4.5	3.9

The contribution of agriculture to GDP was decreasing between 2010 and 2012. In 2012, the value of agricultural exports amounted to 7.8% compared to 17.4% in 2011. In 2012, the percentage of agricultural GPD has reached 3.9%.

3.4.5. Livestock sector

Livestock is a very important sector within the Agricultural sector in terms of the size of investment, employment, and meeting domestic consumers' demand of meat, milk, egg, and other products. The revenue generated from this sector is considered the main source of income for a considerable number of rural and nomad populations.

The livestock sector consists of the following main components (sub-sectors):

- Poultry
- Sheep and goats
- Cattle

Poultry Sector

The poultry sector is one of the most important productive sectors within Agriculture. The investment value of this sector is estimated at JOD 950 million distributed among the following:

- Broiler and layer Farms
- Parents and grandparents Farms
- Hatcheries
- Slaughter houses
- Feed factories and veterinary drugs factories.

The poultry sector assumes an important role in:

- Food and food security.
- Economic integration with supporting sectors such as the veterinary services, fodders, etc.
- The added value achieved on the value chain in the various production and marketing stages starting with preparation of production input and ends with selling.
- Employment opportunities for Jordanians.

Sheep, Goats, and Cattle Sector

The sheep and goats sector contributes about 32,2% to the national agricultural production, and the number of cattle farms in 2012 amounted to 402 licensed reaching 70,385 heads, and 220 unlicensed farms. Number of cows raised in both licensed and unlicensed farms was 53,417 heads in 2012.

3.4.6. Challenges (JIEW, 2015)

Challenges related to production:

- Small production units: vast majority of farms are small which affect their ability to compete in the local and international markets;
- Weak productivity and weak utilization of technology in production;
- High labor cost;
- Instability and fluctuation of labor;

- The use of organic fertilizers which incubate pests and insect's generations that transmit diseases to crops;
- High risk of plant diseases;
- High ratio of production lost and damaged.

Challenges related to government policies:

- Weak partnership between public and private sectors;
- Instability of import and export policies;
- Policies adopted by different government agencies are not harmonized, and in many cases lack stability.

Challenges related to marketing and trade:

Pricing:

- Fluctuation of prices and inadequate conditions for price formation (Biased and not transparent);
- Insufficient control over prices;

Marketing:

- The dominance of oligopoly among the market middlemen which constrains the mechanism of supply and demand;
- Weak marketing information system;
- Insufficient control over quality;

Obstacles to export:

- Unstable export policy;
- The inactivation of the national production protection law according to WTO regulations;
- Weak implementation of the technical specifications on imports and exports;
- Concentration of exports in the traditional markets;
- Contractual and export agriculture is still new and underdeveloped;
- Fierce competition in the export markets resulting from increased market openness;
- Unstable road transportation and high road transportation cost;
- Air shipping of agricultural products is done on passenger airplanes;
- Logistical complications in airports and borders on exports.

4. Collected Data on the Case Study Area

4.1. The Pilot Area

The pilot area is the Greater Karak Municipality, in Al-Karak governorate, which is located 140 km to the south of the capital of Jordan. The boundaries of the governorate are defined by the Dead sea to the West, Wadi El Mujib to the North, Wadi El Hasa to the south and the boundary of Ma'an governorate to the East. The Governorate covers an area of 3,500 Km2, which covers 4% of Jordan's total area. **Figure** shows the location of Al-Karak Governorate in Jordan.

Figure 10 Al-Karak Governorate location

The region of Al-Karak has a Mediterranean climate, which is cold, wet in winter and hot, dry in summer. The average temperature ranges between 25-37 °C during summer and 3-15 °C in winter. Al-Karak municipality is located in Wadi Al-Karak basin, which has a total area of 190.7km2. The basin represents a transitional area between humid in the west and semi-arid in the east.

The Greater Karak municipality is considered the focal point for development in all other areas. It plays a main role in city zoning, infrastructure, waste collection and hygiene control of houses and public facilities.

4.2. Demographic Information

4.2.1. Al-Karak Governorate

Population

The total population of the governorate was 316,629 in 2015, with a population density of 90.6 inhabitants/squared km. 35% of the population is less than 15 years old, 61.5% between 15-64 years, and 3.6% more than 65 years. Population in the Governorate consists of 47.8% females and 52.2% males. There are 63,490 families consisting of on average 5 family members.

Education

The number of students in the governorate exceeds 55,000 students, distributed over 250 schools in the seven administrative districts. There is one university in the governorate, Mutaah University. It has about 15,000 students studying in 10 different fields offered by the university, with almost equal number of males and females. The governorate also has 10 specialized educational and training centers.

As a result, the level of education is relatively high in Al-Karak area. The presence of the university offering all colleges (science, agriculture, engineering, medicine, etc..) has contributed significantly to this. Consequently, an increasing number of inhabitants are shifting away from farming activities to other professional occupations.

Health

There are 6 hospitals, three of them being governmental hospitals with almost 500 beds in total. The governorate also includes 70 health centers, 180 health clinics and 40 maternity centers. The number of human resources working in the health sector reaches 1000 workers including specialists, technicians and support staff.

Work indicators and income

The average annual family income is estimated to be 5,633JODs per person. 41% of the total income is spent on food, 23% on residence and other accompanying services such as water and electricity, and 13% on transportation and communication. The percentage of poverty (people with income below the poverty line or income) is about 13.4. The employment in the governorate is about 24%, leaving about 21% males and 36% females unemployed (DOS, 2016). The percentage of labourers reaches 38%.

4.2.2 Greater Al-Karak Municipality

The Greater Al-Karak Municipality has a population of 101,377 and population density of 132.4 inhabitants per square kilometer. The ratio between males and females is almost 1:1. The number of families is estimated to be 21,074 with an average family size of 5 persons. The percentage of people aged less than 15 years old is 32.8, 63.3% aged between 15-64 years and 3.6% aged greater than 65 years.

Al-Karak municipality has a strategic position historically and geographically as its considered the southern forefront boundary.

4.2.2. Governmental and Organizational structure

The Governmental and administrative structure of Jordan has a central administration and two other national systems. The first is a decentralized system with institutions acting on behalf of the government, at the levels of governorate, districts, sub-districts and chief town. The second is a municipal system which is responsible for the cities in terms of inhabitants, localities and others, and rural councils responsible for villages of the rural areas. Al-Karak governorate is divided into seven administrative districts as follows **Figure 11** shows the surface area distribution within the governorate of Al-Karak among the seven administrative districts.

- Karak Qasabah
- Mazar Janoubi
- Qaser
- Aghwar Janoubye
- Ay
- Faqou'
- Qatraneh

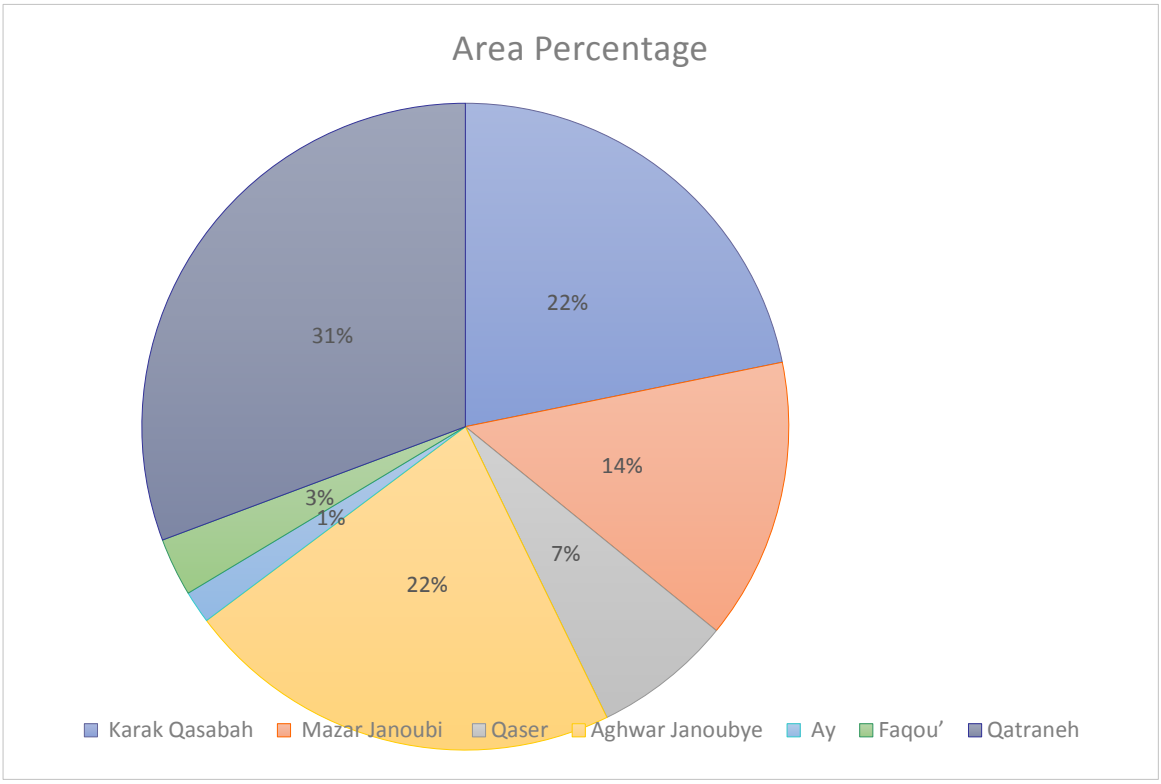


Figure 11 Percentage of areas of the seven administrative districts of Al-Karak Governorate

The Greater Karak Municipality represents 22% of the total area of the governorate, with an area of 765Km2.

