A SOCIO-ECOLOGICAL APPROACH TO COMBAT DESERTIFICATION FOR SUSTAINABLE FUTURE

EcoFuture

Work Package 1.1

Mapping of the Water-Energy-Food-Ecosystem (WEFE) Resources

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Executive summary

The Jordan Valley (JV) is a critical region where the interplay of water, energy, food, and ecosystem dynamics presents both challenges and opportunities for sustainable development and climate change mitigation and adaptation. The valley's unique geographical and climatic conditions have historically made it a focal point for agriculture, requiring intensive water management strategies to overcome its arid climate. Water scarcity in this region is acute, with sources such as the Jordan River and Yarmouk river and underground aquifers under increasing pressure from over-extraction and pollution, directly impacting agricultural productivity and food security. Energy is another critical component, heavily intertwined with water through the energy-intensive processes of water pumping, treatment, and distribution, as well as in agricultural operations and food processing. The food sector in the JV is highly dependent on the sustainable management of water and energy resources, with agriculture accounting for a significant portion of employment and food supply in the three territories, yet facing the challenges of limited water availability and the need for energy-efficient technologies.

The ecosystem of the JV, characterized by its rich biodiversity and unique habitats, plays a crucial role in supporting agricultural activities, providing ecosystem services such as pollination, pest control, and soil fertility. However, these ecosystems are under threat from overuse of natural resources, habitat destruction, and climate change impacts, necessitating integrated approaches to management. The Water-Energy-Food-Ecosystem (WEFE) nexus emerges as a vital framework in this context, emphasizing the interconnectedness of these sectors and the need for a holistic management approach to achieve socioeconomic welfare for the people of the valley.

The objective is to map all WEFE resources in three periods: (1) The current situation, (2) existing plans for the coming years, and (3) The prospected needs of WEFE resources in 30-50 years. The supply and demand of each component of the WEFE will be estimated in terms of geographical distribution, water quality, quota of water devoted per land designation for agriculture, industries, other usage, and environmental services available.

The geographic scope of this project is confined to the Jordanian side of the JV, an area that extends the full length of the valley from the Lake Tiberias in the north to the Dead Sea in the south (Figure ES-1). The Jordan Depression running from Wadi Araba to the Dead Sea is a very distinctive landscape; it forms part of the Rift Valley that extends from North Syria down to East Africa. This linear feature runs north-south with significantly lower elevations than the Highlands to the east, and extends about 360 km from Lake Tiberias to the Gulf of Aqaba. The Depression gradually rises from the Gulf of Aqaba over a distance of about 80 km up to about 250 m above sea level, and then drops gently towards the Dead Sea (417 m below sea level), the depression then rises in elevation from 417 m below sea level to 210 m below sea level at Lake Tiberias. Most of the depression is on average 15 km wide. This region is the lowest depression on earth (with the Dead Sea at 419 m below sea level) and includes the Jordan

River, flowing through the JV, which is considered the food basket of the region. The JV and the Southern Ghor are among the most important agricultural areas.

The JV represents the main agricultural productive area for Jordan. The JV is about 104 km long; its width varies from 4 to 16 km between the Jordan River and the East Mountains chain. Based on the high variability of the physical and chemical natures of the soils along the JV, the areas were classified separately into (1) The Northern Ghor that lies below the Yarmouk River through the village of North Shounah and Addasiya to the village of Kreymeh ;(2) The Middle Ghor that lies between the villages of Kreymeh and Karameh near Al-Maghtas; and (3) The Southern Ghor that lies between the village of southern Karameh to Al-Maghtas to Dead Sea. The JV has a semi-arid hot climate: the average temperature is ranged between 15° and 22° from November to March and between 30° and 33° in summer; rainfall is very irregular: from 180 mm/year in the south, it can reach to 400 mm/year in the north of the valley. Based on water resources availability and quality, the JV 's agriculture suitability varies significantly from Northern to Southern JV, therefore, each of the three parts of the JV has distinct agricultural patterns.

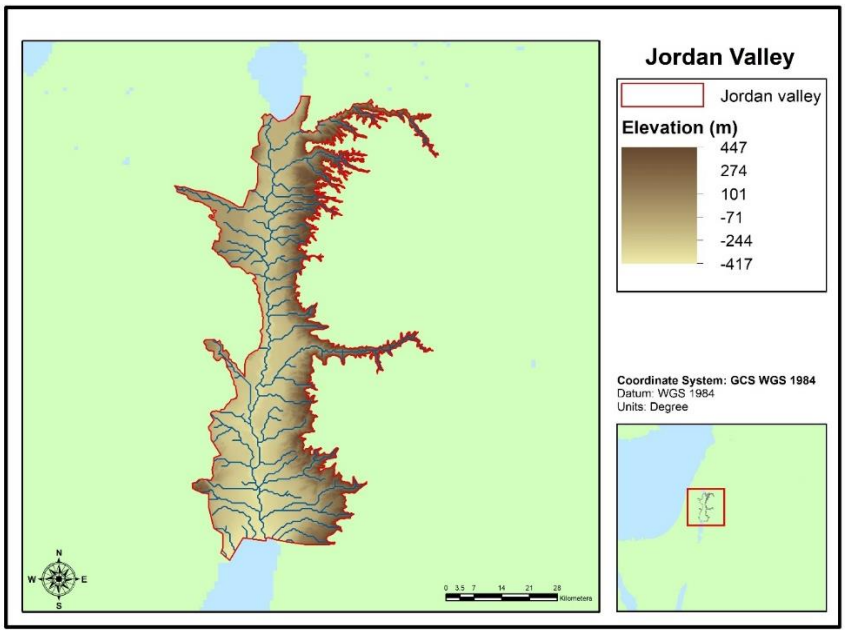


Figure ES-0.1: Topography of study area

The Eastern part (in Jordan) of the JV spans an area of 1,343 square kilometers. The region's current population stands at 260,000, but this figure is projected to rise significantly to 403,699 in the long term. At present, the area is not covered by the wastewater treatment network, however there are future projects to cover JV with a wastewater network by 2030.

The West JV region has a total area of 1574 Km^2. The Israeli part of the JV has a population of 60,000 that it is expected to increase to 72,000 in the short term and to 133,000 on the long term. Most of the villages are “Kibbutzim”, a communal living type that is unique to Israel, where all people belonging to the community share their properties and their enterprises. The Israeli part of the JV in the north is 693 Km^2.

The JV in the West Bank represents 28% of the total West Bank Area. According to the Palestinian Central Bureau of Statistics (2017 Census), 56,908 people live in the Palestinian JV mostly in the Jericho area. The total area of the Palestinian part of the study area is 881 km^2 with a population of around 70,000 habitants.

In the Palestinian JV, there are 39 settlements, the majority of which are agricultural, established on 12000 dunums. An additional 60000 dunums are inhabited by approximately 11,000 settlers. The number of Palestinian communities in the JV area is 27 located in an area of 10,000 dunums, and dozens of herding and Bedouin communities. The area of arable land in the JV is 280000 dunums (38.8% of the total area of the JV), of which the Palestinians exploit 50000 dunums while the settlers exploit 27000 dunums of its agricultural lands.

Water Resources Mapping

The present-day water supply in the three territories of the JV is as follows:

- **The Jordanian section of the JV -** As of 2023, the JV 's municipal water supply, mainly from groundwater sources, is estimated at 23.62 Mm3. This figure suggests an average annual water consumption of approximately 89 cubic meters per person. The projected demand, calculated at a minimum of 100 cubic meters per person per year for a population nearing 260,000, indicates a shortfall of 2.83 MCM. Additionally, the Ministry of Water and Irrigation (MWI) estimates that 50% of the water is lost due to leakage in the drinking water network, attributed to inadequate maintenance. Consequently, the actual per capita water usage annually is believed to be around 60 cubic meters. To mitigate these losses, upgrading and regular monitoring of the drinking water network are strongly advised. In addition, there is 4 Mm3/yr supply of water for industrial purposes. The total supply of irrigation water for the Jordanian section of the JV is 206.4 Mm3/year. About 133 Mm3/yr of treated wastewater is reused for irrigation (94% of TWW) after mixing with surface water in King Talal dam,. In addition, 93 Mm3 of surface water, 73.4 Mm3 in the north King Abdallah Canal, and 19.15Mm3 in the middle Ghors.
- **The Israeli section of the JV -** The Israeli municipal water supply is estimated at 7.09 Mm3. This figure suggests an average annual water consumption of approximately 174 m3/cap/yr (475 L/cap/day) based on a population of 40780. The total supply of irrigation water for the Israeli section of the JV is 134.84 Mm3/year. Aquaculture is using 67 Mm3/yr mostly saline water which is close to 50% of the total irrigation water. Water consumption in the region is primarily agricultural, where 95% of the 140 MCM consumed annually in the region is used for agricultural purposes. About half of the quantity used in agriculture is saline (or brackish) water, which are used primarily for fish farming in open ponds. In addition, freshwater and treated wastewater are used for crop irrigation and account for about 45%, and 5%, of total agricultural water use in the region, respectively.

- **The Palestinian section of the JV -** The freshwater supply in the Palestinian section of the JV originates mostly from local groundwater wells and springs, harvesting of rain water and treated waste water reuse. The Palestinian annual municipal water supply is estimated at 6.4 Mm3. This figure suggests an average annual water consumption of approximately 109 m3/cap/yr (298 L/cap/day) based on a population of 58698. Losses in the drinking water supply network are in excess of 40-50% of the supply which brings the annual consumption to similar levels as in the Jordanian section of the JV. The total supply of irrigation water for the Palestinian section of the JV is around 52 Mm3/year. Only 2.3% of the cultivated land is irrigated. Groundwater wells and springs contribute 48.1 Mm3/yr, harvested rainwater 2.7 Mm3/yr and waste water reuse approximately 0.7 Mm3/yr. Overall the total water supply in the JV is 423.8 Mm3/yr and 90% is used for agriculture and 10% for drinking water and industrial use.

The total agricultural land in the JV covers 87378 ha and accounts for 34% of the total area. The distribution of agricultural land in the three territories are 51.7% for Jordan, 28.5% for Israel and 19.8% for Palestine. The Jordanian agricultural land is 95% irrigated, the Israeli 70.7% irrigated while the Palestinian only 52.6% of the total agricultural area. In addition, the Israeli territory has 1690 ha of fish farms while the Jordan has 73 ha and Palestine 30 ha. These two activities account for the total agricultural water use of the JV Table ES-01 presents a summary of the supply and demand of water for the three territories in the JV. The total agricultural water supply is 374.06 Mm3/yr while the drinking water supply is 37.11 Mm3/yr. The agricultural water uses accounts for 91% of the total water supply where 16% is used for aquaculture and 75% for irrigation. Table ES-02 presents a comparison of the irrigation rate and the drinking water use per capita for the three territories in the JV. The irrigation rate for Israel was estimated to be 385 mm/dunum, for Jordan 623 mm/dunum and for Palestine 360 mm/dunum. The differences in irrigation rates can be explained by the water losses/leakages in the network that is estimated to be about 40% for Jordan and 50% for Palestine. On the other hand, the drinking water use per capita has been estimated to be 443 L/d/cap for Israel, 205 for Palestine and 249 for Jordan. If we account for water losses in the distribution network in Jordan and Palestine, only half of this water is reaching the consumers.

The demand for both drinking and agricultural water use is quite significant in Jordan and Palestine arising the agricultural demand to 715 Mm3/yr in the region and the drinking water demand to 43Mm3/yr. This deficit in the supply and demand of water has prompted the governments of the three territories to develop plans and strategic objectives to reduce its impacts.

Table ES- 0.1: Summary of supply and demand of water for the three territories in the JV

Supply	Unit	Israel	Palestine	Jordan
Agricultural water	Mcm/yr	134.84	32.8	206.42
Drinking water	Mcm/yr	7.09	6.40	23.62
Demand				
Agricultural water	Mcm/yr	134.84	182	400.00
Drinking water	Mcm/yr	7.09	10.00	26.00

Table ES- 0.2: Comparison of irrigation rate and drinking water use per capita for the three territories in the JV

	Unit	Israel	Palestine*	Jordan
Agricultural Area	Km2	249	173	348.9
Irrigated Agriculture	Km2	176	91	331.4
Irrigation water	Mm3/yr	67.8	32.8	206.4
Irrigation Rate	mm/dunum	385	360	622.8
Drinking water	Mm3/yr	7.1	6.4	23.6
Population	cap	43900	70,000	260000
Water use per capita	L/d/cap	443	205	249

Around 11,000 settlers in the Palestinian JV not included

Energy Resources Mapping

Mapping the Energy resources of the JV has been an impossible task due to lack of site-specific data. In some cases, such as in Palestine, we relied on country wide energy supply data that were used to estimate the JV component based on the population ratio. For Palestine the total electricity supply is 5925.5 GWh, supplied 93.4% by Israel, 4.4% by the Gaza Electrical Company and the remaining by Jordan and Egypt. If we assume that the population in the JV is about 5% of the total, then the electricity supply is about 300 GWh with unknown the demand. Similarly, the electricity supply in the Israeli JV is 382 GWh and in the Jordanian JV based on population is 5% of the total energy consumption (23654 GWh) which 1183 GWh (Table ES-3). It appears that the supply in the three territories is meeting the current demand, however, the annual increase in electricity demand in the area and the three countries is increasing at a very fast pace necessitating strategies that will accomplish sufficient increases in energy supply that will cover the future demand. However, the use of solar energy is increasing rapidly in Jordan.

Table ES- 0.3: Electricity supply and demand in the 3 territories of the JV

	Unit	Israel	Palestine	Jordan
Supply	GWh/yr	382	300*	1183
Demand	GWh/yr	382	?	1183

The three countries hold the same strategy and the same obstacles on the way to accomplish their national plans. Most of the land in the JV is rural area, the primary energy consumer is the residential sector and the second is the water sector that is the main resource for agriculture. The current situation is that, in the JV, the three nations can provide satisfactory energy supply and demand services. Most of the energy resources reside out of the JV, but it is not an issue since currently the JV is not in the focus of the nations.

However, there is a major concern on how to evaluate the energy sector needs in the short and the long-term. There are many unknown parameters that must be evaluated in order to plan and propose the design of energy infrastructures for the future of the JV. The two main factors that can influence energy projections in the region are:

1. Population growth - The main factor that influences the planning is the forecasted huge increase in population by a factor of 2 to 4 by 2050 in the region. The energy demand per capita is not expected to be reduced. Except in Jordan as the use of solar energy in the JV (for domestic, and agricultural uses) is expected to increase rapidly. Climate change may impose more energy for climatization of residential, commercial, and industrial areas. The expected increase of electrical mobility may drive the increase in electricity demand. The energy demand per capita in Jordan and Palestine is substantially lower than the Israeli average of 8,000kWh/capita/year. We guess that during the years the Israeli demand will stay almost the same due to energy efficiency improvements. However, the demand per capita in Jordan and Palestine will reach the Israeli level by 2050.
2. Quest for renewable energy - The desire of all nations is to increase substantially the reliance on renewable energy. The Israeli national challenge of 30% in 2030 and 80% in 2050 and the Jordan plans are even more ambitious. It is not expected that the JV will match the nationals' targets. However, the energy security of the JV may strengthen the desire for energy dependence of the area as much as possible on local supply, and mainly on renewable energy. The main primary local energy resource is solar. Wind potential is diminished. However, biofuels and biogas production can be meaningful and can contribute a lot to dispatchable electricity supply and for heat & power supply.

Food Resources Mapping

Mapping of food resources has been the most difficult task of the WEFE resources, especially for the Palestinian territory. Food production has been affected primarily by land degradation and water quality (brackish water) as well as by external factors including climate change and the geopolitical situation.

Since the early 1950s, the JV (JV) has undergone significant agricultural development. Collaboration between public and private sectors has led to advanced irrigation systems and modern farming techniques. In recent years, date palm cultivation has surged, with over 29,000 trees planted, producing 33,000 tonnes annually and creating substantial employment. Despite successes, marketing issues and pest threats persist. Animal production has evolved with a shift to high-yielding dairy cows, while small-scale farms continue to support local livelihoods. The dairy industry has expanded, with modern factories processing various products. Sustainable practices address challenges like water shortages. Additionally, fish production through aquaculture and aquaponics is vital, enhancing local economies and food security with government and international support.

The agricultural land has been degraded due to continuous cultivation for millennia which has as a result extremely low soil organic carbon. The impact of this situation is depicted in the estimated production yields for the JV. This is a common problem for the three territories of the JV necessitating measures for soil restoration using agro-ecological practices that will improve soil quality and soil fertility and health.

Ecosystem Resources Mapping

JV's ecosystems and biodiversity are under pressure due to various factors. The Drivers, Pressures, State, Impacts and Responses (DPSIR) analysis for the examined area is presented in Figure ES-2. The main drivers that affect the system in the area are population growth, climate change, land use change and pollution. The environmental pressures exerted in the JV are the result of intensive agricultural activities (agriculture, livestock and aquaculture), tourism, climate change, geogenic pollution, population and migration and invasive species. These pressures have resulted in significant impacts to the WEFE Nexus with surface water flow decline, groundwater depletion, high groundwater salinity, pollution and loss of biodiversity.

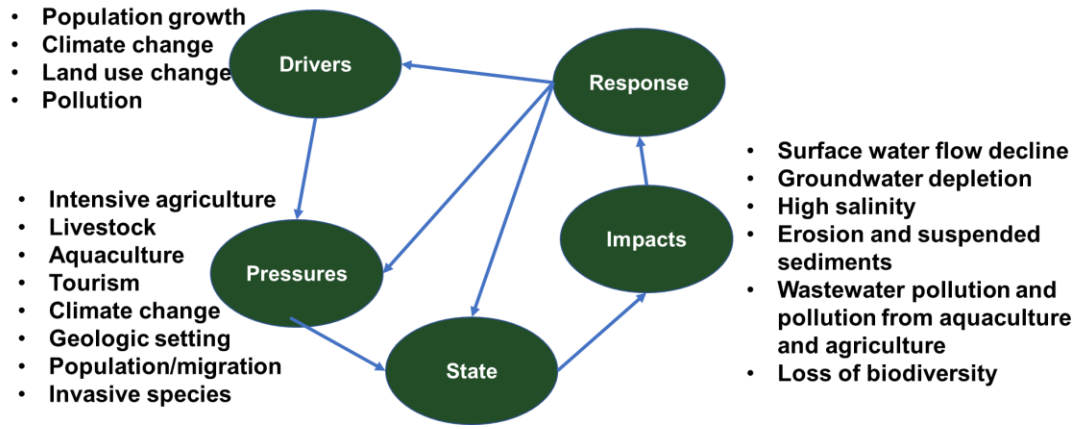


Figure ES - 0.2: DPSIR analysis of the JV

Climate change, following the more general Mediterranean trend of water resources shortages, has been projected as a serious threat for the area. The region's climate is changing, with the potential for increased droughts, higher temperatures, and more extreme weather events, posing significant challenges to the preservation of ecosystem. Climatically, the JV is characterized by hot dry summers and mild wet winters, becoming progressively drier moving southward through the valley towards the Dead Sea. It is predicted that the Eastern Mediterranean will continue to face a reduction in annual precipitation, longer hot summer dry season, and shorter cool wet winter season due to climate change. This change in climatic conditions for the region will have a major impact on the local instrumental value ecosystem of the Harod and Beit Shean Valleys including the Valley of the Springs. Most crops in the valley grow during the winter months. Such a dramatic change in the length of the seasons means that many crops will no longer be feasible to grow in the valley. If farmers do not learn to adapt to these changes in climate patterns, they may have to leave farming altogether, reducing the size of the agroecosystems which currently maintain much of the biodiversity in the valley. Natural ecosystems will also be impacted as rapid changes in the climate may impact endemic species, which have found their niche in the unique ecosystem of the JV. Rapid changes in climate, especially changes in precipitation patterns and season length may encourage the spread of generalist species, which can thrive in changing environments. Invasive species and eruptive species may push out native and endemic species, impacting the biodiversity of the region.

Surface water flow declines have been observed in the Jordan River and the discharge to the Dead Sea has been decreasing dramatically leading to the water level declines over the years. This decline is primarily due to withdrawals of water above the Sea of Galilee and diversion for other uses. The Dead Sea, a critical component of the JV ecosystem, faces severe threats due to declining surface water flow, particularly from the Jordan River. Extensive water withdrawals upstream, especially above the Sea of Galilee, for agriculture, domestic, and industrial uses have dramatically decreased the water reaching the Dead Sea, leading to a rapid decline in its water levels, dropping over one meter per year. This decline has exposed

large areas of the Sea's bed, disrupted its unique saline ecosystem, caused dangerous sinkholes, and posed risks to surrounding infrastructure. The shrinking sea also threatens the tourism industry, vital for local economies, and challenges mineral extraction operations.

Population growth is affected significantly by the political instability in the region that is fueling refugee movements into the area and causing additional pressure on water, energy and food resources. Especially, in Jordan, the population is growing at an annual rate of 3%. Based on this growth rate, it is projected that 338,000 people will inhabit the JV within the next 10 years.

Land use distribution has been stabilized in the region to a large extent. It is not expected to have increases in the cultivated areas in Jordan and Palestine, however, there is the potential for conversion of agricultural land to urban areas in the Israeli sector as discussed earlier. On the other hand, further intensification of agriculture in Jordan and Palestine is expected, especially if more water becomes available in Palestine for irrigation.

The main sources of pollution in the JV are wastewater from treatment plants and unsewered areas, fertilizer, pesticide and herbicide pollution from agriculture, urban solid waste disposal sites, aquaculture water use, and small “industrial” facilities mostly related to agriculture. In addition to the above, the impact to water quality due to saline bedrock, which increases the chloride concentration in the irrigation water, all provide a complete picture of the anthropogenic and geogenic pollution in water and soil.

The presence of saline bedrock often leads to the development of saline groundwater, affecting both the quality and availability of water resources. Additionally, the influence of saline bedrock extends beyond hydrogeological aspects to include soil quality and overall environmental health. In conjunction with saline bedrock, the surrounding soil may also become saline. Saline soil contains high concentrations of salt, which can negatively impact plant growth and soil fertility. The combination of saline bedrock and saline soil poses significant challenges for agriculture in the in the region. Crop selection becomes crucial, as certain plants exhibit greater salt tolerance. Implementing soil amendments and irrigation practices that mitigate the impact of salinity is essential for sustaining agricultural activities in such areas. Saline soil can contribute to the degradation of water quality as salts leach into groundwater and surface water bodies. This has implications for both human consumption and ecosystem health. Poor water quality can lead to health problems for local communities and disrupt aquatic ecosystems. The combined effects of saline bedrock and saline soil can disturb local ecosystems. Native flora and fauna may struggle to adapt to the changing conditions, leading to shifts in biodiversity and potential ecological imbalances. Monitoring and conservation efforts are crucial to mitigate the impact on the environment.

The geologic setting is also prone to high erosion rates and suspended sediments in surface waters. The steep slopes of the JV and the erodible sandstone formations of the deposits in combination with the luck of vegetation are highly erodible and result in high loads of suspended sediments in the surface water with all the associated impacts to the environment.

The abovementioned pressures can lead to negative impacts on ecosystems and biodiversity in the JV. In addition, the rich biodiversity of the JV faces a pressing threat from invasive species, which have become a significant ecological concern in the region. Invasive species, whether introduced accidentally or intentionally, possess the ability to disrupt the delicate balance of native ecosystems. The JV, with its unique flora and fauna, is particularly susceptible to the impacts of non-native species that can outcompete, prey on, or otherwise displace indigenous plants and animals.

To reduce the impact of the pressures, to address these challenges and ensure the long-term sustainability of the region's ecosystems and their role in supporting future WEFE demands, integrated and sustainable management approaches are essential. Sustainable management and preservation of ecosystems and the services they provide will be essential to mitigate these impacts. Long-term projections should focus on the preservation of ecosystem health and services, as well as their role in supporting future WEFE demands.

Conclusions

In this report, we have made an attempt to map the WEFE resources of the JV. It has been a tedious effort that was made more difficult due to the war in Gaza and the availability of the appropriate governmental institutions to provide the necessary data that provide a clear picture of the current WEFE resources supply and demand as well as future projections.

Based on the WEFE Nexus mapping conducted for the JV, the following issues have been identified as of the highest priority to address:

- **Water deficit –** The agricultural water uses accounts for 91% of the total water supply where 16% is used for aquaculture and 75% for irrigation. The irrigation rates range from 385 mm/dunum for Israel to 677 mm/dunum for Jordan and 360 mm/dunum for Palestine. The differences in irrigation rates are due to water losses/leakages in the network that is estimated to be about 30% for Jordan and 50% for Palestine. If we account for water losses in the distribution network in Jordan and Palestine, only half of this water is reaching the consumers. Reuse of treated wastewater is also very low in Palestine. On the other hand, the demand for both drinking and agricultural water use is quite significant in Jordan and especially in Palestine (where only a small fraction of the agricultural land is irrigated) creating a significant deficit between supply and demand.
- **Water quality –** The available water supply in the JV has been impacted by high water salinity levels due to geogenic causes. In addition, the main sources of anthropogenic pollution in the JV are wastewater from treatment plants and unsewered areas, fertilizer, pesticide and herbicide pollution from agriculture, urban solid waste disposal sites, aquaculture water use, and small “industrial” facilities mostly related to agriculture have impacted the water quality of Jordan River and create an additional stress on the ecosystem.

- **Energy mapping –** Energy supply appears to meet current demand; however energy demand increases are expected to be high, necessitating in this way the development of a integrated strategy for the JV that should be based on renewable energy.
- **Soil degradation –** The agricultural land has been degraded due to continuous cultivation for millennia which has as a result extremely low soil organic carbon. The impact of this situation is depicted in the estimated production yields for the JV. This is a common problem for the three territories of the JV necessitating measures for soil restoration using agro-ecological practices and active carbon additions to soils that will improve soil quality, fertility and health.
- **Ecosystem degradation –** The environmental pressures exerted in the JV are the result of intensive agricultural activities (agriculture, livestock and aquaculture), tourism, climate change, geogenic pollution, population and migration and invasive species. These pressures have resulted in significant impacts to the WEFE Nexus with surface water flow decline, groundwater depletion, high groundwater salinity, pollution and loss of biodiversity. To ensure the long-term sustainability of the region's ecosystems, integrated and sustainable management approaches are essential to mitigate these impacts.

The impact of climate change has already been felt in the JV. Figure ES-3 presents the precipitation and temperature trends in two meteorological stations (North and Mid Ghor) in the JV. Precipitation in the North Ghor station was reduced from 395 mm in 1982 to 351 mm in 2021 (11% reduction) and in Mid Ghor from 338 mm in 1982 to 224 mm in 2021 (34% reduction) while the average temperature has increased by 1.9 ^{o}C in both stations during the same period.

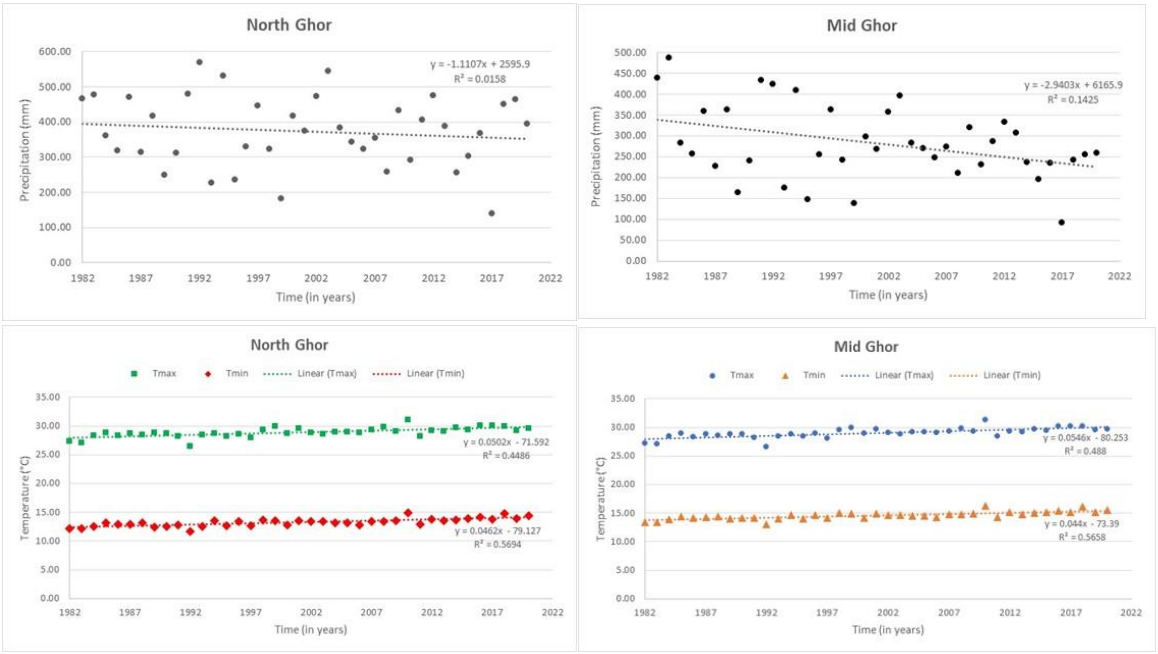


Figure ES- 0.3: Precipitation and temperature trends in two meteorological stations (North and Mid Ghor) in the JV.

1. Introduction

1.1 Background and objectives

The Jordan Valley (JV) is a critical region where the interplay of water, energy, food, and ecosystem dynamics presents both challenges and opportunities for sustainable development and climate change mitigation and adaptation. The valley's unique geographical and climatic conditions have historically made it a focal point for agriculture, requiring intensive water management strategies to overcome its arid climate. Water scarcity in this region is acute, with sources such as the Jordan River and underground aquifers under increasing pressure from over-extraction and pollution, directly impacting agricultural productivity and food security (Al-Bakri et al., 2013; UN-ESCWA and BGR, 2013). Energy is another critical component, heavily intertwined with water through the energy-intensive processes of water pumping, treatment, and distribution, as well as in agricultural operations and food processing (FAO, 2014). The food sector in the JV is highly dependent on the sustainable management of water and energy resources, with agriculture accounting for a significant portion of employment and food supply in the three territories, yet facing the challenges of limited water availability and the need for energy-efficient technologies (World Bank, 2017).

The ecosystem of the JV, characterized by its rich biodiversity and unique habitats, plays a crucial role in supporting agricultural activities, providing ecosystem services such as pollination, pest control, and soil fertility. However, these ecosystems are under threat from overuse of natural resources, habitat destruction, and climate change impacts, necessitating integrated approaches to management (Molle et al., 2009; GWP and INBO, 2012). The Water-Energy-Food-Ecosystem (WEFE) nexus emerges as a vital framework in this context, emphasizing the interconnectedness of these sectors and the need for a holistic management approach to achieve socioeconomic welfare for the people of the valley. By adopting a WEFE nexus perspective, policies and practices can be developed that not only address the immediate needs of water, energy, and food security but also ensure the long-term sustainability and resilience of ecosystems.

Incorporating the WEFE nexus into climate change adaptation strategies is particularly important for the JV. It offers a pathway to enhance resource use efficiency, reduce environmental impacts, and support the adaptive capacities of communities and ecosystems. For instance, nexus-based approaches can facilitate the development of integrated water and energy-saving agricultural practices, such as drip irrigation and solar-powered water pumps, which can significantly enhance food production while conserving resources and protecting ecosystems (FAO, 2017). Furthermore, understanding and managing the WEFE nexus can help mitigate the socio-economic impacts of climate change on vulnerable communities, ensuring that adaptation strategies are equitable and support sustainable development goals (SDGs) (Biggs et al., 2015).

As a result, Integrated management strategies that consider the WEFE nexus are essential in promoting sustainable resource use, enhancing food and water security, and ensuring the health of ecosystems upon which local communities depend. This integrated approach not only aligns with global sustainable development goals but also provides a blueprint for addressing the multifaceted challenges posed by climate change in arid and semi-arid regions.

The current state of WEFE resources in the JV is a result of historical policies, environmental changes, and socio-economic developments. This report delves deep into the current status, analyzing data, trends, and patterns to provide a comprehensive snapshot of the existing WEFE nexus. It's a narrative not only of resource utilization but also of the challenges posed by climate change, population growth, and political complexities.

Finally, the long-term outlook presented in this report transcends the immediate future, venturing into strategic planning horizons. It explores potential pathways for sustainable resource management, considering technological advancements, regional cooperation, and global environmental commitments. This long-term vision is critical for ensuring that the JV remains a region where the delicate balance of water, energy, food, and ecosystems is not only maintained but also harnessed for the collective prosperity and well-being of its inhabitants.

Mapping the WEFE resources now and in the near future is a necessary step to obtain the baseline data that can be used in the planning for improving the socio-economic welfare of the people in JV. The data that will be collected will provide the basis to all other Tasks and Work Packages. The objective is to map all WEFE resources in three periods: (1) The current situation, (2) existing plans for the coming years, and (3) The prospected needs of WEFE resources in 30-50 years. The supply and demand of each component of the WEFE will be estimated in terms of geographical distribution, water quality, quota of water devoted per land designation for agriculture, industries, other usage, and environmental services available. The connection to water and waste-water resources from neighboring regions is important for estimating the waste-water treatment and usage capacity. For energy supply local JV resources (renewables and traditional) would be mapped and the availability of energy from neighboring regions through the networks have to be mapped. Similar considerations will be given to the Food and Ecosystem components and all together will be the background mapping of the WEFE resources.

