Rainwater Harvesting in the Kingdom of Jordan

Scoping Study

--- FINAL REPORT ---

14 October 2021

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Introduction

Jordan is situated in the Middle East region and is bordered by Israel, Palestine, Saudi Arabia, Syria and Iraq. Due to its arid to semi-arid climate and its dynamical demographics, the country has experienced water deficits since the 1960s (Abdulla & Al-Shareef, 2009; Salman et al., 2016). The major reason for the stress on water resources (both surface- and ground- water) is the growing population and the influx of refugees (Al-Karablieh & Salaman, 2016; Hadadin, et. al., 2010). Indeed, the region witnessed five large crisis that led to five waves of migrants taking refuge in Jordan. Nowadays, the country is considered as one of the most water scarce country in the world as its renewable water resources only accounts for 148 m3 per capita per year (Salman et al., 2016). Currently, the country is mainly relying on surface and groundwater resources to meet the national demand for water (Al-Karablieh & Salaman, 2016). However, the water demand in the country surpasses the supply from the groundwater and surface water sources (Figure 1) (Whitman, 2019). Consumptive uses in irrigated agriculture in Jordan exhaust at present 85–90% of all the water made available for all the use sectors (Salameh et al., 2018, p.125). Alternative water sources such as the use of treated waste water and of brackish water are used to bridge the gap between the supply and demand, mainly in the agricultural and municipal sectors.

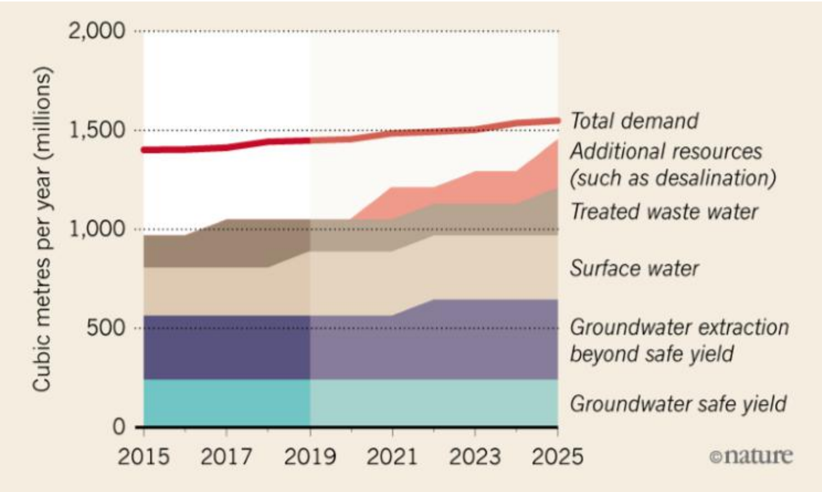


Figure 1: The water demand in Jordan in comparison to the water supply from the various water resources (source: Whitman, 2019)

Rainwater harvesting (RWH) is an ancestral technique that has been used in Jordan as early as 4000 years ago (Abdulla & Al-Shareef, 2009). The Jordanian government is currently promoting the use of RWH in order to alleviate the pressure on groundwater resources as well as to increase total water resources available for the population and its activities (OECD, 2014).

The EKN Amman with support of RVO asked this consortium to research how a program can strategically address this potential. This report therefore provides an analysis of the potential of RWH and selects feasible sites, technologies and stakeholders to facilitate program development and grant-making by the EKN Jordan. It needs to be taken into account that RWH in Jordan cannot be the solution to solve the water shortages caused by irrigated agriculture in Jordan and the overall answer to water resources depletion needs to be found in limiting abstraction and evaporation of non-renewable water. This would be both economic and social reasonable. Indeed, while agriculture does not contribute for more than 4 % of the gross domestic product (GDP) of Jordan (Al Absi et al., 2020).

1. Context of water harvesting in Jordan

1.1. Biophysical context

The biophysical environment determines the potential and limitations of natural resources in an area. Understanding the physical environment and its limits should be the basis for agricultural and water resources development planning. The objective of this biophysical analysis is to provide baseline information for the interpretations on RWH feasibility. The technical feasibility of different groups of RWH interventions will be analyzed based on biophysical characteristics of the area, such as soil, geology, topography, land use/cover and climate. Water supply and scarcity, especially domestic and agricultural scarcity, will be evaluated. The information in this Chapter is mainly based on desk review of existing literature and data.

1.2. Environmental context and challenges in relation to water availability

Jordan faces serious environmental challenges that impact water availability, while reduced water availability causes further environmental issues. The Aligned National Action Plan to Combat Desertification in Jordan 2015-2020 (Haddad et al. 2015), provides highly relevant and detailed information on the challenges. Below follows a summary:

95% of the country's land is arid and hyper arid while the remaining proportion of country's area is semi-arid. These ecosystems include deserts (Badia) with poor plant cover; sub-tropical ecosystems, including Sudanian species of tree and dwarf shrub prominent in the sparse and very open vegetation; aquatic ecosystems, comprised of rivers, wadies and wetlands, the latter varying from salt marshes to marine ecotypes; and the scarp and highland ecosystems, comprising of escarpments and mountains, hills and undulating plateaus with natural woodland (Pinus, evergreen/deciduous oak woodland) and steppe, the latter consisting of a transitional area where desert biota is gradually replaced by "Mediterranean" biota.

Non-sustainable land uses are the main causes of land degradation. The situation will be accentuated further by the threats of climate change and increasing population growth. Non-sustainable land use practices include improper farming practices (see below), overgrazing of natural vegetation, forest cutting, inappropriate land use, random urbanization, land fragmentation and over-pumping of groundwater. In recent years, the trends have been: (i) a reduction of total agricultural use, partly due to decreased capacity of poor land users; (ii) an increase in the permanent crop area at the expense of some annual crops which have become unprofitable and as a result of land fragmentation and a decrease in land holding sizes; and (iii) crop cultivation and grazing in areas of higher risk (steeper slopes and/or lower rainfall and in particular in the marginal and steppe areas).

Rain-fed farming, which is distributed over the northern, middle and southern Highlands, forms the base for agricultural production in Jordan. However, average crop yields are low and productivity is seriously limited by overall scarcity of water, extreme variability of rainfall and limited soil and water conservation (SWC) activities. Consequently, resource- limited land users have been increasingly exposed to decreasing income and declining livelihood security, which in turn have led to:

- Tractor tillage along slopes instead of animal plowing on contour
- Little soil fertility management, lack of rotational practices and fallow in cereal cropping
- Cultivation of marginal lands under field crops (barley and even wheat) as a consequence of urban encroachment, but also due to crop substitution with tree crops on higher potential lands

Livestock is an important component in the farming system in Jordan and a major source of cash income as well as consumption. There is a vicious circle whereby rangeland carrying capacity is decreasing, farmers are unable to supplement feeding with expensive fodder and feed and are thus obliged to downgrade traditional management and extend the grazing season to unsuitable months. This exacerbates pressure on rangelands and further lowers productivity of both, pastures and animals. Overgrazing is also leading to a loss of resilience of the rangeland against droughts.

1.3. Climate

Jordan is an arid to semi-arid country, with an average annual rainfall of around 200mm (Ministry of Foreign Affairs of the Netherlands (MFAN), 2018). According to the Global Aridity Index (Precipitation divided by Reference Evapotranspiration (ET0)) most of Jordan is classified as arid to even hyper arid in the South and South-East - with rainfall that can be as low as 28mm (MFAN, 2018) - while only the high rainfall areas in the North fall within the Semi-Arid zone. In the Upper Northern Highlands rainfall can reach around 570mm (Figure 2) (MFAN, 2018). The wet season takes place between the months of October to March, but 80% of the precipitation occurs between December and March (Figure 3). Because of the extreme low rainfall rates, 80% of the country is left unoccupied by humans.