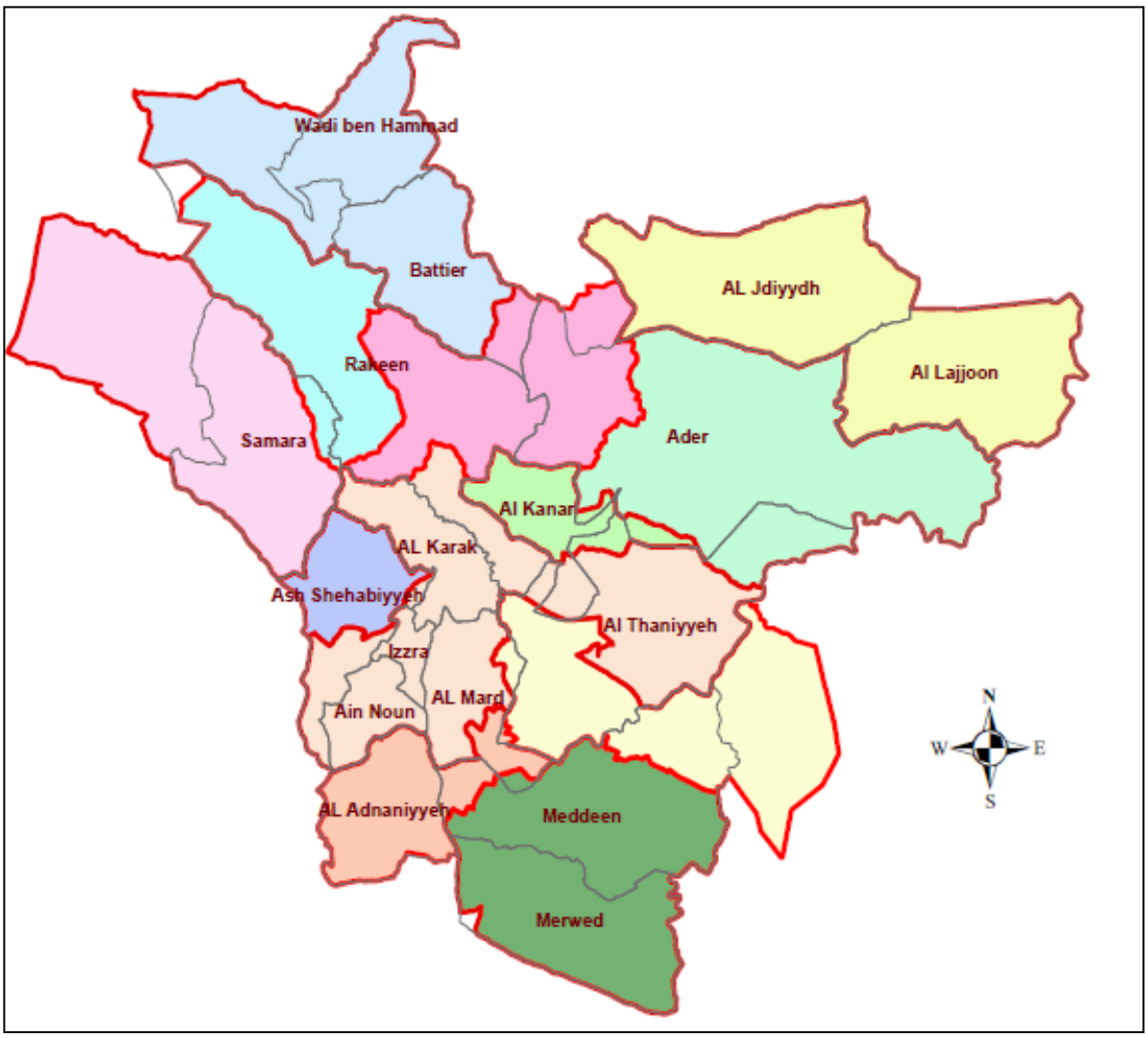


Figure 12 Greater Karak Municipality Regions

4.3. Water specific information

4.3.1. Water governance in Al Karak Governerate

There exists a regional water administrative office of WAJ in Al-Karak Governorate. The WAJ office consists of 6 directorates related to services, namely: Water, Technical Affairs, Wastewater, Unaccounted for Water, Customers, and Administrative Affairs. Among these directorates there are 15 divisions.

There are also four geographic directorates within the office of WAJ in Al-Karak Governorate (**see figure 13).** These directorates are Al-Qasabeh, Al-Mazar Janoubye, Al-Aghwar Janoubye and Al-Qaser.

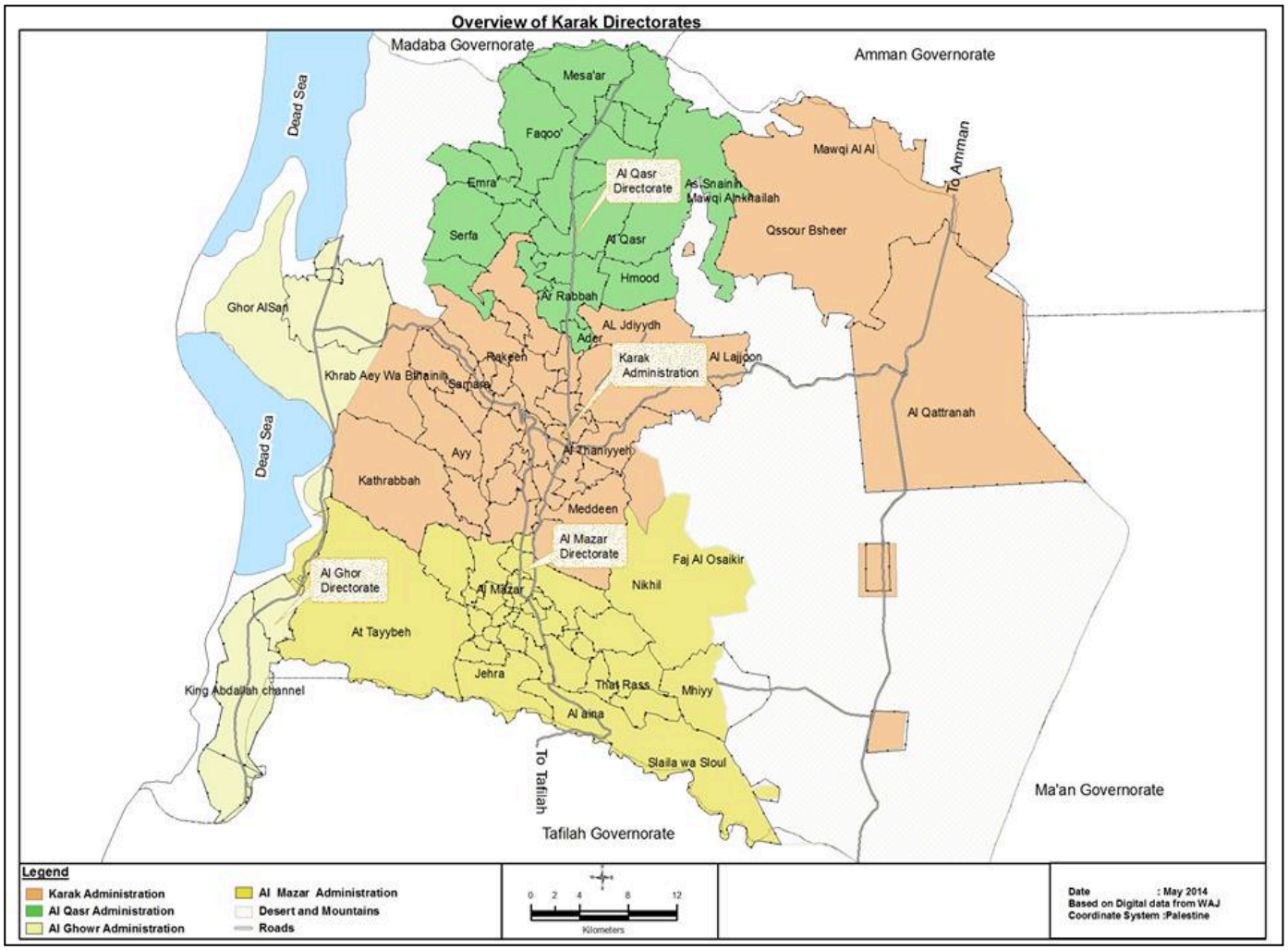


Figure 13 Geographic directorates of Al-Karak WAJ office (directorate)