1.2 Methodology

1.2.1 Data collection methods

The Jordanian data for this report was compiled through a joint effort between the National Agricultural Research Center (NARC) and several ministries: Ministry of Water and Irrigation (MWI), Ministry of Agriculture (MOA), Ministry of Energy and Mineral Resources, and the JV Authority (JVA). Key data sources included the National Water Strategy for 2023-2040, Jordan's Fourth National Communication Report (2022), the Climate Change Policy, Department of Statistics (DOS), and Ministry of Agriculture (annual reports). The Israeli and Palestinian data has been obtained from the relevant stakeholders in each Sector as they are detailed in deliverable D5.1. Experts point of views for the current and future scenarios for the four components (Water, Energy, Food, and Ecosystems) as well as recent literature and desk review were also considered.

1.2.2 Time Periods

Current situation: The assessment of the current situation of the four components in the JV's Water-Energy-Food-Ecosystem (WEFE) Nexus involved the collection of variety of data sources that were utilized to gain a comprehensive understanding of the supply and demand of the Nexus components. This included current reports and datasets from various Ministries and Organizations, which provided updated data and analyses.

Near-future (based on existing plans): For short-term data collection existing foresight and management plans were used to determine the near future supply and demand and ensure a comprehensive and timely understanding of the WEFE Nexus in the JV.

Long-term (30-50 years): For long-term data collection in the JV's WEFE Nexus, several strategies are essential. Referring to longitudinal studies that monitor and track changes in the WEFE Nexus over an extended period to understand evolving trends and predict future scenarios. Additionally, accessing and analyzing data from government agencies and international organizations is crucial. These entities continually update their databases with pertinent information covering aspects like water, energy, agriculture, and ecosystems. Such a multifaceted approach to long-term data collection will provide a robust and detailed understanding of the dynamics within the WEFE Nexus. Both short-term and long-term data collection methods should be complemented by continuous literature reviews and stakeholder consultations to ensure a comprehensive and multi-faceted approach to mapping the WEFE Nexus in the JV.

1.2.3 Geographical scope and resolution

The geographic scope of this project is confined to the Jordanian side of the JV, an area that extends the full length of the valley from the Sea of Galilee in the north to the Dead Sea in the south (Figure 1.1). The Jordan Depression running from Wadi Araba to the Dead Sea is a very distinctive landscape; it forms part of the Rift Valley that extends from North Syria down to East Africa. This linear feature runs north-south with significantly lower elevations than the Highlands to the east and extends about 360 km from Lake Tiberias to the Gulf of Aqaba. The

Depression gradually rises from the Gulf of Aqaba over a distance of about 80 km up to about 250 m above sea level, and then drops gently towards the Dead Sea (419 m below sea level), the depression then rises in elevation from 419 m below sea level to 210 m below sea level at Lake Tiberias. Most of the depression is on average 15 km wide. This region is the lowest depression on earth (with the Dead Sea at 419 m below sea level) and includes the Jordan River, flowing through the JV, which is considered the food basket of the region. The JV and the Southern Ghor are among the most important agricultural areas.

The JV represents the main agricultural productive area for Jordan. The JV is about 104 km long; its width varies from 4 to 16 km between the Jordan River and the East Mountains chain. Based on the high variability of the physical and chemical natures of the soils along the JV, the areas were classified separately into (1) The Northern Ghor that lies below the Yarmouk River through the village of North Shounah and Addasiya to the village of Kreymeh ;(2) The Middle Ghor that lies between the villages of Kreymeh and Karameh near Al-Maghtas; and (3) The Southern Ghor that lies between the village of southern Karameh to Al-Maghtas to Dead Sea . The JV has a semi-arid hot climate: the average temperature is ranged between 15° and 22° from November to March and between 30° and 33° in summer; rainfall is very irregular: from 180 mm/year in the south, it can reach to 400 mm/year in the north of the valley (Al Wedyan, 2022). Based on water resources availability and quality, the JV's agriculture suitability varies significantly from Northern to Southern JV, therefore, each of the three parts of the JV has distinct agricultural patterns (Kool, 2016). Due to high temperatures and their location below sea level, these two regions are the most important areas for producing winter vegetables. The Ghor has approximately 34,000 hectares of farming land, all of which is irrigated.

This study is offering both a broad overview and a detailed analysis by dividing the valley into three distinct areas: the Northern JV, the Middle JV, and the Southern JV. Each area is examined with a resolution that captures the specific hydrological and agricultural characteristics intrinsic to its locale. The Northern section encompasses the regions around the Yarmouk River basin and extends to the lush, water-rich areas near the Sea of Galilee. The Middle segment includes the Deir Alla region, where the Jordan River meanders through central areas with distinct agricultural practices and water management challenges. Lastly, the Southern part covers the arid regions around the South Shouneh, where water scarcity presents unique issues for sustainable resource management. This three division enables a better understanding of the region's WEFE nexus, ensuring that local variations in water availability, energy use, food production, and ecosystem health are captured with clarity.

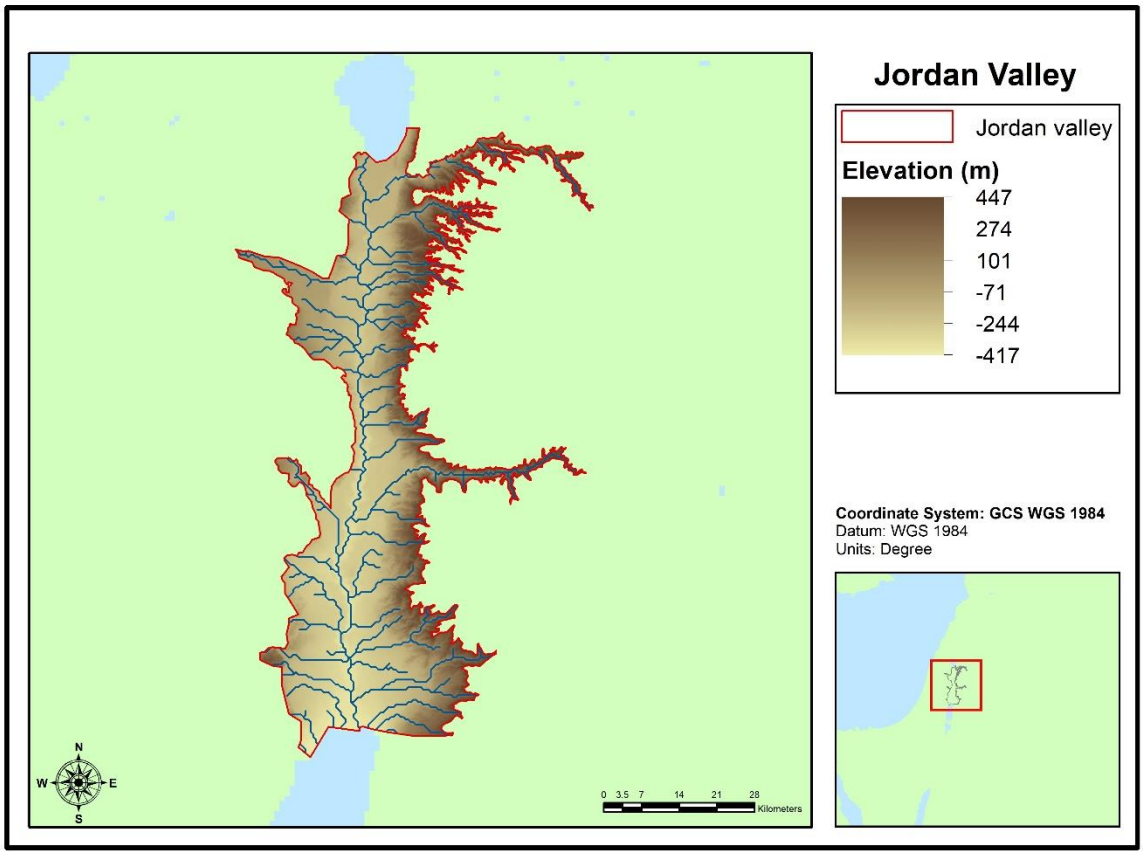


Figure 1.1 Topography of study area

The Eastern part (in Jordan) of the JV spans an area of 1,343 square kilometers. The region's current population stands at 260,000, but this figure is projected to rise significantly to 403,699 in the long term. At present, the area is not covered by the wastewater treatment network, however there are future projects to cover JV with a wastewater network by 2030. The volume of water in the groundwater basins is currently at 20.7 Million m^3. The current water supply from wells in Abu Zeighan near Deir Alla is 6.3 Million m^3, North Shuna is supplied with 7.5 Million m^3 from wells, and South Shuna's well water supply is slightly lower at 6.9 Million m^3. It is known that the JV is a vital agricultural region that relies heavily on the Jordan River and groundwater sources for irrigation. Sustainable management of these resources is critical, considering the pressures from population growth and the need for modern infrastructure to support water distribution and treatment.

Water resources in the JV are characterized by scarcity, variability, and uncertainty. Annual rainfall starts in October and ends in May, with most falling between December and February. The northern area, receives a long-term average of about 400 mm/yr. The annual variations in precipitation are quite high; in dry years the northern parts of the valley may receive 200 mm while on the shores of the Dead Sea there may be as low as 50 mm.

The West JV region of interest is marked by the orange line in Figure 1.2. The Israeli area is located above (north of) the dashed line and the Palestinian region is south of the dashed line. The total area of the study area in the western side of the JV is 1574 Km^2. The Israeli part of the JV has a population of 43,900 that it is expected to increase to 53,514 in the short term and to 96,933 on the long term. Most of the villages are "Kibbutzim", a communal living type that is unique to Israel, where all people belonging to the community share their properties and their enterprises. The Israeli part, north of the dashed line ("The green line") is 693 Km^2.

The JV in the West Bank represents 28% of the total West Bank Area. The JV part of the West Bank is divided into three regions administratively affiliated to three governorates; Tubas and Northren JV (Northern Ghor), Nablus and Central JV (Central Ghor) and Jericho and Southern JV (Southern Ghor). According to the Palestinian Central Bureau of Statistics (2017 Census), 56,908 people live in the Palestinian JV mostly in the Jericho area. This represents 2% of the total Palestinian population in the West Bank. The total area of the Palestinian part of the study area is 881 km^2 with a population of around 70,000 habitants.

The Palestinian territory of the JV is divided according to the "Oslo Accords" into:

- Areas A, under Palestinian Jurisdiction. Its area is 85 km2, Jericho area and surrounding area and its percentage is 7.4% of the total area of the JV;
- Areas B, which is a joint sharing area between the Authority and Israel, has an area of 50 km2 and represents 4.3% of the total area of the JV.
- Area C, which is under full Israeli control, has an area of 1,155 km2 and constitutes the vast majority of the JV area (88.3%).

In the Palestinian JV, there are 39 settlements, the majority of which are agricultural, established on 12000 dunums. An additional 60000 dunums are inhabited by approximately 11,000 settlers. Most of the settlements in the JV belong to the regional settlement councils known as "Arvot Herden" and "Megilot." Israel keeps strict control of the JV and restrict Palestinian expansion and development in the area. Israel controls approximately 90% of all areas of the JV. The JV constitutes the food basket of Palestine. It supplies the Palestinian market with about 60% of vegetables and fruits and contains 50% of the Palestinian groundwater resources. It is considered the second largest groundwater reservoir in the West Bank. Israel controls 85% of the water resources in the Palestinian JV areas, which are not available to Palestinians. The JV area includes about 45% of pastoral areas and 40% of Palestinian livestock.

The number of Palestinian communities in the JV area is 27 located in an area of 10,000 dunums, and dozens of herding and Bedouin communities. The area of arable land in the JV is 280000 dunums (38.8% of the total area of the JV), of which the Palestinians exploit 50000 dunums while the settlers exploit 27000 dunums of its agricultural lands.

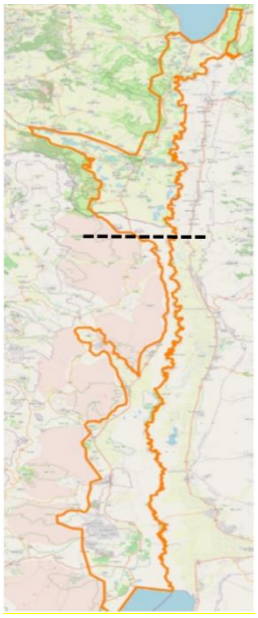


Figure 1.2: Demarkation of the western boundaries of study area. The dashed line identifies the Israeli from the Palestinian territories.

The major water resource in the West Bank is the Jordan River that Palestinians have been denied access since the 1967 Israeli occupation which declared all areas along the river as a military closed area and hence deprived Palestinian access to the river. The river has also reduced flow due to the diversion of Tiberias lake water through the Israeli national carrier and water use and dam storage. This situation has resulted in the shrinking of the Dead Sea shrinkage which has lost more than 60% of its original area as of early 1960's and an annual decline in water level of around 1 meter.

The West Bank major water resource originates from the Mountain Aquifer that has been divided by the Oslo agreement into three sub basins namely the Western Aquifer, the North Eastern Aquifer and the Eastern Aquifer that the Study area lies over.

The water right between Israelis and Palestinians has been postponed to permanent status negotiations as per the Interim agreement signed between the parties in 1995 Oslo II. Article 40 of the Oslo agreements regulates the relation between the Palestinian and the Israelis and all water and sanitation projects has to get a prior Joint Water Committee approval. The JWC is established in Oslo agreement. Yet Palestinians has to obtain another approval on top of the JWC approval called the construction permit from the Civil administration whenever a project is planned to be in Area C that represent 60% of the West Bank. In the past 30 years, the water rights issue and such mechanism of approvals and restrictions has hindered development in the water and sanitation sector in the West Bank. In the JV, Palestinian relies on the Eastern aquifer wells and springs. Jericho area is a wealthy city compared to other Palestinian cites due to massive wells and spring discharge in the Jericho and surrounding area (Nuimeh, Dyook and Auja) specially with springs presence in the area. In the central and north area of the JV water is scare and communities relied on purchased water from Mekerot.

Groundwater is considered the main source of water in the JV, among the existing 209 wells, there are only around 89 functioning due to the old infrastructure and the declining

groundwater level. There are 22 springs in the JV with an average discharge of 44 MCM/yr, not including Ein Fashkha springs which discharges 80 -100 MCM/yr. Palestinians had submitted request to use part of the Fashkha water for agricultural purposes but such request has been denied.

Located along the eastern edge of the West Bank in the JV, Jericho Governorate encompasses over 11% of the region's total land area, spanning approximately 634 km2 with a population of 56256 people. Renowned for its water security, it stands as one of the most resilient areas in the West Bank, boasting an ample supply for domestic uses of approximately 5.4 MCM/yr sourced from wells, springs, and strategic water purchases from Mekorot. The Agricultural use of water is estimated at around 45 MCM yearly mainly from spring (38 MCM) and wells (7 MCM)

The study area of governorate of Jericho and southern and central JV has six main population centers: the city of Jericho,Nuimeh, El Dyook and camps of Aqbat Jaber and Ein Al Sultan ,the town of Al' Auja (Southern JV), where the Central JV composed The towns of Fasayil and Al Jiftlik, The village of Az Zubeidat, the village of Marj Gazal and Marj Na'ja are all located in the Study Area. The population of the Central Ghor area is estimated at around 4000 habitants

The Tubas Governorate spans an area of roughly 440 km2, constituting about 8% of the total landmass of the region, with a population of 70225 people. The governorate faces significant challenges in access to public water infrastructure, with merely 26.1% of its communities being served, or partially served, with 3.3 MCM/yr of supply. This inadequacy impacts approximately 63.9% of the local population, although it represents a mere 2.2% of the entire population of the West Bank. The area has three main population centers known as Northern JV or Northern Ghor: The villages of Kardala, Bardala and Ein el Beida. The Population in this area is estimated at around 3000 habitants

2. Water Resources Mapping

2.1 Current Situation

2.1.1 Water availability and sources

Jordanian section of the JV - The primary sources of water in the JV are the Jordan River from Tiberias Lake, Jordanian main rivers such as Yarmouk and Zarqa, treated waste water from King Talal Dam (blended with rain water) and underground aquifers. The Jordan River, once a significant source of water, has seen its flow dramatically reduced due to upstream usage by neighboring countries (WB,2017). The Yarmouk River, a major tributary of the Jordan River, also contributes, although its flow has similarly decreased over the years. Groundwater aquifers play a crucial role in the region's water supply. In addition to conventional water resources (surface and groundwater), non-conventional water resources including treated wastewater, desalinated sea water and brackish water, and harvested precipitation are also utilized in the Jordan River Basin. Treated wastewater is an important resource in Jordan and mostly used in irrigation. For example, in the Greater Amman municipality, almost 90% of treated wastewater is being reused in irrigation (FAO, 2017). Desalinated water is often produced in small- and medium- facilities, and of quality adequate for irrigation.

Water sources are under constant strain due to factors such as population growth, agricultural demands, climate change, and regional political dynamics, underscoring the need for sustainable water management practices in the JV and across the country. The Jordan River Basin is highly developed with extensive water infrastructure to exploit available water resources, with more than 45 dams (maximum storage capacity of 390 MCM) to the north of the Dead Sea (UN-ESCWA and BGR, 2013).

The Yarmouk River is the main water source of the King Abdullah Canal (KAC), which carries water for irrigation to JV. The Canal also receives water from Lake Tiberias as well as treated waste water. Table 2.1 shows the surface water transboundary source and amount for JV in Jordan (MWI, 2021). In addition, groundwater wells from Abu Zeighan, North Shuna and South Shuna are being used.

Critical water resources and irrigation sectors within eastern part of the JV are: North JV, Middle JV (with a focus on Deir Alla), and South Shouneh. These areas are delineated to indicate varied irrigation zones. In North JV, about 30% of the fresh water comes from the King Abdullah Canal, whereas Middle and South JV benefit from 60% of the canal's water, which is augmented with treated wastewater primarily from King Talal Dam (KTD). This dam is the recipient of treated wastewater from Kherbit AlSamra, the most significant wastewater treatment facility in Jordan. The water from KTD is then combined with the fresh water in the KAC for use in the Middle and Southern regions. The King Abdullah Canal, which runs alongside the Jordan River, represents a crucial artificial channel for irrigation and potentially additional purposes.

Table 2.1: Surface water transboundary source and amount

Source	Amount (MCM)
Alwehdah Dam and Yarmouk river	47.23
KAC from Tiberias	91.86
Total	139.09

Water Budget MWI, 2021

Agriculture, as the predominant land use in the valley, is allocated the largest share of water resources, given the sector's centrality to the local economy and food security. This allocation is guided by the principles of maximizing water use efficiency and crop productivity, with a strong emphasis on modern irrigation techniques such as drip irrigation and the cultivation of crops with lower water requirements. The agricultural water quota system is designed to support the valley's role as the country's breadbasket, while also addressing the constraints imposed by limited water availability (Al-Bakri et al., 2013; MWI, 2016).

In 2021, according to JVA report in water irrigation, the total irrigated area in the JV was about 308,000 dunums (du) including the Southern Ghors; about 170,000 du (55%) was irrigated totally with blended wastewater, 26,000 du (8%) partially with KTD TWW and 113,000 du (37%) totally with fresh water. However, in 2021 the total released amount for irrigation was about 206 MCM; 81 MCM from freshwater (39%) and about 86 MCM from TWW (61%). All irrigation lands are divided into farm units, the area is about 35-45 du, irrigation projects of the JV are pressurized system, the irrigation network equipped with all necessary equipment to keep pressure and discharge as design. There are four dams (King Talal Reservoir, Shuieb, Kafrain and Wadi Al-Karak) that receive effluents from some WWTP. Since these effluents run through wadies and are mixed with fresh surface water they become blended water. All amounts of water stored in these dams are designated for agricultural use in the JV. The estimated total effluent water draining into these Dams is around 86.7 MCM in 2021, of which 75.81 MCM is received by King Talal Reservoir (KTR) alone.

The industrial sector in the JV, though less extensive than agriculture, is also subject to specific water quotas, which are determined based on the industry's water demand, the potential for recycling and reuse, and the imperative of minimizing environmental impact. Industries related to food processing, chemical production, and others that are critical to the national economy receive allocations that consider both their economic contribution and their water footprint, with increasing encouragement for water-saving technologies and wastewater treatment for reuse (JICA, 2001; MWI, 2016). Other land uses, including residential areas, public services, and environmental conservation, are allocated water quotas that reflect their essential needs and the priority of safeguarding public health and ecosystem integrity. Residential water use, for example, is managed through tariffs and regulations designed to encourage conservation, while allocations for environmental conservation aim to maintain the ecological balance, support biodiversity, and preserve natural habitats, acknowledging

the intrinsic value of these ecosystems and their role in sustaining the valley's environmental health (WHO, 2017; FAO, 2017).

The system of water quotas by land designation in the JV illustrates the complex task of water resource management in a context of scarcity and competing needs. It embodies an approach that seeks to harmonize economic development with environmental stewardship, guided by the principles of sustainability and equity. This requires continuous adjustment and optimization of water use across different sectors, innovative water-saving technologies, and policies that support the efficient and equitable distribution of water resources. Ultimately, the success of this quota system hinges on its flexibility and adaptability to changing conditions, including climate variability, economic development, and shifts in societal values towards water conservation and sustainability.

The Northern part of the JV is dominated by the alluvial aquifer, which extends from the northern shore of the Dead Sea in the south to the downstream part of the Yarmouk River in the north (WIT, 2018). The thickness of the alluvium in the JV varies from a few meters along the eastern boundary to about 750m in the deepest part of the basin near the Jordan River. The lithological composition of the aquifer is extremely heterogeneous. It consists of sand, gravel, conglomerate, sandstone, marl, travertine, limestone and evaporates. The sand and gravel of these deposits form good aquifers especially when they are adjacent to the escarpment foothills and subjected to continuous source of recharge (WIT, 2018). The groundwater occurring in the alluvial fans of the major side wadis account for more than 80% of the available fresh groundwater in the JV. The marl facies of these deposits (Lisan Marl) is the main controlling factor of the groundwater salinity within the Valley and contains several kinds of evaporates such as gypsum and anhydrite (Salameh 2001). The groundwater database identified a total of 121 groundwater wells in this area (Table 2.2).

Table 2.2: Statistics of groundwater wells in North JV area. (WIT,2018)

Total no. of wells	121
Governmental wells	70
Private wells (agriculture)	51
Active wells 2016	14
Active legal wells	5
Total abstraction by active legal wells (2016)	0.533 MCM
Total abstraction by active illegal wells (2016)	0.125 MCM

Based on Water Authority in Jordan (WAJ) records only 5 groundwater wells were active in the 5 years (2012 – 2016) due to the high dependency on King Abdullah Canal water for irrigation and the presence of some illegal wells. During field investigations farmers indicated elevated groundwater salinity was a main reason for the decrease in active groundwater wells in the area (WIT,2018). Data was collected from WAJ and the groundwater regional office of Deir Alla. The database identified a total of 1,174 groundwater wells in the south JV area (Table 2.3).

Table 2.3: Statistics of groundwater wells in South JV area. (WIT,2018).

Total no. of wells	1174
Governmental wells	117
Private wells (agriculture)	1057
Active wells (2016)	301
Total abstraction by active private wells (2016)	11.22 MCM

The freshwater supply system in Israel is almost completely integrated, mixing both natural sources (groundwater aquifers, local springs and the Sea of Galilee in the north) with desalinated water from the Mediterranean Sea and saline groundwater sources. The region of interest is distinct in this system being relatively isolated and relies primarily on three sources, the Sea of Galilee and the Eastern and Northeastern Mountain groundwater aquifers. The long-term average annual recharge (net of evaporation) in the Sea of Galilee is about 350 Million Cubic Meters (MCM) and is subject to large inter-annual fluctuations, which amount to about 70% of the average annual recharge. Extractions from the lake are used both, for the supply of fresh water to the north region of Israel, which for the most part still has no access to seawater desalination capacity, and to Jordan as part of the peace agreement. As a result, annual extraction from the lake varies significantly and is designed to balance between water demand and operational decisions, such as maintaining water level in the lake to allow sufficient available storage for incoming inflows in the winter and avoiding over exploitation during the summer, as well as environmental considerations such as pollution abatement, prevention of eutrophication and the loss of aquatic ecosystems. The water supplied from the lake is about a quarter of the total water used in the region of interest. The main sources of freshwater water supply to the region result from local extractions from the Eastern and Northeastern Mountain aquifers. These aquifers are shared resources between Palestine and Israel and are used in both entities. Consequently, efficient monitoring of groundwater dynamics is hard to achieve. In addition to these geopolitical challenges, this aquifer system is naturally characterized by low connectivity between hydrogeological cells, salinization processes, and large gradient flows to the southeast. As a result, even though annual average recharge to this system is about 350 MCM, the production from local wells as well as groundwater levels and flow of springs in this system is very unpredictable and exhibits large variation in quantity and quality over time. In addition, this region is mostly rural and therefore characterized exclusively with local systems for wastewater treatment and reuse.

The available water resources in the West Bank in Palestine are as follows. Surface water discharge in the wadis during the rainy season amounts to a long-term average annual flow of 24.55 Mm3/yr (Table 2.4). Basin: Most of the recharge areas of the North-eastern Aquifer basin are located within the West Bank boundaries and it has an annual sustainable yield of 100-145 MCM. The Oslo agreement allocated 103 MCM/Y for Israel and 42 MCM for Palestine. There are 89 groundwater wells out of existing 209 wells due to old infrastructure

and the declining groundwater level. In addition, there are 42 main springs that run towards the east to the Jordan River Basin through the eastern wadis of the West Bank. Their long-term annual discharge is about 33 MCM. The most important springs of this group are: Bardala, Far'a, Fasail, Diouk, Nou'meh Ein Sultan and Qilt. Finally, in 2020 according to PWA data, the total quantity of water purchased from Mekorot by the Palestinian communities was 90.3 MCM, which reached 98.9 MCM in 2022. Most of the purchased water is used in the domestic sector.

Table 2.4: Estimated discharge West Bank wadis, 2011/2012 season

No.	Flow Direction	Catchment	Average Runoff (MCM)	2012 Estimated Runoff (MCM)
1	Eastern Wadis Flowing towards Jordan River	Malih-Shubash	0.90	0.97
2		Malih	1.20	1.90
3		Abu Sidra	0.80	1.44
4		Faria	6.40	7.24
5		Al'Ahmar	4.35	3.87
6		Auja	4.60	5.54
7		Nueima	1.70	2.53
8		Qilt	4.20	5.88
9		Marar	0.40	0.45
Total			24.55	29.82

Jericho Governorate has supply for domestic use of approximately 5.4 MCM/yr (with 99.88% of residents linked to a water network) sourced from wells, springs, and strategic water purchases from Mekorot and for agriculture 44 MCM is used mainly from spring (76.5%) and at a lesser extent from wells. One third of the domestic water supply is lost due to network leakage and unauthorized connections and only 3.3% of the total water usage within the commercial sector. The Jericho district boasts six primary wadis, also known as springs, each contributing to the region's water resources. These include Wadi Al-Mallaha, Wadi Al Auja, Wadi Abu Ubeida, Wadi An-Nuw'ema, Wadi Al Qilt, and Wadi Al-Ghazal. Among these, Wadi Al Mallah flows in a north-south direction, while the others traverse east-west paths. Notably, only Wadi Al Qilt maintains a consistent, permanent flow, whereas the remaining wadis exhibit intermittent water flow patterns. The primary source of water for the city of Jericho is the Ein Sultan Spring, which yields an impressive capacity of 650 m3/hr or 5.5 MCM/yr. Of this, 42% is allocated for domestic use, while the remaining 58% supports agricultural activities.

The town of Al' Auja has domestic water supply of 936,593 m3/yr, provided by Mekorot, however only 70% of the residents are connected to the water network. While the Mekorot supply is consistent, summertime often witnesses severe water shortages, prompting residents to supplement their water access with tanker deliveries or resort to saline water from agricultural wells. Approximately 63% of the water is not accounted due to aging

distribution system. Plans are underway to modernize the network, including the construction of water reservoirs water harvesting and floodwaters for agricultural purposes.

The towns of Fasayil and Al Jiftlik, situated in the heart of the Jericho Governorate, rely on an aging and intermittently functioning water distribution network. While residents in both areas are connected to the network, they often experience low water pressure during certain periods, particularly when water demands surge in the Israeli agricultural sector, drawing from the same network. The village of Az Zubeidat relies on the Mekorot system to fulfill its domestic water needs, totaling approximately 86,400 m3 annually. Additionally, the community owns two primary artesian wells primarily designated for agricultural use, each with a capacity of 2000 m3/day.

The Study Area of the Tubas Governorate is limited to Kardala, Bardala and Ein el Beida. Only 26.1% of communities being adequately served or partially served. The available quantity of water for domestic consumption within the governorate is 3.3 MCM/yr with network losses estimated at 1.5 MCM/yr. The governorate relies on two wells for its drinking water supply, however, water from these wells does not reach all towns in the governorate, leaving villages such as Ein el Beida, Kardala, and Bardala without direct connections. These villages have a unique arrangement with Mekorot dating back to the early 1970s where their water cost is partially subsidized by the Palestinian Water Authority (PWA) and Palestinian Authority (PA). Overall, the Tubas stands out as the most deprived Palestinian governorate. Finally, the Tubas Governorate has the third-highest agricultural water supply in the West Bank, with a net water availability of 12.553 MCM/yr. This comprises 10.461 MCM/yr sourced from springs and an additional 2.272 MCM/yr from wells.

Israeli settlements control approximately 53% of the total groundwater abstractions in the West Bank. Mekorot, the Israeli water company, provides approximately 75 MCM/yr of water to settlements in the West Bank, with 44 MCM/yr sourced from wells controlled by Israel within the West Bank. Israel operates 42 abstraction wells within the West Bank, all owned and operated by Mekorot. These wells are predominantly drilled in the Eastern Aquifer in the JV, with a collective capacity of 56.9 MCM/yr. The Israeli wells are typically deeper and yield more water compared to Palestinian wells, exacerbating the drying up of Palestinian wells in close proximity. On average, settlers in the JV are allocated 487 liters per capita per day (l/c/d), nearly twice the allocation of the most water-abundant Palestinian community (e.g., Jericho, with approximately 250 l/c/d) and almost 20 times the average available to Bedouin communities in the West Bank. To illustrate, the water allocated to the 9,400 settlers in the JV (44.8 MCM/yr) constitutes roughly one-third of all the water available to the 2.2 million Palestinians in the entire West Bank.

2.2 Water Supply

Drinking water supply for the Jordanian section of the JV - As of 2023, the JV's municipal water supply, mainly from groundwater sources, is estimated at 23.62 Mm3. This figure suggests an average annual water consumption of approximately 89 cubic meters per person.

The projected demand, calculated at a minimum of 100 cubic meters per person per year for a population nearing 260,000, indicates a shortfall of 2.83 MCM. Additionally, the Ministry of Water and Irrigation (MWI) estimates that 50% of the water is lost due to leakage in the drinking water network, attributed to inadequate maintenance. Consequently, the actual per capita water usage annually is believed to be around 60 cubic meters. To mitigate these losses, upgrading and regular monitoring of the drinking water network are strongly advised. In addition, there is 4 Mm3/yr supply of water for industrial purposes

Irrigation water supply for the Jordanian section of the JV – The total supply of irrigation water for the Jordanian section of the JV is 206.4 Mm3/year. About 133 Mm3/yr of treated wastewater is reused for irrigation (94% of TWW) after mixing with surface water in King Talal dam. In addition, 93 Mm3 of surface water, 73.4 Mm3 in the north King Abdallah Canal, and 19.15Mm3 in the middle Ghors.

Water supply for the Israeli section of the JV - Water consumption in the region is primarily agricultural, where 95% of the 140 MCM consumed annually in the region is used for agricultural purposes. About half of the quantity used in agriculture is saline (or brackish) water, which are used primarily for fish farming in open ponds. In addition, freshwater and treated wastewater are used for crop irrigation and account for about 45%, and 5%, of total agricultural water use in the region, respectively.

The Israeli municipal water supply is estimated at 7.09 Mm3. This figure suggests an average annual water consumption of approximately 174 m3/cap/yr (475 L/cap/day) based on a population of 40780.

The total supply of irrigation water for the Israeli section of the JV is 134.84 Mm3/year. Aquaculture is using 67 Mm3/yr mostly saline water which is close to 50% of the total irrigation water.

Water supply for the Palestinian section of the JV - The freshwater supply in the Palestinian section of the JV originates mostly from local groundwater wells and springs, harvesting of rain water and treated waste water reuse.

The Palestinian annual municipal water supply is estimated at 6.4 Mm3. This figure suggests an average annual water consumption of approximately 109 m3/cap/yr (298 L/cap/day) based on a population of 58698. Losses in the drinking water supply network are in excess of 40-50% of the supply which brings the annual consumption to similar levels as in the Jordanian section of the JV.

The total supply of irrigation water for the Palestinian section of the JV is around 52 Mm3/year. Only 2.3% of the cultivated land is irrigated. Groundwater wells and springs contribute 48.1 Mm3/yr, harvested rainwater 2.7 Mm3/yr and waste water reuse approximately 0.7 Mm3/yr.

Overall the total water supply in the JV is 423.8 Mm3/yr and 90% is used for agriculture and 10% for drinking water and industrial use.