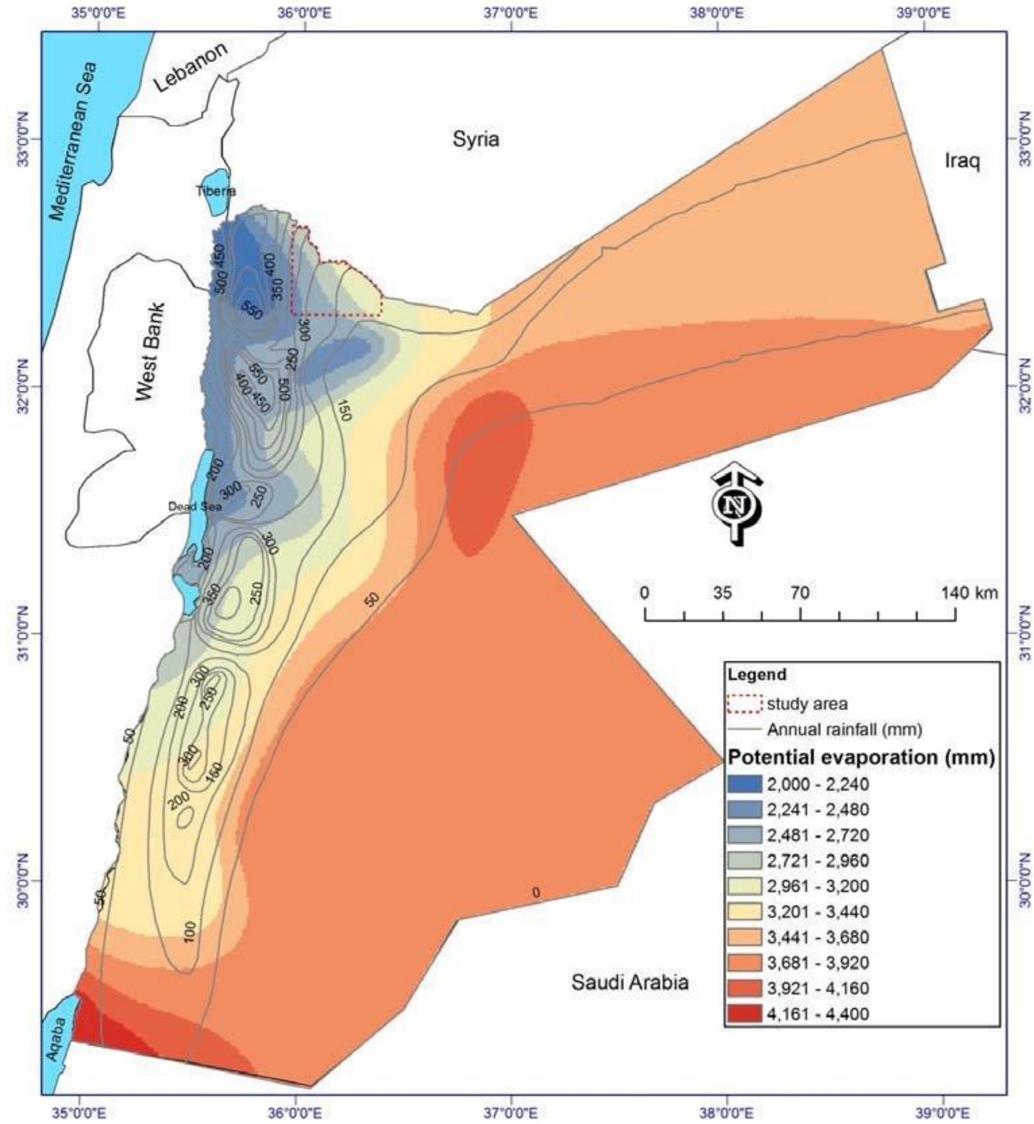


Figure 2: Mean annual rainfall and potential evaporation in Jordan (1971-2005) (source: Suleiman et al. 2011)

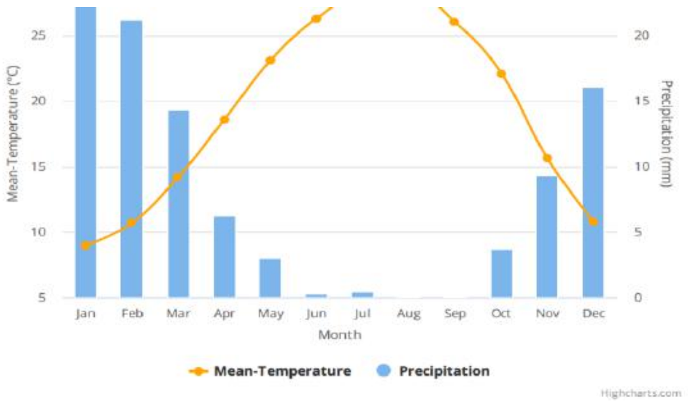


Figure 3: Monthly mean temperature and precipitation in Jordan between 1991-2020 (source: World Bank, 2021)

Climate change is a factor that will likely contribute to the water related challenges, although the actual impacts on temperature and rainfall in Jordan are uncertain. The approaches recommended in this study, are all no-regret measures considering climate change scenarios and an important part of the transition towards sustainable use of resources and adaptation to climate change. RWH and 3R in a catchment approach are increasingly recognized as main strategy for agriculture to adapt to climate change.

1.4. Soil & land use

The soil classification is closely linked to the climate and topography of the area (Lucke et al., 2013). Therefore, in dry desert governate of Al-Mafraq and Maan, dry soils with weak development are found (Figure 4). On the other hand, in the humid northern highland area the soils are richer and are classified as inceptisols.

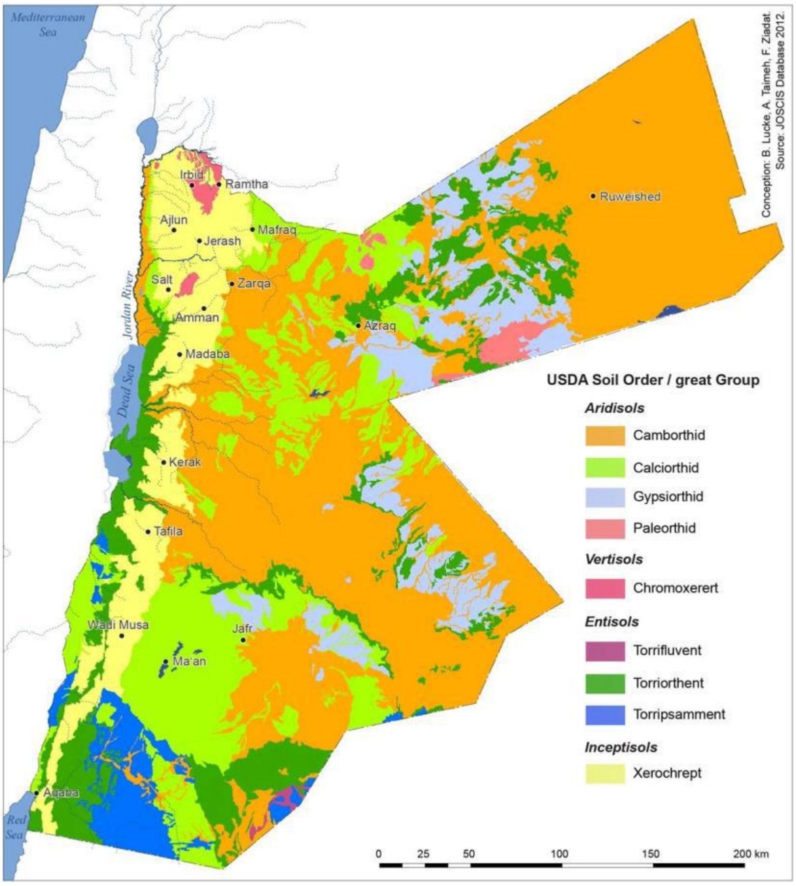


Figure 4: Map of soil classification in Jordan (source: Lucke et. al., 2013)

Figure 5 details the national land use of Jordan. Irrigated agriculture is mainly concentrated in the Jordan Valley and the highlands of Ajlun, Irbid (Ababsa, 2013). Various zones of the Jordan Valley rely on different sources of water based on the cropping pattern that exists (Table 1) (Talozi, et. al., 2015). The percentage of irrigated land as part of total agricultural land in Jordan has shown to increase from 30% in 1990 to around 40% in 2008 (Salman, et. al., 2016), and kept increasing since.