Supply and Demand

The governorate of Al-Karak supplies a total of 26 MCM of water per year, yet this is not meeting demand. Al Karak municipality has grown exponentially in population but the infrastructure has deteriorated and is not capable of dealing with the population increase and the increasing demands for water. The consequences of this water deficit for agriculture are discussed in section 4.4 below.

4.3.2. Available Water Resources

The water sources supplying Karak Governorate include surface water (including dams and natural springs) and groundwater wells (see distributions in **Figure 14** below). The main surface water source is Al-Mowjeb Dam with a discharge rate of 200 m3/hr to 250 m3/hr. Natural springs produce 89 m3/hr (Ain-Sarah and Al Shehabyeh natural spring). Ain-Sara and Ash-Shehabye springs are one of the major sources of water supply in Al-Karak district, which also lie within the area of the municipality. Areas supplied include Ash-Shehabyeh village, Badhan and Baradah.

The Ain Sara spring was visited during the field visit (see photos below) as it is considered the main source of drinking water supply, providing water to Wadi Al-Karak and other parts of Al-karak municipality. Other springs include Ain Franja which the government is currently using for drinking water as well as agriculture. Following observations were made during the visit:

- The water runs through a pipe into the treatment plant, where the water is being disinfected and stored in a tank (150m3). The water is then pumped through a booster into houses. The pumping happens into three areas, two days for each with pumping rate of 120m3/hr.
- As part of a project implemented by IUCN, a retainer was constructed where the water is directed through pipes running under ground. This retainer is holding lots of trash and is meandering the natural flow of the spring.
- Apart from drinking water, other uses of the spring include agriculture. Farmers are dependent on the flow of the water spring. The spring runs along farms through an open channel. Farmers conduct an internal water management: everyone is allowed to side stream the channel for two hours, after which the farmer has to close for the next farmer's turn. As a consequence, too much water is being discharged into each farm randomly and without applying storage, which causes losses of large water quantities. Other farmers however pump water from the stream into collection ponds, so they have water throughout the week. This was also done as part of a recent project through building storage tanks of a size about 40 m3 for the farmers, in order to store water for their plants.

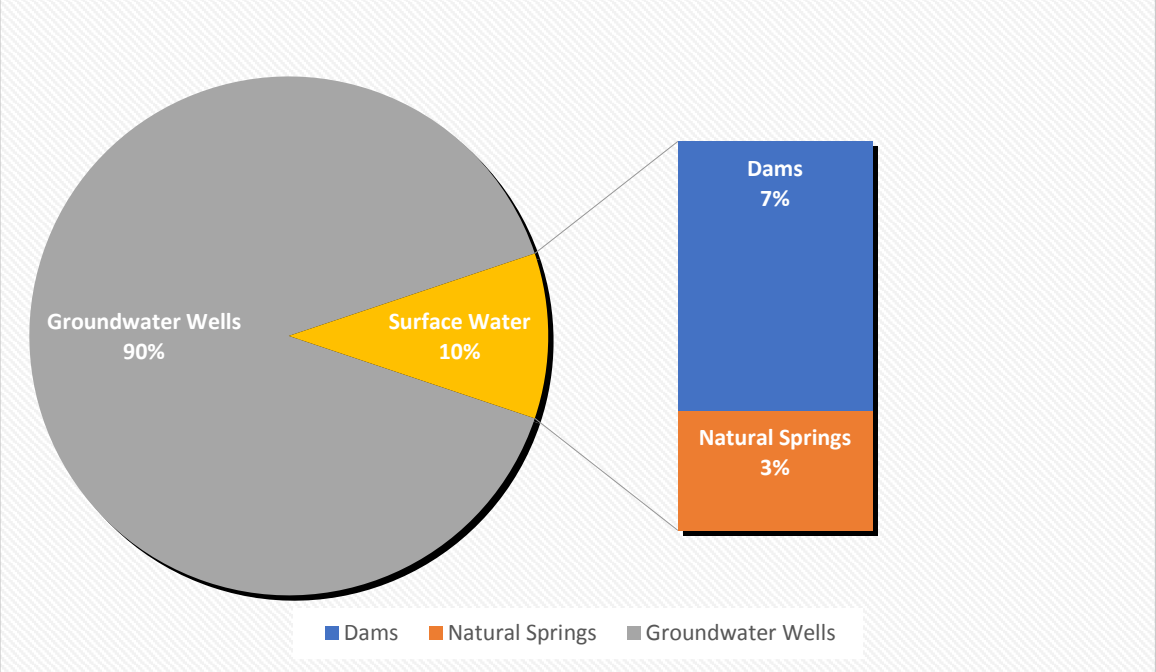


Figure 14 Water resources in Al-Karak Governorate (MWI Annual report, 2016)

Groundwater wells have a total potential capacity of 4,055m3/hr and with current actual capacity of 2,518m3/hr. shows the capacities of the major wells in Al Karak governorate.

Table 9 Groundwater wells in Al-Karak Governorate (MWI annual report, 2016)

Well Name	Design capacity m3/hr	Current M^3/hr
Muhy Wells	575	260
Sultani Wells	560	550
Qatraneh Wells	350	220
Ghwair Wells	120	90
Zahoum Wells	50	38
Al-Safi Wells	250	225
Al-Mazra'a Wells	150	135
Fifa Wells	80	80
Ghwaibeh Wells	25	25
Jada'a Wells	145	95
Al-lajoon	1750	800
Total	4,055	2,518

4.3.3. Water Quality

The quality of the water is monitored by the Ministry of Health and is considered reasonably good. The TDS does not exceed 800 ppm with pH of 7.5-8. The community served is around 112,000 inhabitants. Al-Lajoon water treatment plant uses sand filters and supplies Al-Ghwair pumping station of about 500m3/hr, in which water is distributed to the Karak municipality regions. Another water treatment plant is the Ain-Sara plant. It treats nitrate and has a capacity of about 120m3/hr.

According to the consulted stakeholders, the Ain Sara WWTP is improperly functioning because it is currently operating at an inflow of 1200 m3 per day whereas the design capacity is 800 m3 per day. This has led to a major pollution problem in the area. The partially treated effluent is discharged into the wadi, causing contamination along its path. On top of this, Ain Sara is a main source for drinking as well as irrigation water for many of the surrounding farms. The problems were evident during the site visit. The lowering water table caused a reduction in the water flow of the spring reducing the water quantities available for use. In addition, solid waste accumulation along the course of the spring is also causing contamination to the water.

4.3.4. Water Supply technical facilities

Pumping stations

There are several pumping stations for groundwater wells (27) and harvesting tanks (23) within the Karak governorate from where water is distributed to different areas. The pumping stations and tanks have a total capacity of 36,720m3.