2.3 Water Demand and Near-Future Projections

Looking towards the short-term future (by 2040) for municipal water supply and demand in the JV, projections from the National Water Strategy 2023-2040 estimate the water supply to be around 27.5 MCM. The anticipated demand, calculated on the assumption of a minimum annual water consumption of 100 cubic meters per capita, is expected to be 32.4 MCM. This scenario suggests a modest increase in the deficit from current levels, reaching 4.9 MCM. These figures consider the expectation that the drinking water network will undergo improvements within the next decade, leading to reduced losses and making these estimates more achievable (Table 2.5).

Table 2.5: Drinking water supply and demand in the Jordanian territory of the JV at the current, short, and long terms, National Water Strategy (2023-2030)

Drinking Water (MCM)	Supply	Demand	Deficit
Current 2023	23.62	26	-2.38
Short term	27.5	32.4	-4.9
Long term	34.31	40.3	-5.99

In terms of irrigation, the water supplied from the KAC is approximately 206.42 MCM (Table 2.6). However, the demand, influenced by weather conditions and crop patterns, is estimated to be around 400 MCM. This substantial shortfall, amounting to 193.58 MCM, has been examined. Published documents reveal that many farmers are illicitly using groundwater for irrigation. Therefore, the actual deficit in irrigation water might be less, as suggested by Al Bakri 2021. Satellite data indicates that the estimated use of groundwater for irrigation exceeds the official records: in the Northern JV, the difference is 18.2 MCM, and in the Middle-South JV, it is nearly 22.5 MCM more than what is recorded by the Ministry of Water and Irrigation (MWI), (Al-Bakri, 2021).

Table 2.6: Irrigation water supply and demand in JV, current, short, and long terms. (The National Water Strategy (2023-2030).

Irrigation Water (MCM)	Supply	Demand	Deficit
Current 2023	206.42	400	-203.58
Short term	370	400	-30
Long term	370	-	-

On a national scale, over 50% of wastewater generated in Jordan is treated and reused in the JV for irrigation purposes through the KTD and the KAC. This percentage is expected to increase during the coming several years with the additional treated wastewater from the northern governorates. In total about 100 MCM/year of TWW is reused for irrigation in Jordan. This is 94 % of total amount of wastewater treated in Jordan. Jordanian wastewater reuse licenses and standards strictly regulate the reuse of wastewater. In the Northern part of the Lower JV, fresh water is transported through the KAC, which is used for irrigation. Along the way to the south water from various dams is added to the canal.

More to the South, water from the KTD is brought to the canal through 3 water carriers (the Zarqa carriers 1, 2 and 3). The water in the KTD is a mixture of fresh water from the hills and springs, water from the Zarqa River and treated wastewater from Amman and Zarqa. The lower 14.5 km section of the irrigation network of the KAC has never been taken into use. Farms there just use local water resources that contain high salt concentrations. This causes a lot of salinity problems in the agricultural area in this lower part of the Lower JV including soil siltation related problems. In addition, farmers tend to combine large amounts of fertilizers with the use of local wastewater, which adds to the soil deterioration problems.

The Israeli Water Authority (IWA) had initiated several processes in the last decade designed to fulfill the vision stated in its long-term Master Plan (IWA, 2012). These processes comprise both policy changes and infrastructural development plans. Two such processes hold the potential to dramatically impact the availability of water resources in the region and their quality.

Seawater desalination capacity in Israel has more than doubled in the last decade, and is predicted to increase by an additional 25% of current capacity by 2030, bringing the total desalination capacity to 1000 MCM annually. At present, most of the country's desalination plants are connected to the central part of the national system, generally conveying water to the south regions of the country. Growing scarcity conditions in the north regions have accelerated the process of building an additional desalination plant in the north end of the Israeli coastline, enabling supply of desalinated water to regions currently disconnected from the national system, which was designed originally to convey water from the rainy north to the arid south of the country. In addition to the construction of desalination plants in the north, which will reduce the reliance of connected regions on the Sea of Galilee and therefore allow additional availability of water from the lake to the region of interest, there are existing plans to enable the conveyance of water from the national system in the central region of the country all the way up to the Sea of Galilee, increasing the flexibility of using the lake as an operational storage.
The Israeli territory of the JV is meeting the current supply and demand in the area and it is not expected to increase in the future. Table 2.7 presents the supply and demand in the Israeli territory of the JV and their distribution according to their usage.

Table 2.7: Water resources and their distribution according to their usage.

	Supply – Current **[MCM]**	Supply Short term	Supply Long term	Demand - Current	Demand Short term	Demand Long term
Ground and Surface Brackish (Saline) Water						
Municipalities	1.174			1.174		
Industrial						
Irrigation	65.335			65.335		
Livestock						
Total	66.509			66.509		
Treated Wastewater						
Industrial						
Irrigation	11.1982			11.1982		
Total	11.1982			11.1982		
Ground and Surface Fresh Water						
Municipalities	5.9175			5.9175		
Industrial						
Irrigation	58.3073			58.3073		
Livestock						
Total	64.2248			64.2248		
Irrigation water (MCM)	134.8405					
Drinking water (MCM)	7.0915					
Industrial water (MCM)						

The Palestinian communities in the JV is estimated at around 70,000 habitants. The current use of water is reflected and impacted by the political situation in the valley in term of access and control. Based on WHO per capita allocation of 100 liter a day, the current demand for domestic use is estimated at 2.6 MCM not considering the losses which estimated between 40-50%. But due to the valley nature conditions, heat, evaporation and adaptation using air conditioning the current domestic use is quite triple of the demand calculated. The future demands depend on the political development and the status of the valley. Palestinians plan the future of the valley after withdrawal of settlements and settlers and building new cites to absorb returnees to the Palestinians future state. In the optimistic scenario two new cites (overall population of the valley becomes around 0.5 million) are planned and current irrigable lands estimated at 260,000 donum and touristic and industrial activities reveals the

need of a quantities varies between 200-300 MCM. Such amount comes from restoration of the water right from the Eastern Aquifer, from the Jordan River and the reuse of treated wastewater.

The total West bank Palestinian agricultural water use for irrigation is estimated to be 51.8 Mm3/yr. The Jericho and Al-Aghwar irrigation supply is 32.8 Mm3/yr for an irrigated area of 42000 dunums.

Table 2.8: Drinking water supply and demand in the Palestinian territory of the JV.

domestic Water (MCM)	Supply	Demand	Deficit
Current	6.4	-	-
Short term	10.0	-	-
Long term	18.0	-	-

Table 2.9: Irrigation water supply and demand in the Palestinian territory of the JV.

Irrigation Water (MCM)	Supply	Demand	Deficit
Current*	32.8	182**	-149
Short term		-	-
Long term	65.60	200-300***	-135-235

- * Current irrigated land is estimated at around 42,000 dunum
- ** irrigatable lands is estimated at around 260,000 dunum with 700 m^3 per dunum
- *** to meet population growth and development of the valley under the assumption of Israel withdrawal from the valley and the establishment of the Palestinian state.

2.4 Other Considerations

Water Quality - In the JV, particularly on the Jordanian side, the geographical distribution of water resources plays a crucial role in supporting the region's socio-economic activities, including drinking, irrigation, and industry. The primary sources of water in this area are surface water and groundwater. Surface water is predominantly derived from the Jordan River and the Yarmouk River, which are crucial for the agricultural activities that dominate the valley. Groundwater, on the other hand, comes from several aquifers providing essential water supplies for various uses (Salameh & Bannayan, 1993; UN-ESCWA & BGR, 2013). The utilization of these water resources is critical to sustaining the agricultural sector, which is the backbone of the JV's economy. Irrigation consumes the largest portion of the water,

employing both surface and groundwater to cultivate crops in an area characterized by its arid climate. This intensive use of water for agriculture has necessitated the implementation of water-saving technologies and practices, such as drip irrigation, to enhance water use efficiency (Al-Bakri et al., 2013). For drinking purposes, groundwater is the main source due to its generally better quality compared to surface water, which is often affected by salinity and pollution issues. The treatment of surface water for potable use is, therefore, crucial to ensure safety and compliance with health standards. In the industrial sector, water is used in various processes, including food processing and chemical manufacturing, with a preference for groundwater due to its lower salinity levels compared to surface water (JICA, 2001; MWI, 2016).

The quality of water in the JV has undergone significant changes over time, primarily due to over-extraction, pollution from agricultural runoff, and wastewater discharge. Surface water in the Jordan River has seen increased salinity levels. Similarly, groundwater quality has been affected by overuse, leading to the lowering of water tables and the intrusion of saline water in some areas, which complicates its use for drinking and agriculture without adequate treatment (WHO, 2017; FAO, 2017). These dynamics highlight the complex interplay between water availability, use, and quality in the JV. The challenge of managing these water resources is exacerbated by the region's arid conditions and the growing demands of its population and economy.

When Treated Wastewater (TWW) is mixed with surface water to be used in irrigation as blended source of water irrigation, it is expected to have a better water quality than direct reuse. The table below shows the average annual values of different water quality parameters from KAC in 2021, mainly the quality is good to be used in all categories except the cutting flower, also there is a concern about the level of Escherichia coli as for all other TWW of Wastewater treatment Plants (WWTPs).

Infrastructure development - One of the most important projects that is currently under construction aims to reuse of treated wastewater (TWW) in irrigated agriculture in the Northern JV

The objective of the project is to substitute a substantial share of fresh water currently used for irrigation in JV by Treated Wastewater.

The total irrigated area of the North Directorate is about 78,560 du. The TWW will be conveyed by single transmission pipeline from three plants at Wadi Al-Shallaleh, Central Irbid and Wadi Al Arab to a mixing station in the North JV near Wadi Al Arab dam. The TWW discharged from WWTPs is mixed with fresh water and directly inject into the irrigation systems.

A new WWTP near Irbid with a capacity of 13,000 m^3 /day will soon start its operation, in addition to the existing Al-Shlalha WWTP. Near the Wadi Arab Dam the treated wastewater will be mixed in a mixing station and then supplied to farmers to be used mainly for irrigating citrus trees.

Treated wastewater have become the primary water source for irrigation of agricultural crops. From obvious economic reasons, most systems were developed to supply the treated effluent locally, supporting agricultural production in the vicinity of the urban center producing the sewage. However, the distribution of population is not equally dispersed and as a consequence, most of the treated wastewater are produced in the central urbanized region of the country whereas, the larger agricultural production takes place in the rural northeast and southwest periphery. As a result, primarily during the winter months, due to the lack of sufficient storage or conveyance infrastructure, an annually increasing volume of treated wastewater is being discharged to the sea through natural waterways. The IWA has identified this trend in recent years and designed a new national plan to construct conveyance and storage infrastructures in order to try and balance these asymmetries. However, the plan holds several uncertainties regarding cost recovery and the materialization of demand predictions, which delay its implementation.

The majority of towns and villages across the West Bank in Palestine face a notable absence of wastewater networks, compelling reliance on septic tanks and cesspits, as network coverage extends to a mere 32% of the population. Merely 56 communities in the West Bank enjoy connections to wastewater networks, with the majority being only partially connected. It's crucial to acknowledge the pressing need for proper treatment of collected wastewater, a matter of significant concern.

An estimated 93% of all wastewater in the West Bank remains untreated, discharged into neighboring wadis and valleys, ultimately infiltrating aquifers and reaching the Jordan River. Palestinians in the West Bank alone generate approximately 56 MCM of wastewater annually, constituting 62% of the region's total. Of this volume, 32.3 MCM originates from villages, while 23.8 MCM stems from towns and cities across the West Bank.

Since 2010, with easing the JWC restrictions, the Palestinian authority has embarked on building massive regional wastewater treatment plants in most governorates. The plants built since 2010 and added to the only one existed before (Al Bireh wastewater plant) are the following:

- Nablus West WWTP operated since 2013
- Jericho WWTP operated since 2013
- Salfit WWTP operated since 2020
- Tayseer WWTP in operation since 2021
- Hebron WWTP under construction and will be completed mid 2025
- Nablus East under construction
- Ramallah Ein Jaryout WWTP under construction

The waste water treatment plant in Jericho was designed with a capacity up to 10,000 m3/d however due to political reasons it is currently treat up to 2000 m3/d and the discharge is used for palm trees irrigation. Most Palestinian communities lack wastewater treatment and rely on cesspits and septic tanks which are then discharged in nearby wadis. Kardala is an exception because it has a sewage system with 60% however this network discharges directly into Wadi Kardala, and the remaining 10% of households still resort to cesspits or septic tanks.

Desalination of brackish water to achieve acceptable levels of drinking water quality is an important option that is implemented in the West Bank on a limited scale, mostly as pilot projects. In Marj Naaja the the EcoFuture demonstration site will install PV and reoperate an small desalination plant on an existing well with brackish water (around 1000 ppm of salinity). The plan is to mix with treated wastewater and maximize water use for irrigation.

Changes in quotas and land designation

Land changes - Land use distribution in JV according the Jordanian "National Master Plan for the Jordan River Valley, 2016", outlines the current and short-term allocation of land areas across various categories in hectares (ha).

- Uncultivated/Nature Reserves: The current area designated as uncultivated land or nature reserves is 81,029 ha, which is proposed to be reduced in the short term to 67,358 ha. This suggests a shift in land use policy or development plans that might repurpose some of these lands for other uses.

- Agriculture (Irrigated area): The area under irrigation for agricultural purposes is 45,183 ha, and there is no change projected in the short term. This reflects a stable agricultural policy with a sustained commitment to maintaining the current level of irrigated lands for crop production.

- Built-up Area: The built-up area, which includes residential, commercial, and industrial zones, is currently 4,462 ha, with an anticipated expansion to 9,133 ha in the short term. This more than doubling indicates urbanization strategy in the valley.

- Water Reservoirs: Water reservoirs cover 555 ha, essential for water storage and management in the valley, and this area is not expected to change in the short term. The stability of this figure suggests a balance has been found between water storage needs and other land uses.

The proposed changes in land use, particularly the reduction in uncultivated/nature reserves and the expansion of built-up areas, could have significant implications for the region's water, energy, food, and ecosystem nexus. The reduction in natural reserves might impact biodiversity and ecosystem services, which are vital for maintaining the ecological balance and supporting agriculture. The expansion of built-up areas could increase the demand for water and energy, potentially leading to greater stress on these resources. A dynamic landscape is expected where development, agriculture, and conservation efforts need to be carefully balanced to ensure sustainable management of natural resources and the socioeconomic welfare of the valley's inhabitants.

2.5 Synthesis

The total agricultural land in the JV covers 87378 ha and accounts for 34% of the total area. The distribution of agricultural land in the three territories are 51.7% for Jordan, 28.5% for Israel and 19.8% for Palestine. The Jordanian agricultural land is 95% irrigated, the Israeli 70.7% irrigated while the Palestinian only 52.6% of the total agricultural area. In addition, the Israeli territory has 1690 ha of fish farms while the Jordan has 73 ha and Palestine 30 ha. These two activities account for the total agricultural water use of the JV. Table 2.10 presents

a summary of the supply and demand of water for the three territories in the JV. The total agricultural water supply is 374.06 Mm3/yr while the drinking water supply is 37.11 Mm3/yr. The agricultural water uses accounts for 91% of the total water supply where 16% is used for aquaculture and 75% for irrigation. Table 2.11 presents a comparison of the irrigation rate and the drinking water use per capita for the three territories in the JV. The irrigation rate for Israel was estimated to be 385 mm/dunum, for Jordan 623 mm/dunum and for Palestine 360 mm/dunum. The differences in irrigation rates can be explained by the water losses/leakages in the network that is estimated to be about 40% for Jordan and 50% for Palestine. On the other hand, the drinking water use per capita has been estimated to be 443 L/d/cap for Israel, 205 for Palestine and 249 for Jordan. If we account for water losses in the distribution network in Jordan and Palestine, only half of this water is reaching the consumers.

The demand for both drinking and agricultural water use is quite significant in Jordan and Palestine arising the agricultural demand to 715 Mm3/yr in the region and the drinking water demand to 43Mm3/yr. This deficit in the supply and demand of water has prompted the governments of the three territories to develop plans and strategic objectives to reduce its impacts.

Table 2.10: Summary of supply and demand of water for the three territories in the JV

Supply	Unit	Israel	Palestine	Jordan
Agricultural water	Mcm/yr	134.84	32.8	206.42
Drinking water	Mcm/yr	7.09	6.40	23.62
Demand				
Agricultural water	Mcm/yr	134.84	182	400.00
Drinking water	Mcm/yr	7.09	10.00	26.00

Table 2.11: Comparison of irrigation rate and drinking water use per capita for the three territories in the JV

	Unit	Israel	Palestine*	Jordan
Agricultural Area	Km2	249	173	348.9
Irrigated Agriculture	Km2	176	91	331.4
Irrigation water	Mm3/yr	67.8	32.8	206.4
Irrigation Rate	mm/dunum	385	360	622.8
Drinking water	Mm3/yr	7.1	6.4	23.6
Population	cap	43900	70,000	260000
Water use per capita	L/d/cap	443	205	249

Around 11,000 settlers in the Palestinian JV not included

The Jordanian government's vision and considerations for the future of municipal, industrial, and irrigation water in the JV are encapsulated in the National Water Strategy 2023-2040.

This comprehensive strategy aims to address key challenges such as water scarcity, population growth, and climate change.

Key elements of the strategy include:

- Reducing Water Loss: The plan targets a 2% annual reduction in water loss, aiming for a 25% reduction by 2040. This is crucial for preserving valuable water resources.
- Enhancing Energy Efficiency: The strategy seeks to improve energy efficiency and reduce associated costs in water management, promoting the use of alternative energy sources.
- Exploring Non-Conventional Water Sources: The strategy emphasizes the exploration and implementation of non-conventional water sources. This includes projects like the National Water Carrier Project, which are essential for boosting water supply and sustainability.
- Improving Drinking Water Supply Efficiency: A significant focus is on enhancing the efficiency of drinking water supply systems.
- Expanding Wastewater Treatment for Irrigation: There is an emphasis on the expansion of wastewater treatment facilities, which would be instrumental in meeting the water requirements for agriculture, industry, and tourism.
- Effective Management System Building: The strategy highlights the importance of building an effective management system to tackle climate change and minimize groundwater depletion.

These initiatives are part of a broader effort to ensure sustainable water management and supply across various sectors in Jordan. The strategy underscores the need for modernizing water sector institutions, streamlining processes, and saving costs to improve governance, management, and operation in the water sector.

The implementation of this strategy involves collaboration among various stakeholders, including government ministries, the private sector, donors, academic institutions, and civil society organizations. These efforts are in alignment with His Majesty King Abdullah's vision for long-term water security in Jordan. The National Water Strategy 2023-2040 represents a proactive and forward-thinking approach to addressing the complex water challenges in Jordan, including those in the JV.

The Israeli Water Authority produced for the first time a long-term strategic Master Plan (IWA, 2012) designed to define long-term objectives, the list of related areas and action plans related to each such topic to support the main vision of the plan. The stated vision of the plan is as follows: “Water is an existential basic need for man and the environment. The water sector comprises a strategic infrastructure for Israel and an essential factor in its development and achieving its national goals as a Jewish, Zionist and democratic State. These include developing and maintaining agriculture, building new settlements, land conservation, strengthening the periphery and the development of the national economy. Management and sustainable development of the water sector will be carried out professionally, efficiently,

fairly and transparently, in accordance with advanced criteria, for the benefit of the public and for the preservation of its health. The natural water sources will be rehabilitated and preserved. The Israeli national water sector will serve as a global center of knowhow for water-related technologies and innovations, water-related professional advancement, and exemplary groundbreaking management of water resources in shortage conditions" (IWA, 2012).

In view of this vision, the authors of the plan listed 16 sub-topics, in which action plans are laid out throughout the plan's documents. A partial list of these topics includes, realization of national goals, governance, economic regulation, management of natural resources, freshwater system, wastewater and effluent, runoff and drainage, as well as, uncertainty, water quality and interlinkages with demand sectors (urban and agriculture) and other sectors in the economy such as energy and the environment. Since the introduction of the Master Plan several of these action plans have already been put in motion. For example, seawater desalination capacity, which more than doubled in the last decade has been utilized to its limits over a sequence of recent years, relieving the pressure on natural aquifer systems allowing them to rehabilitate and for groundwater levels to rise. Another prominent effort of the IWA in recent years is related to pricing policies. Specifically, as part of its objective to reduce cross-sector subsidization and to recover the full cost of the water sector, the IWA are currently engaged in a negotiation process with the Ministry of Finance, the Ministry of Agriculture and Rural Development, with farmers and farmers' organizations regarding the future path of water prices to agriculture.

The Palestinian part of the JV is under Israeli control with 90% as restricted area. Only Jericho area is under Palestinian jurisdiction. Access to water and land is subject to permeant status negotiation including water rights from the Jordan River and the Aquifer. The Palestinian future plan of the valley include the following:

- Jordan river - allocation estimated at around 250 Mm3/yr
- Dead sea and Fashkhah spring - around 100 Mm3/y
- Access to area currently classified as C to build new cites for absorbing returnees
- Irrigating an additional of 260,000 donum
- Building West Ghor Canal parallel to the East Ghor canal known as King Abduallah Canal
- Reuse of treated wastewater from Jericho, Tayseer WWTP, Nablus East and West WWTP and Piping treated wastewater from Al Bireh WWTP to Al Auja area.
- Developing solar energy stations and building agro industrial parks along the valley.

3. Energy Resources Mapping

3.1 Energy Resources Mapping in Jordan

3.1.1 Current Situation

According to the National Water Strategy 2023 - 2040 Summary for Jordan (2023) and as illustrated in Figure 3.1, a striking correlation emerges, revealing that the electricity cost for water closely mirrors the total revenues generated from all water bills. This stark relationship underscores the substantial impact of energy costs on the overall financial dynamics of the water sector. The convergence of these two key metrics provides a clear and insightful depiction of the significant role played by energy expenses in shaping the economic landscape of the water sector.

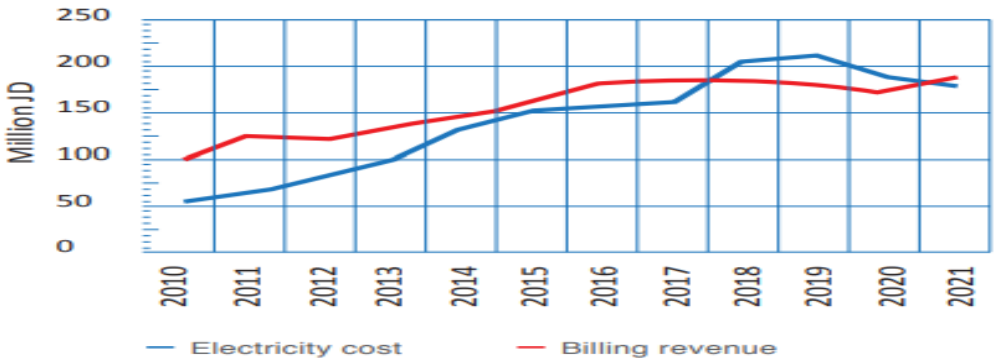


Figure 3.1: Electricity cost and billing revenues during the period 2010-2021

The Energy & Minerals Regulatory Commission (EMRC) stated in its Statistical Year 2022 data that the electricity consumption for water pumping, including agriculture, reached 2576 GWh. This figure accounts for around 14.6% of the country's total electricity consumption, which amounted to 17691 GWh during the same period. As an illustrative example from the JV, consider the energy-intensive process of pumping water from Deir Alla, situated 200 meters below sea level, to Zay station, located at an elevation of 889 meters above sea level. The substantial difference in altitude, known as static head, necessitates a considerable amount of energy for the pumping process

Referring to the "Utilities Performance Monitoring Report 2020" from the Ministry of Water and Irrigation, key data are drawn, depicted in table (3.1) and analyzed. The table shows the electricity expenses and its percentage from the total Operation and Maintenance (O&M) cost over three years (2018, 2019 & 2020). The percentage of electricity to O&M column shows the proportion of electricity expenses in the total O&M expenses for each year. The higher the percentage, the more important the electricity cost is for the O&M budget. The table shows that the electricity expenses and the percentage of electricity to O&M were

consistently high over all years, ranging from 50% to 55%. This means that the electricity cost was a major component of the O&M cost. It is obvious that the electricity cost is a high priority to consider and investigate, Alsaraireh,2018.

Table 3.1: Electricity cost and its percentage from the total Operation and maintenance cost

Year	Electricity expenses in 1000 JOD	O&M Expenses in 1000 JOD	% of electricity to O&M
2018	124082	223867	55%
2019	132298	239098	55%
2020	117241	236396	50%

Noteworthy projects in the JV:

- A project by the Royal Scientific Society that replaced 214 diesel water pumping systems with solar-powered systems in the JV and southern valleys, focusing on climate change mitigation, community engagement, and clean energy adoption.
- The Social Security Investment Fund (SSIF) initiated solar power station projects in Ghor Kabid and Ramah/JV to supply energy to hotels in the Dead Sea area.
- The Tal Almantah wastewater treatment plant implemented a new photovoltaic system, meeting 90% of its electricity requirements.
- IFAD project (2015-2018) with the National Agricultural Research Center (NARC) replaced 40 diesel water pumps with solar-powered electric pumps in addition to 2 solar-powered Desalination units for brackish water in the JV.
- An EU project (2020-2022) with NARC implemented 2 solar-powered Desalination units for brackish water in the JV.
- Implementing Solar photovoltaic projects for dams.
- Water is pumped from Deir Alla, 200m below sea-level, to Zay station, 889m above sea-level, where it is treated before being pumped into the supply networks of Greater Amman.

Key indicators of the NEPCO Annual Report 2022:

- The total cost of kWh sold is; 82.42 Fils/kWh
- High availability of the National Transmission Grid overall Jordan (99.94%),

- Available capacity in renewable (1584 MW) and traditional (4212 MW) sources,
- Peak load for the interconnected system at 4010 MW.

Baselines

According to the Department of Statistics (DOS) data for the year 2022:

- The percentage of the population supplied with electricity is reported to be 99.9%. This figure is comprehensive and nearly includes the entire JV area (JV), suggesting that there is no substantial electricity supply problem or shortage in the JV.
- The demographic distribution of Jordan and the JV is outlined and scrutinized in Table 3.2. The analysis reveals that the JV represents a proportion of 2.626% within the overall population of Jordan.

Table 3.2: Estimated Population of the Kingdom by Administrative Divisions- 2022

Administrative Divisions	Population	Area Km2
	Ref.: DOS, 2022	Ref.; Ministry of Interior
Dair Alla District	86,980	243
Southern Ghor District	64,950	350
Northern Ghor District	144,830	247
JV(JV) total	296,760	840
Total for Jordan	11,302,000	89342
% of JV	2.626%	0.94%

Based on the previous data and in light of the extensive electricity network that spans the entirety of Jordan and recognizing the limited availability of specific information pertaining to the JV, this study endeavors to provide a holistic overview of the electricity landscape in Jordan. Given the inherent challenges in obtaining detailed data for the JV, the study adopts a pragmatic approach. By utilizing the population percentage as a reliable metric (2.626%), the study aims to extrapolate and estimate specific figures for the JV based on the broader national statistics. This methodology ensures a comprehensive understanding of the overall electricity scenario in Jordan, while concurrently acknowledging the unique circumstances and considerations associated with the JV. By anchoring the analysis in population-based proportions, the study endeavors to provide a nuanced and realistic portrayal of the electricity dynamics within the JV region.

3.1.2 Near-future projections

The water sector, encompassing diverse processes such as water abstraction, transport, distribution, irrigation systems, and water treatment, including desalination, operates with a significant demand for energy. The energy-intensive nature of these operations, primarily driven by electricity consumption, notably for pumping purposes, has witnessed a pronounced surge in recent decades. Groundwater abstraction, a critical facet of water resource management, involves the consumption of energy, with the energy requirements escalating in tandem with well depth. As the demand for water grows, there is a concurrent increase in the over-exploitation of aquifers, resulting in a decline in water tables and a subsequent rise in associated energy consumption. This situation is further exacerbated by water shortages induced by droughts, where the energy-intensive nature of groundwater sources becomes evident compared to surface water resources. Sewerage systems, integral to wastewater management, contribute significantly to the overall energy consumption in the water sector. The ever-growing volume of wastewater, driven by population growth, increased water usage, and the expansion of sewerage systems, adds to the escalating energy consumption. Within wastewater treatment plants (WWTPs), the complexity of the treatment process directly correlates with energy demands. Key components such as aeration, pumping, and solids processing constitute the majority of electricity needs. Additionally, factors including climate conditions, inlet and outlet parameters, system size and age, and specific design characteristics intricately influence the energy intensity in WWTPs and sewerage systems.

The energy-intensive dynamics extend to the desalination process, a pivotal aspect of water supply in certain regions. Notably, Reverse Osmosis (RO) desalination plants exhibit electricity demands ranging from 0.5-2.5 kWh/m^3 for brackish water and 5-9 kWh/m^3 for seawater. Meanwhile, Multi-Stage Flash (MSF) systems necessitate 1.2-5 kWh/m^3 of electricity and 25-120 kWh/m^3 of heat. Despite the prevailing utilization of RO as the primary desalination technology in Jordan, mostly powered by the electric grid, there is a scope for exploring renewable energy technologies, such as solar collectors, photovoltaic (PV) systems, or wind power, especially in decentralized applications in rural off-grid areas.

The domestic water supply in Jordan is plagued by deficiencies, marked by intermittent availability. This intermittent supply not only leads to increased pipe burst and corrosion but also results in water and energy losses. Furthermore, the Non-Revenue Water (NRW) associated with damaged equipment, inadequate maintenance, non-working meters, and unauthorized connections accounts for significant water supply losses in the domestic sector. Efforts to enhance energy efficiency across the water sector can contribute significantly to reducing primary energy consumption. Strategies encompassing the improvement of operation and maintenance (O&M), optimization of processes through monitoring and control systems like SCADA, and the upgrading of equipment in water facilities hold immense potential to increase efficiencies and reduce losses. The integration of renewable energy into

water utilities presents an opportunity for low-carbon water production. In particular, off-grid renewable energy holds promise in promoting rural electrification, water pumping, and irrigation, thereby contributing to low-carbon food production. The integration of renewable energy into water utilities represents a pivotal avenue for achieving low-carbon water production. The implementation of off-grid renewable energy production holds significant potential in fostering rural electrification, facilitating water pumping, supporting irrigation practices, and promoting low-carbon food production.

In the context of decentralized systems, their coupling with user-scale energy systems is particularly noteworthy for covering the energy needs associated with water treatment at the source. This integration not only enhances energy efficiency but also contributes to the overall sustainability of water resource management. To ensure responsible and controlled utilization of water resources, especially in systems coupled with water-pumping, the implementation of net metering schemes or analogous strategies is strongly advisable. Such monitoring and regulation mechanisms play a pivotal role in limiting and controlling the exploitation of water resources, fostering a harmonious balance between energy needs and sustainable water management practices. This multifaceted approach underscores the importance of aligning renewable energy integration with strategic measures to safeguard water resources, thereby fostering a resilient and sustainable water-energy nexus.

As shown in Table 3.3, based on the data from the Ministry of Water and Irrigation (MWI), as referenced in the "Energy Efficiency and Renewable Energy Policy for the Water Sector, 2020 – 2030," the total billed water in the JV (JV) in 2019 amounted to 182,420,000 cubic meters, with an associated electricity consumption of approximately 49,300 megawatt-hours (MWh). Assuming a non-revenue water percentage of 50%, the estimated water produced is approximately 364,840,000 cubic meters. This leads to an energy consumption per unit of water produced at a remarkably low rate of 0.135 kWh/m^3, which stands as the lowest in Jordan. In comparison, the national average for Jordan in the same year was significantly higher, at 3.4 kWh/m^3. The significant disparity in energy consumption per unit of water between the JV and the national average, with the JV demonstrating a notably lower value of 0.135 kWh/m^3 compared to the national average of 3.4 kWh/m^3 in 2019, implies that the energy cost associated with water pumping for irrigation in the JV does not have a highly impactful effect on the overall cost of agricultural products.

Table 3.3: Water produced and Non-Revenue Water for 2019 (Ref.; MWI, 2021)

Utility / WSC	Water Produced (m^3)	Water Billed	NRW (m^3)	NRW %	Total (GWh/yr)	(kWh/m^3 billed)	(kWh/m^3 Produced)
Miyahuna Amman[1]	200,059,000	122,657,143	77,401,857	38.7	968.2	7.9	4.8
Miyahuna Zarqa	60,978,011	23,443,466	37,534,545	61.6	99	4.2	1.6
Miyahuna Ma'daba	10,152,003	5,412,600	4,739,403	46.7	38.6	7.1	3.8
Miyahuna (Overall)	271,189,014	151,513,209	119,675,805	44.13	1,106	7.3	4.1
YWC[2]	99,164,018	53,008,437	46,155,581	46.5	336.4	6.3	3.4
WAJ-Balqa	41,814,100	13,053,706	28,760,394	68.8	54.8	4.2	1.3
WAJ-Karak	22,514,996	7,513,267	15,001,729	66.6	70.8	9.4	3.1
WAJ-Tafileh	7,883,273	2,841,490	5,041,783	64	21.2	7.5	2.7
WAJ-Ma'an	15,551,332	4,221,331	11,330,001	72.9	25.1	5.9	1.6
AWC[3]	27,114,087	17,102,992	10,011,095	36.9	37.3	2.2	1.4
Total potable water[4]	485,230,820	249,254,432	235,976,388	48.6	1,654.4	6.6	3.4
JVA	NA	182,420,000	NA	NA	49.3	0.27	NA

[1] Electric consumption for Disi project and Samra were added to Miyahuna Amman for this calculation
[2] YWC is comprised of several departments which are Irbid, Jerash, Ajloun, and Mafraq
[3] About 5 GWh/yr of AWC energy consumption is used up for operation contracts of WWTP outside Aqaba
[4] Energy consumption of 3.0 GWh/yr is added for central administration buildings to the total energy use

Water pumping stations in the JV

Within the King Abdallah Canal (KAC) network, there are six strategically positioned pumping stations located at various turnouts. These stations play a critical role in pumping irrigation water from the canal and facilitating its transfer to the farms. To gain insight into the energy dynamics of these pumping stations, the JVA provided data outlining the monthly power consumption of the existing pumping stations for the years 2019 and 2020. By leveraging this information, an estimate of the average annual power consumption for all pumping stations was derived, as detailed in Table 3.4.