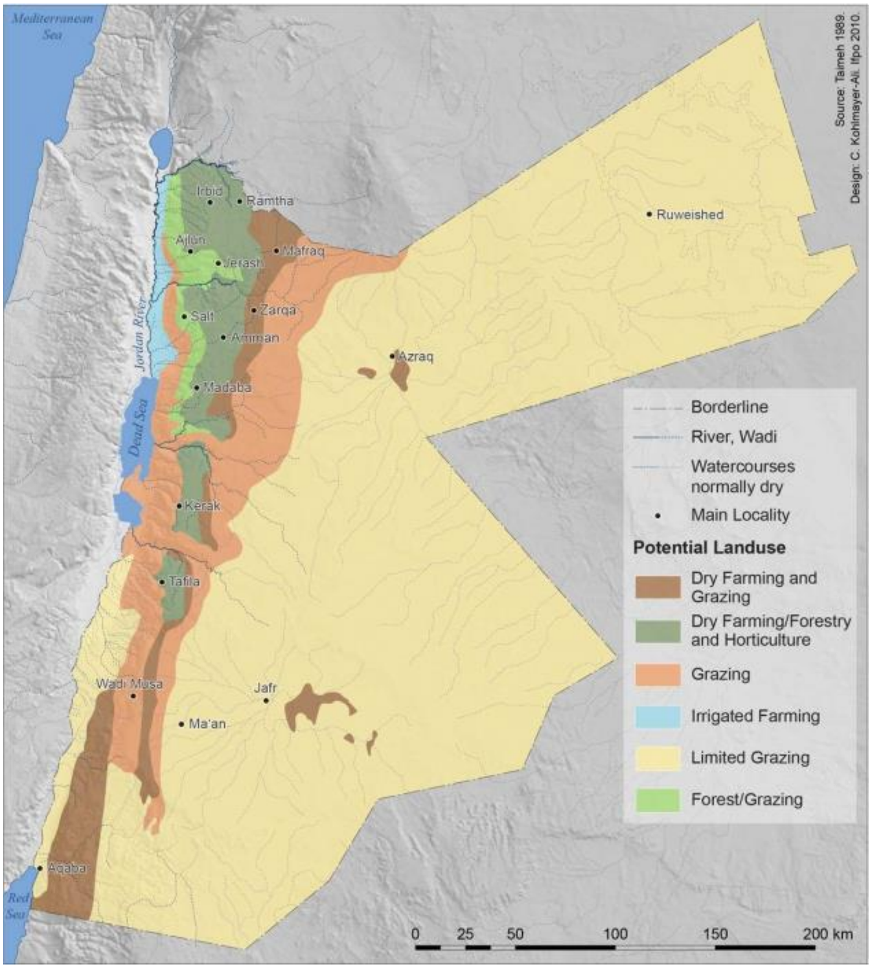


Figure 5: Land use in Jordan (source: Ababsa, 2013)

Table 1: The cropping patterns present in Jordan valley according to the water resources availability (source: Talozi, et. al., 2015)

Subzone	Water resources	Cropping pattern
North	➢ Surface water from the Jordan and Yarmouk Rivers ➢ Limited use of treated wastewater from the King Talal Dam ➢ Rainfall	➢ Citrus trees ➢ Vegetables (open-field)
Middle	➢ Treated wastewater from the King Talal Dam ➢ Limited rainfall	➢ Vegetables (mainly greenhouse but also open-field)
Karama (including South Shouneh)	➢ Treated wastewater from the King Talal Dam ➢ Limited rainfall ➢ Brackish groundwater	➢ Vegetables (open-field) ➢ Date palms
South	➢ Surface water from fresh springs and side valleys	➢ Vegetables

1.5. Surface water

There are 15 surface water basins in Jordan as established by the Ministry of Water and Irrigation (MWI), which for a large extend overlap with the groundwater basins. Figure 6 provides the surface water basins (blue) and the groundwater basins (green) in Jordan. Most of Jordan surface water basins discharges their flows into the Jordan Rivers, the Dead Sea, Wadi Araba and the Red Sea, or they stay within Joran within the so-called closed basins. Within the streams and rivers (wadis) water gets harvested in dams, hafirs, wadis, Qa'a, agricultural fields, or finally settles on some desert fields. Evaporation is a major concern where most of the water gets lost, since temperatures in summer when water is needed are high. A detailed evaluation of the characteristics of the 15 surface water basins is provided in the Basin Evaluation Table (Separately provided in Excel). This evaluation was used for the selection of focus Basins, which is elaborated in Chapter 4.

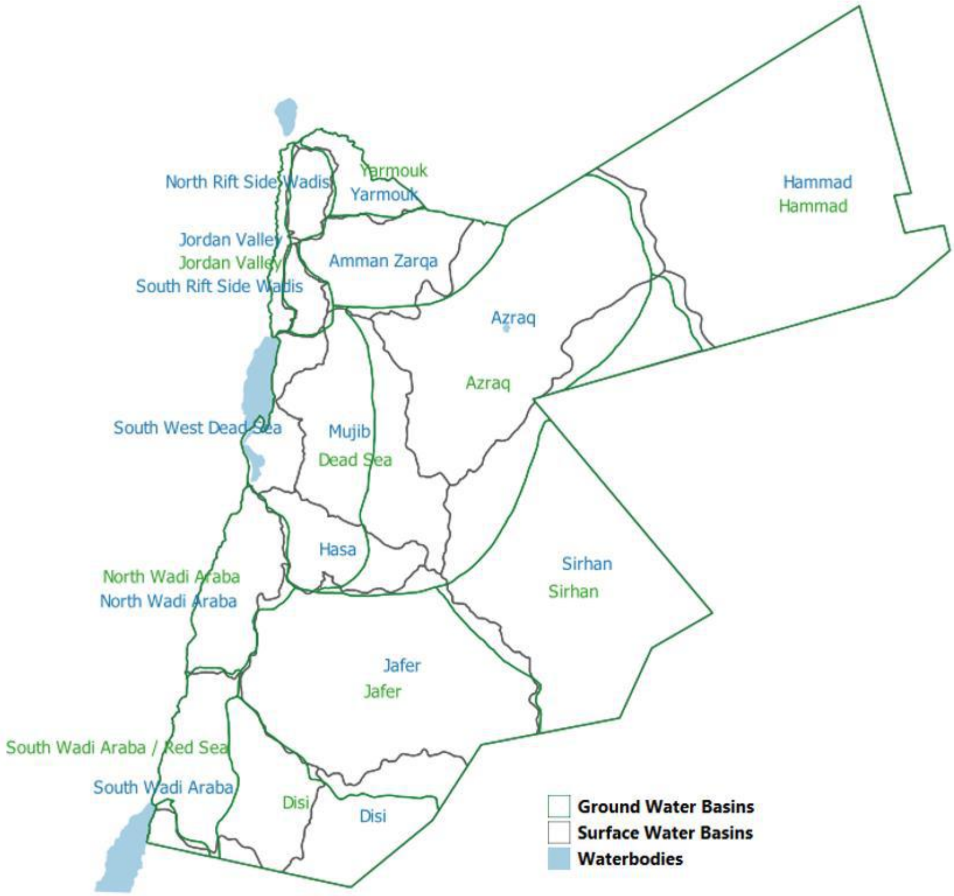


Figure 6: Surface and groundwater Basins in Jordan

The water resources in Jordan are as it is in stress which gets aggravated as Jordan shares many of its surface water resources with the neighbouring countries (Hadadin, et. al., 2010). Over the years, the flow of water in these rivers like Lower Jordan River and Yarmouk River have reduced (Bromberg, 2008; Frenken, 2009). In addition, the Jordan River is mainly saline and cannot be used for irrigation and drinking (Hadadin, et. al., 2010). Zarqa River is highly polluted as the river passes through Jordon's main industrial area (Mohsen, 2007) making it unsuitable for domestic or agricultural use (Hadadin, et. al., 2010). It is only during the floods that the water quality of the river improves. Although Yarmouk River is less polluted compared to the others, it still gets an influx of municipal wastewater (Hadadin, et. al., 2010).

1.5.1. Closed basins and Qa'a

Many catchments in Jordan are so called closed basins, which are hydrological basins that do not have an outlet. Water usually ends in a flooding area where it leaves as seepage or evaporation. These areas are known as Qa'a. Qa'a is an almost flat land with an area with a large surface area up to 100 square kilometers or more. It is temporarily flooded with flash floods from the slopes of the surrounding hills or Mountains. Usual water depth goes from zero at the edges to three or more meters in the middle. The volume of water collected heavy winter storm can be huge, amounting to tens of millions of cubic meters. Most of them evaporate quickly and part goes to feed the groundwater. Examples of large Qa'a are:

- Qa'a Al Azraq is one of the very few such sites in the Saharo-Arabian region and it is recognized locally, nationally and internationally as an important wetland. Such recognition is primarily based on the site ecological, physical, hydrological, historical, cultural, and recreational characteristics. The ecological characteristics of the oasis were found to fulfill the criteria of many internationally reputable organizations, conventions and programs including The United Nations' List of Biologically Interesting Places (1962). Currently, Azraq is the only site designated as a Wetland of International Importance, with a surface area of 73.72 km².
- Qa'a Jafr is mainly saline seasonal marshes which attract waterfowl. Due to over-pumping from the basin, water salinity has increased. Very little cultivation is practiced.
- Qa'a Khana is a seasonal salty marches and mud flats with very few plant communities consisting mainly of halophytes
- Qa'a Disi belongs to the Disi basin, which is a rich fossil water aquifer which has lately been heavily extracted for agricultural irrigation and urban consumption. The Qa'a consists of salty mud flats filled from rain water in good seasons. Those attract waterfowl.