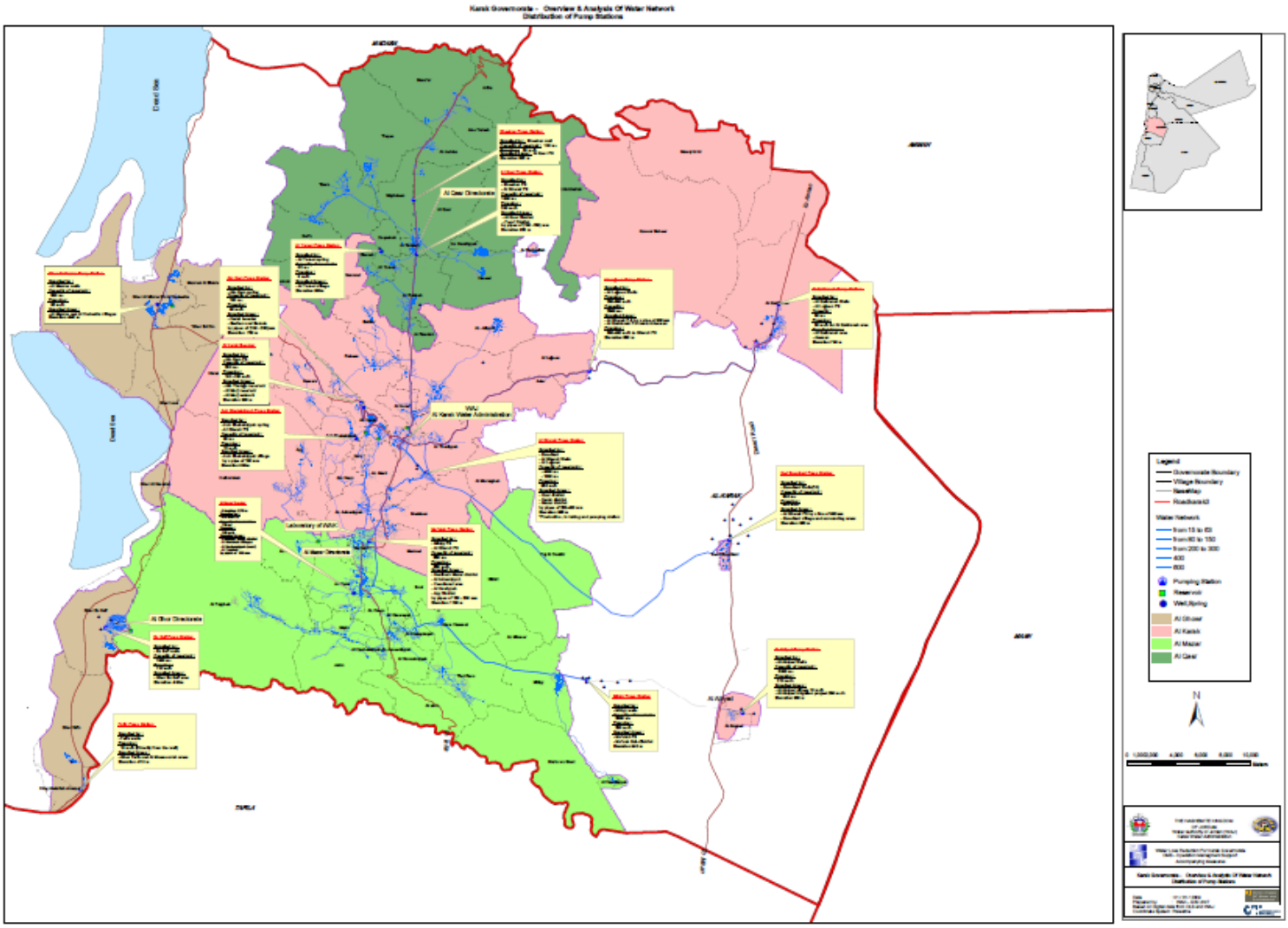


Figure 15 Water Distribution Network and Pumping stations in Karak Governorate (MWI report, 2016)

The pumping stations are spread within the distribution network in the 4 WAJ Directorates (see **Figure 15)**

There are three pumping stations (PS) in Al-Qaser Directorate:

- Sheehan PS supplied from Sheehan well with reservoir capacity of 100m3, and supplies Al-Qaser PS at an elevation of 885m and pumping at 50m3/hr;
- Al-Qasar PS supplied from Sheehan and Ghwair PS with reservoir capacity of 1000m3 and supplies Al Qaser and Faqo' districts at elevation of 920m;
- Yaroot PS supplied from Al-Yaroot spring with reservoir capacity of 60m3 and supplies Al-Yaroot village.

Another three pumping stations are located in Al-Aghwar Janoubye Directorate:

- Ghour Al-Mazraa PS supplied by Al-Mazraa wells with reservoir capacity 500m3 supplying the area of Al Mazraa and Al-Hadethah village at elevation -345 m;

- Es Safi PS supplied from Es Safi wells with reservoir capacity of 1000m3 , supplying the area of Ghor Es Safi at elevation of -340m and pumping at 110m3/hr;
- Falfa PS supplied from Falfa wells for the arera of Al-maamouramah and Ghor Falfa.

Al-Mazar Directorate has two pumping stations:

- Mo'utah PS supplied from Mhiyy and Ghwair PS with reservoir capacity of 550m3 and supplying the areas of Aladnanyeh, AlHawiyyah, Ayy district, southern Mazar district and vocational areas;
- Al-Mazar booster pumps supplied by Mo'utah PS provides water for Al-Krisheh villages, Al-Hashmiyeh, Al-Tayybeh and southern Mazar district.

Al-Karak directorate which includes the Greater Karak Municipality, depends mainly on groundwater resources and supplies 89% of the total water produced every year. The age of the aquifer is about 25 Million years. There are seven pumping stations, four of which are within the municipality boundaries (Ain Sara, Shehabuyyeh, Al-Ghwair and Al-Lajoon):

- Ain Sara PS, supplied from Ain Sara spring with reservoir capacity of 100m3 and pumping at 80 m3/hr, where Karak booster, Badhan and Barada are supplied;
- Ash Shehabiyyeh PS supplied by Al-Shehabiyyeh springs and Ghwair PS that provides Al-Shehabiyyeh villages at an elevation of 860m and pumping at 12 m3/hr;
- Al Ghwair station supplied by Sultani, Al Lajjon and Ghwair wells with capacities of 4000 and 1000 m3 supplying al-Qaser district, Al-Karak district and Mazar district;
- Al-Lajoon PS supplied by lajoon wells with capacity of 2000 m3 and pumping at 300 m3/hr;
- Al-Qattraneh PS supplied by Al-Qattraneh wells and Al-Lajoon PS, with capacity of 50 m3, which supplies Al-Qatraneh and Amman;
- Essultani PS supplied by Essultani wells with reservoir capacity of 300 m3 and pumping at 600 m3/hr, supplying Al-Ghwair PS and Essultani villages;
- Al-Karak booster supplied by Ain Sara PS with reservoir capacity of 200 m3 and pumping at 100-150 m3/hr to supply Al-Marj reservoir, Al-Marj network and Al-Thalajja reservoir.

Distribution Network

Water supply network is used for distribution of water from different sources all over the area. Current water network serves 100% of its capacity and will not meet the increasing demands in the future with the anticipated per capita share of 174 l/day. It serves 424,666 subscribers in 83 cities with a service coverage of 99%. The total length of the distribution system is 1941.3Km with diameter range from 15 to 600mm (see **figure 16**).

There is not only a competition between the domestic and agricultural sectors but also livestock breeders use drinking water for their livestock, thus reducing the amount of water delivered to farmers. In addition, network pipelines are made of iron, hence high frequency of breakage due to rust and pipe breaks, which in return increase the losses with a percentage of around 61% (MWI annual reports).