Table 3.4: Annual Energy Consumption of Pumping Stations at T.OFs between 72 – 95 (Ref.: JV Water Resources Efficiency: Environmental and Social Impact Assessment Study Report, 2021)

Turn Out #	(2019) Energy Consumed as Received from JVA (kW.h/ year)	(2020) Energy Consumed as Received from JVA (kW.h/ Year)	Estimated Average Power Consumption (kW.h/year)
72	341,760	405,000	373,380
78	270,720	272,280	271,500
81 & 82	176,160	196,240	186,200
86 &87	578,320	489,040	533,680
91&92	208,400	233,190	220,795
95&96	112,800	277,720	195,260
Total	1,688,160	1,873,380	1,780,770

Solar water pumping in JV

According to information available on the National Energy Research Center website (nerc.gov.jo), a notable project was undertaken involving the replacement of inefficient electrical and diesel irrigation pumps. The initiative aimed at operating a total of 214 water pumps in the JV and southern valleys, along with an additional 106 pumps in the highlands, specifically in Azraq, Mafraq, and Madaba, using Photovoltaic (PV) solar energy. In the JV and Southern Ghor, the water pumps draw water from irrigation ponds at the farms, and these irrigation pumps are supplied with water from the KAC. This water is facilitated through a pumping station and a gravity inlet owned and operated by the JVA. Conversely, in the Highlands (Madaba, Azraq, Mafraq), the pumps draw water from irrigation ponds at the farms, and the irrigation pumps are supplied by water from the water well at the farm. The project aimed to comprehensively assess and address the diverse needs and challenges within an ecosystem, considering elements such as population dynamics, agricultural and industrial activities, climate change impact, and energy and water management. By engaging with all aspects of energy, water, and food security, the project sought to provide a holistic solution to the identified challenges.

Additionally, an IFAD project (2015-2018) with the National Agricultural Research Center (NARC) replaced 40 diesel water pumps with solar-powered electric pumps in addition to 2 solar-powered Desalination units for brackish water in the JV in areas without connection to the electric GRID.

Projection of solar pumping projects in JV

There is a plan for the replacement of 500 surface water pumps, with a capacity of around 7,655 kilowatts, with energy-efficient solar pumps, generating an annual output of 7,655 megawatt-hours. The pumps will be operated by solar photovoltaic.

Potential of Solar Energy resources in Jordan

As per the information available on the National Energy Research Center website (nerc.gov.jo), Jordan is bestowed with a remarkable abundance of solar energy, evident from the annual daily average solar irradiance (insulation intensity on a horizontal surface) ranging between 4-7 kWh/m^2.day This places Jordan among the countries with one of the highest solar irradiance levels globally. Solar energy is extensively harnessed for water heating, especially in the domestic sector where approximately 25% of households utilize this renewable resource. Moreover, solar energy plays a pivotal role in electricity generation through various stand-alone applications employing Photovoltaic systems. Successful implementations include applications such as water pumping, tele-communications, desalination, and lighting for remote sites, showcasing the diverse and effective utilization of solar energy in Jordan.

Global horizontal irradiation

Figure 3.2: is a solar resource map showing the global horizontal irradiation in Jordan. This is a measure of the total amount of solar energy that reaches the Earth's surface per unit area and time. It is useful for estimating the potential of solar power generation in different regions.

The color gradient from yellow to red indicates increasing levels of Global Horizontal Irradiance, which vary from 5.4 to 6.4 kWh/m² per day, and from 1972 to 2337 kWh/m² per year. The highest levels of irradiation are found in the southern and eastern parts of the country, while the lowest levels are in the northern and western areas. This means that the south and east of Jordan have more favorable conditions for solar energy production than the north and west. The JV has an average irradiance between 5.4 to 5.8 kWh/m^2.day. Although it is considered low in Jordan but considerably high in reference to many places in the world. The World Bank Group, ESMAP, and Solargis, using data from the period 1999–2018, created the map.

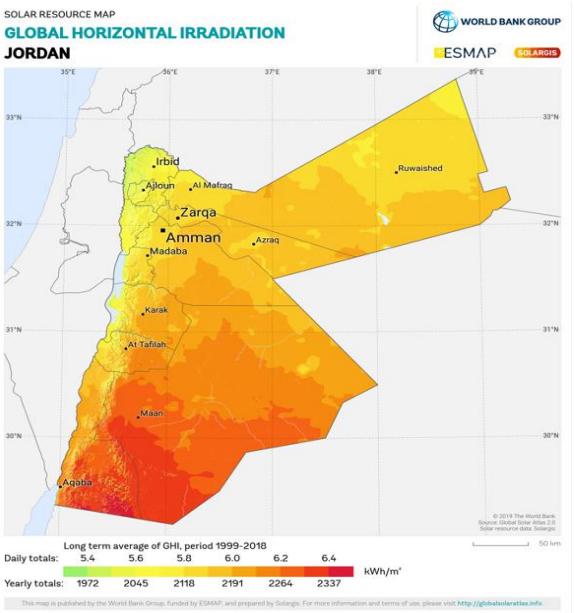


Figure 3.2: Global horizontal irradiance distribution in Jordan

Direct normal irradiation

Figure 3.3 is a solar resource map that shows the direct normal irradiation (DNI) in Jordan. DNI is a measure of the amount of solar energy that reaches the Earth's surface per unit area and time from a beam of sunlight coming from a specific direction. It is useful for estimating the potential of concentrated solar power (CSP) systems, which use mirrors or lenses to focus sunlight onto a receiver.

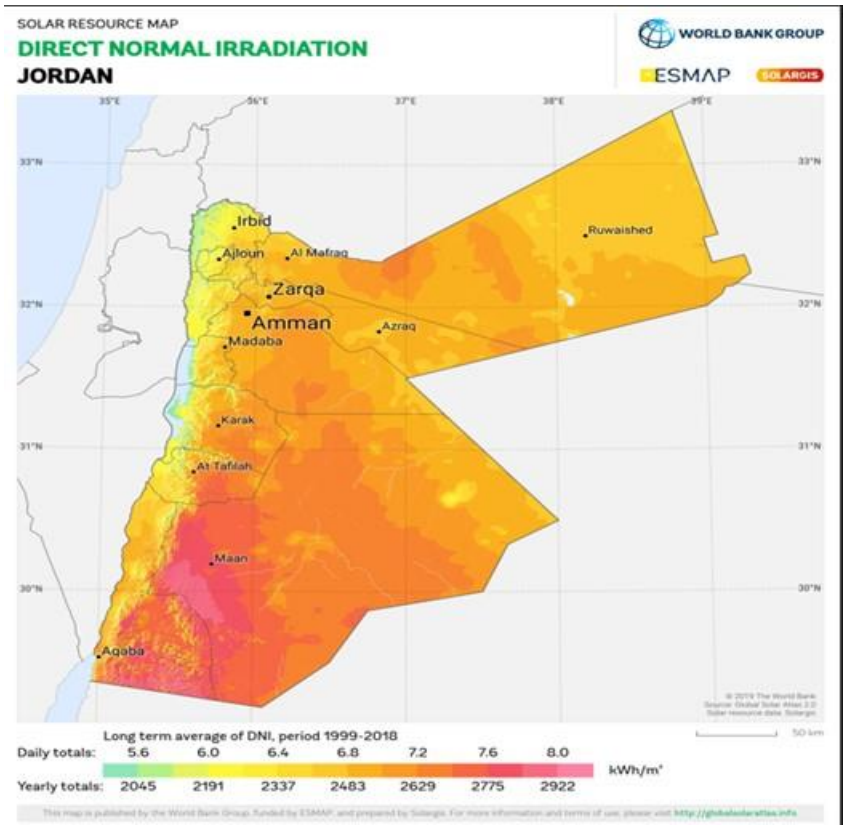


Figure 3.3: The direct normal irradiation in Jordan

According to the map, the DNI in Jordan varies from 5.6 to 8.0 kWh/m² per day, and from 2045 to 2922 kWh/m² per year. The highest levels of irradiation are found in the eastern and southern parts of the country, while the lowest levels are in the northern and western areas. This means that the east and south of Jordan have more favorable conditions for CSP development than the north and west. According to the map, the direct normal irradiation (DNI) in the JV area varies from 6.0 to 7.2 kWh/m² per day, and from 2191 to 2629 kWh/m² per year. The World Bank Group, ESMAP, and Solargis, using data from the period 1999–2018, created the map.

Potential of PV Power Output

Figure 3.4 is a solar resource map showing the photovoltaic power potential in different regions of Jordan. Photovoltaic power potential (PVOUT) is a measure of the amount of electrical energy that can be generated by a photovoltaic system per unit area and time. It depends on several factors, such as solar irradiance, temperature, panel orientation, and system efficiency. According to the map, the PVOUT in Jordan varies from 1680 to 2045 kWh/kWp per year. The highest levels of power potential are found in the eastern and southern parts of the country, while the lowest levels are in the northern and western areas. This means that the east and south of Jordan have more favorable conditions for photovoltaic development than the north and west. According to the map, the photovoltaic power potential (PVOUT) in the JV area varies from 1753 to 1972 kWh/kWp per year. The World Bank Group, ESMAP, and Solargis, using data from the period 1999–2018, created the map.

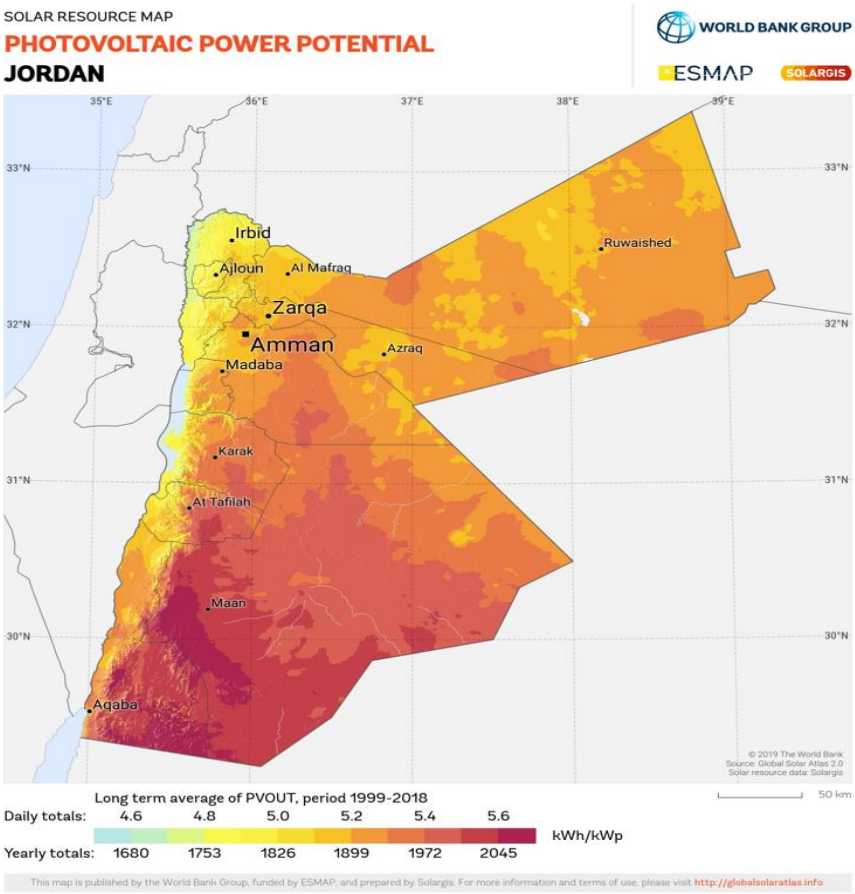


Figure 3.4: PV Power potential distribution in Jordan

Data on wind power in the Irbid area of Jordan including part of the JV. It indicates that the mean power density for the 10% windiest areas at a height of 100m is 330 W/m², which is a moderate to low level of wind resource. Data on wind power in the Balqa area of Jordan including part of the JV (Southern Shouna) indicates that the mean power density for the 10%

windiest areas at a height of 100m is 329 W/m², which is a moderate to low level of wind resource (WB, 2018).

Energy for agriculture

The agricultural sector is a substantial consumer of energy, with both direct and indirect dependencies on energy playing a crucial role. Any disruption or challenge in the energy sector, such as reliance on fuel imports or intermittent electricity services, can impact the ability to provide consistent water services and ensure food safety. The energy input in agriculture is intricately linked to the level of technological adoption and production levels. In Jordan, the ongoing modernization of agriculture, essential for meeting the food demands of the growing population and enhancing productivity and water efficiency, is also leading to an increased demand for energy. This heightened energy requirement can have long-term implications for climate change. Agricultural and water-pumping systems can be integrated with renewable energy technologies utilizing the abundant solar energy resources.

The Ministry of Water and Irrigation (MWI) estimated an average energy consumption of 3.4 kWh/m^3 in 2019, with significant variations in specific energy-water ratios for the Water Authority of Jordan (WAJ) and the JVA, ranging from 9.4 kWh/m^3 to 0.27 kWh/m^3, respectively. These differences may be attributed to factors such as extensive pumping needs over long distances and altitudes, water source variations (surface water pumping typically requiring less energy than groundwater pumping), treatment methods, intended end-use, topography, or the amount of water loss in the system.

In terms of agriculture for energy, the interlinkage often involves producing gaseous or liquid biofuels from crop residues, specific crops, wild plants, algae, or agro-industrial wastes. Future considerations should primarily focus on waste-to-energy technologies based on agro-industrial, human, and animal residues as secondary energy sources. This approach is preferred due to the water and energy consumption involved in cultivating and processing crops, as well as the essential need to cover scarce water resources. Waste-to-energy strategies not only produce energy but also reduce the quantities of waste requiring final disposal, which, in turn, also demands energy.

As previously mentioned, importing agricultural products serves as a virtual supply of water and energy, thus avoiding some of the energy consumption associated with agricultural production. Conversely, by exporting agricultural products to international markets, the embedded energy in food is also exported. While pressurized irrigation systems offer benefits, including increased productivity, they come with higher energy inputs and a larger environmental footprint. The initial cost and ongoing energy expenses associated with these systems make them prohibitive for small farmers, limiting their widespread adoption.

Electricity

Tables 3.5 and 3.6 provide a comprehensive overview of the electricity sector in Jordan. Estimated values for the JV are calculated based on the assumptions discussed in the baseline section above. Key insights derived from this table include:

- The total generation of electric energy in Jordan including JV increased by 7.9% from 2021 to 2022.
- The most dominant source of electric energy in both regions is combined cycle, which accounts for 64.2% of the total generation in Jordan including JV.
- The second most dominant source of electric energy in both regions is solar - transport network, which accounts for 15.6% of the total generation in Jordan including JV.
- The least dominant source of electric energy in both regions is hydro, which accounts for only 0.1% of the total generation in Jordan
- The source of electric energy that had the largest increase in generation from 2021 to 2022 was **steam**, which increased by **three times** overall Jordan.

Table 3.5: General Data on Electric Energy in GWh

	Jordan			JV		
	2021	*2022	Reference	2021	2022	Reference
Total Generation	21924.2	23654.0	DOS	575.73	621.15	Estimated
			DOS	0.00	0.00	Estimated
Steam	327.8	1301.4	DOS	8.61	34.17	Estimated
Diesel gensets	702.0	1127.0	DOS	18.43	29.60	Estimated
Simple cycle	490.2	498.5	DOS	12.87	13.09	Estimated
Combined Cycle	14277.6	13947.7	DOS	374.93	366.27	Estimated
Wind	1628.1	1783.9	DOS	42.75	46.85	Estimated
Hydro	18.3	19.1	DOS	0.48	0.50	Estimated
Biogas	3.5	3.5	DOS	0.09	0.09	Estimated
Solar - transport network	2206.7	2267.7	DOS	57.95	59.55	Estimated
Solar - distribution network	1300.0	1605.2	DOS	34.14	42.15	Estimated
Total electricity generation	20954.2	22554.0	DOS	550.26	592.27	Estimated

Table 3.6: General Data on Electric Energy in GWh (continued)

	Jordan			JV		
	2021	*2022	Reference	2021	2022	Reference
Big Industries	970.0	1100.0	DOS			
Consumed energy (GWh)	19311.0	20577	DOS			
Losses %	13.0	13.30	DOS			
Fuel consumption in electricity1000 Toe	3136.4	3311.9	DOS			
Peak load (MW)	3770.0	4010	NEPCO			
Available Capacity (MW) traditional	3977	4212	NEPCO			
Available Capacity (MW) Renewable	1564.0	1584	NEPCO			
Purchased electricity (GWh)	19619	20763	NEPCO			
Sold Electrical Energy (GWh)	19281	20446	NEPCO			
Wheeling Energy (GWh)	77	119	NEPCO			
Transmission Losses (%)	1.72	1.94	NEPCO			
Total Cost of kWh sold (Fils/kWh)	77.21	82.42	NEPCO	77.21	82.42	NEPCO
Cost of Energy Purchased (Fils/kWh)	67.58	71.33	NEPCO	67.58	71.33	NEPCO
Other Costs (Fils/kWh)	9.63	11.09	NEPCO			
Revenues (Fils/kWh)	68.1	66.78	NEPCO			

Consumed electricity by usage

Table 3.7 shows the electricity consumption by usage for the years 2021 and 2022 in Jordan. The data is sourced from the National Electric Power Company. The table has five types of usages: Household, Industrial, Commercial, Water Pumping, and Street Illumination. Each type of usage has the amount of electricity consumed in GWh and the percentage of total consumption for both years as well as the percentage increase.

Some observations from the table are:

- Approximately 14% of Jordan's total electricity consumption is attributed to water pumping, primarily serving the water and agriculture sectors. This percentage has seen a

slight decrease of 2.9% from 2021 to 2022, due to the implementation of energy efficiency measures.

- The total electricity consumption increased from 19311.3 GWH in 2021 to 20,577.1 GWH in 2022, which is a growth of 6.55%.
- Household usage was the largest consumer of electricity in both years, accounting for nearly half of the total consumption. It also increased by 6.1% from 2021 to 2022.
- Industrial usage was the second largest consumer of electricity, but its share of total consumption remained almost constant at around 21%.
- Commercial usage saw the highest growth rate of 44.5% from 2021 to 2022, increasing its share of total consumption from 14.5% to 14.7%.
- Street Illumination usage was the smallest consumer of electricity, with only about 2% of total consumption in both years. It increased by 5% from 2021 to 2022.

Table 3.7: Consumed Electricity by Usage, 2021 & 2022 (Source: National Electric Power Company)

Usage	2021		*2022		percentage of increase
	GWh	Percentage of Total	GWh	Percentage of Total	
Household	9,296.4	48.1	9,862.6	47.9	6.09%
Industrial	4,048.0	21	4,370.1	21.2	7.96%
Commercial	2,808.9	14.5	3,019.3	14.7	7.49%
Water Pumping	2,769.4	14.3	2,916.9	14.2	5.33%
Street Illumination	388.6	2	408.2	2.0	5.04%
Total	19,311.3	100	20,577.1	100	6.55%
*Primary + Appreciation					

Development of electrical energy purchases 2018-2022

Table 3.8 shows the electrical energy purchases made by NEPCO, the National Electric Power Company in Jordan, from 2018 to 2022. The table has five categories of energy sources: Traditional, Oil Shale, Renewable, Imported, and Others. Each category has subcategories that represent specific projects or companies that supply the energy. The table also shows the percentage share and the yearly average change of each category and subcategory.

Some interesting facts that can be derived from the table are:

- The Traditional Projects category had the highest share of purchased electrical energy in 2022, with 74.74%, but also had a negative yearly average change of -2.40%.
- The Renewable energies contribution reached 19 % by 2022.
- Excluding the Oil shale, the Wind Energy subcategory had the highest yearly average change among all subcategories, with 41.80% followed by solar 36.96%.

Table 3.8: NEPCO's Electrical Energy Purchases (GWh) (Ref. NEPCO Annual Report 2022)

	2018	2019	2020	2021	2022	2022 percentage share	Yearly average change
A- Traditional Projects	17164	16793.9	15768	15261.1	15518	74.74%	-2.40%
B- Oil Shale – Atarat Projects	--	--	--	183.5	993	4.78%	441.14%
C- Renewable Projects	1541.6	2215.7	3024	3758.1	3970.5	19.12%	39.39%
- Wind Energy	705.4	874.5	1378.8	1595.5	1748.2		36.96%
- Solar Energy	836.2	1341.2	1645.2	2162.6	2222.3		41.44%
D- Others	18.8	23.8	21.6	21.3	19.2	0.09%	0.53%
- KTD	14.1	18.4	18.3	18.7	19.1		8.87%
- Indo-Jordan Chemical Co.+ Fertilizer Co.	4.7	5.4	3.3	2.6	0.1		-24.47%
E- Imported Energy / Egypt	188.3	239.3	380.6	394.8	262.5	1.26%	9.85%
Total Energy Purchased	18912.7	19272.7	19194.2	19618.8	20763.2	100.00%	2.45%

Development of electrical energy sales 2018-2022

Table 3.9 shows the electrical energy sales made by NEPCO, the National Electric Power Company in Jordan, from 2018 to 2022. There are six categories of consumers and distributors of electrical energy: Distribution Companies, Large Consumers, Exported Energy, Jerusalem Co (Jericho), Iraqi Border (Traabeel), and Others. Each category has subcategories that represent specific projects or companies that receive the energy. The table also shows the percentage share and the yearly average change of each category and subcategory.

Below is a brief summary of the main trends and insights from the table:

- The total electrical energy sales increased from 2018 to 2022, with an average yearly change of +2.57%.
- The Distribution Companies category had the highest electrical energy sales, with a consistent increase over the years and a share of 97% in 2022.

- The Exported Energy category had the highest yearly average change among all categories, with +26 %.

- The Jerusalem Co (Jericho) subcategory had the highest yearly average change among all subcategories, with +20.10%.

Table 3.9: NEPCO's Electrical Energy Sales (GWh) (Ref. NEPCO Annual Report 2022)

	2018	2019	2020	2021	2022	2022 percentage share	Yearly average change
A. Distribution Companies	17985	18391	18349	18679	19811.7	97%	2.54%
JEPCO	11066	11230	11106	11289	12073.5		2.28%
JEPCO /	--	37	45	49	61		21.62%
EDCO	3577	3680	3730	3727	3814.7		1.66%
IDECO	3342	3444	3468	3614	3862.5		3.89%
B. Large Consumers	460	363	324	428	442.3	2%	-0.96%
C. Exported Energy	94	98	190	173	191.5	1%	25.93%
Jerusalem Co. (Jericho)	88	92	184	167	184.9		27.53%
Iraqi Border (Trabeel)	5	6	6	6	6.6		8.00%
D. Others	0.6	0.8	1	0.8	0.8	0%	8.33%
Total	18540	18853	18864	19281	20446.3	100.00%	2.57%

Generation Capacities

Table 3.10 shows the available capacity of generating plant and transmission network in MW, as referenced from NEPCO Annual Report 2022. The table has seven categories of energy sources: Steam, Gas Turbines, Combined Cycle Diesel, Hydro, Wind and Solar. The data presents the years 2018 to 2021.

The main trend that can be observed from the table is that the total renewable energy capacity increased significantly over these years, from 735 MW in 2018 to 1564 MW in 2021, while the total conventional energy capacity remained relatively constant. The solar energy category had the largest growth, from 449 MW in 2018 to 938 MW in 2021

Table 3.10: Available Capacity of Generating Plant / Transmission Network (MW) (Ref. NEPCO Annual Report 2022

Year	Steam	Gas Turbines	Combined Cycle		Renewable Energy			Total	
				Diesel *	Hydro	Wind	Solar	Renewable	Conventional
2018	605	83	2740	814	6	280	449	735	4242
2019	605	83	2740	814	6	369	637	1012	4242
2020	363	83	2740	814	6	518	887	1411	4000
2021	363	60	2740	814	3.6	622	938	1564	3977
*** HFO, Diesel, NG**									

Table3.11 compares the available capacity of generating plants between conventional and renewable energy from 2018 to 2021, as referenced from NEPCO Annual Report 2022. The table shows the total megawatts (MW) and yearly change percentages for both renewable and conventional energy sources. The main trend that can be observed from the table is that the renewable energy capacity increased significantly over these years as discussed before in the previous table. The renewable energy category had a higher yearly change percentage than the conventional energy category in each year. The yearly change is calculated by comparing the current year's capacity with the previous year's capacity and expressing the difference as a percentage.

The table shows that the renewable energy sources had a higher yearly change than the conventional energy sources in each year from 2018 to 2021. This means that the renewable energy capacity increased faster than the conventional energy capacity. The renewable energy sources had a positive yearly change, indicating an increase in capacity, while the conventional energy sources had a negative or zero yearly change, indicating a decrease or no change in capacity. The table also shows that the yearly change for renewable energy sources varied over the years, from 37.69% in 2019 to 10.84% in 2021. This means that the renewable energy capacity growth rate slowed down over time. The yearly change for conventional energy sources also varied, from 0% in 2019 to -0.58% in 2021. This means that the conventional energy capacity decline rate increased slightly over time. It is obvious that the renewable energy sector is expanding more than the conventional energy sector, but the expansion rate is decreasing. The conventional energy sector is shrinking, but the shrinkage rate is not very high.

Table 3.11: Comparison between conventional and renewable of available Capacity of Generating Plant(MW) (Ref. NEPCO Annual Report 2022

	Total		Total	
Year	Renewable	Yearly change	Conventional	Yearly change
2018	735		4242	
2019	1012	37.69%	4242	0.00%
2020	1411	39.43%	4000	-5.70%
2021	1564	10.84%	3977	-0.58%

Sources of electricity production

Table 3.12 shows the sources of electricity production from 2010 to 2022. The table outlines several categories: Peak Load (MW), Atarat Oil Shale, Wind Generation, Solar Generation, Conventional, and Total Production. The table also shows the percentage of change in total production for each year. The % column in the table shows the percentage change in total production for each year. The percentage change is calculated by comparing the current year's production with the previous year's production and expressing the difference as a percentage. The table shows that the total production increased over these years, from 14272 GWh in 2010 to 23654 GWh in 2022, with some fluctuations. The percentage of change also varied over the years, indicating different rates of growth and demand. The highest increase was seen in 2012 with a rise of 13.31%. However, there were significant reductions as well, notably a drop of -1.36% in 2018.

Some of the important figures from the table are:

- The peak load, which is the maximum demand of electricity at a given time, increased from 2564 MW in 2010 to 4010 MW in 2022, with some fluctuations but an overall upward trend. This shows that the electricity demand in the Kingdom has been growing over these years.

- The Atarat, which is a project that uses oil shale to generate electricity, started in 2021 with a production capacity of 187.2 GWh and increased to 1013.3 GWh by 2022. This shows that the Kingdom has been diversifying its energy sources and using its natural resources.

- The wind generation, which is the electricity produced by wind turbines, increased from 0 GWh in 2014 to 1783.9 GWh in 2022, with a significant jump in 2020. This shows that the Kingdom has been investing in renewable energy and harnessing its wind potential.

- The solar generation, which is the electricity produced by solar panels, increased from 0 GWh in 2014 to 3872.9 GWh in 2022, with a steady growth over these years. This shows that the Kingdom has been utilizing its abundant solar radiation and promoting clean energy.

- The conventional, which is the electricity produced by gas turbines, combined cycle, and diesel, decreased from 14272 GHh in 2010 to 16983.9 GWh in 2022, with some fluctuations but an overall downward trend. This shows that the Kingdom has been reducing its dependence on fossil fuels and increasing its share of renewable energy

Table 3.12: Sources of Electricity Production and peak loads

	Peak load (MW)	Source of Electricity Production in GWh					
		Atarat Oil Shale	Wind-generation	Solar generation*	Conventional	Total	% of change
					14272	14272	
2010	2564				14777	14777	3.54%
2011	2680				14647	14647	-0.88%
2012	2790				16596	16596	13.31%
2013	2995				17262	17262	4.01%
2014	2930				18266.5	18266.5	5.82%
2015	3330		121	2	18885.9	19008.9	4.06%
2016	3250		391	422	18851.8	19664.8	3.45%
2017	3320		448	894	19417.1	20759.1	5.56%
2018	3205		719.8	1414.9	18341.3	20476	-1.36%
2019	3380		892.4	2086.2	18051.7	21030.3	2.71%
2020	3630		1406.9	2852	17032.1	21291	1.24%
2021	3770	187.2	1628.1	3506.7	16602.7	21924.7	2.98%
**2022	4010	1013.3	1783.9	3872.9	16983.9	23654	7.89%
Average percentage of yearly production change							4.02%
Source : National Electric Power Company							
solar energy projects on the transmission and distribution networks Including *							
Primary+Appreciation**							

Table 3.13 shows the local production of new and renewable energy from 2009 to 2021. The table demonstrates four technologies: Water, Wind, Solar, and Bio. The table shows the data in tons of oil equivalent (t.o.e) for each year.

The table shows that the local production of new and renewable energy increased over these years, from 136680 t.o.e in 2009 to 614232 t.o.e in 2021, with some fluctuations. The total production is the sum of the production from water, wind, solar, and bio sources.

Some of the details and insights from the table are:

- The water data shows the production from hydroelectric power plants. Data shows modest contribution over the years.
- The wind data shows the production from wind turbines. It starts from 725 t.o.e in 2009 then increases significantly from 2015 onwards. It reaches 117988 t.o.e in 2021, indicating a growing investment in wind energy.
- The solar data shows the production from solar panels. It starts from 120000 t.o.e in 2009 and increases steadily over the years. It reaches 493536 t.o.e in 2021, showing a high potential and popularity of solar energy in the Kingdom.
- The bio column shows the production from biomass sources, such as organic waste, wood, and crops. It remains relatively stable throughout the years, ranging from 1451 t.o.e to 2176 t.o.e. It does not contribute much to the total production compared to other sources.
- The total column shows the total production of new and renewable energy from all sources. It increases over the years from 136680 in 2009 to 614232 in 2021,

Table 3.13: Local Production of New & Renewable Energy, 2009 -2021 (t.o.e)

Year	**Water**	**Wind**	**Solar**	**Bio**	**Total**
2009	14,263	725	120,000	1,692	136,680
2010	14,746	725	124,000	2,176	141,647
2011	13,296	725	130,000	1,934	145,955
2012	14,746	725	130,000	1,451	146,922

2013	13,296	725	145,000	1,451	160,472
2014	14,021	580	152,100	1,451	168,152
2015	12,691	29,749	152,100	1,548	196,088
2016	10,056	94,419	162,400	1,587	268,462
2017	9,186	108,556	344,801	1,587	464,130
2018	9,674	114,912	438,902	1,591	565,079
2019	9,879	115,718	466,861	1,596	594,054
2020	9,987	116,821	485,592	1,603	613,703
2021	1,095	117,988	493,536	1,613	614,232
Source: National Electric Power Company/Annual Report 2021					

Projection of electricity production

Table 3.14 shows the projection of electricity production from 2022 to 2070. The % of change estimated is assumed constant at 4.03% which is the average growth rate calculated from the previous years. The table shows that the total production increases steadily over these years, from 23,654 GWh in 2022 to 157,215 GWh in 2070.

Table 3.14: Projection of electricity production

Year	Total production	% of change estimated
	GWh	
2022	23,654	Base year data
2025	26,627	4.03%
2030	32,434	4.03%
2035	39,508	4.03%
2040	48,126	4.03%
2045	58,622	4.03%

2050	71,408	4.03%
2055	86,983	4.03%
2060	105,955	4.03%
2065	129,065	4.03%
2070	157,215	4.03%

Fuel consumption

Historical data

Some of the main trends can be summarized in the following:

- The total country consumption increased from 7739.0 (000 Ton) in 2009 to 10008.8 (000 Ton) in 2017, but then declined to 8726.0 (000 Ton) by 2021. The highest increase was seen in 2012 with a rise of 10.04%. However, there were significant reductions as well, notably a drop of -7.37% in 2020. Year 2018 is the turnout point in which renewable energy projects start to replace conventional resources leading to decreasing fuel consumption after then.

- The consumption by electricity increased from 3357.0 (000 Ton) in 2009 to 3312 (000 Ton) in 2022, with some fluctuations but an overall upward trend. The most significant increase was 12.49% in 2012, while there was a sharp decline of -7.31% in 2018.

- The percentage of electricity to total consumption started at 43.4% in 2009 and had fluctuations reaching its lowest at 35.9% in 2021.

- The per capita consumption has exhibited a notable decrease from 1190.6 in 2009 to 789.2 in 2022, showcasing a consistent downward trend with some fluctuations. This decline is attributed to the impactful introduction of renewable energy projects, particularly in the year 2018 onwards, along with the successful implementation of energy efficiency measures.

- The crude oil & oil products column shows the consumption of crude oil and its derivatives, such as gasoline, diesel, kerosene, etc. It slightly increased from 4454 t.o.e in 2009 to 5789 t.o.e in 2021. This shows that the Kingdom has been reducing its reliance on oil and its products over these years.