In addition to the above-mentioned Qa'a, there are many other smaller flooding areas within these basins and in the Sirhan and Hamman Basins. These areas still receive large amounts of floodwater and could also have high potential for managed aquifer recharge (MAR). Although these areas are often seen as wastelands, they often have an ecological and socioeconomic function. These areas need further exploration for suitability for MAR in Qa'a is needed. The environmental impact of large large-scale usage of these floodwaters would have to be assessed, the wetlands of the Azraq are commonly known, but an element that is not mentioned in the studies is that the Azraq's closed basin and many other smaller flooding areas provide seasonal grazing lands. This was observed by the consultant from satellite imagery and from the many livestock enclosures surrounding those areas. Normalized Difference Vegetation Index (NDVI) images from MODIS and Landsat were analyzed to identify the flooding areas. Multiannual (2015-2020) time series of MODIS images were made and analyzed to see which areas flood, how often and if (seasonal) vegetation is present. The larger flooding areas are indicated in The RWH suitability map (Figure 18, page 34).

1.5.2. Dams and surface water abstractions

In order to cope with its growing population and increasing water demand for agriculture, Jordan has constructed 28 dams from 1950 to 2008 (Figure 7) (Fanack Water, 2015b).

Dam	Storage (MCM/yr)
Unity Dam	110.0
Wadi Arab	17.0
Ziglab	3.8
King Talal	75.0
Karama	55.0
Shueib	1.4
Kafrein	8.4
Waleh	9.3
Mujib	35.0
Tannour	16.8
Total	331.7

Legend
Dam
Town
River and Wadi
National border

Figure 7: Dams constructed on the rivers and their tributaries in Jordan and their annual storage capacity (source: Fanack Water, 2015b)

However, since Jordan shares its surface water with its neighboring countries, it also shares the consequences of dams built upstream. This is how the Lower Jordan River flow has been reduced by 2% compared to its historic flow due to the National Water Carrier dams built by Israel in 1953, which diverts water from Lake Tiberias to its coastal plains (Bromberg, 2008). The flow of the Yarmouk River also reduced in the last 30 years when Syria built around 45 dams upstream (Frenken, 2009). Syria therefore committed to provide 208 MCM/year from the Jordan River. Furthermore, in addition to its reduced flow, the water quality of the Jordan River has deteriorated due to untreated wastewater and agricultural fertilizers from Israel upstream (Fanack Water, 2015a).

1.6. Groundwater

Jordan's groundwater is found in three main aquifer complexes (the Deep Sandstone Aquifer, the Upper Cretaceous Aquifer and, the Shallow Aquifer) and is separated into twelve groundwater basins (Figure 8) (Al-Karablieh & Salaman, 2016; Salameh et al., 2018). Figure 8 shows the annual extraction yield per groundwater basin that enable their sustainable recharge. It is estimated that an average of 275MCM per year is the total renewable yield of all groundwater basins in Jordan.

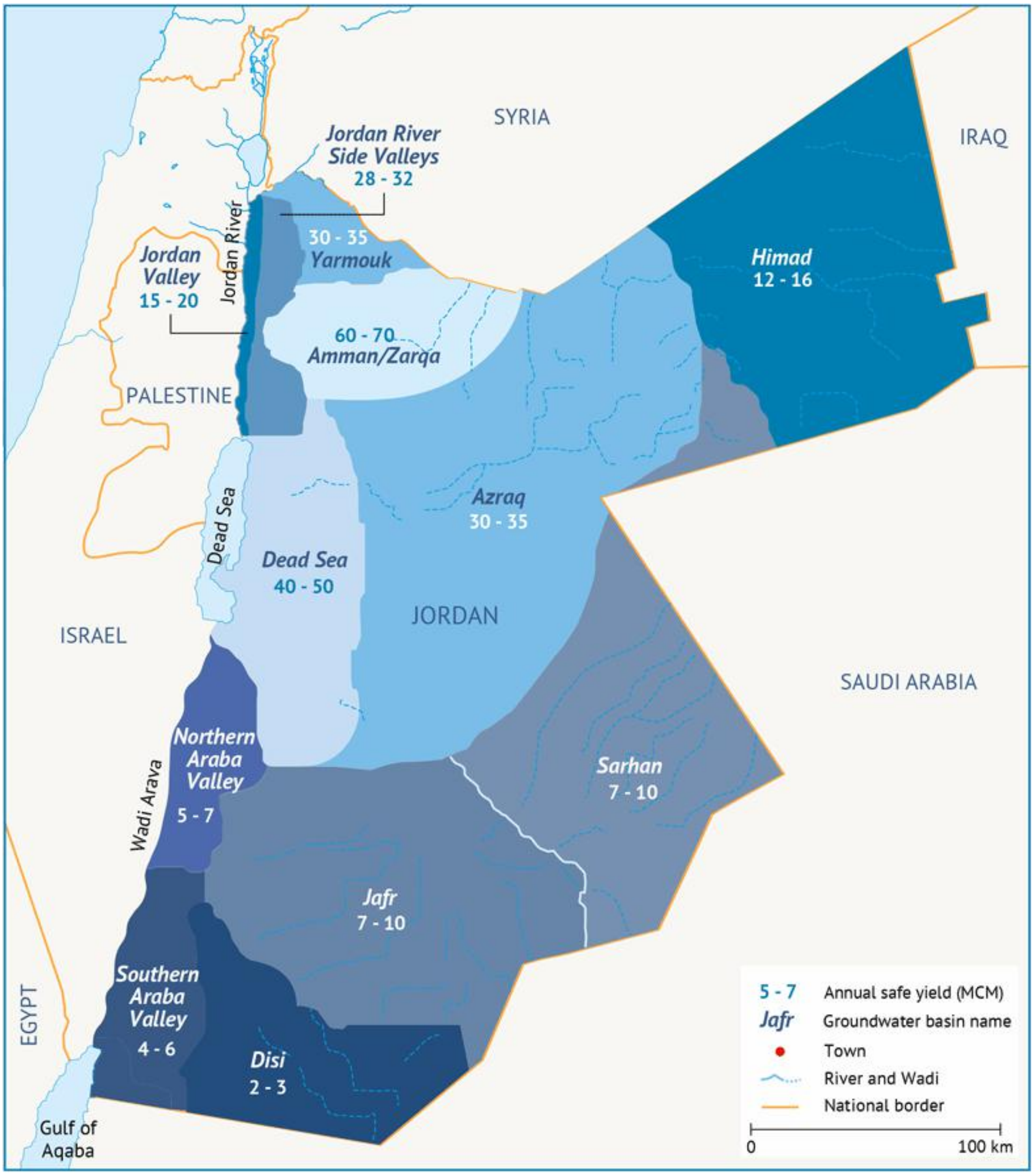


Figure 8: The twelve groundwater basins of Jordan (source: Fanack Water, 2015a)

1.6.1. Geology and hydrogeology

Hydrogeology is an important factor when looking at RWH suitability. Most of Jordan is covered by sedimentary rock formations, while only in the South-West Basement Geology is found (Figure 9). The sedimentary rocks have different water conductivity characteristics. The main differences are indicated in the map as Aquifer (water bearing, permeable formation) or Aquitard (formation with very low permeability). Basement Complex is an impermeable rock formation, unless it is fractured and/or weathered. These different formations provide different opportunities and limitations for RWH, which are incorporated in the RWH suitability map, presented in Paragraph 4.1.