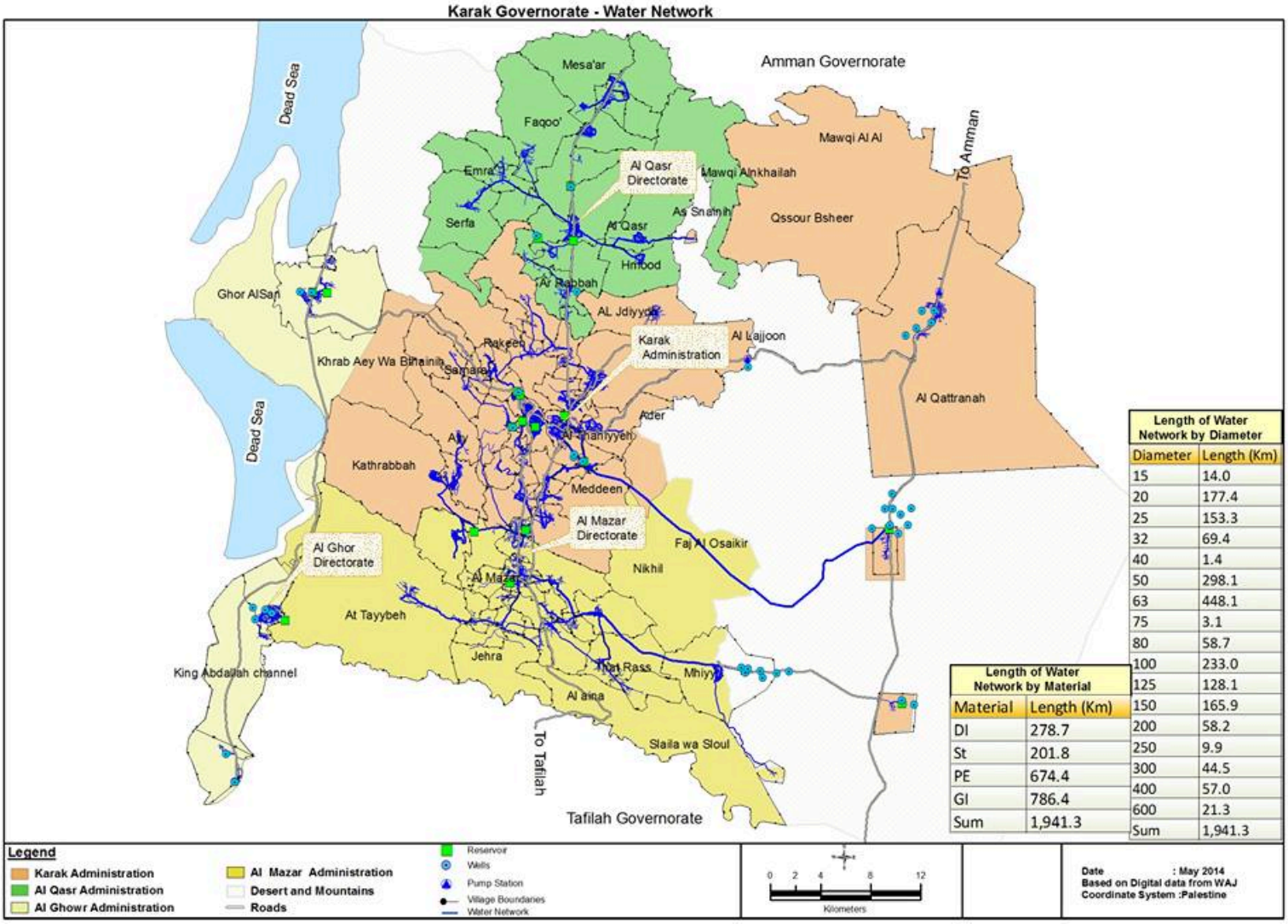


Figure 16 Water distribution network in Al-Karak (MWI annual report, 2016)

4.3.5. Wastewater treatment

Al-Karak Wastewater Treatment Plant (WWTP)

The WWTP is located in Wadi Al-Karak 2.5KM north west of Al-Karak city, and lies within the municipality boundaries. It is used for the collection and treatment of wastewater received from households. Treatment units include mechanical and biological treatment for a discharge within standard limits to natural systems and for agricultural reuse. The treatment plant serves three areas including: Al-Karak, Al-Marj and Al-Thalajja. Design capacity of the plant is 800m3/hr but with current influent of 1250 to 1736 m3/hr, the treatment plant is working over its capacity and hence not meeting effluent discharge national standards requirements.

The intention is to reuse the treated water for irrigation. An artificial forest was planted using the treated water, and farmers are using some of the treated water for their lands (see photos below). Despite the bad water quality, the treated effluents are still being pumped through a pipe through several farms and into to the forest and stored in a tank for usage. The quality of the effluent is adversely affecting the trees irrigated with this water.

Al-Lajoon WWTP

It is located 25Km away east from Al-Karak city, and serves areas that are not connected to the sewage system receiving water from septic tanks. The WWTP was renovated in 2013, in order to enhance the quality of effluents discharged to be reused in accordance with the Jordanian standards 893/2006 for restricted irrigation.

Merwed WWTP

It is situated within the municipality boundaries and has a capacity design of 7500m3/hr while it receives 1200 m3/hr. It serves the areas of Merwed, Madeen and Aldananyeh.

Mo'tah and Al-Mazar WWTP

There are 5 pumping stations that pump the wastewater to the WWTP. It has a design capacity of 7060 m3/day and serves the areas of Mo'tah, Mazar, Merwed, Adnanyeh, and Madeen. The treated effluents are used for irrigation in line with Jordanian standards 893/2006.

4.4. Agriculture

In Karak, there are only four major crops (barley, wheat, olives and tomatoes) occupying 85% of the cultivated area (DOS, 2015). Wheat, barley and olives are mostly rainfed crops and their yields vary considerably from year to year due to rainfall variation. Vegetables are mostly irrigated from deep wells with the use of drip irrigation networks. Whereas livestock production is important at the national level, it has much less relevance in Karak. Livestock animals are mostly sheep and cows that are usually raised in specialized farms with little integration with crop production (Al-Jaloudy, 2006).

4.4.1. Cultivated crops

The evolution of yields in Karak show different patterns by crop but they resemble the national trends for the region's important crops. While those of wheat and barley are declining, those of vegetables and olive still show a climbing trend despite yearly fluctuations (**Figure 17**). Fluctuations from year to year might be attributed to rainfall variations.

Karak's olive yields fluctuates more than national yields. The positive trend for tomatoes is explained by the use of irrigation that enables the cultivation of improved varieties. Also for olive trees, supplemental irrigation is sometimes used by olive farmers in Karak when available from private tube wells, or through rainwater harvesting techniques (Oweis and Hachum, 2009).

The main factors affecting agricultural production in the area include:

- Climatic factors, mainly decrease in precipitation;
- Poor quality of surface water resources;
- Water scarcity: despite efforts of the farmers to manage the distribution of water among the farmers, the shortage of water is becoming the main obstacle hindering the agricultural production in the area;
- Lack of extension services;
- The high cost of unskilled labor and materials for farming and agricultural production.

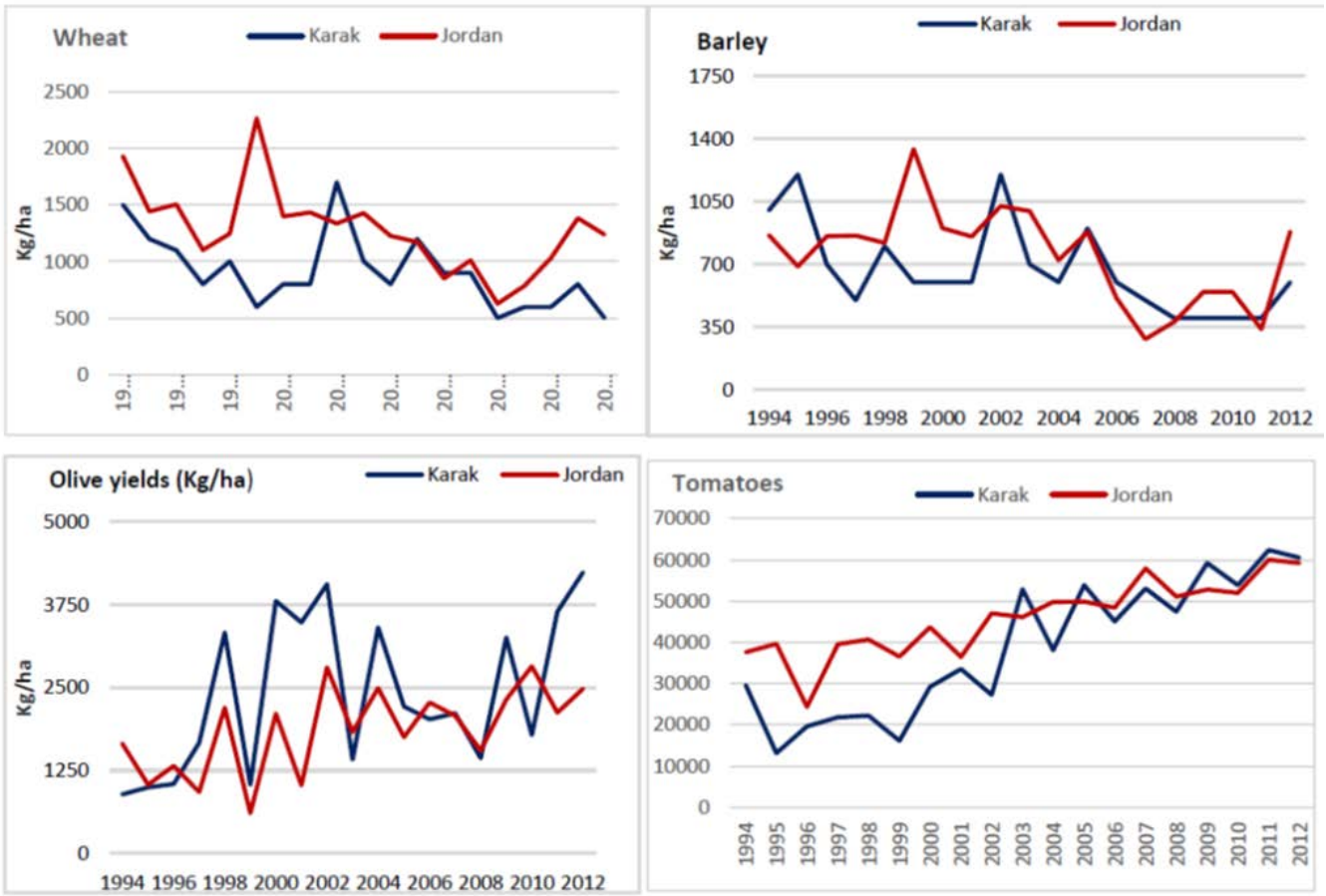


Figure 17 Evolution of yields for Karak's most important crops compared to their national counterparts (Source: DOS, 2015)