- The natural gas column shows the consumption of natural gas, which is a cleaner and cheaper alternative to oil. It increased from 3086 t.o.e in 2009 to 3768 t.o.e in 2021, with

some fluctuations but an overall upward trend. This shows that the Kingdom has been increasing its use of natural gas over these years.

- The renewable energy column shows the consumption of renewable energy sources, such as hydro, wind, solar, and bio. It increased from 120 t.o.e in 2009 to 787 t.o.e in 2021, with a steady growth over these years. This shows that the Kingdom has been investing in renewable energy and promoting green energy over these years.

- Total consumption is increasing over the years, with some fluctuations. The highest increase is seen in 2012, with a rise of 9.8%. However, there are also some reductions, such as a drop of -5.9% in 2013.

Projection of fuel consumption

The demand for imported fuel is not anticipated to experience a significant increase, and this can be attributed to the following factors:

- Shift Towards Electric Cars: Jordan is actively transitioning towards the usage of electric cars as opposed to traditional fuel-powered vehicles. This shift in consumer preference contributes to a reduction in the overall demand for imported fuel.

- Renewable Energy Expansion: Jordan has strategic plans to augment the share of renewable energy in the electricity sector. By increasing the utilization of renewable sources, such as solar and wind power, the country aims to decrease its reliance on imported fuel for electricity generation.

These initiatives align with a broader trend towards sustainable and environmentally friendly energy practices, reflecting Jordan's commitment to diversify its energy mix and reduce dependence on conventional fuel sources.

3.1.3 Long-term projections

The Energy Strategy outlined by the Ministry of Energy and Mineral Resources (MEMR) reveals several significant findings:

- Energy Dependency Challenges: The report underscores the significant challenges posed by Jordan's heavy reliance on imported energy resources, reaching 93% of the total energy needs in 2018. This dependence is a notable decrease from the 97% reported in 2014.

- Green Corridor Project Impact: The construction and implementation of the Green Corridor Project, connecting Ma’an to El-Qatraneh, stand out as a major achievement. This initiative has substantially increased the electricity transmission capacity from the southern regions to the central areas of the Kingdom, elevating it from 500 MW to an impressive 1400 MW.

- Enhanced Electrical Connections: The report highlights the successful completion and improvement of Jordan's electrical connections with neighboring countries. Ongoing electricity exchange with Egypt has contributed to the stability of Jordan's electrical grid. Additionally, agreements have been reached to increase the export capacity of the Jericho region, negotiations for electricity supply to Iraq are underway, and memos have been signed to establish electrical connections between Jordan, Egypt, and the GCC countries. A recent agreement with Saudi Arabia further solidifies electrical cooperation between the two nations.

- The government approved the National Energy Efficiency Action Plan (NEEAP) for the period 2018-2020. This strategic plan, implemented in collaboration with various partners, aims to enhance energy efficiency by achieving a 20% reduction in energy consumption by 2020 compared to the average consumption during 2010-2016. Aligned with renewable energy initiatives, NEEAP plays a crucial role in mitigating greenhouse gas emissions, contributing to global efforts in emissions reduction.

These findings collectively illustrate Jordan's proactive measures in addressing energy challenges, enhancing infrastructure, and promoting sustainability through efficiency and renewable energy initiatives.

Moreover, the following two tables are concluded:

- Table 3.15 shows the electricity demand forecast for 2020-2030, referenced from the Summary of Jordan Energy Strategy. The percent column in the table shows the percentage change in electricity demand for each period. The percentage change is calculated by comparing the current period's demand with the previous period's demand and expressing the difference as a percentage. The scenario suggests that the electricity demand increases steadily over these years, from 17672 GWh in 2020 to 19701 GWh in 2030.

Table 3.15: Electricity demand forecast for 2020-2030. Ref: Summary of Jordan Energy Strategy 2020-2030, MEMR

	Electricity demand GWh	% of change
Year		
2020	17,672	
2021	17,831	0.9%
2022	17,860	0.2%
2023	17,950	0.5%
2024	17,958	0.0%

2025	18,686	4.1%
2030	19,701	5.4%

- Table 3.16 outlines the projected primary energy demand in Jordan spanning the years 2020 to 2030, as per the "Summary of Jordan Energy Strategy 2020-2030, MEMR". Key insights drawn from this table include:
    - The primary energy demand in Jordan is expected to increase by 17% from 2020 to 2030, reaching 11,760 ton (ton of oil equivalent) in 2030.
    - The average annual growth rate of primary energy demand is projected to be 1.6% over the decade.

Table 3.16: Primary Energy Demand Forecast for (2020-2030) - Ref: Summary of Jordan Energy Strategy 2020-2030, MEMR

	Primary Energy Demand (Overall domestic consumption)	% of change
Year	(toe)	
2020	10,039	
2021	10,267	2.3%
2022	10,420	1.5%
2023	10,595	1.7%
2024	10,668	0.7%
2025	10,967	2.8%
2030	11,760	7.2%

As per the National Master Plan for the Jordan River Valley, the strategic initiative is to plan for and implement renewable energy generation schemes in the Lower Jordan River Basin. This plan takes into consideration the anticipated population growth of 600,000 people by the year 2050. To meet the energy needs associated with this growth, an estimated 1.8 billion kilowatt-hours (KWh) of energy would be required in the year 2050. This highlights the imperative to develop and implement sustainable renewable energy solutions to accommodate both the envisioned population expansion and the energy demands of the region in the specified timeframe.

Energy efficiency opportunities in the water sector

Energy Efficiency in Water Supply and Treatment Facilities; Water supply and treatment facilities play a crucial role in providing essential services but are inherently energy-intensive. The Jordan Ministry of Water and Irrigation's Utilities Performance Monitoring Unit (UPMU) revealed in its Utilities Monitoring Report 2020 that energy costs constitute a significant portion, ranging from 19 to 55%, of total operating costs for water utilities.

Challenges in Energy Use: The inefficiency of energy use in water utilities, including the JV, stems from various factors such as outdated pumping equipment, insufficient equipment maintenance, significant non-revenue water (NRW), and suboptimal distribution and collection system design.

Recommendations for Improvement: To address the current energy inefficiencies, strategic investment projects are proposed, encompassing measures like replacing inefficient pumps, installing variable speed drives, optimizing pumping operations, reducing physical losses, implementing pressure management, improving metering, and integrating renewable energy sources (e.g., solar photovoltaic generation, small hydro, and biogas from sludge).

Energy Efficiency Initiatives: Energy efficiency efforts should commence with water efficiency initiatives, progress to enhancing pump and motor efficiency, and incorporate comprehensive energy management strategies, including intelligent load profiling and balancing. On-site energy generation should be explored where feasible, with a focus on drinking water production and transmission systems, as well as wastewater treatment plants.

Key Energy Consumption Processes: Within the water sector, energy consumption primarily occurs in four key processes: water production, water distribution, sewer systems, and wastewater treatment plants (WWTPs). Each process requires tailored energy efficiency measures to optimize performance.

EU Guidelines and Challenges: The European Union (EU) guidelines set benchmarks for energy use per population equivalent (PE) as 20 KWh/PE/y for plants above 100,000 PE and 35 KWh/PE/y for plants below 10,000 PE. practical challenges often hinder meeting these standards. The annual electricity consumption per PE frequently surpasses the recommended levels, often exceeds 50 per PE, necessitating a comprehensive approach to energy efficiency.

Holistic Approach to Energy Efficiency: A holistic approach to energy efficiency encompasses water efficiency, motor and pump efficiency, energy management practices, and on-site energy generation. This multifaceted strategy provides a comprehensive framework for achieving sustainable energy efficiency in water supply and treatment facilities. The areas of energy efficiency that, taken together, provide a holistic picture of what should be looked at when trying to achieve energy efficiency:

- Water Efficiency: Minimizing water losses to reduce the need for pumping.

- Energy Efficiency: Enhancing motor and pump efficiency, optimizing energy-intensive processes.

- Energy Management: Utilizing SCADA systems, establishing reliable load profiles, optimizing energy procurement, and leveraging reservoir buffers.

- Energy Generation (on-site): Exploring the potential for methane capture, Combined Heat and Power (CHP) production, on-site solar, and micro-hydro generation where feasible.

3.2 Energy Resources Mapping in Israel

3.2.1 Current situation

The JV comprises the eastern section of the Jezreel Valley, known as the Harod Valley, located at the foot of Mt. Gilboa, the area to the west of the Jordan River, south of the Sea of Galilee and north of the Green Line. The JV (JV) lies about 120 meters below sea level, and it has been an important agricultural and tourism region in Israel. Its importance continues to grow, placing additional demands on its essential services, including energy supply.

The JV's current energy mix is generally like that of Israel more broadly, with a combination of renewable and fossil-based resources. Israel's energy mix reflects its islanded electric system and limited trade opportunities for other energy sources with neighboring countries. The JV presents unique opportunities for renewable energy, particularly for photovoltaic systems on existing agricultural and residential structures. It is reasonable to assume that the JV will be one of the regions most likely to meet Israel's targets for renewable electricity generation of 30% and 80% for 2030 and 2050, respectively. Moreover, the diversity of agricultural customers (crops, aquaculture, etc.) concentrated in the JV should foster customization of energy resources, primarily PV, water, and biofuels, to their energy needs. In the case of photovoltaics (PV), the JV has the combination of solar radiation, humidity level, proximity to roads and the Israel electric grid, and distance from built areas (i.e., minimal visual environmental impact) to make it an especially promising area relative to other areas (Schriki et al., 2023). Therefore, the JV offers the opportunity for a more reliable and resilient energy sector, based on a more diverse set of resources and economic trade with neighboring markets. thereby sustainably reducing both the costs and risks of meeting increases in energy requirements.

Key stakeholders, government entities and ministries

As mentioned in D5.1 the energy sector in the JV is subject to the policy directives of Israel's Ministry of Energy and Infrastructure (IMoE), the Electricity Authority (Israel's electricity regulator within the IMoE). The IMoE is responsible for all of Israel's energy sectors and its natural resources, including electricity, fuel, LPG, natural gas, conservation of energy, petroleum explorations, minerals, earth science and marine research and more. The IMoE

supervises the public and private bodies operating in these fields, while regulating the market, protecting the consumer, and protecting the environment[1]. The Electricity Authority regulates the provision of and supervises public services in the field of electricity, and its main functions are setting electricity rates, setting criteria and indicators for the quality of service and electricity for consumers and licensing[2].

The JV includes the regional councils. These regional councils include representation of anywhere between 3 and 54 communities, usually spread over a large area within geographical vicinity of each other. Each community within a regional council usually does not exceed 2,000 in population and is managed by a local committee. Community representatives are either chosen directly or through an election. The predominant form of communities represented on regional councils are kibbutzim and moshavim (Two methods of collaborative rural inhabitance).

The electricity distribution system supporting the JV is under the responsibility of the Israeli Electrical Company (IEC) regional managements: The JV area within the Green Line is served by the IEC Northern Region management.

IEC currently limits renewables' access to these points to 60% of the interconnection capacity of these part of the grid. Therefore, no supplier with total capacity exceeding 15 kW of installed capacity may receive a supplier license by now unless the grid and the transformation sub-station are upgraded.

Electricity

Current situation

The JV area under consideration in our project is currently served by 4 substations feeding the distribution grids at 22KV.

IEC is committed to connecting renewable energy suppliers according to the substation capacity and technology under the restriction of leaving spare capacity of 40% of the substation power capacity feeding the distribution grid. The 40% limit is defined by the ratio of the average power demand to the maximum substation power capacity.

It should be noted that starting 2028 IEC plan to install 5 additional substations in order to enable a vast expansion of renewable energy distributed generation connecting to the grid. However, till their final planning and approval the design data cannot be provided.

[1] https://www.gov.il/en/departments/ministry_of_energy/govil-landing-page
[2] https://www.gov.il/en/departments/the_electricity_authority/govil-landing-page

Table 3.17 – Feasible Renewable-Energy added capacity on the JV distribution grids

Substation	Production technologies	Added Power Production during Day time [MVA]	Added Power Production during Night time [MVA]	Available spare in the distribution grid for production installations [MVA]
1	NG	0.00	0.00	101
	PV	110.02	0.00	
	PVS	39.20	68.77	
	WT	30.11	30.11	
Total		**179.33**	**98.88**	
2	BG	2.37	2.37	49
	PV	4.74	0.00	
	PVS	8.74	12.83	
Total		**15.85**	**15.20**	
3	PV	2.69		55
	PVS	0.00	3.89	
Total		**2.69**	**3.89**	
4	BG	4.67	4.67	66
	PV	81.85	0.00	
	PVS	4.93	16.33	
	WT	10.39	10.39	
Total		**101.84**	**31.39**	
Total of the 4 SS		**299.71**	**149.36**	

Legend:
NG – Natural Gas
PV- Photovoltaic
PVS – PV including battery energy storage
WT – Wind turbines
BG - Biogas

3.2.2 Near Future projections

The near-term future outlook depends on Government decision to ensure compliance with the nationwide renewables target of 30% by the year 2030.

The outlook for the energy sector depends also on developments within the global energy sector, especially in the technologies supporting intermittent renewables, demand response, distributed energy resources and the virtual power plant paradigm. These technologies will include efficiency improvements to inverter-based technologies supporting photovoltaic facilities, distributed energy storage, dynamic line rating applications, and “smart” meters and end-use devices. It should be noted that natural gas will be used only for electricity

generation; a natural gas distribution infrastructure to directly serve end-use customers is not assumed. Nevertheless, biofuels and methane should be expected to replace natural gas to the maximum extent possible. Energy storage will be added to ensure supply-demand balance and frequency regulation; however, there are no assumptions regarding the mix of storage technologies (pumped storage, compressed-air, batteries) used to maintain system balance and frequency. The technologies included will be PV, natural gas/methane-fueled turbines or microturbines, and the storage capacity needed to support that PV.

We envision the need for improved electricity and natural gas delivery systems within an Infrastructure Ring that will optimize supply-side and demand-side resources that will be available after 2030.

3.2.3 Long Future projections

The long-term outlook for JV's energy sector will depend on a combination of changes to the global energy sector, Government targets for renewable resources, and changes to regional geopolitics. In modeling the energy sector, we focus on projected changes to the costs of existing commercial technologies and **achieving the 80%-renewable target currently set by the Government of Israel by 2050**. Natural gas is assumed to be both a resource for electricity generation and as a substitute for more polluting fossil fuels in agriculture and industry. We have not addressed changes to regional geopolitics that could open the JV to energy resources present in neighboring countries but are uncommon or uneconomic in Israel. We have also not addressed hydrogen or newer storage technologies that have not demonstrated their commercial viability.

The table below (Table 3.18) summarizes the current estimated electricity consumption in the JV by customer type (in GWh) by customer type and the electricity consumption forecasts for the years 2030 and 2050.

Table 3.18 – Current and forecasted (Y2030 & Y2050) annual JV electricity consumption [GWh].

	Forecasted Jordan Valley electricity consumption through 2050 (GWh)				
Customer type	**JV Population 2022**	**JV Customers 2022**	**JV consumption - current**	**JV consumption - 2030**	**JV consumption - 2050**
Residential	59,953	18,794	154.5	190.9	349.3
Commercial		448	29.0	35.8	65.4
Water			50.7	67.2	126.5
Agriculture		8,457	147.8	182.6	334.1
Total			**382.0**	**476.4**	**875.4**

The 2nd column in Table 3.19 gives the number of consumers according to their classification.

Table 3.19 - Current annual electricity supply forecast in GWh (by resource type) and demand forecasts (by those resource types) for the years 2030 and 2050.

	Supply			Demand		
Source	Current	Short term (If available) 2030	Long-term (If available) 2050	Current	Short term (If available) 2030	Long-term (If available) 2050
1. Renewable energy (GWh)						
Solar	62.2	147.4	722.0	60.3	142.9	700.3
Water	NE	NE	NE	NE	NE	NE
Wind ..	NE	NE	NE	NE	NE	NE
Biofuel	NE	NE	NE	NE	NE	NE
2. Non Renewable (GWh)						
Crude oil	NE	NE	NE	NE	NE	NE
Gas (calculated as residual)	331.6	343.8	180.5	321.7	333.5	175.1
TOTAL	393.8	491.2	902.5	382.0	476.4	875.4
NE = No estimate for these resources yet exists.						

Table 3.20 - Share of water sector electrical consumption by water usage type to be met by renewable and non-renewable resources.

	Renewable					
	Supply			Demand		
Consumption for water sector	Current	Short term (If available) 2030	Long-term (If available) 2050	Current	Short term (If available) 2030	Long-term (If available) 2050
Drinking	1.2	3.2	17.3	1.2	3.1	16.8
Wastewater	0.4	0.9	3.1	0.4	0.8	3.0
Irrigation	4.3	11.2	56.3	4.2	10.9	54.6
Industrial	2.1	5.6	27.9	2.1	5.4	27.1
TOTAL	8.1	20.8	104.6	7.8	20.2	101.4

	Non-Renewable					
	Supply			Demand		
Consumption for water sector	Current	Short term (If available) 2030	Long-term (If available) 2050	Current	Short term (If available) 2030	Long-term (If available) 2050
Drinking	6.3	7.5	4.3	6.1	7.2	4.1
Wastewater	2.0	2.0	0.8	2.0	1.9	0.7
Irrigation	22.9	26.0	13.9	22.2	25.3	13.5
Industrial	11.4	12.9	6.9	11.0	12.5	6.7
TOTAL	42.6	48.4	25.9	41.3	46.9	25.1

Table 3.21: Main assumptions underlying these energy projections for the JV:

Item	Assumption	Values	Sources
Solar PV – supply and demand	% of total energy	6% in 2022; 30% in 2030; 80% in 2050	Nurit Gal presentation[3] and Israel Environment Ministry[4]
Water sector energy consumption	Total energy consumption for each water use for 2030 and 2050. The water uses are: drinking, irrigation industrial, and wastewater treatment.	Conversion of MCM water consumption to GWh; varies per water use type.	Ecopeace (2015)[5] ; conversion of MCM to GWh based on prior studies.
Agricultural consumption	Number of JV agricultural consumers and electricity consumption based on Israel data		Knesset report on agriculture sector [6]; R&D report on the JV[7]
Forecast of total JV load growth	Average of Bank of Israel, NOGA, and BDO electricity load forecasts	Average of 2.7%, 3.0%, and 3.5%	Average of Bank of Israel[8], NOGA, and BDO forecasts[9]
Biofuel	Current share of agricultural energy consumption[10]; forecasted growth rates[11]		Arava Institute[12]; Israel Central Bureau of Statistics[13] European growth forecast[14]
Natural gas	Exclusive non-renewable fuel deployed after all renewable fuels are deployed.	Calculated as residual.	Israel Energy Ministry[15]

[3] https://unece.org/sites/default/files/2021-12/6.1%20Energy%20Policy%2C%207Dec.pdf
[4] https://www.calcalistech.com/ctech/articles/0,7340,L-3781010,00.html
[5] https://ecopeaceme.org/wp-content/uploads/2022/03/Regional_NGO_Master_Plan_Final.pdf
[6] https://fs.knesset.gov.il/globaldocs/MMM/270ba95d-f71d-eb11-811a-00155d0af32a/2_270ba95d-f71d-eb11-811a-00155d0af32a_11_16452.pdf
[7] http://www.mop-bika.org.il/130651/haklaut_babika
[8] https://boi.org.il/media/mxufzcvv/dp202117e.pdf
[9] https://en.globes.co.il/en/article-as-power-shortage-looms-solutions-lag-1001445866#:~:text=Forecasts%20of%20demand%20for%20power,3.5%25)%20according%20to%20BDO.
[10] https://pubmed.ncbi.nlm.nih.gov/32149195/
[11] https://www.statista.com/statistics/1297018/global-biofuels-market-cagr-by-region/
[12] https://arava.org/wp-content/uploads/2022/04/2021-11_Arava-Institute_Sustainable-transformation-of-Israels-Energy-System_en-digital.pdf
[13] https://www.cbs.gov.il/he/subjects/Pages/%D7%9E%D7%A9%D7%A7%D7%99-%D7%91%D7%99%D7%AA.aspx
[14] https://www.statista.com/statistics/1297018/global-biofuels-market-cagr-by-region/
[15] Per e-mail sent by Chaim Melamed of Israel's Energy Ministry to Shlomo Wald, there are natural gas facilities capable of providing 500 thousand and 400 thousand m^3 per second.

Below are some additional notes on these assumptions:

Solar PV: All PV supply is either: (1) consumed entirely within the JV; or (2) any PV supply exported out of the JV "ring" (See the Synthesis paragraph below) is matched completely by a PV import into the JV. Since we are considering the JV as a "ring" functioning as a closed system to the maximum extent possible, we should consider all solar PV output to be consumed within the JV.

Natural gas

Although, as mentioned above, we assume that natural gas will be used exclusively for generating electricity not provided by renewable resources, we will be addressing natural gas more broadly as a fuel to meet other energy needs of the JV as well. Currently, there are natural gas supply points in the Bet Shean area, both downstream toward Jordan and upstream toward Alon Tavor. There are sites available to construct Pressure Regulating and Metering Stations ("PRMS") to reduce pressure to levels necessary for delivery to end-use gas customers, including power stations. The gas supply flowing from Alon Tavor to Neve Or in the northern section of the JV is about 500 thousand m^3 per hour. Consumption in the area of the Alon Tavor power station varying around 200 thousand m^3 per hour. Similarly, the maximum capacity of Tzemach (South of the Sea of Galilee) customers is around 4 thousand m^3 per hour. More detailed information on plans for the natural gas distribution system is still under discussion.

3.3 Energy Resources Mapping in Palestine

3.3.1 Current situation

From the data supplied the energy supply and demand in the JV (JV) is unknown. Some assumptions are given hereunder for the electricity market. Therefore, the total Palestine is described. It includes Gaza and the West Bank.

Palestine is heavily dependent on Israel for meeting its energy requirements. Almost all petroleum products and most of the electricity are imported from Israel and the possibility of diversifying the energy development and imports from other countries is currently limited due to political constraints mainly Israel control of area C (60% of the West Bank). Population growth, increasing living standards and rapid industrial growth has led to tremendous energy demand in the Palestinian territories in recent years. The energy situation in Palestine is restricted and depends on Israel. The Palestinian energy market has limited options to develop indigenous sources of electricity and Israeli restrictions have prevented the construction of power networks in large parts of Area C which comprises 60% of the West Bank. Thus, exploitation of renewable energy resources is required at a mass-level so as to ensure a cheap and sustainable source of energy to the Palestinians and reduce dependency on Israel.

Palestine is a net importer of oil and petroleum products. Total energy consumption in the Palestinian Territories is considered the lowest in the region, while its costs are relatively high compared to its neighbours. The largest portion of the different types of imported fossil fuels consumed in the Palestinian Territories originates from Israel, while the remainder comes from Jordan and Egypt. The energy provided by the three sources, however, does not meet the power needs of the Palestinian Territories.

The distribution of the energy consumption among the various demands is given in Figure 3.5.

It is seen that the major consumption (45%) is for the residential sector. The demand of the agricultural sector is diminished. The residential sector consumes mainly electricity while the energy for transportation and for many of the industries is based on fossil fuels. This fact provides a hint for estimation of the JV electricity demand based on the population ratio between the JV and the whole Palestine residential energy demand.

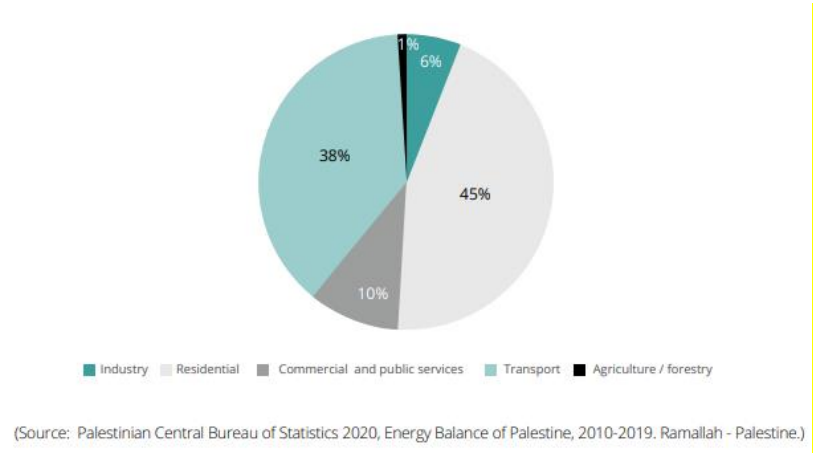


Figure 3.5 Final energy consumption in Palestinian Territories by sector

Electricity

Electricity supply and demand

According to the Palestinian Central Bureau of Statistics (PCBS), the total electrical energy consumption in Palestine in 2019 was reported to be 5,929.5 GWh. This quantity is almost entirely imported from outside sources, mainly from the Israel Electric Corporation (IEC), as shown in Table 3.22.

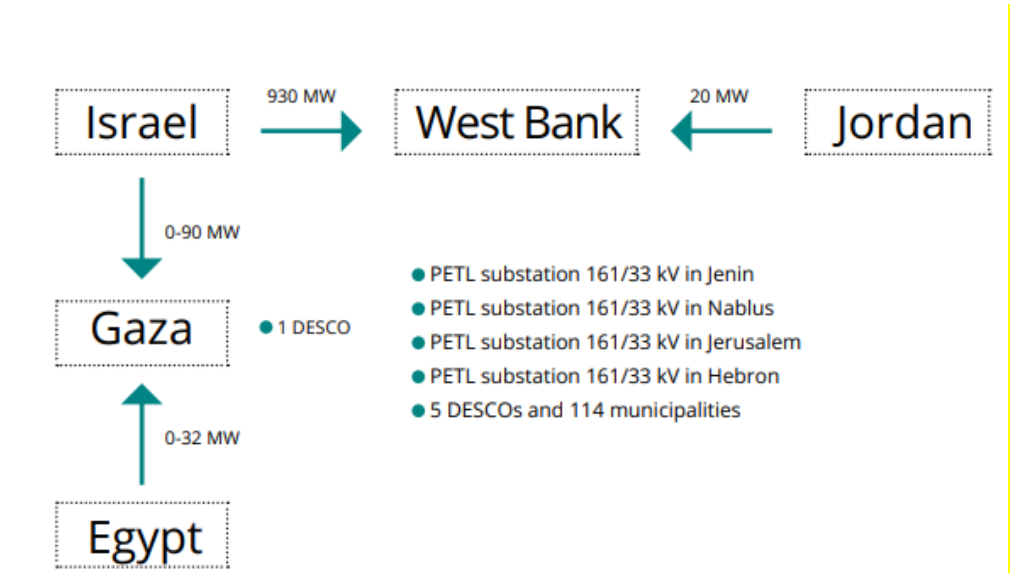
There is only one domestic power plant, at Nusseirat in Gaza. It was built in 2002 and has a capacity of 140 MW but currently runs at only 50% capacity due to fuel price hikes and its partial destruction from Israeli bombardment (Hamed and Peric, 2020). In 2020, this Gaza power plant (GPP) provided enough power to supply 6% of the total electricity demand. While a share of 5% of the total electricity supply was imported from Jordan and Egypt, the largest

electricity supplier (accounting for 86%) was the Israeli Electricity Corporation (IEC). It provided 99% of the total electricity supply in the West Bank and 64% in Gaza (Milhem, o. J.). Solar PV accounted for 3% of the electricity supply.

Table 3.22: Sources of Electricity in Palestine Based on Yearly Consumption (PCBS 2019).

N	Electricity source	Quantity (GWh)	Percentage of total supply
1	Israel (IEC)	5537.7	93.4
2	Gaza Electricity Company	260.9	4.4
3	Egypt	36	0.6
4	Jordan	94.9	1.6
	Total	**5929.5**	**100**

The electricity interconnections between Palestine and her neighbors is displayed in Figure 3.6. It shows the total electricity supply capacity to Palestine.



(Source: own creation based on Khaldi and Sunikka-Blank, 2020)

Figure 3.6 Structure of the electricity interconnections in Palestine

Estimated power supply to the JV

The Israeli Electrical Company (IEC) operate 2 substations (SS) on the Israeli transmission grid that are supplying power to the west bank. The first SS is in Mahale Efrim, near Nablus, with the capacity of 150MW. It supplies energy to Area C that includes most of the JV. The second SS is in Jerico (Area A) and can provide 50MW. The total capacity is available for the JV consumption. That provides an estimate of more than 150MW capacity that is available at the JV. One should consider the IEC rule that this capacity reflects an estimate of at least 40% reserved capacity over the measured past average power consumption. We estimate electricity demand based on population ratio as stated above. The total consumption from Table 2.1 is about 6,000 GWh. We estimate the population in the JV to be ~5% out of the total population. Therefore, the total current electricity demand in the JV is about.

Renewable energy

The Palestinian Energy Authority issued a renewable energy strategy in 2012 that aims to gradually achieve 10 percent of electricity production from renewable sources by the end of 2020. According to the strategy, it is foreseeable that 130 MW would be installed from renewable resources projects by the end of 2020, and the major portion of green power would be generated by solar energy. The strategy comprises of two phases. The first phase involves conducting feasibility studies and preparing bids for the Palestinian market, as well as deploying small-scale projects and implementing the Palestinian Solar Initiative. The first phase was implemented between 2012 and 2015 and aimed to attain 25 MW from predetermined sources of renewable projects.

The NREAP proposes the following new RE targets:

- December 2020 target: 100 MW, mostly PV
- 2030 target – scenario A: 300 MW, including only areas A and B
- 2030 target – scenario B: 500 MW, including areas A, B, and C

Eighty percent of the 2030 targets will be achieved with solar PV, 10 percent with wind energy, and 10 percent with biogas/biomass.

- The current electricity supply level is not sufficient to cover the needs in all areas of the West Bank and Gaza Strip, and more than 65 communities still either lack adequate electricity or are not connected to the electricity grid.
- Electricity consumption is higher in the areas with higher population, which indicates that households are responsible for the main electricity consumption, followed by commercial and light industrial activities.

- Solar radiation is best in the central and southern parts of the West Bank and Gaza, with the highest values in Gaza and the lowest in Jericho.
- Land availability and financial concerns constitute the main challenges to investment in large solar energy projects.

This situation affects the potential to install renewable energy capacities. In the West Bank, Area A comprises 18% of the total land area, with Area B accounting for 22% and Area C for 60% (Hamed and Peric, 2020). Accordingly, Israel's partial/complete control of Areas B and C severely hinders the potential development of renewable and traditional energy infrastructure, as well as impeding.

In Areas A and B, the potential for large-scale solar amounts to 103 MW, while the most promising potential is for Area C, which could generate 3,374 MW. The JV potential is included in the areas A, B and C potential. Area C, which covers over 60% of the Palestinian Territories, has some promising mountainous zones that are not densely populated where wind energy could potentially be harvested. However, these areas remain beyond the control of the Palestinian Authority, which is a major barrier. In contrast, Areas A and B are too densely populated, making them widely unsuitable for the development of wind energy. (The coastal area of the Gaza Strip has wind speeds of around 2.5-3.5 m/s, which is considered to be too low for harnessing wind power (Juaidi et al., 2016)).

3.4 Synthesis

The three countries hold the same strategy and the same obstacles on the way to accomplish their national plans. Most of the land in the JV is rural area, the primary energy consumer is the residential sector and the second is the water sector that is the main resource for agriculture. The current situation is that, in the JV, the three nations can provide satisfactory energy supply and demand services. Most of the energy resources reside out of the JV, but it is not an issue since currently the JV is not in the focus of the nations. The future climate change treats in the JV are not at the center of the policy agenda.

However, there is a major concern on how to evaluate the energy sector needs in the short and the long-term. There are many unknown parameters that must be evaluated in order to plan and propose the design of energy infrastructures for the future of the JV. The following insights, that are similar to the three countries, can be drawn:

> Population growth - The main factor that influences the planning is the forecasted huge increase in population by a factor of 2 to 4 by 2050 in the region. The energy demand per capita is not expected to be reduced. Except in Jordan as the use of solar energy in the JV (for domestic, and agricultural uses) is expected to increase rapidly. Climate change may impose more energy for climatization of residential, commercial, and industrial areas. The expected increase of electrical mobility may drive the increase in electricity demand. The energy demand per capita in Jordan and Palestine is substantially lower than the Israeli average of 8,000kWh/capita/year. We guess that

during the years the Israeli demand will stay almost the same due to energy efficiency improvements. However, the demand per capita in Jordan and Palestine will reach the Israeli level by 2050.

Quest for renewable energy - The desire of all nations is to increase substantially the reliance on renewable energy. The Israeli national challenge of 30% in 2030 and 80% in 2050 and Jordan plans are even more ambitious.

It is not expected that the JV will match the nationals' targets. However, the energy security of the JV may strengthen the desire for energy dependence of the area as much as possible on local supply, and mainly on renewable energy.

The main primary local energy resource is solar. Wind potential is diminished. However, biofuels and biogas production can be meaningful and can contribute a lot to dispatchable electricity supply and for heat & power supply.

Land allocation for solar installations – besides Area C in Palestine there is very limited open space in Jordan and Israel for large installations that can be connected to the transmission grids. Most of the future solar facilities are expected to be connected to the distribution grids and dual use of land will be the dominant form. Agri photovoltaic, roofs cover public areas, floating systems on water reservoirs and ponds, etc.