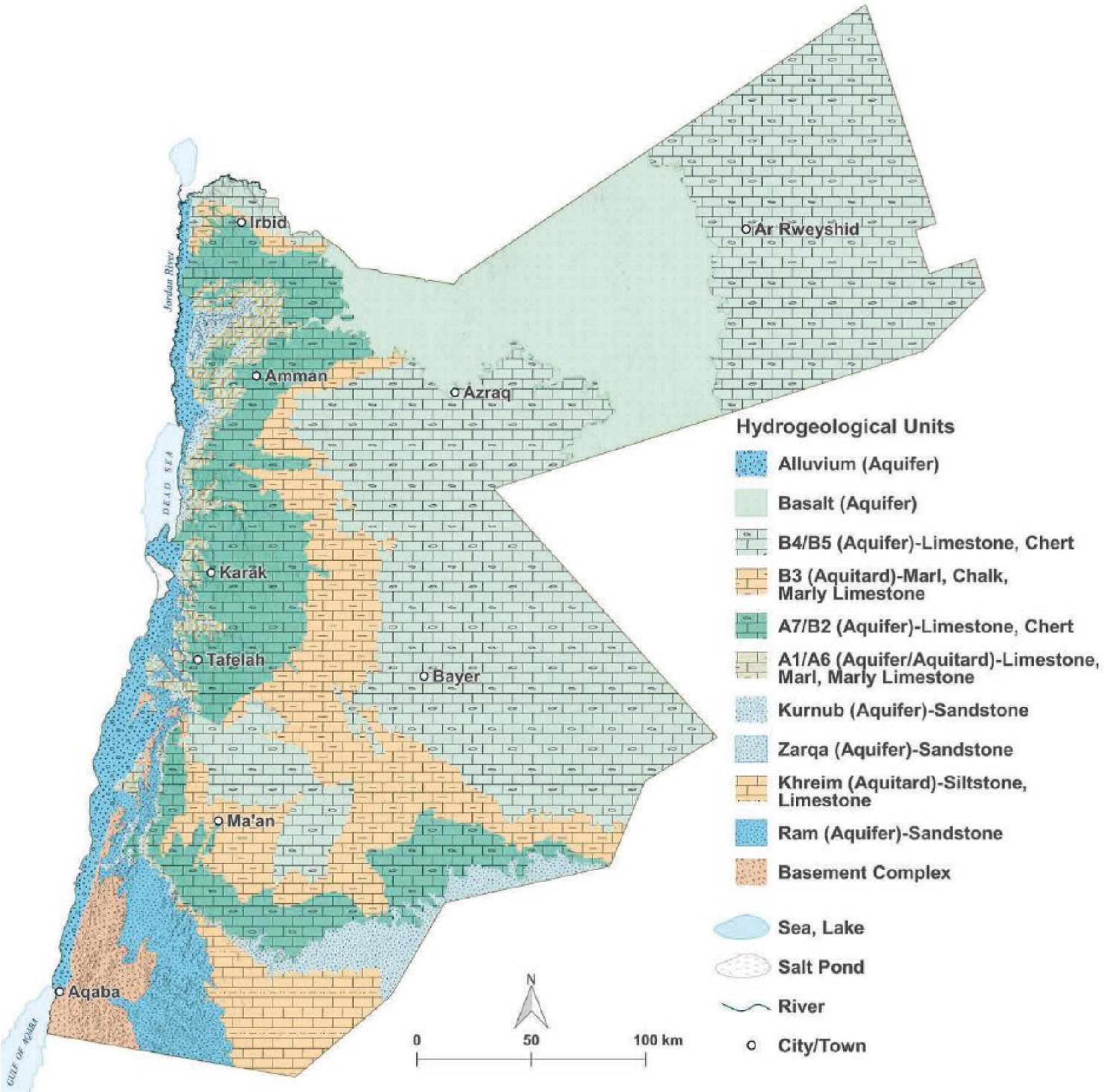


Figure 9: Simplified Hydrogeological Units of Jordan (source: MWI/BGR 2017)

1.6.2. Groundwater abstraction

Because of the increase of water demand, groundwater is over exploited and its quality undermined (Al-Karablieh & Salman, 2016). This over exploitation takes place both in non-renewable and renewable groundwater resources. Regarding the latter, it was estimated in 2011 that as much as 55% of the recommended safe yield is extracted. The non-renewable groundwater resources helping to bridge the gap between the supply and demand, are located in the Disi basin and a section of the Jafin basin. In 2013, the Disi fossil water carrier was constructed and the water could supply Aman and other governates with 170 MCM water in addition to the original use of the basin for irrigation purposes (50 MCM annually) and drinking water in Aqaba city (15 MCM annually). Table 2 reports the different extraction rates and compared them to the safe yield established in 2015. Such high level of extraction induces a global decrease in the national groundwater sources (Figure 10).

	Basin	Safe yield MCM	Total uses (MCM)	Balance	No of wells	Percent of Safe yield
1	Yarmouk	30-35	54.16	-14.16	203	135
2	Amman Zarqa	60-70	166.11	-78.61	955	190
3	Jordan Rift Side Wadis	28-32	46.73	-31.73	139	312
4	Jordan Valley	15-20	17.02	3.98	334	81
5	Dead Sea	40-50	89.98	-32.98	469	158
6	Azraq basin	30-35	52.54	-28.54	580	219
7	Hammad basin	12-16	1.87	6.13	15	23
8	Wadi Araba North	5-7	6.33	-2.83	37	181
9	Wadi Araba south	4-6	8.48	-2.98	62	154
10	Sirhan	7-10	1.71	3.29	23	34
11	Jafer non-renewable	7-10	32.85	-21.85	205	343
12	Disi, non-renewable	100	146.96		116	118
	Total	**338-391**	**624.74**		**3138**	**129**

Table 2: The safe yield and over exploitation rates of the different Jordanian groundwater basins (source: Al-Karablieh & Salaman, 2016)

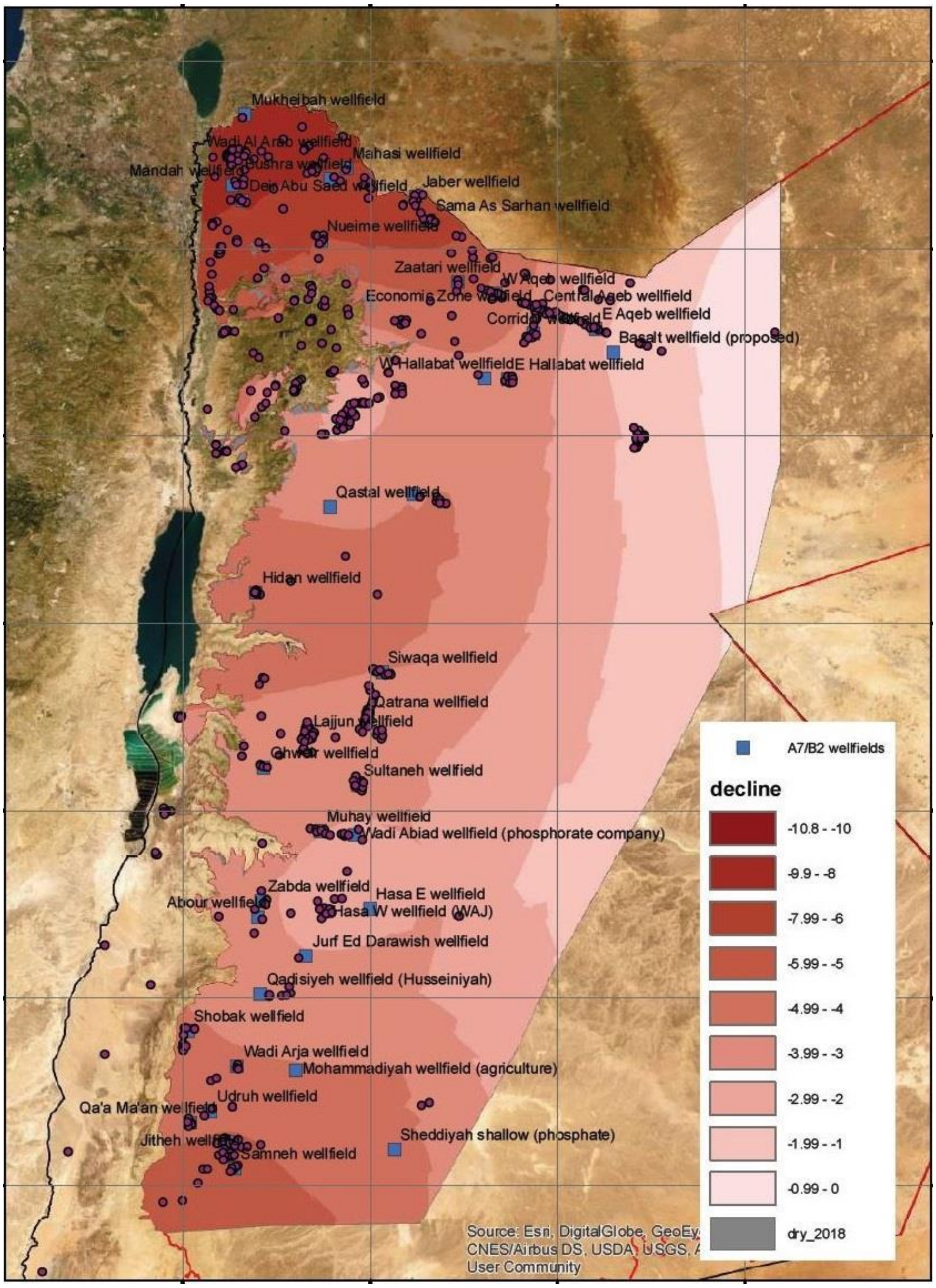


Figure 10: National decrease in groundwater level (source: Al-Absi et al. 2020)