4.4.2 Irrigation and Water Use Efficiency

Based on survey analysis (see more details in section 4.4.3), the chosen irrigation technique is a function of (1) water availability, (2) proximity to water sources, and (3) the cost associated with adopting a more efficient irrigation technique at the farm level. Most of the farmers are relying on available surface water resources for irrigation, and do not implement water harvesting within their farms. This has led to spillage of the already scarce water. This dependence on river and source flow has made them more vulnerable to climate change and precipitation variations. However, all farmers seem to accept the idea of a transition to a more efficient water use technique as they are becoming more aware of the water saving necessity.

4.4.3 Agricultural Survey Results

On July 17th 2017, a survey was conducted among 10 different stakeholders related to water, agriculture or environment at Al-Karak. The purpose of the survey was to discover information related to the current agricultural situation in the area.

The survey was conducted by means of a questionnaire (see Appendix B). The first part of the questionnaire dealt with the current agricultural situation in terms of types, irrigation techniques, water sources. The second section aimed to assess the perception of farmers and related entities to the environmental impact of current practices and their willingness to adopt new behaviors. The third section aimed to gauge the stakeholders' perception of the severity of selected issues.

Respondents' profile based on their sex, age, educational level, professional occupation:

- Gender: all respondents were male;
- Age: half of the respondents were older than 55 years; the other 50% were younger (25% between 36-45, 13 % between 46-55, and 12% between 26-35;
- Education: 75% had finished high school, whereas 13% had reached higher education and 12% had a diploma;
- Professional occupation: 50% of the respondent were farmers.

Selected results include:

1. Agricultural situation

    - Cultivated crops include: olives, grapes, fig, citron, vegetables and cereal crops.
    - Most of the respondents cultivated cash crops as a main income generation source. Some of the farmers cultivated subsistence crops for their use.
    - 99% of the farmers uses fertilizers to enhance the growth of their plants.
    - Water is either provided from rainfall or irrigation.
    - As for irrigation techniques: 50% of the respondents used drip irrigation where others were dependent the traditional technique of surface irrigation methods.
    - Sources of water for irrigation include grey water, springs (mainly Ain Sara) as well as rain.
    - Livestock includes sheep, goats, cows, and chicken.

2. Behavior related to environmental impact

    - Irrigation techniques: 88% of the respondents approved the use of advanced more water-efficient techniques for irrigation if available to reduce water losses, whereas the others believed that the current systems are efficient and reduce labor use, hence less expenses on the farmers.
    - Farmers mentioned various factors that they believed to affect their production rates, including: drastic changes in weather, shortage in water quantities, fertilizers inflated prices and low income.
    - They also mentioned problems affecting the environment, including: pollution, desertification, climate change, drought and water scarcity. They stated that these problems are also directly affecting the production, hence economic growth in the area.
    - They also suggested some possible interventions to overcome these problems, including:
        - Setting up a strategic development plan,
        - Enhancing the quality of re-used water by upgrading wastewater treatment plant,
        - Awareness campaigns for the community and governmental institutions, as they can envisage a better community and agriculture in the area.

Stakeholders' perception of the severity of selected issues:

- high severity is assigned at least once to most of the issues, except for biodiversity;
- energy consumption was most frequently perceived as highly severe;
- water sanitation and water quality was perceived as either highly or medium severe;
- drought and water availability was mainly perceived as being of medium severity.

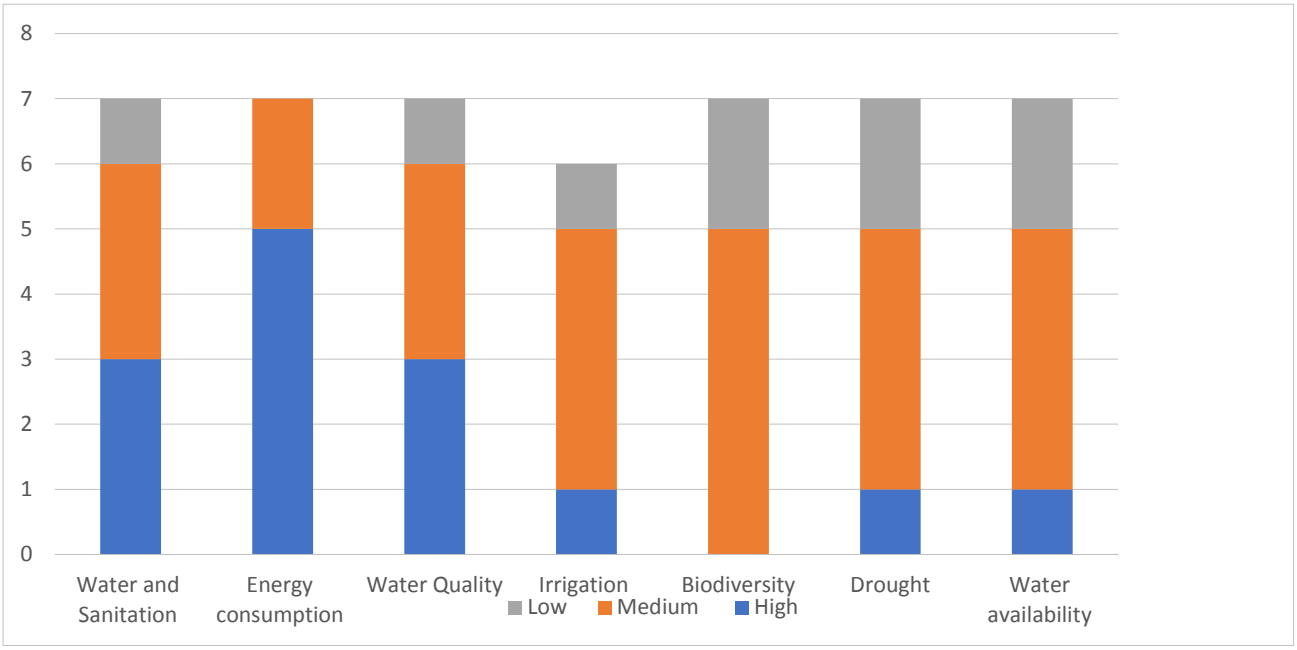


Figure 18 Perception of severity of environmental problems in the area

5. Analysis and Discussion

Despite severe limitations of data both at national and local levels that were available for this report, and the limited timeframe for this study, some observations can be made that will be helpful in determining practical opportunities for synergies between different sectors and interest groups to improve human well-being while not jeopardizing sustainable development.

First, potential opportunities for the NEXUS approach need to take the context of Jordan into account. Jordan's division in three main physiographic regions very much determines the concentration of population and agricultural activities: the Highlands east of the Jordan River hosting most of Jordan's population, the Jordan Valley with the northern part being the most fertile region, and the desert which occupies two thirds of the country's territory. Climatic conditions vary over the country with differing impact on the amount and distribution of precipitation and on the potential of evaporation, which is generally relatively high. The effects of climate change are also becoming obvious with anticipated decrease in annual rainfall in many regions especially those in the rather wet north-east, further increase in temperature, and an increased occurrence of consecutive dry years. The country is generally poor in natural resources, not in the least the natural supply of water, which makes it one of the most water-scarce countries in the world. The pressure on these resources has increased due to several influxes of refugees over the last decades, with the massive entry of Syrian refugees being the most recent, resulting in 12% of the population officially censused as refugees in 2016.