Energy for water - The water supply in agricultural areas like the Jordanian and Israeli JV areas, is a major electricity consumer. The energy is needed for pumping and wastewater treatment and desalination. The amount of water used in the region may not grow much since the designated agricultural areas in the region are nearly exhausted. But, if we wish to use treated waste water for preserving all the region's environmental services, the quality of the treated water must be improved. For water-treatment energy demand we may take a high reference figure such as 3kWh/m^3 and the pumping cost may be estimated by less than 0.5kWh/m^3. With enough water storage ponds, most of the energy can be supplied by solar systems.

Energy shift between sectors – Due to the vast increase in population on one hand, and the limited expansion of agricultural areas combined with the fact that the automatization in agriculture and less enthusiasm of the young generation to work in agriculture, may cause substantial changes in the labor market. We may expect a large increase of the industrial and commercial sectors. Those are currently less presented in the JV but their future contribution needs to be studied and estimated. Maybe, advanced food industries have to be promoted. This last statement is based on the importance of post harvesting to food security and environmental preservation.

Grid vs. off-grid and behind-the-meter energy usage – In the three nations the current transmission grid and even distribution grids may not be developed enough to absorb a significant grow in energy demand. The plans to add and/or increase the capacity of the existing and future substations feeding the JV are not mature and the future ability to absorb a lot of renewables cannot be trusted.

Selling and buying energy from the national providers may be economically justified. But such agreements may contradict the quest for best energy security. Therefore, self-usage of the energy produced by consumers, behind the grid, is advocated. Total off-grid installation is less favorable since the grid connection provides flexibility and better security of supply.

Heat and Power resources – In view of the expected grow in the industrial and commercial sectors, more attention should be given to the needs of industries, especially food industries, to the needs of heat and power resources. This market was almost ignored in the national reports in this deliverable as its present contribution is diminished. For example, many food industries make use of low temperature steam that can easily be achieved by thermo-solar panels, by biogas heater and so on. The efficiency of thermal energy is much higher than that of PV and the use of waste-heat is very important as well.
Diverse type biofuels produced from waste can contribute to the H&P resources and also as a primary energy resource (PER) for dispatchable electricity production.

Natural gas and biogas – In order to overcome the intermittency and the non-dispatchability of renewable energy biofuels and mainly biogas can serve as PER for electricity and H&P. Lack of biogas can be compensated by natural gas supply. The easiest way to employ this option is to feed regional distribution lines, at low pressure (6-8bar) from the Israeli PMRS near Beit Shean. The biogas and NG can be mixed and used by the customers.

In the short term each nation can follow the remarks given above separately. But, they should have in mind that segregation of three national plans is not optimal. It doesn't take into account the great advantage of a common 3 nations regional collaborations sharing the JV WEFE resources.

4. Food Resources Mapping

4.1 Food Resources Mapping in Jordan

4.1.1 Current Situation

Early in 1950's the JV with it is underdeveloped water and land resources was identified as a national priority for development. During more than 60 years of development effort, which was intensified from 1978 onward, the public and private sectors have jointly implemented an integrated social and economic development plan, which culminated in the creation of a promising irrigated agricultural system.

Micro-irrigation systems have increased rapidly in the JV area, particularly for vegetables and fruit trees. New and superior varieties of vegetable seeds, use of plastic mulch, plastic tunnels, greenhouses and hydroponic are much in evidence and they are used more and more to optimize water use. The agricultural production and crop pattern in the JV, reflect a combination of environmental challenges and evolving agricultural practices. The region's agriculture has historically been significant but has faced various challenges in recent years. A key feature of agriculture in the JV is the concentration of crop cultivation in two main areas: rain-fed uplands and the fertile Jordan River valley. In the rain-fed northern and central higher elevations, crops such as wheat, barley, tobacco, lentils, and olives are commonly cultivated. However, the output of these rain-fed crops often falls short of domestic demand due to periodic droughts and limited arable land. Only about 20% of Jordan's geographic area receives sufficient rainfall for rain-fed agriculture, and the variability in rainfall further exacerbates the challenge. In contrast, the Jordan River Valley, which receives little rain, relies heavily on irrigation, primarily from the East Ghor Canal. This region is more fertile and focuses on the cultivation of fruits and vegetables like cucumbers, tomatoes, eggplants, melons, bananas, and citrus crops, often producing surplus amounts. Despite the potential for agricultural productivity, the actual output has been constrained by economic factors and environmental constraints, including water scarcity (Kool J., 2016).

Recent years have seen a decline in vegetable production in the JV by about 50% (FAO Country brief, 2022). This drop is attributed to various factors including rising production costs, labor costs, the soaring cost of inputs like fertilizers and pesticides, and challenges related to irrigation and water availability. The region has also been affected by unstable weather conditions, which have led to successive losses for farmers. Furthermore, external factors such as regional market dynamics have impacted the export potential of the valley's produce. Despite Jordan being among the top ten world exporters of phosphate fertilizer, the high cost of agricultural inputs domestically constrains the planted area for many crops. The country heavily relies on imports for its cereal food and feed requirements, with over 97% of its domestic cereal needs met through imports. The recent global cereal price hikes have affected the country, though it continues to manage its cereal stocks strategically to avoid market turbulences (FAO, 2022).

Overall, the agricultural sector in the JV is marked by a mix of traditional practices and modern challenges. The region's farmers are adapting to changing environmental conditions and market demands while grappling with the rising costs of production and the limitations imposed by water scarcity and soil conditions. Table 4.1 below shows the crop pattern in JV. (Al Bakri, 2016)

Table 4.1: Crop patterns in JV. (Al Bakri, 2016)

Crops	Description
	JV
Vegetables–open fields	Farm units cultivated with tomato, eggplant, pepper, onion, Okra (NJV) and others.
Vegetables – Plastic houses	Tomato, cucumber, strawberry, beans and others. Includes nurseries and multi-spans.
Trees	Citrus, date palm and grapes, fruit trees, olives and banana
Mixed crops	Parts of farm units cultivated with fruit trees, vegetables and cereals.
Fodders and cereals	Farm units cultivated with wheat and barley under supplementary irrigation or alfalfa with full irrigation.

Date palm cultivation in the JV has seen significant growth and development over recent years. This shift in agricultural focus is driven by several factors, including the climatic suitability of the region for date palms, the high market value of dates, and the challenges faced in traditional vegetable farming. The Jordan Valley's hot summers and moderate winters, combined with its nutrient-rich soil, make it an ideal location for growing date palms. Over the past decade, there has been a notable increase in the number of date palm trees planted in the Jordan Valley, with over 29,000 trees added, reflecting a shift from traditional vegetable farming to date palm cultivation. This change is partly due to the high economic value of date farming and serves to reduce the oversupply of vegetables on the local market, which had been affecting farmers' incomes.

Jordan is particularly renowned for two types of date palms: Medjool and Berhi. Medjool dates, often referred to as the king of dates, are especially popular and in demand both regionally and internationally. The country produces around 10,000 tonnes of Medjool dates annually, with about half of this quantity being exported to high-end markets. The total date production in Jordan reaches around 33,000 tonnes per year, and the country exports around 5,000 tonnes of dates, mainly to Europe and the United States.

The date palm sector has created substantial employment opportunities, generating around 4,000 jobs for skilled laborers and an additional 2,000 jobs during the harvest season. The industry also contributes significantly to the national economy, with annual profits estimated at around JD50 million. Despite these successes, the sector faces challenges, such as marketing difficulties for small farmers who lack packaging facilities and the threat posed by

pests like the Red Palm Weevil. The Jordanian government and other organizations are taking steps to address these challenges, including increasing water allocations for irrigation and supporting the expansion of date palm cultivation ((https://www.hollandhortisupportjordan.com/pilot-activities/dates).

The total irrigated area under fruits and vegetables has increased 10 times in the 1990's from its size in early 1950's, but crop production has increased 30 times . The 2021 cropping pattern for the JV irrigated from KTD consisted of 36,289 du vegetables, 23,560 du of fruit trees and 9,384 du of citrus (Figure 4.1).

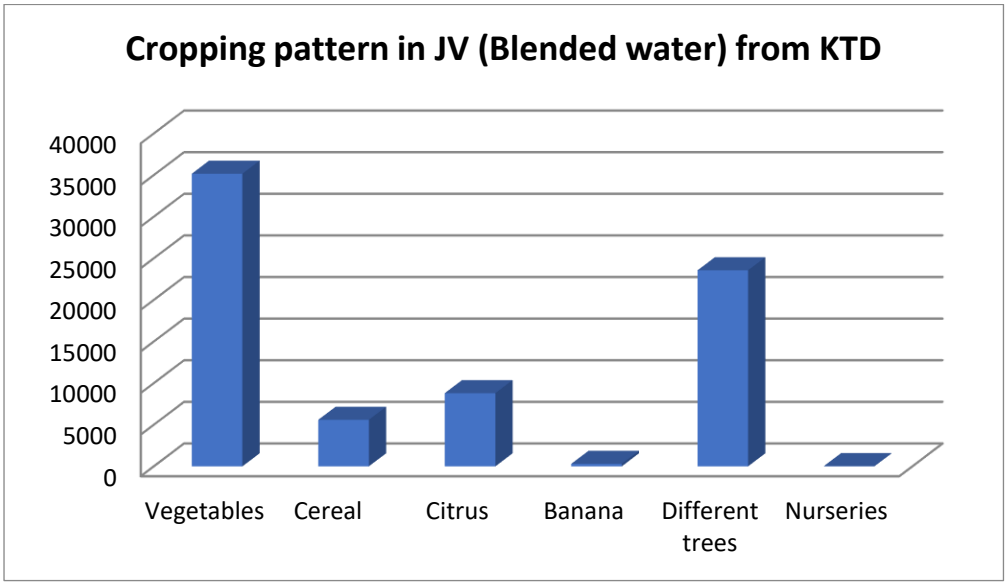


Figure 4.1: Cropping pattern in JV with blended water (The y axis is the area in dunum).

Animal production in the JV has evolved significantly over the years, reflecting changes in agricultural practices and adaptation to environmental conditions. The valley, known as the Ghor, offers a year-round agricultural climate with fertile soils and a reliable water supply, which have made it a key area for agriculture, including animal farming.

In the past two decades, there has been a noticeable shift in dairy farming. Farmers have largely transitioned from local cow breeds to high-yielding Holstein Friesians (international cattle) due to their higher productivity. The local Baladi cows, which are well-adapted to the harsh environment, have seen a decrease in numbers. Small-scale farming often involves an interdependency between crop and livestock production, with farmers utilizing a portion of their land for dairy farming and the rest for crop production. Despite the lower milk yield due to less intensive management and poorer feed quality, these small farms contribute significantly to the livelihoods of local communities, providing subsistence and a source of income through the sale of milk and dairy products like cheese and yoghurt.

The dairy industry in Jordan has also seen growth, with the per capita consumption of dairy products reaching 78 kg. Most milk produced is delivered to dairy factories, which process it into various products, including yogurt, laban, cheese, and ghee. There are 21 modern dairy factories in Jordan, mainly located in regions of milk production and near big cities. These factories have sufficient capacity to process the fresh milk produced by farmers. However, the region faces challenges such as water shortages, rising energy costs, and increasing fodder prices. Farmers have been uniting to promote sustainable agriculture, focusing on renewable energy projects and water harvesting to ensure more efficient use of limited resources. There have been efforts to support livestock farmers by planting fodder shrubs like saltbushes, which are known locally as "qataf." These initiatives aim to help farmers cover their fodder needs and reduce costs in the long run.

The Jordan Valley's animal production is also influenced by its history as a migratory route for animals and birds, which has contributed to the biodiversity of the region. Today, the valley continues to play a role in animal migration, including significant bird populations that rely on the valley during their migratory seasons. Overall, animal production in the JV is characterized by a mix of traditional practices and modern developments, with an increasing focus on sustainability and efficiency in the face of environmental and economic challenges.

Fish production in the Jordan Valley has emerged as a vital sector for local economic development, job creation, and food security. The region has seen significant efforts to establish aquaculture and aquaponics systems that are both sustainable and efficient. Aquaculture in the JV has been largely dominated by the private sector, which has seen significant growth in recent years. The most commonly farmed fish in the valley are tilapia and the common carp. These species have been chosen due to their profitability and reproductive capabilities. As of 2018, fish farms in Jordan produced approximately 1,300 tonnes of fish, substantially more than the output from maritime fishing, which was 264 tonnes for the same period. The higher productivity of fish farms, despite the limited variety of species compared to maritime fishing, points towards a focused and efficient use of resources, emphasizing profitability and sustainability in a challenging environment.

Recent initiatives have further aimed to enhance the sector's contribution to the local economy. For example, the Ministry of Agriculture has partnered with the Jordan Agricultural Engineers Association to set up fish farming and aquaponics facilities in the Northern Jordan Valley. This project is supported by a grant from the United Nations Food and Agriculture Organization (FAO) and is expected to create jobs for over 15 agricultural engineers and 20 indirect jobs in related sectors. Aquaponics combines fish farming with hydroponics, creating a symbiotic environment where the waste produced by farmed fish serves as nutrients for plants, which in turn purify the water. This system is praised for its water efficiency and has the potential to produce fish and plants year-round, bypassing seasonal limitations (FAO, country profile, 2019).

Moreover, there has been a royal endorsement and involvement in the promotion of aquaculture projects. HRH Princess Basma inaugurated an aquaculture and fish farming project in the Northern JV that not only aims to provide job opportunities for local women but also focuses on the sustainability aspect of fish production. It utilizes greenhouses with hydroponic systems and establishes fish ponds, reflecting a push towards eco-friendly and sustainable agricultural practices in the region. These developments reflect a broader trend of utilizing modern farming techniques to maximize the potential of the Jordan Valley's agricultural sector. Given the region's limited water resources and the need for efficient use of land, these aquaculture and aquaponics projects represent innovative solutions to the challenges faced by the Jordanian agriculture sector (FAO, country profile, 2019).

The emphasis on fish farming is also seen as a measure to address food security concerns and to provide stable sources of income for local communities in the Jordan Valley. The government's support for these projects indicates a commitment to enhancing self-sufficiency in fish production and to creating economic opportunities in rural areas.

Import and export patterns

The Jordan Valley, recognized as a critical area for agricultural production in Jordan, has a distinctive pattern of import and export related to food production, shaped by its geographic features, water resources, and economic factors

The nation is highly dependent on food imports due to its water scarcity, with agriculture consuming a substantial portion of Jordan's water resources yet only contributing to a small fraction of the GDP. Despite this, the sector employs a significant portion of the labor force. The country imports up to 98 percent of its consumable items, including staples such as wheat, barley, sugar, rice, powdered milk, tea, coffee, corn, vegetable oil, cheese, chickpeas, vermicelli, and lentils. Imports have increased to meet the demands of a population that has nearly doubled in the past decade. Jordan's food imports are notable from countries such as Saudi Arabia, Argentina, United Arab Emirates, Egypt, and the Netherlands.

On the export side, Jordan has seen an increase in agricultural exports, including horticultural products, poultry, and small-scale herding. However, the export of water-intensive crops has been curtailed in favor of less water-demanding varieties, reflecting a conscious move towards more sustainable practices given the country's limited water resources.

Jordan's import and export patterns in food production exhibit strengths in its ability to produce a variety of fruits and vegetables in the Jordan Valley, supported by infrastructure. However, the dependence on food imports due to water scarcity and the economic limitations of expanding agricultural land are challenges. Efforts to improve water efficiency and the introduction of sustainable practices, such as aquaponics, indicate a move towards addressing these challenges. The strong bilateral relationship with the United States,

including a free trade agreement, further supports the agricultural sector's growth and diversification in Jordan.

while the JV plays a pivotal role in the country's food production, Jordan's overall food security strategy remains centered on a mix of domestic production optimization and strategic imports, leveraging international partnerships to ensure a diverse and stable food supply for its people. The strategic interplay between these imports and domestic production reflects Jordan's adaptive measures to maintain food security amidst environmental and economic constraints. Key challenges include the logistics of transporting produce to markets, which can be hindered by inadequate infrastructure and transportation facilities are main concern to farmers and decision makers in Jordan Valley. Moreover, farmers face difficulties in accessing markets due to geopolitical constraints and regulatory barriers, which affect the export potential of crops. Another challenge is the reliance on a limited number of crops, which makes the agricultural sector vulnerable to market fluctuations and climate change impacts.

The agricultural sector in the JV faces several challenges related to the food value chain. A significant issue is the closure of the Syrian borders, which previously served as a major export route for Jordanian produce to Russia and Europe. This closure has severely impacted the agricultural workers in the region, leading to a lack of income for farmers who sometimes see minimal or no profit from their labor-intensive work. The challenges are compounded by the effects of climate change and drought, which have contributed to a decrease in agricultural production and income.

Moreover, the sector has been facing mounting challenges including changing weather patterns and rising production costs. These issues have left many farms in the JV empty and uncultivated, leading to a decrease in production by as much as 50%. Farmers have resorted to delaying their planting seasons to avoid producing at the same time as other regions, which could lead to significant losses. However, delaying cultivation affects the overall amount of production. The increase in costs for essential inputs such as fertilizers, labor, pesticides, seeds, and electricity for water delivery from wells has also significantly affected the sector's viability. Labor costs, in particular, have seen a substantial increase, further straining the financial sustainability of farming in the Jordan Valley. The challenges in the supply chain and food processing of tomatoes in the Jordan Valley are multifaceted and impact the economic viability of tomato farming in the region. One of the primary challenges faced by tomato farmers in the JV is the imbalance between supply and demand. There is an abundance of high-quality tomatoes produced locally, but this supply exceeds the demand in the market, leading to prices that are lower than the input costs. This issue is compounded by difficulties in exporting tomatoes to traditional markets such as the Gulf Cooperation Countries (GCC), where Jordanian tomatoes now face competition from imports from countries like Iran. The challenges in exporting to GCC markets are exacerbated by long wait times for produce approvals and high inspection costs borne by the farmers, along with high export taxes.

Farmers in JV choose to delay their cultivation to avoid producing at the same time as other regions, which would lead to significant losses. This strategy, however, affects the amount of production. Other contributing factors include the scarcity of water, soaring costs of labor, pesticides, seeds, and electricity for water delivery from wells. Furthermore, the tomato value chain in Jordan faces challenges due to unplanned expansion leading to excess supply and decreased local prices. The small size of the tomato processing industry (e.g., for products like ketchup and juice) and labor issues, particularly the increased cost of labor due to recent labor laws and regulations, add to the challenges. Production must be sold through central markets, where prices are controlled by agents and wholesalers. This system often leads to increased indebtedness among farmers. Export potentials are not fully realized due to these challenges and the limited added value post-harvest services (grading, packaging, processing).

4.1.2 Near-Future Projections

Projected changes in agricultural patterns

The agricultural patterns in the JV are projected to undergo significant changes, primarily due to the impacts of climate change. According to World Bank (2017), the suitability of key crops currently grown in Jordan is expected to shift. For example, the suitability for potato cultivation will deteriorate, and crops like barley and wheat will become more marginal. However, there is an expectation for stable olive yields and potential increases in tomato and date production.

The World Bank's Climate-Smart Agriculture Action Plan for Jordan emphasizes the need for agriculture in the region to adapt to and mitigate the effects of climate change. This plan suggests investing in areas such as the expansion of date palms and protected vegetables in irrigated parts of the JV and highlands, olive production and processing, and barley production in rain-fed regions. Furthermore, it highlights the development of small ruminant value chains and Badia restoration in agro-pastoral areas. These efforts are expected to increase water productivity, create jobs in high-value export chains, and benefit farmers and vulnerable populations. Additionally, the World Bank report points out that Jordan is one of the most water-scarce countries globally, and agricultural water resources are expected to decrease by 20 to 25 percent in the coming years. This reduction poses a particular threat to the irrigated agro-ecological zone, a major contributor to Jordan's agricultural GDP. Moreover, the Global Green Growth Institute's National Action Plans for Jordan from 2021 to 2025 also indicate a strategic shift towards sustainable practices. The region faces accelerating land degradation and desertification, which is exacerbated by the loss of vegetative cover. Solutions to these issues are challenged by funding shortages and weak institutional coordination, which the Climate-Smart Agriculture Action Plans aim to address.

The anticipated changes in Jordan's agricultural patterns highlight the need for innovation and sustainability in farming practices to ensure food security and economic growth despite environmental challenges. These changes are in line with Jordan's national climate priorities

and international commitments, including the Nationally Determined Contributions to the Paris Agreement.

Infrastructure and policy changes

Short-Term Projections:

Infrastructure:

- Water Management Improvements: Initiatives to improve water efficiency, including the rehabilitation of existing irrigation systems and the introduction of water-saving technologies, are expected in the short term.

- Renewable Energy: With Jordan's commitment to green growth, short-term infrastructure projects may include the integration of renewable energy sources in agricultural operations, such as solar-powered water pumps.

Policy:

- Incentivization Programs: Short-term policy initiatives may involve the introduction of incentives for farmers to adopt more sustainable practices and for the development of climate-resilient crops.

- Subsidy Adjustments: Adjustments in subsidy schemes to favor water-efficient and climate-adapted agricultural practices might be implemented.

- Regulatory Frameworks: Establishment or enhancement of regulatory frameworks to manage water rights and usage efficiently, including measures to prevent over-extraction of groundwater.

Long-Term Projections:

Infrastructure:

- Advanced Agricultural Technologies: Long-term infrastructure plans are likely to focus on incorporating advanced technologies for precision agriculture, enabling better resource management and yield prediction.

- Expanded Water Infrastructure: Large-scale projects to expand and modernize water storage and distribution infrastructure, potentially including new reservoirs or desalination plants, are anticipated to meet the increasing water demands of agriculture.

- Climate Resilient Structures: Infrastructure to withstand extreme weather events, like reinforced greenhouses and storm water management systems, may be developed.

Policy:

- Comprehensive Agricultural Policy: Development of a comprehensive agricultural policy that aligns with national economic goals, food security concerns, and climate change mitigation efforts.

- Research and Development Support: Increased investment in research and development to create drought-resistant crop varieties and to understand the long-term impacts of climate change on agriculture.

- Trade Agreements: Negotiation of trade agreements that support the export of agricultural products, ensuring that Jordanian farmers have access to international markets.

Both the short and long-term projections for infrastructure and policy in the JV will be aimed at achieving sustainability and resilience in the face of climate change, water scarcity, and the need for economic development. These projections will depend on cooperation between governmental agencies, the private sector, international partners, and the farming communities themselves.

The actual implementation of these projections will need to adapt to the dynamic geopolitical, environmental, and economic contexts of the region. It will also be influenced by Jordan's compliance with international agreements and the country's evolving climate action plans and sustainable development goals.

4.1.3 Long-Term Projections

Predicted food demand and supply challenges

The long-term scenario for food demand and supply in the JV is shaped by several key factors, including population growth, economic development, climate change, and water scarcity. Here's a detailed projection based on these factors:

Population Growth: As the population increases, the demand for food is expected to rise. The JV, being a fertile region, will face pressure to increase its agricultural output to feed the growing number of residents.

Economic Development: With economic growth, dietary patterns are likely to shift towards a higher consumption of meat, dairy, and processed foods, which could lead to greater demand for these products. This shift would require a corresponding increase in livestock and dairy production, as well as food processing capabilities.

Climate Change: Predicted changes in climate conditions, with higher temperatures and more frequent extreme weather events, may lead to reduced crop yields and a more challenging environment for livestock. This could tighten food supplies and necessitate the import of certain foodstuffs.

Water Scarcity: Given that agriculture in the JV relies heavily on irrigation, the long-term availability of water is crucial. The demand for water for agricultural purposes is likely to grow, but supply may be constrained due to over

-extraction, pollution, and competition from other sectors. Strategies for water conservation and more efficient irrigation techniques will be critical.

Agricultural Shifts: Adapting to climate change might involve shifting to crops that are more tolerant to heat and drought, potentially reducing the variety of crops grown in the valley. There may be a move towards greenhouse farming and other controlled-environment agriculture to maintain production levels.

Food Import Dependence: Jordan's reliance on food imports is expected to continue in the long term, especially for cereals like wheat and barley, which are essential but water-intensive. Efforts to increase self-sufficiency will be balanced against the economic and environmental costs of production.

Technology and Innovation: Technological advancements in agriculture, such as genetically modified crops that can withstand harsh conditions, precision agriculture, and alternative farming methods like aquaponics, could play a significant role in meeting food demand.

Policy and Governance: Government policies will likely focus on ensuring food security through a combination of supporting domestic production, managing food reserves, and securing import agreements. Subsidies, research and development, and trade policies will be key tools in managing food supply and demand.

Sustainability and Food Systems: The long-term scenario will need to incorporate sustainable food systems that minimize environmental impact, use resources efficiently, and ensure equitable access to food. This might include promoting local food production and consumption, reducing food waste, and enhancing the value chain from farm to table.

In summary, the long-term food demand and supply scenario for the JV will depend on balancing increased food production with sustainable practices, given the constraints of water scarcity and the impacts of climate change. Technological advancements, policy support, and international cooperation will be key to achieving this balance.

4.1.4 Potential solutions and alternatives

To effectively address the challenges and leverage opportunities in the food and agricultural sector in the JV, a comprehensive and dynamic approach is essential. This approach should integrate modern irrigation techniques such as drip and sprinkler systems to maximize water use efficiency, alongside water harvesting and storage infrastructure. This is crucial for managing the region's water scarcity and reducing reliance on dwindling groundwater sources.

In response to climate change, the development and dissemination of climate-resilient crop varieties capable of withstanding heat, drought, and pests is vital. Practices like crop rotation, intercropping, and the use of organic matter can enhance soil health and resilience to climate extremes. Additionally, technological advancements such as precision agriculture, utilizing data and analytics, sensors, drones, and satellite imagery, are key for efficient farm management and real-time monitoring.

Policy support is crucial, with the formulation of policies that incentivize sustainable practices, support research and development, and facilitate access to finance for small and medium-sized farms. Encouraging public-private partnerships can bring in investment and technical expertise. Diversifying crops and diets, especially with less water-intensive alternatives and local crops, can contribute to dietary diversity and food security. Investing in aquaponics and hydroponics offers a water and space-conserving solution, potentially yielding high-value products. Moreover, developing the food processing sector can add value to agricultural products, extend shelf life, and reduce post-harvest losses, enhancing food security and creating job opportunities. Improving market access for farmers and strengthening connections between producers and consumers, including through farmers' markets and cooperatives, is vital for ensuring fair prices and a robust value chain. In livestock management, sustainable practices like rotational grazing and integrated livestock-crop farming systems should be prioritized, along with the development of less water-intensive and cost-effective feed alternatives.

Education and capacity building for farmers in sustainable agriculture and resource management are equally important. This, combined with increased awareness of the economic and environmental benefits of sustainable farming practices, can drive change. Utilizing renewable energy sources like solar panels and biogas plants in agriculture can reduce both the carbon footprint and operational costs.

This multi-faceted approach, involving stakeholders from government, private sector, local communities, and international partners, requires continuous monitoring, evaluation, and adaptation. These strategies, blending modern technology with traditional knowledge, policy reform, and market development, aim to create a robust, sustainable, and resilient food system in the JV, equipped to thrive in the long term.

4.2 Food Resources Mapping in Israel

4.2.1 Current Situation

Israeli agricultural sector uses 25% of the Israeli land, 50% of the water and provides most of the vegetables and fruits for the population. However, the relative importance of the agricultural sector in the Israeli economy has declined over the last decades, with its share in total employment and in domestic product falling to just 2.5% and 1%, respectively, in recent years. In monetary terms, total production amounts to about 9 billion $, from which about 60% are the product of the vegetation subsector and rest are animal products. Israeli agriculture supplies 90% of the domestic consumption of vegetables and fruits and most of the demand of animal products. However, 90% of cereals consumption for both human food and animal feed is based on import. Considering that the domestic livestock sector relies on imported feed, Israeli agriculture supplies only 30% of total calories consumed by the population (Almador 2020, Kislev 2005, Kan et al 2023).

Agricultural yield and food production data

Cultivated land and water use for vegetative agricultural products in the region of interest accounts for about 8% of total cultivated land and water use in the country. Crop specialization varies across the landscape of the region. In the area closest to the Sea of Galilee, Avocado, banana and mango groves cover the majority of cultivated lands. The central part of the region grows primarily field crops, about a third of which are purposed for animal feed, dates plantations cover about 10% of area cultivated and a variety of vegetables for industrial use, or of lower value, such as tomatoes for industry, onions and garlic, and watermelons for seeds comprise the rest of the land. Further down south in the region, dates are predominantly the most important crop grown followed by field crops. While the region of interest accounts for small shares of the entire sector's use of land and water resources, it has a vital role in local production of several crops (Table 4.2). As described in Figure 4.2, almost 70% of dates production in the country is concentrated in the area of interest. Other important crops in terms of local production shares are tomatoes for industry (about 40%), banana and garlic (about 30%, and watermelon and mango (about 20%).

Table 4.2: Production data approximated using normative per dunam yield for each crop, based on cost studies conducted by the Israeli Ministry of Agriculture

Crop	Land Area (Dunam)	Approximated Yield (Ton)
Wheat grains	34387	27510
Hay	1261	794
Silage	8120	7714
Chickpea	890	321
Maize	6430	15726
Sunflowers	1003	612
Cotton	688	374
Other Field crops	45355	12949
Table Olives	501	626
Irrigated Olive Oil	6142	1216
Not irrigated Olive Oil	675	34
Avocado	5412	8119
Wine grapes	47	66
Table Grapes	2704	5409
Almond	101	18
Dates	44105	52926
Banana	10537	66280
Mango	4861	14582
Pomegranate	77	345
Other Fruits	6172	5227
Oranges	106	522

Grapefruit	2096	14669
Lemon	1217	6085
Easy peelers	1013	4054
Other Citrus	628	3138
Capsicum	3116	28040
Carrots	2862	25757
Regular table Tomatoes	836	10035
Cherry tomatoes	129	1683
Tomatoes Industry	3929	44597
Onion	3398	25488
Sweet_potatoes	238	1071
Cabbage	147	993
Zucchini	225	618
Table Cucumber	283	7633
Eggplants	510	3572
Garlic	2696	9437
Other Veg	2962	12484
Spring Potatoes	388	1900
Watermelon	6210	49680
Melon	176	792
Aquaculture	16899	10000
Dairy Farms		95940

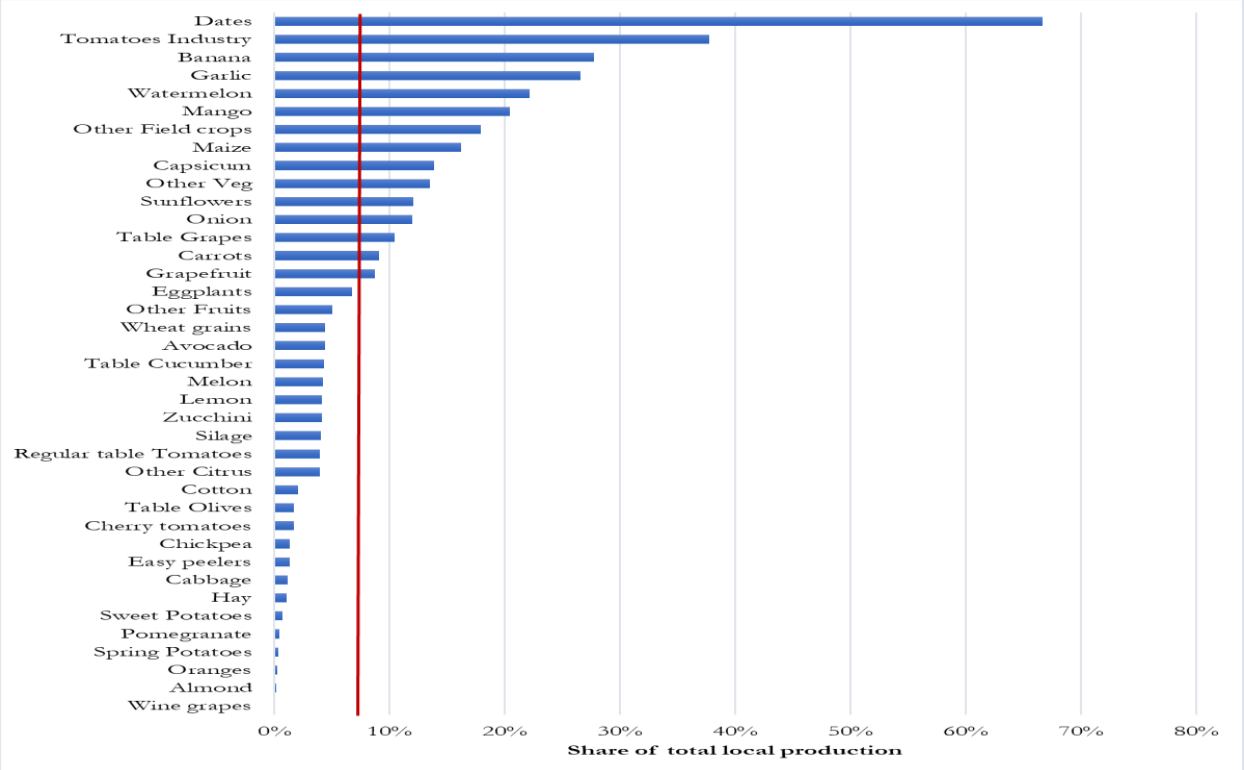


Figure 4.2 Share of local production grown in the area of interest

Aquaculture is predominantly the largest agricultural activity in the region, accounting for about 80% of local fresh fish production in the country (Southern Jordan River Drainage Authority, 2017), covering almost 10% of the agricultural land in the region and accounting for about half of the water use in it. This industry is suffering in recent years from growing global competition, specifically after the removal of protective import tariffs, starting from 2016, actively reducing consumer prices by almost 30% (Bar-Nahum, 2019; Orlev-Sharon, 2023). As a result of that reform, local production share of national consumption decreased from 15% to 8% over less then a decade, farms' production and revenues also dropped significantly even though direct and indirect support were administered to farmers by the country during the tariff abolishment period and concurrently per capita national consumption of fish increased by about 50% (Bar-Nahum, 2019; Orlev-Sharon, 2023).