2. The uptake and scaling of Water harvesting technologies in Jordan

2.1. The current uptake of water harvesting in studies and work shows promise

2.1.1. Ancient water harvesting techniques exist and can still inspire new

Jordan is the birthplace of rainwater harvesting system (Nasr, 1999). Remnants of the oldest RWH structures have been found in south Jordan and were dated to 9000 years old (Nasr, 1999; Oweis et al., 2001). Throughout the Southern Mesopotamia region, simple RWH structures such as cisterns were used around 4500 BC. In addition, in Mafraq (32.335847° 37.003054°), the world's oldest remnants of a dam were found. The structure was part of an intricate spate and water provision system around Jawa dam: "Jawa is the site of the oldest proto-urban development in Jordan, dating from the late 4th millennium BC (Early Bronze Age). It is located in one of the driest areas of the Black Desert (Harrat al-Shamah) of Eastern Jordan" (Helms, 1981).

Nowadays, traditional RWH techniques are still in use. The Petra region is an interesting area that exemplify how many traditional RWH structures are still part of the every-day life of Jordanians. Indeed, in the region, one can see "[…] terraces, channels, settling basins, aqueducts, dams, rainwater harvesting, flood harvesting, groundwater harvesting, a large range of size and types of cisterns, reservoirs created by dams, water distribution tanks, and springs" (Iwmays, 2014).

2.1.2. Roof water harvesting has demonstrated its use in higher rainfall area

In areas with higher rainfall, the population gained considerable experience in the building of cisterns. A cistern is an underground reservoir carved out of the rocks or stable formations and grouted or sealed with cement. The cisterns usually range from 40 cubic meters to 65 m3. It can collect water from the roof or water from local runoff of slopped areas. Due to the digging the investments costs are high, but once the cistern is in place there is hardly any operational costs. The average cost of construction of 40 cubic meter cistern is one thousand Jordanian Dinar (1400 US$). In the high rainfall area, many houses have their cisterns and many others are willing to construct it once having the budget.

2.1.3. Government and non-government actors increasingly involved in implementation of subsidized water harvesting technologies

Hafir and other infrastructure implemented by the Ministry of Agriculture (MoA) and NARC have started to take a participatory form. In most cases the nature of the infrastructure (high capital investment and operational costs) precludes the ownership and commitment of the end users. For instance, the MoA shared a list of and a map on the potential locations to implement hafirs and other open water reservoirs in the Badia. Many of these locations show the limited to no population. It is therefore difficult to predict the extent of the benefits end users would gain from such structures. In our analysis of potential sites for implementation, we took into account the availability of local participants for labor or operation and maintenance. All over the world there are different ways in which governments encourage or entice citizens to work on RWH structures. Textbox 1 briefly outlines the context of the watershed campaigns in Ethiopia as an example. Many other ways exist and will be described in chapters 3 and 4.

Text Box 1: Watershed campaigns in Ethiopia

Following several severe ecological disasters the Ethiopian government enrolled a policy of campaigns based on voluntary labour in the 1970. These campaigns ask people to participate at community level in reducing runoff and increasing water storage. Although the program had a relatively unproductive start (Worku, 2015), currently a focus on community based integrated watershed management programs mobilizes large groups of citizens to put labour in landscape restoration. Under this program, thousands of kilometres of farm bunds, hedgerows and thousands of farm ponds have been constructed. In some areas, the integration of upstream and downstream measures have made spring water return, increase yields by 40% and dramatically, reduce soil erosion (see for instance https://wle.cgiar org/thrive/2021/04/30/community-participation-greening-aba-gerima-watershed-ethiopia; Haragaweyn et.al 2015)

2.1.4. NGOs successfully piloted water harvesting

Some of the technologies that are not easy for individual or government to take up have been promoted by NGOs and knowledge institutes (see textboxes 2 & 3). These have delivered definite proof that RWH increases productivity of non-irrigated agriculture. ICARDA for instance developed a successful pilot site south of Amman where the valarani plough and traditional Murab systems produced enough moisture for barley production. This poses RWH as an alternative to groundwater abstraction for irrigation. Another successful example is the one from IWMI, which stimulated the development of terraces west of Amman through farm support and loans. Swales and terraces or trenches have also been promoted through different regenerative agriculture and permaculture projects such as the greening the desert farm, carob farm and Regamena farm. Permaculture or regenerative agriculture includes water harvesting as part of the ways to minimize the need for external resource. In situ RWH through terraces or swales and increasing organic content in the soil reduces runoff and increases water holding capacity of the soil. Permaculture sites can be good demonstration sites of the potential of water harvesting. However, in their efforts to show the proof of RWH in for instance permaculture or fodder production the opportunities for popular uptake by the users have been explored but remain underdeveloped. Possibly the road taken by IWMI in the loan scheme for roof tanks and terraces is one of the few examples where users were taken into the program from the start and the main support was in offering the technical and financial instruments. An example is described in textbox 2 where local entrepreneurs play a pivotal role in the promotion of rainwater.

Text Box 2: Private sector investment like Rain4sale.

The NGO RAIN (part of Aidenvironment) developed a program whereby local entrepreneurs receive a loan in the form of a 100 or 50 cubic meter water harvesting tank. The RAIN4Sale concept tests the business case of selling stored rainwater by local entrepreneurs in urban and peri-urban environments. More specifically, the project aims to test and prove a business case whereby money either “collected from selling water” or “saved as a result of not-buying water” is used to finance the construction of rainwater harvesting installations. The idea is that local entrepreneurs get are provided with a rainwater harvesting installation on credit. Consequently, they can sell the harvested rainwater for a reasonable amount of money. So that water availability in the community is increased. In instalments they pay back the initial investment of the installation, while making profit from their water selling business. People from around buy the water and this prevents them from relying on poor water sources. The water undergoes filtration and treatment.

Text Box 3: Irrigation from shallow aquifers in sandy seasonal rivers

Led by Delft IHE the A4Labs action research explores the potential and pitfalls of introducing solutions designed for individual smallholder farmers. This entails innovation in three domains: the technology used (manually-installed shallow well-points in or next to a sand river combined with solar-powered water pumps), the arrangement (individual smallholder farmers), and the purpose (market-oriented farming). Pilots were established in the Limpopo river basin in Zimbabwe and Mozambique. The results show that storing water in sandy rivers through technologies as sand and subsurface dams can open up lands for irrigation that were previously untapped. This form of irrigation is sustainable and not dependent on non-renewable water (see for instance Duker et al, 2020).

2.2. The policy setting is favorable for upscaling RWH but focused on high capital investment agriculture

2.2.1. The Multi Annual Country Strategy (MACS)

In the MACS 2019-2022 Jordan (drafted for internal planning purposes within the Ministry of Foreign Affairs of The Netherlands), the approach on food security was to focus on high capital investment agriculture so that the farmers would be supported and could then have access to new ideas and technologies. The focus on high capital investment agriculture can be strengthened by other forms of agriculture such as adaptation in small scale agricultural systems. The water resources situation of Jordan will benefit more from approaches such as regenerative agriculture. The experts we interviewed on this topic stated that they see less added developmental benefit in investing in the capital-intensive agricultural sector. They stated that alternatives to capital intensive agriculture will demand less external resources such as water. Several interviewees voiced strong opinions against the investment in capital intensive agriculture, stressing that popular adoption and business cases remain problematic and that more pressure on water resources can be the negative side effects.

2.2.2. Jordan Policies around rainwater harvesting

Early to mid-1990s, research began on the application of rainwater harvesting in modern agriculture context (Figure 11) (Sixt et al., 2018). While the Jordanian government has identified RWH as an important support to the national agricultural sector, the current national strategies such as the "National Water Strategy 2016-2025", the "National Strategy for Agricultural Development 2016-2025", or the "Agriculture Sector Green Growth National Action Plan 2021-2025", lack an integrated plan to increase the use of rainwater harvesting in the agricultural sector (see following section) (FAO, 2016; Ministry of the Environment, 2020; Ministry of Water and Irrigation, 2016; Salman et al., 2016).