This challenging environment affects several sectors such as energy, education, infrastructure, and environment. Due to a lack of domestic energy sources, the energy import bill is very high, which was recently compounded by the continued disruptions of oil and gas flows from Iraq and Egypt. This affects the national economy, that is also facing effects of chronic high rates of poverty, unemployment and underemployment, budget and current account deficits, and government debt. The education sector, despite high education enrolment rates and a relatively well-educated workforce, is ineffective in providing the appropriate human capital for the various economic sectors in Jordan. Many of the challenges are being amplified by a weak legal and institutional framework.

Most of these aspects also indirectly or directly impact the water and agriculture situation. As for the water sector, the biggest concern is the huge water deficit, which has considerable impacts on Jordan's economy and public finances, including pressure on available foreign currency reserves due to the need to import water, exaggerated water subsidies to compensate for high supply costs, high energy-costs of pumping groundwater resources above ground especially to the highlands. Another huge concern is the water quality with increased pollution levels due to insufficient capacity of wastewater treatment plants, improper treatment of industrial effluents, over-abstraction of groundwater, and unregulated fertilizer and pesticide application.

One of the main effects of Jordan's deficient water supply is that it is limiting the share of land that can be utilized for agricultural purposes, with almost 40% of the cultivated area being irrigated. The agriculture sector, despite of its moderate contribution to GDP (about 3%), is still considered the base for integrated rural development, a source of income and employment for rural and Badiya (semi- desert) people, and a generator of activities in the other economic sub-sectors. Agriculture also plays a central role in food security and trade balance improvement.

The challenges affecting the sector are many-fold and they relate to productivity, government policies, and marketing and trade. Most of the farms are small with low productivity levels, relatively high labor cost, high rates of lost/damaged crops. All this, combined with other issues such as weak and unstable export/import policies and logistical complications, result in limited ability to compete in the local and international markets.

These issues trickle down to the local level, and the case study in this report is a representative example. The Greater Municipality of Al-Karak, one of the seven administrative districts in the Al-Karak governorate, is situated in a transitional zone between the Jordan Valley, the Highlands and the desert. The municipality is considered the focal point for development in the surrounding areas, playing an important role in city zoning, infrastructure, waste collection and hygiene control of houses and public facilities. Despite this, the infrastructure of Al-Karak municipality has deteriorated and is not capable to deal with the exponentially growing population and the increasing demands for water. At the governorate level, the education level is relatively high and an increasing number of inhabitants are shifting away from farming activities to other professional occupations.

Agricultural production in the study area is composed of four major crops who are either rain fed (barley, wheat, olives) or irrigated from deep wells (vegetables). Whereas livestock production is important at the national level, it has much less relevance in Karak. Most of the consulted farmers cultivated cash crops as a main income generation source, with some of the farmers also cultivating subsistence crops. The selected irrigation technique is a function of (1) water availability, (2) proximity to water sources, and (3) the cost. The farmers are mainly relying on available surface water resources for irrigation, and do not implement water harvesting, leading to spillage of the already scarce water. The majority of the consulted farmers would approve the use of advanced more water-efficient techniques for irrigation if available to reduce water losses, whereas others still believe that the current systems are efficient while also reducing labor use and other expenses.

Water scarcity and poor management of water are considered the main problems in the study area, as also pointed out during group discussions during the workshop and interviews with stakeholders. The field visit to the poorly maintained infrastructure at the Ain Sara spring, which is considered the main source of drinking water supply, demonstrates these issues. The adjacent WWTP is working over-capacity, resulting in a major pollution problem in the area caused by the discharge of partially treated effluents into the wadi.

Other issues that were identified as affecting the agriculture sector in the case study area, include: climatic factors, mainly decrease in precipitation; pollution; desertification; lack of extension services; and the high cost of unskilled labor and materials for agricultural production.

Possible interventions were suggested to overcome these problems, including: setting up a strategic development plan; enhancing the quality of re-used water by upgrading the wastewater treatment plant; and conducting awareness campaigns for the community and governmental institutions.

6. Conclusion and Recommendations

6.1. Recommendations and Conclusions

As indicated above, the water sector is facing the most urgent challenges in the study area, the most serious concerns being: severe shortages in the available surface waters, ground water over-exploitation, and poor management of irrigation waters. Therefore, the recommendations as an outcome of this study, are mainly related to solving these to enhance agricultural production

At the institutional level, there is certainly room for supporting the farmers in the area and all those affected by the deteriorating water supplies and decreasing water quality. Central government should take efforts to upgrade the capacity and treatment efficiency of the Al-Karak WWTP to improve the discharge quality of the treated effluents so they can be re-used in many areas (e.g., planting of forage crops, ornamental trees, and restricted irrigation). This could all be done within the framework of the water policies, investments programs, and action plan that are part of the MWI National Water Strategy 2016-2025.

At the municipal level, more efficient management of water resources should be implemented in many ways. As part of this, specific techniques to maximize water resources should be implemented such as water harvesting at the farm level, installing and maintaining recharge structures such as dams and hill lakes. This way, supply from the groundwater reserves could be avoided, leading to better protecting soil fertility due to lower salinity levels of the irrigation water. Also, the water demand of all users should be controlled. This could be done by strengthening the management capacities and the decision-making process of the existing Water Users Association towards more efficient water distribution amongst the farmers. At the Ain Sara spring, a conservation protocol should be implemented for the retainer, to keep it free from trash and solid waste, with the aim to improve water quality and lower treatment cost at the WWTP. The farmers would benefit from capacity building programs that focus on adjusting to changes in weather patterns, water shortage, droughts, types and costs of fertilizers and other expenses. Those farmers cultivating cash crops should be supported with better extension services. This could help them implement initiatives at the farm's level, e.g.:

- Adopting new solar PV (or any other renewable energy) systems for treatment of saline groundwater in to increase water supply;
- Implementing better irrigation techniques (trickle and sprinkler) to minimize losses;
- Implementing a revolving fund program for water harvesting, water storage, and efficient irrigation.

The existing Farmers Association and Union could serve as the management body for such programs. Other identified partners include: Al-Karak Municipality, the WAJ directorate in Karak, Jordan Cooperative Corporation (JCC), and the Al-Karak Women Union.

In conclusion, the bottom-up participatory method adopted by the MINARET project has helped identify the main local, national and regional stakeholders involved in energy, water, and food security, the three axes of the NEXUS approach. This has led to a better understanding of the administrative, governmental and local frameworks of energy-water-agriculture sectors as well as the natural and physical aspects governing these sectors. The adopted approach has also helped raise and develop awareness amongst stakeholders and authorities on the importance of this concept. Their input was crucial in identifying the needs of the Al-Karak area, and related cross-cutting interventions.

As a result, four intervention projects were proposed aiming at achieving energy efficiency, sustainable water management and food security. A brief description of each is presented hereafter.

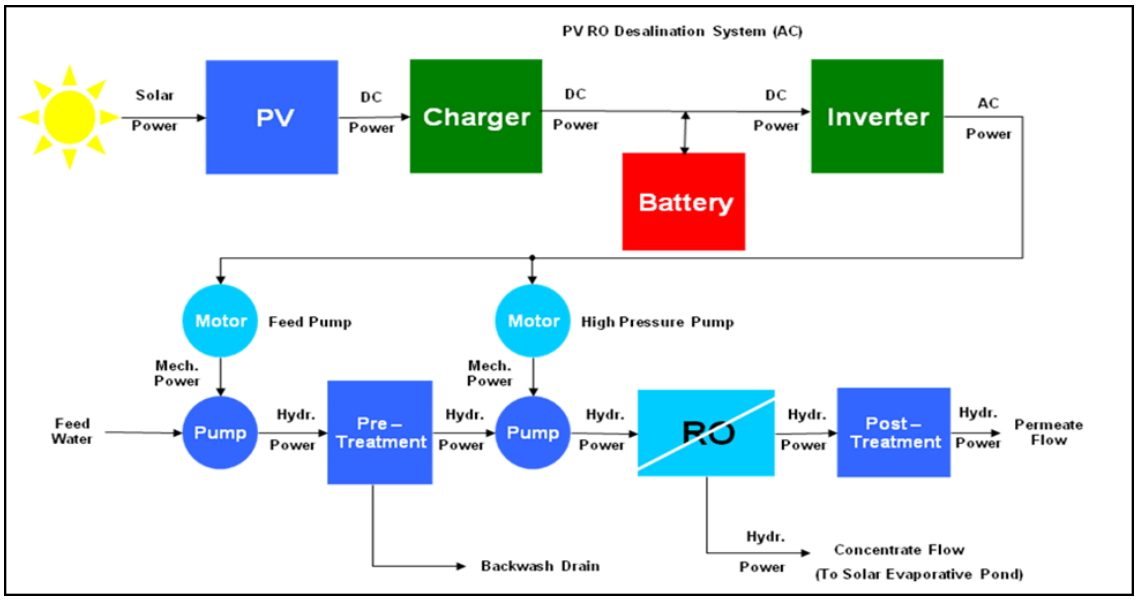
6.2. Proposed Interventions

6.2.1. Water treatment using solar PV system

The project objective is to develop a technically reliable, economically feasible well-optimized integrated small scale system for both brackish water pumping and Reverse Osmosis (RO) desalination powered by solar (Photovoltaic) energy in a poor and underprivileged agricultural area in Al-Karak area.