Livestock agriculture in the region is primarily dairy production—out of the 40 communities included in the area of interest, 25 operate a dairy farm. The total regional production is about 6.5% of the dairy production in the country. Other dairy farming (from sheep or goats), poultry and cattle for meet activities in the region account for very small shares of their respective national industries.

Import and export patterns

As aforementioned, Israel highly depends on imported cereals for both animal feed and direct human consumption. The import of most fruit and vegetables is still limited due to a system of protective tariffs. Still some crops are imported in relatively larger shares like apples, tomatoes, cucumbers and onions, all in the magnitude of about 10% of total local market consumption. In recent years import tariff policies have been the center of a loud public debate, negotiations were conducted between the government and farmers' organizations

and reforms were examined and initiated, however the future of these policies remains uncertain. This subject will be further elaborated in section 5.2. As was also mentioned earlier, fish consumption levels in the country are on a rising trajectory, where the source of supply is primarily imports, and local production only accounts for small and decreasing share of the market following the removal of protective import tariffs in that sector almost a decade ago. The dairy sector is one of the most regulated industries in Israel. Backed up by legislation, the Israeli Dairy Board (IDB) controls farm entrance and exit and production level through an elaborated system of quotas and permits. Farm gate prices, as well as consumer prices of selected products are administratively determined by the IDB, and most imports are blocked through high tariff rates, except for selected products, such as butter, hard cheese and dairy powder.

The value of exported agricultural products for year 2022 was about 1.1 billion $ and accounted for about 12%, and 22%, of the total value of agricultural production, and vegetative agriculture, respectively (Katz and Bar-Nahum, 2023; Orlev-Sharon and Katz, 2023). Fruit and vegetables products together account for more then 60% of total exports, about additional 20% are herbs and seeds, the rest are flowers (about 8%), field crops (mainly cotton and peanuts, about 5%), and animal products (about 3%). Primary crops exported are: avocadoes, dates, mangos, easy peelers and grapefruit in the fruit category; and potatoes, carrots and capsicum in the vegetable category (Katz and Bar-Nahum, 2023; Orlev-Sharon and Katz, 2023). The European union is still the largest export market for Israel, followed by former USSR countries, primarily Russia.

4.2.2 Near-future projections

The Israeli agricultural sector faces some immediate and long-term challenges. After several decades of business-as-usual behavior from both policy makers and farmers, it seems that the agricultural sector is receiving growing attention in recent years, long-time policies are being revisited, new economic tools are examined and in the private sector innovative technologies are explored.

Projected changes in agricultural patterns

The rapid technological growth that characterized the Israeli agriculture in the past has led to an unprecedented increase in Total Factor Productivity (TFP), which in turn resulted in expansion of supply beyond the growth in demand, resulting in declining terms of trade. The average profits of an Israeli farm have fallen below the alternative nonfarm wage, leading to exits and a decreasing number of farms, as well as aging of farm managers and stagnation in farm's capital renewal and new investments. Exploiting economies of scale, it seems, had been the most attractive strategy used by farmers to adapt to the changing conditions, and large enterprises have become prominent in every agricultural sector. In the vegetative agricultural sector this phenomena manifests in the form of less diversification and therefore higher exposure to world price fluctuations and larger dependency of the sector on protective import policies. In other agricultural production branches exploiting scale economies has left other routes for efficiency improvements unexplored. Whether or not a new generation of farmers would take their place in the industry and arise to the challenges ahead still remains uncertain and highly depends on the ability of policy makers in Israel to promote stability,

incentivize efficiency and reduce to some extent the inherent uncertainty embedded in agricultural production.

The appreciation of the shekel, driven by the rapid growth of the high-tech industry in Israel and the discovery of natural gas, has adversely affected the profitability of agriculture, particularly for sectors reliant on exports. Consequently, the value of agricultural exports is on a declining trend in the last decade, at a rate of about 5% annually on average (Katz and Bar-Nahum, 2023; Orlev-Sharon and Katz, 2023). Mangos, avocadoes and dates, all vital crops in the JV area of interest, are exported in the magnitude of 50% to 70% of local production, making the region very reliant on export markets. Concurrently to the decline in terms of trade for exporters, the exports of avocadoes and dates, doubled and tripled, respectively in the last decade, suggesting that thus far farmers specializing in these crops were able to avoid the adverse effects of these trends.

The accelerated economic growth has also led to increased labor costs, prompting the agricultural industry to resort to importing foreign workers. The risk in that dependency has recently manifested due to the war situation in the region, in which Palestinian workers are not allowed to enter Israel and the other foreign workers (primarily from Thailand) have left the country due to the situation. As a response to these events the government and the Ministry of Agriculture have introduced new policies to support farmers, as well as to incentivize the hire of local labor. The outcomes of using these incentives are not yet measurable.

As earlier mentioned the aquaculture industry in Israel is on a declining trend, supplying less then 10% of local fish consumption in the country. Local fish farmers specialize in fish types for which consumers' demand in Israel is decreasing, whereas fish types for which demand increases are mainly imported (Bar-Nahum, 2019; Orlev-Sharon, 2023). Fish farming in open ponds is concentrated in three areas of the country, and predominantly in the JV area of interest. The increase in alternative costs for land have already materialized in the coastal area, where fish ponds area was repurposed for housing, although still in relatively small scale. Support policies issued by the government in recent years failed so far in preventing the detrimental economic impacts on the sector, and it seems that without unique innovations or tailored policies this sector will have hard time sustaining if existing trends continue. One promising venture is the dual use of open fish ponds with electricity production through the installment of PV panels on the water surface. A pilot PV field is already producing power in the coastal area of the country, creating additional source of income for land owners. However, that alternative creates tradeoffs with ecosystem services provided by the open ponds and therefore the social cost-benefit outcome of this practice is not yet clear.

Infrastructure and policy changes

As earlier mentioned, the immediate future conditions governing the agricultural sector, and specifically in the JV area of interest, depend on several policy and infrastructural development processes and their materialization. One crucial component is the recent reform in import tariff policies. In recent years the cost of living in Israel is on the rise, which has prompted a lively public debate concerning protective agricultural policies. Additionally, to

comply with international trade agreements, policy makers in Israel are encouraged to replace the existing high import tariffs on fruit and vegetables with other support policies that are considered non-distortionary. These considerations have triggered the former government to initiate a reform gradually removing import tariffs for some vegetative crops and reducing them substantially for others over the course of 5 years, while at the same time direct support to farmers would be given based on land area cultivated, and would be differentiated by crop type. The reform was initiated in 2022, and effectively abolished tariffs for a group of crops and reduced to varying levels the tariffs for other groups until it was halted by the current government. Among the crops from which tariffs were completely removed and are substantial in the area of interest are avocado, mango and garlic. For onions tariff were reduced to 85%, for bananas to 70% and for watermelon and dates tariffs were reduced to 50%. Processed tomato products experienced a tariff drop of 30% to 50% (IMARD, 2022).

Other important processes with the potential to impact the region of interest were reviewed in section 3.2 and are associated with policy changes and infrastructure development plans in the water sector. As was mentioned, the IWA plans on the one hand, to increase the diversity of connected sources of water to the JV region, as well as their availability, but on the other hand to recover the costs of the water sector through an increase in the prices of water to agriculture from the various sources of supply. These two processes have contradicting impacts on the future development of agricultural activities in the region in terms of crop diversification, farm exit rates and many other aspects.

4.2.3 Long-term projections

The two main promoters for long-term policies, and consequently future projections of food supply and demand patterns in Israel and in the JV area in specific are food security objectives and predictions regarding climate change impacts.

Predicted food demand and supply challenges

Israel's population is steadily growing at an unprecedented rate for a developed economy. According to current projections, in 2050 food supply from local production and imports would need to suffice for over 15 million people. Examination of current patterns of food supply suggest that Israel relies almost completely on imports of cereals for human consumption and animal feed, using storage as a buffer for emergency conditions, whereas the provision of fresh agricultural products (fruit and vegetables) is self-sufficient. It was estimated that to maintain this strategy going into the future existing cultivated land area is sufficient, however rainfed agricultural land and other irrigated field crops areas should be repurposed for fruit and vegetables production. This strategy though would necessitate an increase of about 60% of water supply to the agricultural sector with respect to existing quantities (Kronfeld-Schor and Calvao-Chebach, 2023). The majority of that increase could potentially be supplied from municipal treated wastewater, however as was mentioned earlier would require large investments in supporting infrastructures. This need for infrastructural development is coupled by predictions regarding future availability of natural water resources. According to current predictions, existing patterns of natural recharge and temperatures are expected to change dramatically in the future. Rainfall and recharge levels

are expected to decline by an average of 10% in Israel on a national scale, and in the JV area it is projected that the reduction would be even larger and in the magnitude of 20% (Itzhak and Livshitz, 2023). Temperature changes are also not expected to be evenly distributed, and growing conditions might change such that the ability of the agricultural sector to supply according to existing quantities and level of crop diversification would be impaired. An additional challenge, which is still unaccounted in these different projections, is the future of animal protein-based diets. Current studies suggest that the production of animal protein is inefficient in terms of resource use, and that current consumption levels are environmentally unsustainable and exacerbating climate changes. In Israel, per-capita consumption of meat and specifically poultry is ranked among the highest in the world. The high level of uncertainty embedded in the future demand for protein products from alternative sources, vegetative or manufactured, as well as the ability of local economies to supply these alternatives have left that issue unaddressed explicitly in current analyses and projections.

4.2.4 Potential solutions and alternatives

Recently the Ministry of Environmental Protection initiated a strategic planning process aimed at mapping risk patterns associated with climate change and identifying ways forward. As part of these planning efforts an intragovernmental committee was appointed to design and implement processes that would create resilience in food systems in Israel in view of projected climate changes. Most of the committee recommendations focused on closing the gaps in existing governmental decision making and legislation needed to support implementation of policies that would strengthen the food system resilience. Several wide level suggestions were made such as, coordinated policy making between different ministries, adoption of a strategic plan for the agricultural sector, formulating decision making from a socio-environmental-economic perspective and creating regulatory clarity, as well as aligning policies with global sustainable development goals. More practical and measurable suggestions were made with respect to reducing food waste, creation and maintenance of a national level database for the entire food value chain, mapping and analyzing Israel's dependence and vulnerability associated with food imports, reduction in sugar and animal-based protein consumption, and better information conveyance to consumers through food labeling.

An efficient, resilient and diversified local agricultural sector is a crucial component to meet Israel's long-term objectives with respect to climate change and food security. Therefore, policies should be designed to achieve these goals, with as little as possible friction generated in active efficient markets. One promising venture with that respect is supplying a larger array of insurance schemes for farmers, such that farmers can choose the scheme that best fits their heterogenous inherent risk and preferences. Dual use of the land for aquaculture/vegetative crop production and electricity production using PV panels is another promising solution, in which additional income is generated for farmers insuring them against fluctuations in revenues which characterize almost every agricultural activity.

On a larger scale, it seems that the most promising solutions are found in the regulatory and legislative domain. Policy makers should strive to generate stability for initiatives and productive sectors that are already facing high level of uncertainty regardless of the

regulatory structure in which they operate. Whether it will be entrepreneurs experimenting with animal-based protein substitutions, developers of new crop growing methods such as vertical structures or farmers jeopardizing short-term yield to examine the efficiency of dual use systems, they are all taking the entire risk without certainty that they will realize future revenues. The country shouldn't necessarily support these individuals, rather to plan the relevant legislation and policies and prepare their implementation, should the markets for these goods or services emerge. For example, with respect to animal-based protein substitution products, the government should be ready to administer health standards, monitoring and enforcement capacities and policies regarding conveyance of necessary information, should that market emerge. A regulatory discussion should also precede these realities, in which it should be decided if animal-based protein is indeed generating negative externalities for the economy, and if that is the case then these should be realized in the form of an appropriate Pigouvian tax.

4.3 Food Resources Mapping in Palestine

4.3.1 Current Situation

Within Palestinian agriculture inside the study area for the year 2020-21, there are 1879 Agricultural holders (individuals or groups responsible for operating and managing an agriculture entity). 93.5% (1757) are household holdings headed by males, 5.3% (99) are household holdings headed by females and 1.2% (23) are non-household entities.

In terms of individual agricultural holdings, there are a total of 2024 holdings within the study area, of which 235 are mixed holdings, 948 are horticulture and 841 are animals. Of the total holdings 98.7% (1998 holdings) were household based, and 26 (1.3) were non-household holdings. Note that the data suggests that there are more discrete holdings than there are listed holders, meaning some holders will hold multiple holdings.

Of those holdings listed, 54.7% (1107) were small holdings of less than 3 dunams, 221 were 3-5.99 dunams, and 162 holdings were 10-19.99 dunams. In terms of agricultural purpose, production is split between mixed commercial and producer consumption, and subsistence production. The majority of holdings (1171 or 57.9%) comprising 31651 dunams, were producing crops for sale and personal consumption, while 264 holdings (13.0%) totaling 962 were for subsistence consumption.

The total agricultural area in the Palestinian study region is 55053 dunams (as of 2021). Permanent (tree) crops accounted for 29298 dunams equating to 53.2% of land area, while vegetables and field crop cultivation accounted for 20852 dunams (37.9%). Remaining areas comprised as follows:

- 19 dunams of temporary pastures,
- 1366 dunams of fallow,
- 318 dunams of permanent pasture,
- 658 dunams of agricultural buildings
- 21 dunams of forest or wooded areas
- 2458 dunams other uses including parks
- 63 dunams aquaculture

The total area of land cultivated for 2021 was 52780 dunams. 22042 dunams were cultivated with field crops (41.8%) while tree crop area was 29103 (55.1%). 1635 dunams (3.1%) was cultivated with field crops of which 965 dunams were harvested that year.

For field crop area, rainfed crops comprised 562 dunams (34.4% of field crops) while 1073 dunams were irrigated (65.6%).

Official data indicate a significant decline in the agricultural sector's contribution to the economy of the Palestinian Territory over the past few decades. In 1967, agriculture contributed about 53 percent of the total GDP. By 2016, this figure had dropped to approximately 2.8 percent in the West Bank and 4.0 percent in the Gaza Strip (UNSCO, 2016). However, these figures can be misleading, as they suggest that agriculture's economic importance is now minimal. They fail to account for informal agricultural activities and do not include agricultural industries like dairy processing, olive oil production, and cucumber pickling, which are categorized under "industry." Additionally, agricultural activities on plots smaller than 1,000 m² and part-time farming are not included. Despite the dramatic reduction in GDP contribution, the agricultural sector remains crucial to the economy. It significantly enhances food security for a society under occupation, particularly in marginalized rural areas, and generates employment opportunities.

Figure 4.3 illustrates the structure of production in the agriculture sector of Palestine in 2019 according to FAO report in 2021. Approximately half of the value comes from livestock products, including meat from chickens (22 percent), sheep (5 percent), goats (3 percent), and cattle (1 percent); milk from cows (4 percent), sheep (4 percent), and goats (1 percent); and eggs (4 percent). Notable shares also come from olives (13 percent), tomatoes (8 percent), cucumbers and gherkins (5 percent), grapes (4 percent), and almonds (3 percent), along with other fruits and vegetables.

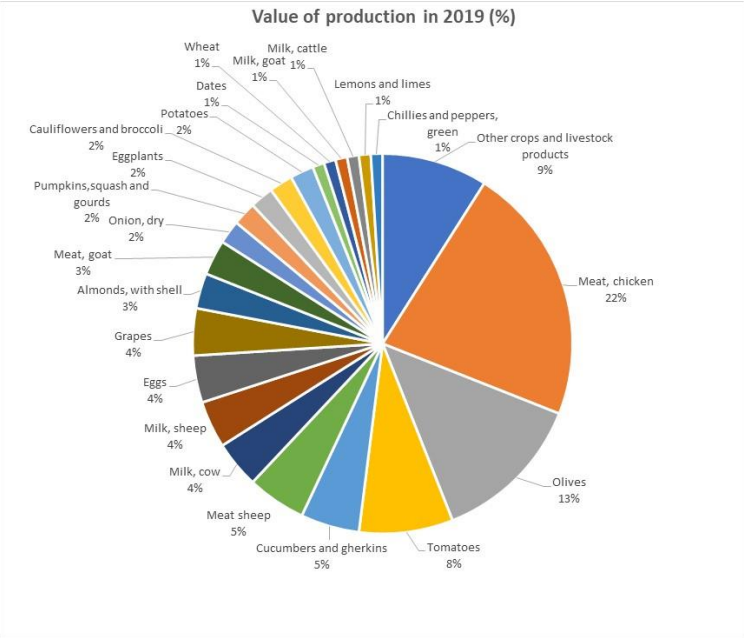


Figure 4.3 Structure of production (%) in 2019 (Source: FAO. 2021. FAOSTAT Production Database. In: FAO. Rome. Cited 20 March 2023. www.fao.org/faostat/en/#data)

Figures 4.4 and 4.5 illustrate the production trends for key agricultural and livestock commodities over the past 25 years. The production of fruits has decreased significantly, a shift largely driven by Israeli policies implemented after 1967 and continuing even after the establishment of the Palestinian Authority. This shift included a move from orange cultivation to vegetables and flowers in the Gaza Strip, and a decrease in commercial crop cultivation in favor of crops for personal consumption in the West Bank. Consequently, while vegetable production increased somewhat, there has been a declining trend over the past decade.

Preliminary results from the latest agriculture census (PCBS, 2022b) show that olive tree cultivation now occupies the largest agricultural area, covering approximately 57 percent of cultivated land in the Palestinian Territory, and 85 percent of the horticulture area. Field crops, vegetables, and other fruit trees make up the remaining areas, at 19.8 percent, 18.5 percent, and 9.3 percent, respectively. Compared to the 2010 census (PCBS, 2010), the area cultivated with vegetables has increased by about 58 percent. In the Gaza Strip, vegetable crops rose from 32 percent to 53 percent of the total cultivated area, followed by olive trees and other field crops and fruit trees, which occupy 26.2 percent, 16.4 percent, and 4.6 percent of the total cultivated area, respectively. It is important to note that almost 90 percent of the agricultural area is in the West Bank, while only 10 percent is in the Gaza Strip.

The livestock sector accounts for approximately 45 percent of the total agricultural value in the Palestinian Territory (FAO, 2021). Rural households often raise livestock as a secondary income source, with women playing a significant role in this activity (FAO, 2013). Over the past decade, the poultry industry has seen notable growth, with the number of birds more than doubling between 2010 and 2021 (PCBS, 2022a). This growth is evident in all governorates, including the Gaza Strip, with increases in both broiler and layer farms supported by significant modernization.

Apiculture has also seen remarkable expansion, with the number of beehives increasing by 68 percent between 2010 and 2021 (PCBS, 2022a). Dairy farms are expanding as well, although they have not reached the same level of mechanization as poultry farms. As illustrated in Figure 4, milk and poultry meat production have increased over the years. However, overall production has not kept pace with population growth in the territory.

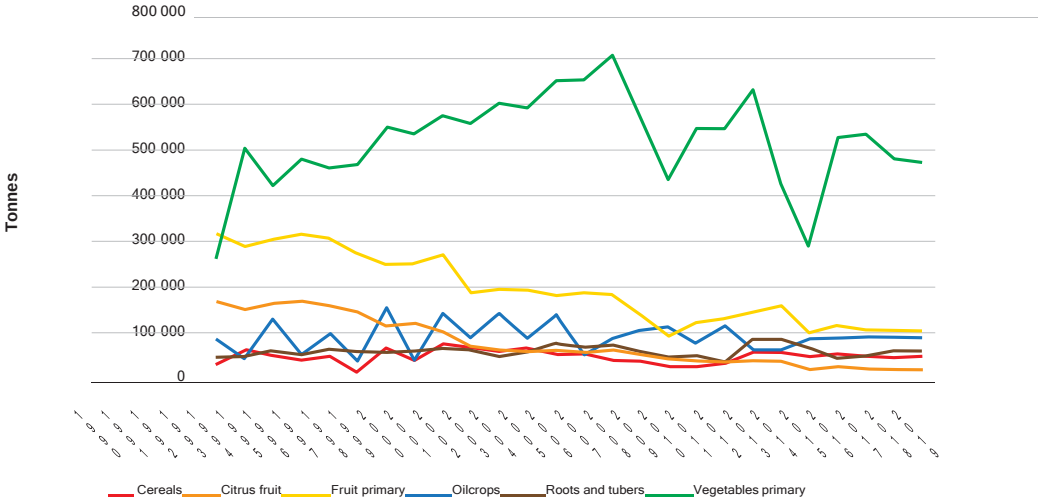


Figure 4.4 Key agricultural commodities production volume (1990–2019) (Source: FAO. 2021. FAOSTAT Production Database. In: FAO. Rome. Cited 20 March 2023. www.fao.org/faostat/en/#data.)

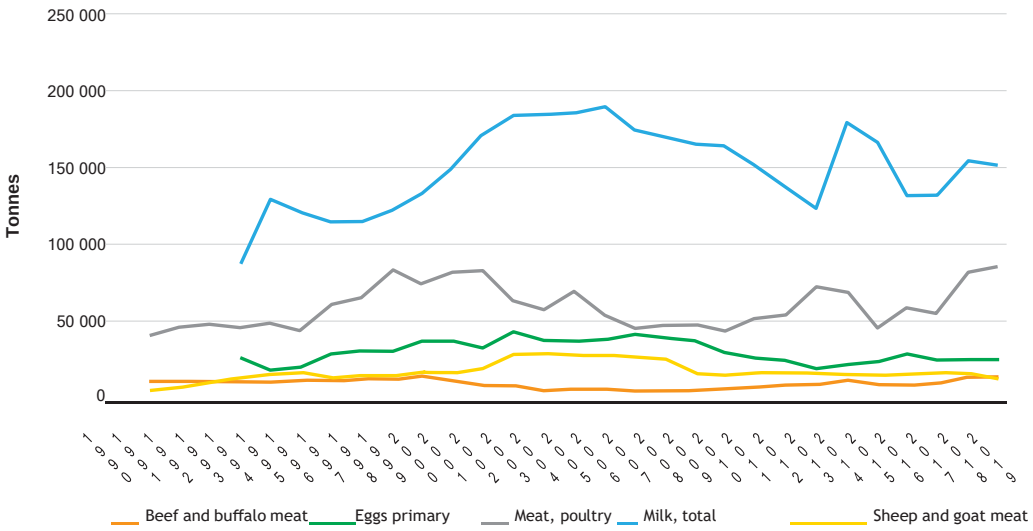


Figure 4.5 Key livestock commodities production volume (1990–2019) (Source: FAO. 2021. FAOSTAT Production Database. In: FAO. Rome. Cited 20 March 2023. www.fao.org/faostat/en/#data.)

Another crucial element is the food processing industry. Although still in its early stages in the Occupied Palestinian Territory, this sector has seen steady development, particularly in the production of dairy products, olive oil, and pickled goods. A significant portion of the raw materials, including cucumbers, dates, tomatoes, eggplants, almonds, and grapes, are sourced locally. This growth has been welcomed by farmers and other stakeholders, given the positive spillover effects on other sectors and industries.

Population growth and rapid urbanization have increased pressure on the agriculture sector. The growing gap between local production and consumption has made imports increasingly essential to meet food needs. While the Occupied Palestinian Territory is largely self-sufficient in vegetables, grapes, figs, olive oil, poultry, meat, eggs, and honey, it remains highly food

insecure at the national level. The territory relies on imports for 40 percent of its main food items and more than 95 percent of its cereals and pulses. The import dependency ratio, indicating the share of food consumed from imports, has risen noticeably, reaching 32 percent in 2022, while agricultural production has continued to decline. Even with efforts to boost domestic food production to enhance food security, the Occupied Palestinian Territory will need to continue relying heavily on imports to meet a significant portion of its food needs.

4.3.2 Near-future projections

The reviewed literature and statistics indicate that Palestinian agricultural exports have been adversely impacted by occupation-imposed restrictions and political instability. Lacking control over most aspects of its international trade, the territory faces a chronic trade deficit.

Among Palestine's imports, animal feed and live animals constitute the largest commodity groups, together making up about 22 percent, followed by tobacco and beverages at 17 percent. Significant trends include a 140 percent increase in live animal imports from 2015 to 2020, an 89 percent rise in feed imports, and an 80 percent increase in dairy product imports. Additionally, imports of flour and cereal preparations grew by 77 percent. Imports of sugar and soda beverages also increased by 16 percent and 35 percent, respectively, indicating a shift in consumption patterns towards Western lifestyles. Overall, foodstuff imports surged by 44 percent over the five-year period.

The conflict in Ukraine and economic sanctions on Russia have exacerbated global shortages of essential products like oil, gas, and cereals, upon which Palestine heavily relies, leading to rising food prices.

Conversely, agrifood exports from Palestine declined by 14 percent over the same period, with the largest drops in vegetables and tobacco. However, revenue from edible nuts and fruits, including their preparations, nearly doubled. Key exports, such as olives, olive oil, and fruits, make up almost 40 percent of the export value, primarily destined for Israeli markets.

Consumption trends in Palestine have shifted significantly over the years due to globalization. Although food consumption data is not frequently collected, recent surveys reveal that Palestinian households predominantly consume calorie-dense diets, with carbohydrates, such as cereals, sugar (empty calories), and fats being the primary sources of energy. Approximately 86 percent of the population consumes less than the recommended amount of fruits and vegetables daily, indicating a widespread deficiency in dietary fiber. Pulse consumption is also notably low, despite their affordability and nutritional benefits, with pulses being eaten less than twice a week on average.

The prevalence of suboptimal diets in Palestine is closely linked to poverty and a lack of nutritional knowledge. Data show that many healthy foods, especially fruits, vegetables, and grains, are unaffordable for a significant portion of the population. Some commodities, like avocados and honey, are rarely affordable for poorer Palestinians. Numerous studies confirm that fruit and vegetable consumption in Palestine is below the minimum recommended levels, lagging behind global and Asian intakes. Additionally, the consumption of salt and sugar-sweetened beverages significantly exceeds recommended levels, which is equally alarming.

4.3.3 Long-term projections

Long term projections in the food sector are heavily impacted by the political situation and how it will evolve, and it is impossible to make at this point of time.

4.3.4 Potential solutions and alternatives

To face the many challenges in the food production sector and based on the different reviewed literature, a set of policies for the future agriculture and food production in Palestine can be identified. Most of these policies are seen as levers to mitigate the different challenges facing the agricultural and food production in Palestine. These policies or levers can be summarized in the following:

- Invest in Nutrition-specific interventions comprise investments that help address the immediate causes of malnutrition.
- Facilitate diversification and increase production of nutrient-rich crops. An immediate lever to improve food and nutrition security would include mobilization of investment and expertise to enhance the production and marketing of highly nutritional and high-value horticulture, livestock and aquaculture products.
- Effective and widespread investments for climate change adaptation. Higher temperatures and increasing droughts and warm spells call for additional effort in optimizing the use of natural resources and in ensuring adoption of climate adaptive and energy efficiency approaches.
- Increased availability of water for agriculture, including treated wastewater. This includes enhancing the development of alternative water resources, rehabilitating agricultural wells and springs, scaling up water- harvesting projects to increase water-harvesting capacity and improving water governance.
- Public-private dialogue on policy shifts towards value chain integration. Such dialogue should involve all stakeholders and be sector-specific, constructive, evidence-based, and transparent. It would aim to form the basis for progress through the appropriate legal and regulatory frameworks to draw up a road map for the recognition of the Palestinian agricultural heritage by defining goals and designating responsible stakeholders, activities, deadlines and performance measures. Shifting investments and policy attention in favour of smallholders' empowerment is vital to secure the future of the agrifood value chain in the Occupied Palestinian Territory.
- Professional advisory services to farmers, including consultancy on the use of digital technologies. This lever would aim to catalyse the adoption of market-oriented, sustainable practices and technologies, pursuing value chain integration. As international experience shows, support programs subsidizing access to professional advisory services are effective.
- Public investment in aggregation and market infrastructure. Value chain integration requires reinforcement of market infrastructure, backed by public intervention in partnerships with the private sector.
- Policy dialogue towards a better enabling environment for inclusive entrepreneurship. An enabling environment is a precondition for the establishment of a vibrant business community capable of generating profits and job opportunities. The right mix of effective policies and services is required to address the needs of the private

entrepreneurs with a particular focus on marginalized groups, such as women, young people, Bedouins and people with disabilities.

- Investment in human capital to enable the employability of Palestinians in agriculture and agrifood industries. Investment in human capital is necessary to ensure that high-quality skills and services are available to food system stakeholders. This proposed lever targets the gap in technical and managerial knowledge, and skills among different food system stakeholders.

4.4 Synthesis

Mapping of food resources has been the most difficult task of the WEFE resources, especially for the Palestinian territory. Food production has been affected primarily by land degradation and water quality (brackish water) as well as by external factors including climate change and the geopolitical situation.

Since the early 1950s, the JV has undergone significant agricultural development. Collaboration between public and private sectors has led to advanced irrigation systems and modern farming techniques. In recent years, date palm cultivation has surged, with over 29,000 trees planted, producing 33,000 tonnes annually and creating substantial employment. Despite successes, marketing issues and pest threats persist. Animal production has evolved with a shift to high-yielding dairy cows, while small-scale farms continue to support local livelihoods. The dairy industry has expanded, with modern factories processing various products. Sustainable practices address challenges like water shortages. Additionally, fish production through aquaculture and aquaponics is vital, enhancing local economies and food security with government and international support.

The agricultural land has been degraded due to continuous cultivation for millennia which has as a result extremely low soil organic carbon. The impact of this situation is depicted in the estimated production yields for the JV. This is a common problem for the three territories of the JV necessitating measures for soil restoration using agro-ecological practices that will improve soil quality and soil fertility and health.

5. Ecosystem Resources Mapping

5.1 Current Situation

The Jordan Valley (JV) is a vital and diverse environment, encompassing various ecosystems, including freshwater, shrublands, drylands, agricultural and urban ecosystems in a sub-tropical climate. It serves as the biological heart of the Middle East, supporting its unique flora and fauna, and acting as an important migratory pathway for birds travelling between Africa and Europe. The JV is characterized by a wide range of bio-climatological and physical conditions supporting all human activity, vegetation, and wildlife.

The JV stands as a vital repository of freshwater ecosystems, prominently exemplified by the winding course of the Jordan River and its tributaries. These freshwater habitats play a pivotal role in sustaining the region's biodiversity, offering a sanctuary for numerous plant and animal species uniquely adapted to the aquatic environment. The Jordan River, originates from the Dan and Hasbani streams, located at the northern of Israel, and flowing into the Hula Valley, the Sea of Galilee, to then cross the JV, forming a complex network of interconnected ecosystems. Its tributaries contribute to this complex web, creating diverse habitats ranging from flowing watercourses to quiet pools. These freshwater ecosystems are critical breeding grounds for various aquatic species, fostering biodiversity and supporting the delicate balance of the entire ecosystem. Endemic species, such as the indigenous fish populations and migratory birds, rely on these habitats for their survival. In addition to the Jordan River, several other freshwater ecosystems within the JV contribute to its high biodiversity. Seasonal streams and wetlands, often fed by runoff from the surrounding hills, provide dynamic environments that host a variety of flora and fauna. These ecosystems are essential not only for the intrinsic value they hold but also for the ecosystem services they provide, including water purification, nutrient cycling, and the regulation of water flow. The interconnected nature of these freshwater habitats underscores their significance in the larger Water-Energy-Food-Ecosystem nexus, as they contribute to the agricultural productivity, and the overall health of the region.

The Dead Sea Basin is the lowest elevation on land, located about 41 meters below sea level. It is characterized by Sudanese trees with long roots that take advantage of the high-water table in the area of poor rainfall, making parts of it resemble the East African savannas. The Jordan River and its tributaries provide essential habitats for a diverse range of plant and animal species, including several freshwater ecosystems.

Status of ecosystems and biodiversity

The eastern section of the Harod Valley, located at the foot of Mt. Gilboa, on the Western part of the Jordan River, south of the Sea of Galilee (The Kinneret Lake) and north of the green line demarcating the beginning of Area C of the Palestinian Authority, lies about 120 meters below sea level and receives between 250 to 400 ml of precipitation annually. Rain falls in the winter months, leaving the summer months hot and dry

(https://ims.gov.il/sites/default/files/inline-files/ANN_MEAN.pdf). The relatively large amount of precipitation on Mt. Gilboa, which is over 600 meters above sea level, during the winter months and the steep drop in altitude from the Gilboa to the valley below has created an abundance of springs in the region, which flow all year long and from which the regional council takes its name, Valley of the Springs. Historically, these springs and the surrounding forests served as an important habitat for a large variety of species in the region including mammals such as wild boar, foxes, jackals, and porcupines. Humans have been living in this valley from the beginning of the agricultural revolution and it is the cradle of urbanization for over 11,000 years. The wetlands, as an aquatic ecosystem, have been playing a major role for biodiversity conservation in the region, which remained for the most part, intact until the 1920s when the kibbutzim (communal farming settlements) were established . The Israeli farmers drained the swamps (wetlands), turning them into agricultural land and fish farms. While many of the wetlands have disappeared from that area, the fishponds fulfill the ecological role that wetlands played in the past, providing habitats for local species and feeding stations for over a billion of migrating birds from Asia to Africa in the winter and back again in the fall.