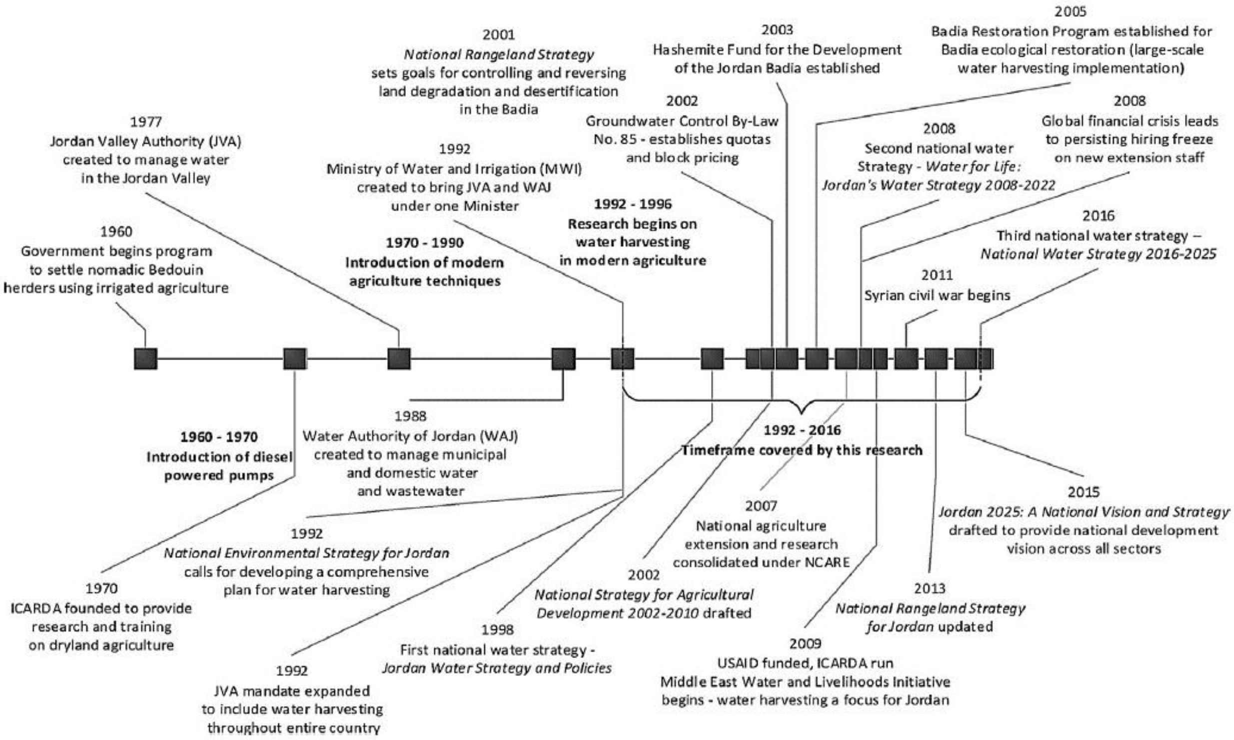


Figure 11: Key development promoting the development of rainwater harvesting in Jordan (source: Sixt et al., 2018)

2.2.2.1. *"National Water Strategy" (2016-2025)*

The "National Water Strategy" 2016-2025 is a continuation of the National Water Strategy 2008-2015 and also builds on previous national documents that helped to shape the water sector i.e., "Jordan Water Strategy and Policy" (1998) and the "Water for Life: Jordan's Water Strategy 2008-2022"

(Ministry of Water and Irrigation, 2016). The first National Water Strategy was set along the MDGs and did allow the country to achieve significant positive outcomes in the water sector. The strategy for 2016-2025, builds on these achievements and wants to further improve the water resiliency of the Kingdom of Jordan. There are five key strategic areas targeted by this strategy: (i) Integrated water resource management, (ii) WASH services, (iii) water for irrigation, energy and other uses, (iv) institutional reform, and (v) sector information management and monitoring.

This strategy includes a water resource development plan which advices to supplement and relieve the pressure on the water sector by using new water sources such as RWH, brackish water, desalinized water, surface runoff storage, artificial recharge, and increased the amount of wastewater that is treated (Ministry of Water and Irrigation, 2016). The additional water resources needed to bridge the gap between demand and supply are detailed in Table 3. Furthermore, the Ministry of Water and Irrigation envisions the use of RWH on a national scale as a complement for household demand (7 MCM annually) for remote areas (15 MCM annually), and for irrigation purposes (no amount stated). (Al-Karablieh & Salaman, 2016). The Strategy argue that new buildings should, when technically possible, contain RWH tanks.

Table 3: Additional water supply source to bridge the gap between supply and demand (source: Ministry of Water and Irrigation, 2016)

Year	2020	2021	2022	2023	2024	2025
Groundwater Safe yield	275	275	275	275	275	275
Non-renewable groundwater	189	174	240	241	242	243
Groundwater Over Abstraction	140	136	131	127	122	118
Surface water	276	284	293	306	311	329
Treated wastewater	181.6	191	191	195	195	235
Desalination and SWAP	20	106	107	108	109	260
Total Resources	1082	1165	1237	1251	1253	1459
Total Demand	1,455	1,485	1,493	1,503	1,536	1,548
Deficit in MCM/a	(373)	(320)	(256)	(252)	(283)	(88)

2.3. Stakeholders in the sector

This section provides an overview of the relevant stakeholders in the sector (Figure 12). The different stakeholders were identified when reviewing the different projects and programs (past and present) targeting rainwater harvesting in Jordan. The power and interest matrix thus identify current stakeholders that have an interest or have shown an interest in the implementation of rainwater harvesting in the country. While several international organizations have already worked on projects to identify effective RWH structures, the key stakeholder of the sector is the Jordanian Ministry of Water and Irrigation, which works closely with most of the foreign organization and which has the power to upscale their pilot studies in the eventuality of success.

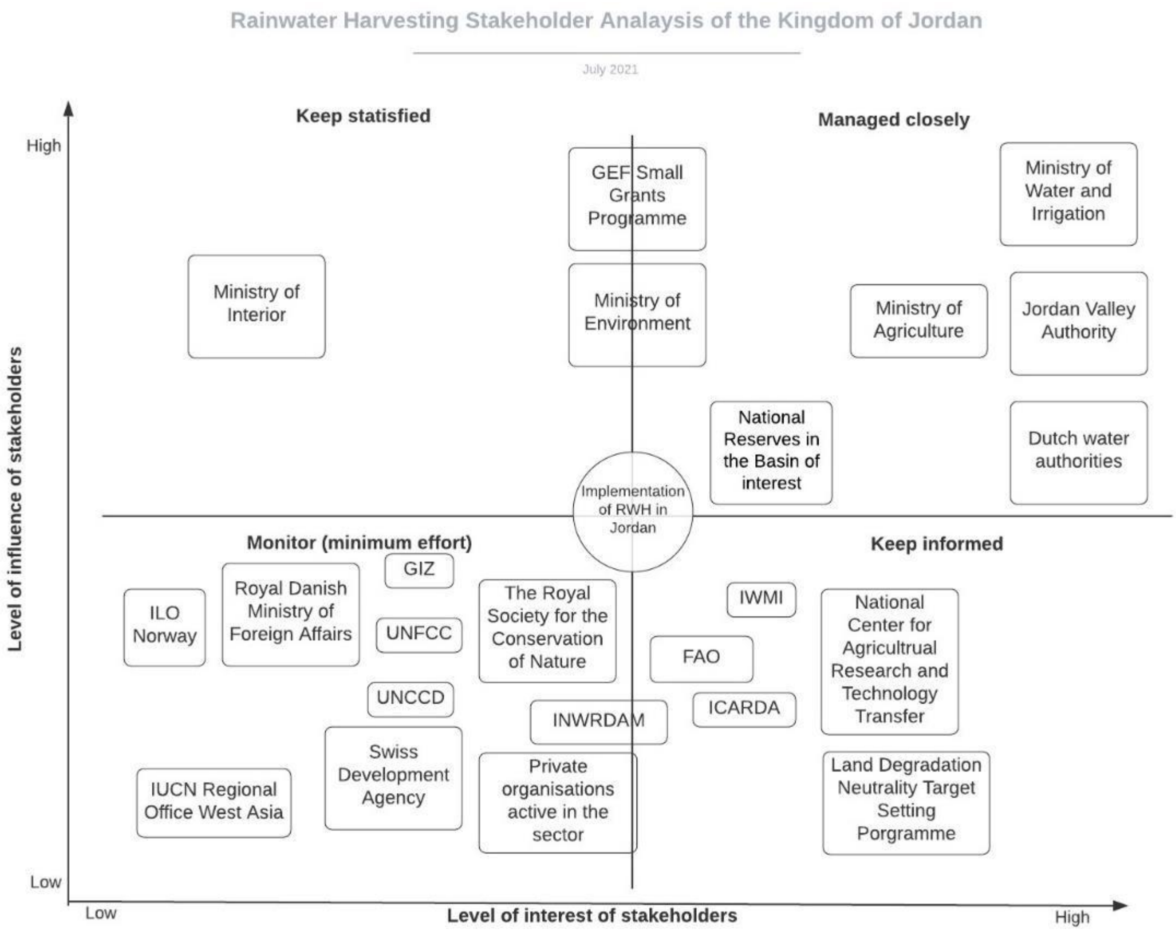


Figure 12: Matrix representing the interest and influence of the main stakeholders of the RWH sector in Jordan