This project will help the target farms (identified after a rapid assessment step) by providing them and their cattle with fresh water and to improve their living situations (economic, health, and ecologic).

The system usually consists of PV panels unit with accessories, a desalination unit, and a reservoir for the treated water. Below is a sketch of the project components.



Al-Karak Municipality (who is a partner of this study) in cooperation with JCC, Farmers Union, Water Users Association, Mutah University, and Women Union of Al Karak can run the project.

A capacity development program is needed for the following:

- Farm site preparation,
- Operation and maintenance of the system components (PV panels, inverters, RO unit, pumps, etc.)

A core team at the farm level should be created through a Train the Trainer (TOT) program who could then deliver the training components on the above topics.

6.2.2. Upgrading Al Karak wastewater for reuse of effluent in forage crops production

Al Karak WWTP has an inflow capacity of 800 m3/day serving areas within the municipality's boundaries. Secondary treatment is operated in the plant. The treatment process includes screening, aeration tank, two trickling filters and sedimentation tank. The intention is to re-use treated water for irrigation. An artificial forest was already planted using the treated water, and farmers are using some of the treated water for their lands.

However, the plant is currently not operating appropriately since it receives 400m^3/day over its capacity, and thus the outflow quality is not complying with the Jordanian Standard for the Effluent of Domestic wastewater treatment plants. Despite all that, outflow is still being pumped through a pipe through several farms and into to the forest and stored in a tank for usage.

The concept of this project is to upgrade the WWTP to accommodate the 50% increase of its capacity so the treated effluents can be used for forage crops production.

This will allow better utilization of the treated wastewater as a valuable source of water, decreasing the overexploitation of the groundwater (GW) resources, decreasing the pollution of the soil within the vicinity of the treated wastewater flow and the conveyance pipe end point at the forest, and finally providing a good source of income to the farmers through the production and selling of forage crops.

The project would require the allocation of a piece of land of about 50,000 m^2 that will be used for forage production. The land should also be equipped with an appropriate irrigation system to minimize the water losses.

The capital investment for the WWTP upgrade should be provided by the MWI investment program.

The project can be led by Al-Karak Municipality, the WAJ directorate in Karak, Farmers Union, Water Users Association, and the Al Karak Women Union.

This project will require training cycles, for the site preparation, irrigation system operation and maintenance, wastewater effluent monitoring, and harvesting and packaging of the forage crops.

6.2.3. Adoption of a hydroponic agricultural production technique in one pilot farm

Hydroponic agriculture is being used in many farms of Jordan especially for the production of strawberries. The hydroponic technique saves on water and land needs. The Jordanian example of strawberries was very successful and the revenues were high. Other crops, especially cash crops and fodders, can be grown using this technique.

The aim of this project is to set the ground for replication and scaling up of this technique. This would warrant providing some training tools and have a set up for the reception of audience/trainees for delivery of a training module.

This project can be managed and implemented by Municipality of Al Karak in cooperation with the Water Users Association, Farmers Union, and Jordan Cooperative Corporation (JCC).

A capacity Development program on the following is needed:

- Farm preparation,
- Crop selection,
- Fertigation,
- Harvesting,
- Post harvesting activities (Marketing of the production for example)

A core team at the farm level should be created through a Train the Trainer (TOT) program who could then deliver the training components on the above topics.

6.2.4. Water harvesting and collection tank system at the farm level

The proposed zone of the project is along the Ain Sara trail. Along that area there are many farms that abstract water from the wadi and use it for agricultural production. Additionally, the location has enough precipitation that will generate enough runoff that can be harvested. This harvested rainwater can be used by farmers during periods of high precipitation. The water is usually of adequate quality for irrigation and requires no treatment other than allowing the suspended matter to settle with time in the reservoir.

This project can be implemented and managed by Al Karak Municipality.

No capacity building needed but only exposure and dissemination for replication will be needed

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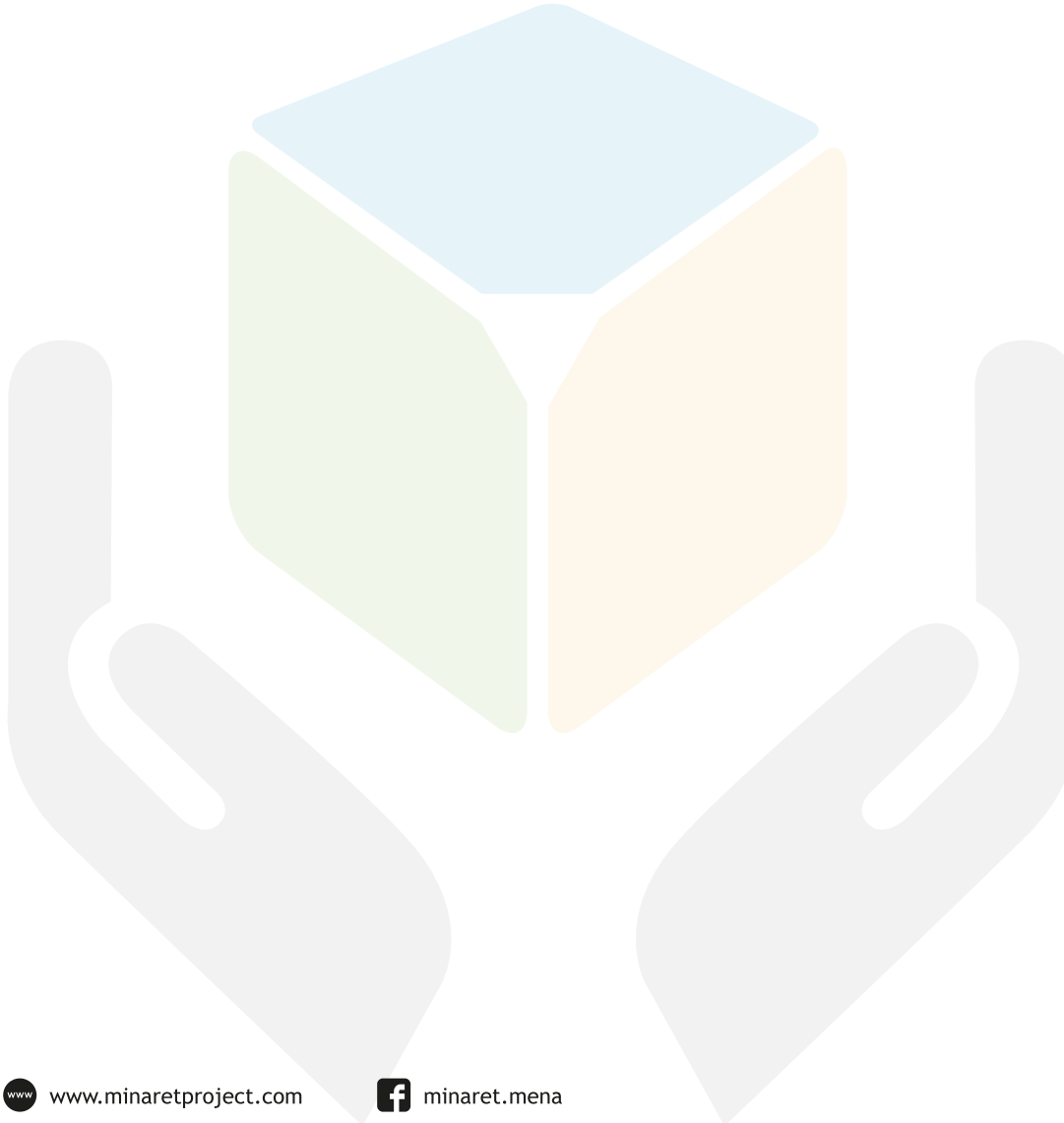

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