The agricultural sector in the area has changed tremendously in the last 70 years. In the mid-20th century about 20% of the inhabitants were farmers, while nowadays only a small percent of inhabitants is still practicing traditional farming. The type of agricultural activities, size of farms and types of crops have changed in the past 50 years. Several developments have driven these changes: global urbanization; modernization and automatization of agricultural practices that improved crop yield, while reducing labor costs, and reduced water and energy costs. On the other hand, liberal economic policies promoted by consecutive Israeli governments over the past few decades led to the lifting of protections on local producers by reducing import taxes on agricultural products, reducing subsidies on water and farming equipment etc., leading to much less profitable farming. The results have forced farmers to move to search for more profitable crops, to adopt state-of-the-art technologies or to leave agriculture altogether.

Over 70% of the Israeli aquaculture industry is located in the Valley of Springs. Fishponds in the JV function as an agroecosystem, providing many of the ecosystem regulating services, once provided by natural wetland ecosystems that existed before the Jewish farmers came to the valley. The local fishing industry is under threat from several sources as described above and is affected by the strict environmental regulation that has been imposed in the last few decades on growers, and which were intended to protect ground water quality. In addition, improper disposal of dead fish from fishponds creates conditions for eruptive species like the jackal population to flourish.

Traditional fish farming has been replaced by Recirculatory Aquaculture Systems (RAS) that enable fish to be grown more efficiently in smaller volumes of water with a greater automatization and control over water quality and other inputs as a capital intensive industry. RAS enables farmers to grow a larger variety of more profitable fish species. It may also reduce the demand for manual labor, a critical problem due to the lack of interest of younger generation of the valley to work in fish farms.

While RAS transforms aquaculture into small and controlled environment ponds, water feeding those ponds can be circulated through large ponds that enables the regulation of oxygen, pH, etc and to regulate the water quality. Such a model maintains and enhances the ecosystem regulatory role of fish farms.

Predicted changes in ecosystem health and services are likely to be influenced by ongoing challenges such as food insecurity, water scarcity, and energy dependence. Integrated approaches that address the WEFE Nexus are essential to mitigate potential threats and ensure the sustainable management of ecosystem.

The role of ecosystems in supporting future Water, Energy, and Food (WEF) demands in the JV is critical, encompassing various aspects that are integral to the region's long-term sustainability and resilience. The biodiversity within ecosystems directly influences the resilience of agricultural systems. Healthy ecosystems support a diverse range of plant and animal species that contribute to pollination, pest control, and soil fertility. This biodiversity enhances the overall resilience of agricultural landscapes, making them less vulnerable to pests, diseases, and climate-related challenges. The preservation of ecosystems ensures their continued role in climate regulation, helping the JV adapt to changing climatic conditions. Vegetative cover within ecosystems plays a crucial role in preventing soil erosion. The roots of plants help bind the soil, reducing the risk of landslides and maintaining soil fertility. This, in turn, supports sustainable agriculture by preserving the quality of arable land and preventing the loss of fertile topsoil.

Beyond their instrumental value, ecosystems in the JV hold cultural and recreational significance for local communities. Preserving these natural spaces not only sustains traditional practices and cultural heritage but also provides opportunities for recreation and tourism. This, in turn, can contribute to local economies and enhance the overall well-being of communities.

Wetlands and riparian ecosystems act as natural filters, purifying water before it enters larger water bodies. Preserving these areas is crucial for maintaining water quality, especially in the context of increasing urbanization and industrial activities. Healthy ecosystems contribute to the availability of clean water resources for both human consumption and agricultural use.

Ecosystems support sustainable resource management by providing a basis for traditional and sustainable land-use practices. Incorporating Indigenous knowledge and practices into ecosystem management helps ensure the longevity of resource utilization, without depleting essential natural assets. Preserving and managing ecosystems in the JV requires inclusive and empowering governance and the active engagement of stakeholders. Involving local communities, governmental bodies, non-governmental organizations, and the private sector in sustainable ecosystem management fosters a collective commitment to preserving these vital natural resources.

Ecosystem in that area provide the following services:

Provisioning services:

a. Food – orchards, field crops, fish from aquaculture, milk production and poultry.
b. Water – drinking and irrigation water from the springs and aquifers.
c. Raw materials – cattle fodder from agricultural lands

Regulating services:

a. Air purification (dust and pollutants mitigation and collection) – trees, shrubs, and vegetation.
b. Global climate regulation (carbon sequestration) – trees, shrubs, and vegetation.
c. Flood protection – Protection from extreme events – floods and storms effects' mitigation through tree and vegetation cover and reservoirs.
d. Water regulation – groundwater recharge, discharge, and storage of winter rain in the Sea of Galilee.
e. Wastewater treatment – water from fishponds discharged can be purified in wetlands.
f. Erosion prevention – trees, shrubs, and vegetation cover.
g. Pollination – carried out by bees and birds.
h. Biological control used near and in agricultural fields – natural predators.

Cultural and heritage services:

a. Aesthetic values – landscapes and views.
b. Cultural values – Sea of Galilee, Harod Springs, Gan Hashlosha, Beit Shean National Park, bike trails, hiking trails, kayaking, and birdwatching.
c. Spiritual/heritage values – Sea of Galilee and the Jordan river baptism sites, Beit Alpha Synagogue, Beit Shean archeological park.
d. Cognitive values – education and research provided by different ecosystems, focusing on: historical, agricultural and ecological aspects.

Non-use values – existence, bequest and altruistic values. For example, many Israelis see the region as integral to Israel's pioneering history and would not want the area over developed, even if they themselves do not plan to spend time there.

5.2 Driver-Pressure-State-Impact-Response (DPSIR) analysis of JV

JV's ecosystems and biodiversity are under pressure due to various factors. The DPSIR analysis for the examined area is presented in Figure 5.1. The main drivers that affect the system in the area are population growth, climate change, land use change and pollution. The environmental pressures exerted in the JV are the result of intensive agricultural activities (agriculture, livestock and aquaculture), tourism, climate change, geogenic pollution, population and migration and invasive species. These pressures have resulted in significant impacts to the WEFE Nexus with surface water flow decline, groundwater depletion, high groundwater salinity, pollution and loss of biodiversity.

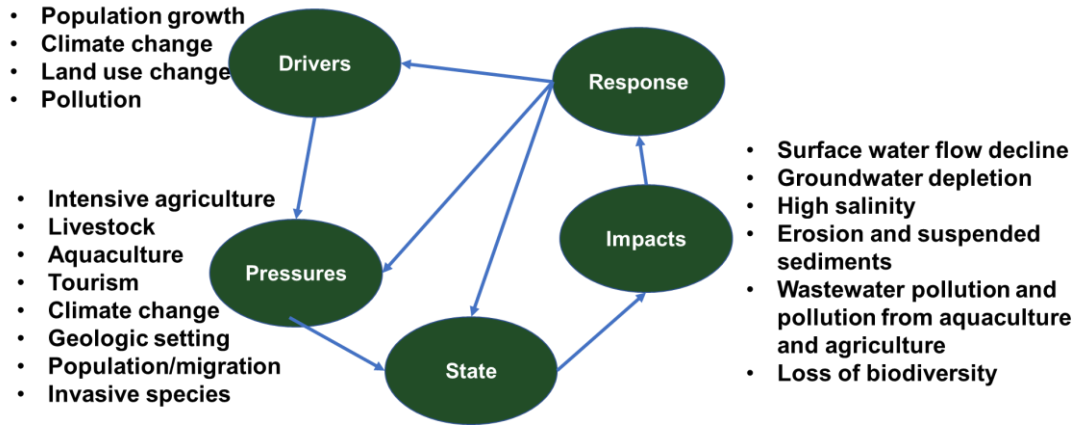


Figure 5.1. DPSIR analysis of the JV

Climate change, following the more general Mediterranean trend of water resources shortages, has been projected as a serious threat for the area. The region's climate is changing, with the potential for increased droughts, higher temperatures, and more extreme weather events, posing significant challenges to the preservation of ecosystem. Climatically, the JV is characterized by hot dry summers and mild wet winters, becoming progressively drier moving southward through the valley towards the Dead Sea. It is predicted that the Eastern Mediterranean will continue to face a reduction in annual precipitation, longer hot summer dry season, and shorter cool wet winter season due to climate change (Hochman 2018). This change in climatic conditions for the region will have a major impact on the local instrumental value ecosystem of the Harod and Beit Shean Valleys including the Valley of the Springs. Most crops in the valley grow during the winter months. Such a dramatic change in the length of the seasons means that many crops will no longer be feasible to grow in the valley. If farmers do not learn to adapt to these changes in climate patterns, they may have to leave farming altogether, reducing the size of the agroecosystems which currently maintain much of the biodiversity in the valley. Natural ecosystems will also be impacted as rapid changes in the climate may impact endemic species, which have found their niche in the unique ecosystem of the JV. Rapid changes in climate, especially changes in precipitation patterns and season length may encourage the spread of generalist species, which can thrive in changing environments. Invasive species and eruptive species may push out native and endemic species, impacting the biodiversity of the region.

Surface water flow declines have been observed in the Jordan River and the discharge to the Dead Sea has been decreasing dramatically leading to the water level declines over the years. This decline is primarily due to withdrawals of water above the Sea of Galilee and diversion for other uses. The Dead Sea, a critical component of the JV ecosystem, faces severe threats due to declining surface water flow, particularly from the Jordan River. Extensive water withdrawals upstream, especially above the Sea of Galilee, for agriculture, domestic, and

industrial uses have dramatically decreased the water reaching the Dead Sea, leading to a rapid decline in its water levels, dropping over one meter per year. This decline has exposed large areas of the Sea's bed, disrupted its unique saline ecosystem, caused dangerous sinkholes, and posed risks to surrounding infrastructure. The shrinking sea also threatens the tourism industry, vital for local economies, and challenges mineral extraction operations.

Population growth is affected significantly by the political instability in the region that is fueling refugee movements into the area and causing additional pressure on water, energy and food resources.

Land use distribution has been stabilized in the region to a large extent. It is not expected to have increases in the cultivated areas in Jordan and Palestine, however, there is the potential for conversion of agricultural land to urban areas in the Israeli sector as discussed earlier. On the other hand, further intensification of agriculture in Jordan and Palestine is expected, especially if more water becomes available in Palestine for irrigation.

The main sources of pollution in the JV are wastewater from treatment plants and unsewered areas, fertilizer, pesticide and herbicide pollution from agriculture, urban solid waste disposal sites, aquaculture water use, and small “industrial” facilities mostly related to agriculture. In addition to the above, the impact to water quality due to saline bedrock, which increases the chloride concentration in the irrigation water, all provide a complete picture of the anthropogenic and geogenic pollution in water and soil.

The presence of saline bedrock often leads to the development of saline groundwater, affecting both the quality and availability of water resources. Additionally, the influence of saline bedrock extends beyond hydrogeological aspects to include soil quality and overall environmental health. In conjunction with saline bedrock, the surrounding soil may also become saline. Saline soil contains high concentrations of salt, which can negatively impact plant growth and soil fertility. The combination of saline bedrock and saline soil poses significant challenges for agriculture in the in the region. Crop selection becomes crucial, as certain plants exhibit greater salt tolerance. Implementing soil amendments and irrigation practices that mitigate the impact of salinity is essential for sustaining agricultural activities in such areas. Saline soil can contribute to the degradation of water quality as salts leach into groundwater and surface water bodies. This has implications for both human consumption and ecosystem health. Poor water quality can lead to health problems for local communities and disrupt aquatic ecosystems. The combined effects of saline bedrock and saline soil can disturb local ecosystems. Native flora and fauna may struggle to adapt to the changing conditions, leading to shifts in biodiversity and potential ecological imbalances. Monitoring and conservation efforts are crucial to mitigate the impact on the environment.

The geologic setting is also prone to high erosion rates and suspended sediments in surface waters. The steep slopes of the JV and the erodible sandstone formations of the deposits in combination with the luck of vegetation are highly erodible and result in high loads of suspended sediments in the surface water with all the associated impacts to the environment.

The abovementioned pressures can lead to negative impacts on ecosystems and biodiversity in the JV. In addition, the rich biodiversity of the JV faces a pressing threat from invasive species, which have become a significant ecological concern in the region. Invasive species, whether introduced accidentally or intentionally, possess the ability to disrupt the delicate balance of native ecosystems. The JV, with its unique flora and fauna, is particularly susceptible to the impacts of non-native species that can outcompete, prey on, or otherwise displace indigenous plants and animals. Prosopis juliflora, commonly known as mesquite, is indeed found in the area.

Prosopis juliflora has exhibited invasive characteristics in some locations. It can outcompete native vegetation, leading to a reduction in biodiversity. The plant's extensive root system allows it to tap into water sources, potentially impacting local water availability and exacerbating competition with native species. The invasiveness of Prosopis juliflora can have cascading effects on ecosystems. Its presence may alter soil composition, affect nutrient cycling, and create challenges for native plants adapted to different ecological conditions. Additionally, the dense growth of mesquite can alter habitat structure, potentially impacting local fauna and their natural habitats.

To reduce the impact of the aforementioned pressures, to address these challenges and ensure the long-term sustainability of the region's ecosystems and their role in supporting future WEFE demands, integrated and sustainable management approaches are essential. Sustainable management and preservation of ecosystems and the services they provide will be essential to mitigate these impacts. Long-term projections should focus on the preservation of ecosystem health and services, as well as their role in supporting future WEFE demands.

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Appendix

Appendix 0-1: Drinking , Irrigation, and Industrial water supply and demand for current, short, and long term. The current from water balance report (MWI, 2021). Short and long terms from National Water Strategy (2023-2030).

	Supply (Current)	Supply short term 2030	Supply long term 2050	Demand (Current)	Demand short term	Demand long term
Drinking water (MCM)	23.62	27.5	34.31	26	32.4	40.3
Irrigation water (MCM)	206.42	370	370	400	400	400
Industrial water (MCM)	4	4	4	4	4	4

Appendix 0-2: cropping pattern in the area of JV reusing blended water. (Al Bakri, 2016).

Crop	Vegetables	Cereal	Citrus	Banana	Different trees	Nurseries
Area (du)	36289.8	5590	9384.4	898	23560.5	48
Percentage (%)	47%	0.07%	0.12%	0.01%	31%	00

Appendix 0-3: Plant and animal production in JV. Ministry of Agriculture, annual report, 2023.

	Current
1. Crop production (ton)	
Cereals	6,746
Vegetables	625,179
Citrus trees	159,475
Fruit trees	85,400
2. Animal production (ton)	
Category 1 (Beef and sheep)	2,325
Category 2 (poultry)	360
Category 3 (milk)	40
Category 4 (Egg)	700

Category 5 (Honey bees)	6445 heeve
Category 6 (Fish)	954

Appendix 0-4: Land use in JV, current and short term projection, (National Master Plan for JV, 2016).

Area (ha)	Current	Short term (If available)
Uncultivated / nature reserves	81,029	67,358
Agriculture (Irrigated area)	45,183	45,183
Built up area	4,462	9,133
Fish Farms	73	73
Water reservoirs	555	555
Wadis	2,416	2,416
TOTAL	133,718	124,718

Appendix 0-5: Drinking , Irrigation, and Industrial water supply and demand for current, short, and long term. The current from water balance report (MWI, 2021). Short and long terms from National Water Strategy (2023-2030).

	Supply (Current)	Supply short term 2030	Supply long term 2050	Demand (Current)	Demand short term	Demand long term
Drinking water (MCM)	23.62	27.5	34.31	26	32.4	40.3
Irrigation water (MCM)	206.42	370	370	400	400	400
Industrial water (MCM)	4	4	4	4	4	4

Appendix 0-6: cropping pattern in the area of JV reusing blended water. (Al Bakri, 2016).

Crop	Vegetables	Cereal	Citrus	Banana	Different trees	Nurseries
Area (du)	36289.8	5590	9384.4	898	23560.5	48
Percentage (%)	47%	0.07%	0.12%	0.01%	31%	00

Appendix 0-7: Plant and animal production in JV. Ministry of Agriculture, annual report, 2023.

	Current
1. Crop production (ton)	
Cereals	6,746
Vegetables	625,179
Citrus trees	159,475
Fruit trees	85,400
2. Animal production (ton)	
Category 1 (Beef and sheep)	2,325
Category 2 (poultry)	360
Category 3 (milk)	40
Category 4 (Egg)	700
Category 5 (Honey bees)	6445 heeve
Category 6 (Fish)	954

Appendix 0-8: Land use in JV, current and short term projection, (National Master Plan for JV, 2016).

Area (ha)	Current	Short term (If available)
Uncultivated / nature reserves	81,029	67,358
Agriculture (Irrigated area)	45,183	45,183
Built up area	4,462	9,133
Fish Farms	73	73
Water reservoirs	555	555
Wadis	2,416	2,416
TOTAL	133,718	124,718

Appendix 0-9: Kingdom Fuel Consumption, 2009-2022 (000 Ton)

Year	Total country consumption	Percentage of change	Per capita	Consumption by Electricity	Percentage of change	Percentage of electricity consumption to total
2009	7739.0		1190.6	3357.0		43.4%
2010	7357.0	-4.94%	1098.1	3194.0	-4.86%	43.4%

2011	7457.0	1.36%	1065.3	3092.7	-3.17%	41.5%
2012	8206.0	10.04%	1108.9	3479.0	12.49%	42.4%
2013	8157.0	-0.60%	1007	3598.9	3.45%	44.1%
2014	8461.0	3.73%	1272.4	3726.1	3.53%	44.0%
2015	8927.0	5.51%	1373	3833	2.87%	42.9%
2016	9614.8	7.70%	981.3	3735.3	-2.55%	38.8%
2017	10008.8	4.10%	995.6	3804.4	1.85%	38.0%
2018	9759.0	-2.50%	946.6	3526.4	-7.31%	36.1%
2019	9266.0	-5.05%	878.0	3360.5	-4.70%	36.3%
2020	8583.0	-7.37%	794.3	3202.1	-4.71%	37.3%
2021	8726.0	1.67%	789.2	3136.4	-2.05%	35.9%
*2022	....		...	**3311.9	5.59%	...
		1.14%			0.033%	
Source : National Electric Power Company						
*Primary						
**Does not include oil shale/generating plant bids						

Appendix 0-10: Consumed Primary Energy, 2009- 2021(000 t.o.e)

Year	Crude Oil & Oil Products	Natural Gas	Renewable Energy	Coal & petroleum	Electricty	Total	Percentage change %
2009	4,454	3,086	120	-	79	7,739	5.5
2010	4,774	2,289	124	-	168	7,355	-5.0
2011	6,141	873	146	-	313	7,473	1.6
2012	6,992	659	140	226	188	8,205	9.8
2013	6,689	907	145	320	96	8,157	-5.9
2014	7,479	301	152	420	109	8,461	3.7
2015	6,331	1,944	160	326	183	8,944	5.7

2016	5,327	3,389	412	402	84	9,614	7.5
2017	5,671	3,510	515	313	13	10,022	4.2
2018	5,225	3,438	753	297	47	9,760	-2.6
2019	5,518	3,509	756	311	42	10,136	3.85
2020	5,319	3,492	744	288	39	9,882	1.1
2021	5,789	3,768	787	329	46	10,719	4
Source: Ministry of Energy and Mineral Resources/Annual Report 2021							

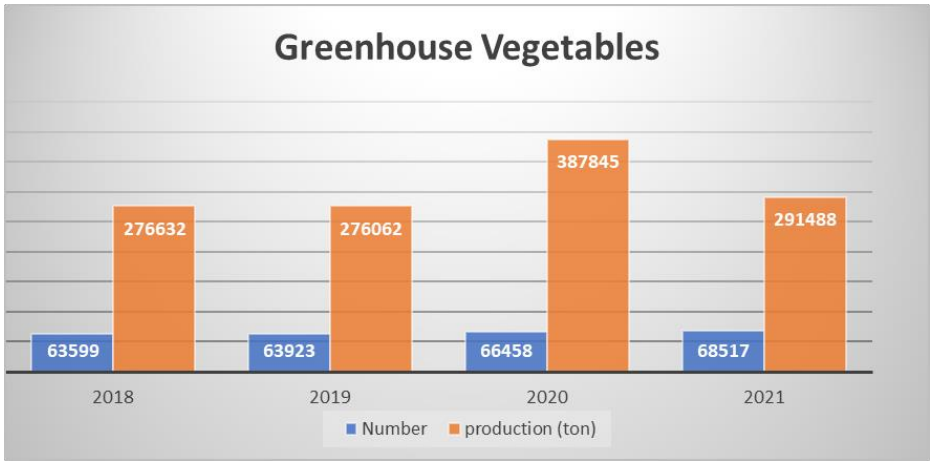


Figure 0.1: Production and number of greenhouse vegetables in JV through the years (2018-2021). Ministry of Agriculture, annual reports.

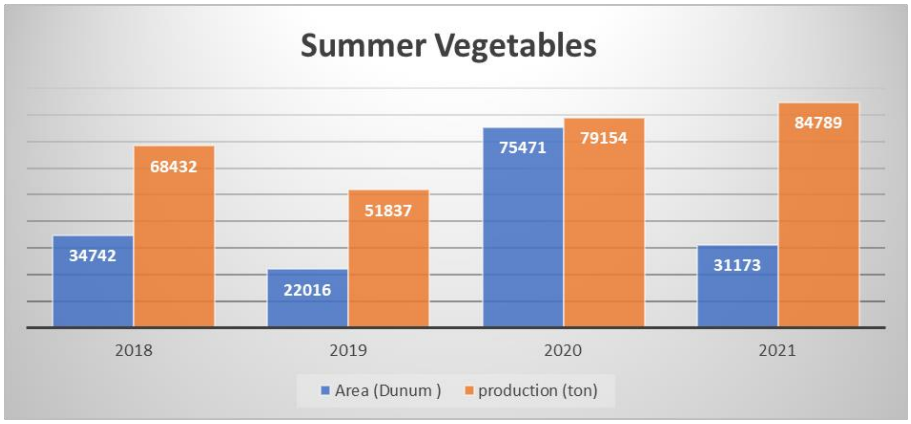


Figure 0.2: Area in dunum and production in ton for vegetables in summer at Jordan Valley through the years (2018-2021). Ministry of Agriculture, annual reports.

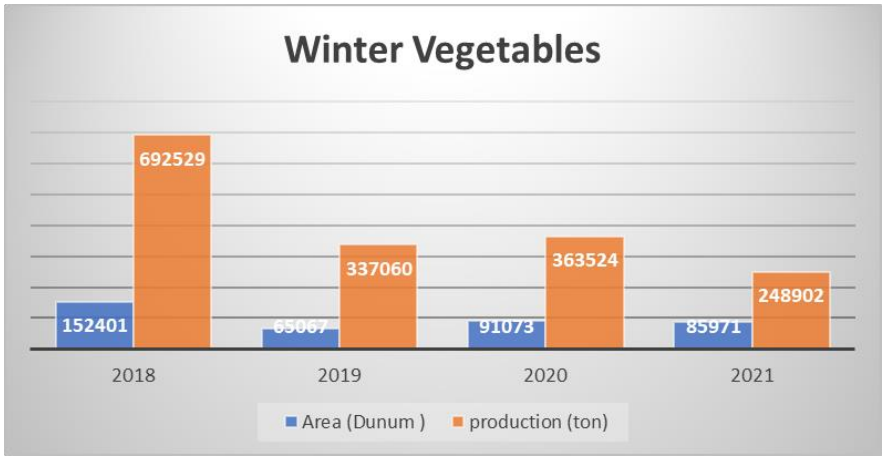


Figure 0.3: area and production of vegetables in winter at JV through the years (2018-2021). Ministry of Agriculture, annual reports.

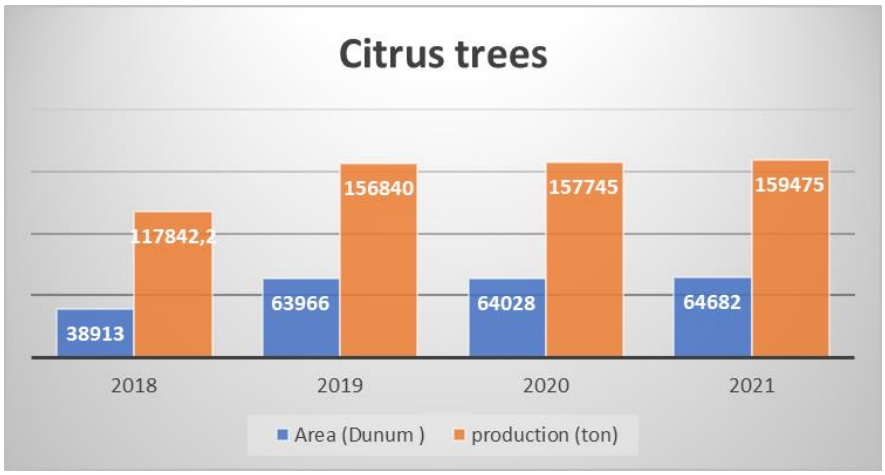


Figure 0.4: Area in dunum and production in ton for citrus trees in Jordan Valley through the years (2018-2021). Ministry of Agriculture, annual reports.

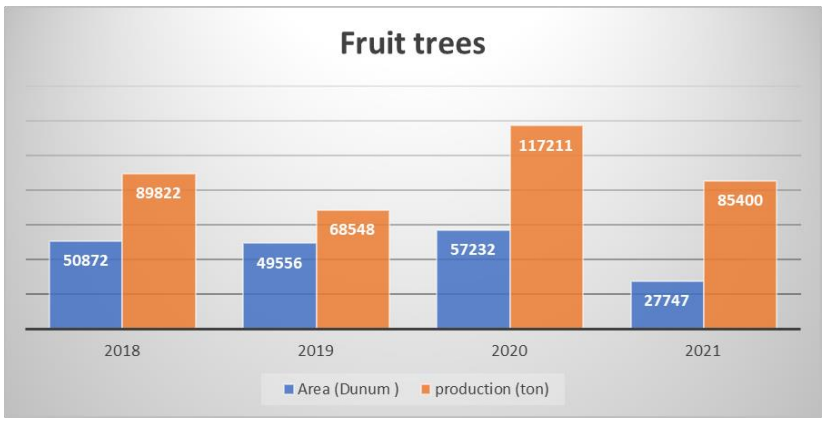


Figure 0.5: Area in dunum and production in ton for fruit trees in Jordan Valley through the years (2018-2021). Ministry of Agriculture, annual reports.

Appendix 0-10: Population projection in Palestine

Cluster Name	Population 2010	Population 2015	Population 2020	Population 2030	Population 2050
Bardala kardala einbeida	5259	5830	6841	18583	55451
Al-Jiftlik	6499	7205	8455	22965	62631
Fasayil	1157	1282	1505	4088	31699
Al-Auja	4423	4903	5754	15629	50610
Jericho	34112	37820	44379	120540	247520
Total	56014	62103	72873	197935	499340

Appendix 0-11: Wastewater generation in Palestine

Cluster Name	2015	2020	2030	2050
	m^3 Wastewater	m^3 Wastewater	m^3 Wastewater	m^3 Wastewat
Bardala	399,744	469,056	1,697,024	4,519,616
Al-Nassariya	346,880	407,040	1,613,696	4,376,320
Al-Jiftlik	493,952	579,648	1,845,632	4,775,360
Fasayil	87,936	103,168	1,205,312	3,673,664
Al-Auja	336,192	394,496	1,596,800	4,347,200
Jericho	2,592,896	3,042,560	5,155,584	10,469,824
Total (m^3)	**4,257,600**	**4,995,968**	**13,114,048**	**32,161,984**
Total (million m^3)	**4.3**	**5.0**	**13.1**	**32.2**

Appendix 0-12: Amount of consumed water for Multipurpose in Kardala and Bardala Village (source: WBWD, 2022)

Community	Population in service (capita)	Total amount of water consumed during 2022 (m^3/year)
Kardala	224	4,405,889
Bardala	1,776	

Appendix0-13: Irrigated areas and water demand

Cluster Name	Year 2015		Year 2020		Year 2030		Year 2050	
	Irrigated Area Donum	Additional Water Demand MCM	Irrigated Area Donum	Additional Water Demand MCM	Irrigated Area Donum	Additional Water Demand MCM	Irrigated Area Donum	Additional Water Demand MCM
Bardala kardala ein beida	**13,500**	**4.627**	**13,500**	**4.627**	**25,200**	**17.64**	**48,800**	**34.16**

Al-Nassariya	**5,300**	**1.342**	**5,300**	**1.342**	**10,800**	**7.56**	**21,800**	**15.26**
Al-Jiftlik	**5,500**	**5.334**	**5,500**	**5.334**	**13,900**	**9.73**	**30,800**	**21.56**
Fasayil	**1,200**	**0.789**	**1,200**	**0.789**	**9,100**	**6.37**	**25,000**	**17.5**
Al-Auja	**4,000**	**2.825**	**4,000**	**2.825**	**6,700**	**4.69**	**12,000**	**8.4**
Jericho	**12,500**	**14.134**	**12,500**	**14.134**	**16,500**	**11.55**	**24,500**	**17.15**
Total	**42,000**	**29.05**	**42,000**	**29.05**	**82,200**	**57.54**	**162,900**	**114.03**

Appendix 0-14: Amount of consumed water for each use in Ein Al Beda village (source: MoA & the Directorate of Agriculture in Tubas, 2022)

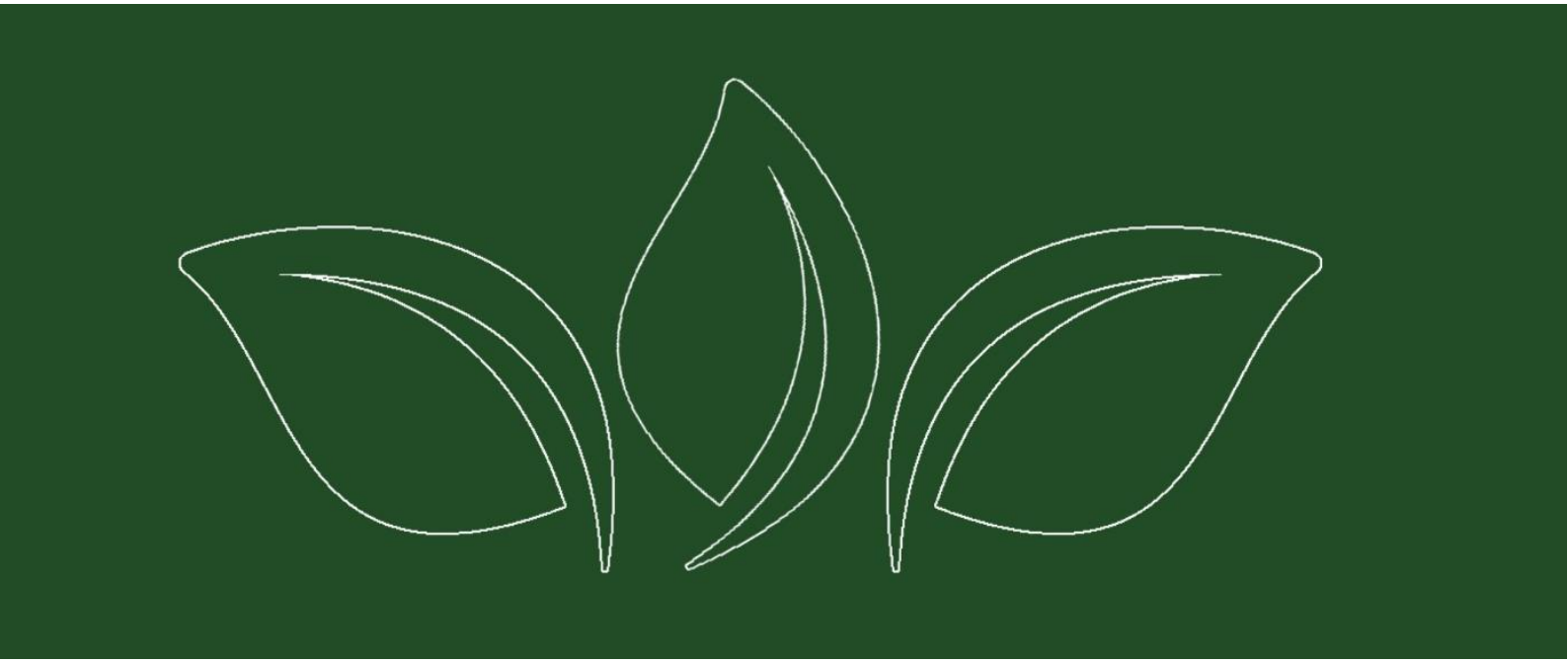
Types of use	**Amount of water consumed during 2022** (m^3/year)
Consumed amount from WSP	2,703,193
Agricultural use	3,600,000
Livestock use	9,563

Appendix 0-15: Amount of consumed water for each use in Kardala and Bardala villages (source: MoA & the Directorate of Agriculture in Tubas, 2022)

Types of use	**Amount of water consumed during 2022** (m^3/year)
Consumed amount from WSP	4,405,889
Agricultural use	3,600,000
Livestock use	21,623

Project Coordinator

Project Partners



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