After identifying the above-mentioned stakeholders, several stakeholders were interviewed in order to better understand their role in the development of the RWH sector (Annex A). The interviews focused on both the RWH programs and the experience of the interviewees in working in Jordan within this sector. The interviews also aimed at identifying other potential stakeholders that were not already identified. Most interviewees were positive about the potential of RWH to support the national water sector and were very much aware of the unsustainability of the current agricultural system, which relies heavily on irrigation. In addition, several potentially interesting Dutch organizations were also interviewed in view of a future program targeting RWH in Jordan (Annex A).

In the following chapters, we incorporated the knowledge gained during the interviews. Specifically, chapter 4 details the different stakeholder and explains their role in the current RWH sector of Jordan as well as their potential future role in the EKN program.

3. Water harvesting technologies and projects

In order to understand the potential of RWH in Jordan, the first step was to identify and analyze existing RWH interventions. The consultant reviewed literature, interviewed different organizations and added international experiences. This chapter describes several RWH projects and technologies within and outside of Jordan.

3.1. RWH projects in Jordan

In Jordan, ICARDA plays a major role in promoting a variety of RWH techniques in the semi-arid regions. Their project in Badia uses Mechanized Micro Rainwater Harvesting (MIRWH) technology by using the 'Vallerani plough', which creates a type of contour trenches. It helps to restore the degraded rangelands by increasing capture and infiltration of surface runoff. Alongside National Agricultural Research Center (NCARE), ICARDA is also implementing such water harvesting methods to improve livelihoods of the communities in the WANA region (West Asia and North Africa) (Shawahneh, 2011). Additionally, the mentioned partnership is known to promote cost-effective techniques of water harvesting combined with indigenous knowledge amongst the Mhareb and Majdieh communities (Keser, 2017).

Currently, German Federal Ministry for Economic Cooperation and Development (BMZ) along with United Nations Educational, Scientific and Cultural Organization (UNESCO), the German Jordanian University (GJU), the Petra Development and Tourism Region Authority (PDTRA), are restoring the storage capacity of the reservoirs and taking measures to reduce erosion in the catchment areas of the dams. These labour-intensive measures also generate employment opportunities (GIZ, n.d).

The FOA along with the Ministry of Water and Irrigation (MWI) has selected a pilot project in Al Mashare' for contributing to the harvesting and storage of rainwater on a side wadi in the Jordan Valley. With financial support from the Swedish International Development Cooperation Agency (SIDA), the first water harvesting structure was built in Al Mashare' area to store around 100 thousand cubic meters. It has helped to store winter rains, improve the quality of irrigation water, increase the available water for livestock watering, which is important for the livestock breeders' livelihoods (FAO, 2020). Additionally, there are various projects by the Netherlands Water Partnerships (NWP), European Commission, Adaptation Fund (UNFCCC), Royal Danish Ministry of Foreign Affairs (DANIA), The World Bank, etc that fund land restoration and livelihood projects that focus on RWH.

3.2. Suitable RWH technologies

When researching RWH technologies and their implementation modalities, the Water Harvesting – Guidelines to Good Practices (Studer & Linger, 2013), developed by WOCAT is a good starting point as it reports successful examples from over the world. Additional examples may also be found on the WOCAT database: https://www.wocat.net/en/.

Table 4 outlines the various RWH techniques that have been used within the different countries of the Middle East and North African region. The list shows the different RWH per water source, showing the great knowledge of the region regarding RWH. Some RWH technique may have names that vary between or within countries. Therefore, there are several hundred different RWH technologies around the world. In order to categorize the different technologies, this section uses the categorization of the Water Harvesting - Guidelines to Good Practices. The following paragraphs provide more information on a number of those techniques that are considered highly suitable for the Jordanian context.

Table 4: Overview of the water harvesting techniques of the Middle East and North African region (source: Nasr, 1999)

Water Source	Objectives	Water Harvesting Techniques	Country
Rainfall	To increase rainfall effectiveness	Terraces	Yemen, Jordan, Tunisia
	To conserve water (and soil)	Contour-ridge terracing	Libya, Syria, Tunisia, Jordan
		Dams	Libya, Egypt, Tunisia, Jordan
Local runoff	To collect water	Micro-catchment	Yemen, Egypt, Libya, Syria, Jordan, Morocco
	Too store harvested water (also used for domestic supply)	Cisterns	Yemen, Egypt, Libya, Morocco
Wadi flow (flood and base flow)	To divert water for irrigation	Earth dykes (spate irrigation and small-head pumps and earth canals)	Yemen, Egypt, Libya, Tunisia, Jordan
	To protect land against floods (soil erosion control)	Wadi-bank enforcements	Yemen, Libya
Spring water	To divert water to participants within water rights limits	Earth canals	Yemen
	To store limited quantities of water for short periods (also used for domestic supply)	Cisterns	Yemen, Egypt, Libya, Tunisia, Jordan, Morocco
Groundwater	To abstract water from shallow aquifers (also used for domestic supply)	Shallow dug wells and pits	Yemen, Egypt, Libya, Morocco
	To exploit groundwater stored in the coastal sand dunes	Galleries	Egypt

3.3. Floodwater harvesting

3.3.1. Hafir or desert ponds

Besides the cistern the hafir is the most obvious example of RWH in Jordan. The hafir is a form of floodwater harvesting because it depends on flowing water in the wadi to fill and when the wadi retreats the hafir is full and it remains behind. The hafir average size is usually between 100,000 m^3 to 300,000 m^3 with a depth varying between 3 to 5 meters. The exact dimension of the technology will vary depending on the land conditions. Annex B provides a map developed by the JVA with hafirs (desert ponds) and other surface water storage reservoirs and proposed sits for such interventions.

The selection of hafir location is usually based on simple hydrological and geological studies. The hydrological study will dictate the hafir's volume while the geological study is necessary to assess its stability. In the southern and Eastern parts of Jordan it is common to construct hafirs due to the land availability and the low cost of excavations in the dominant sandy soils. The Jordan valley Authority (JVA) constructed a lot of hafirs, especially in the southern and eastern parts of Jordan. However, it did not consider the optimization of the use of the harvested water. Indeed, the JVA is mainly interested in maximizing the harvested water volume but with little consideration regarding how this water will be utilized and will participate in solving the country water shortage.

3.3.2. Spate irrigation

This technique is not commonly used in Jordan despite its potential within the country. It would therefore be interesting to further explore. The basic principle is that in arid lands, rainfall comes in short bursts and then disappears. Water starts flowing in wadi beds, sometimes quite violently. Spate irrigation depends on the diverting water from the wadi bed in a controlled manner into the field, often using a diversion weir or a simple soil bund/dam. This technology is quite common in arid lands with wadis. Considering this water system, the system in itself is perfectly sustainable since the water that would otherwise disappear with the flood gets utilized and becomes productive.

Harvesting this floodwater in Jordan happens already in the form of big dams in the tributaries to the Jordan river. An example of a smaller floodwater-based systems there is also for example the spate irrigation systems that can be found in north araba.

Figure 13: Spate irrigation marked in light green at North Wadi Araba Basin, Wadi Fidan (source: google earth)

3.3.3. Marab

Similarly, the Marab can also be seen as a form of floodwater harvesting. The idea of marab construction comes from nature, as naturally when water flows to the Wadi sometime it passes through flat to semi flat area that causes sedimentation over an area beside wadis and formation of boundaries. The land covered by sedimentation can keep the moisture for longer period and crop can be planted accordingly. Artificial marabs are being constructed to act as natural ones, to form a relatively fertile soil for planting of crops like barley, as in the one constructed/rehabilitated by ICARDA constructed/rehabilitated on their Badia Research Site (BRS) (Figure 14).

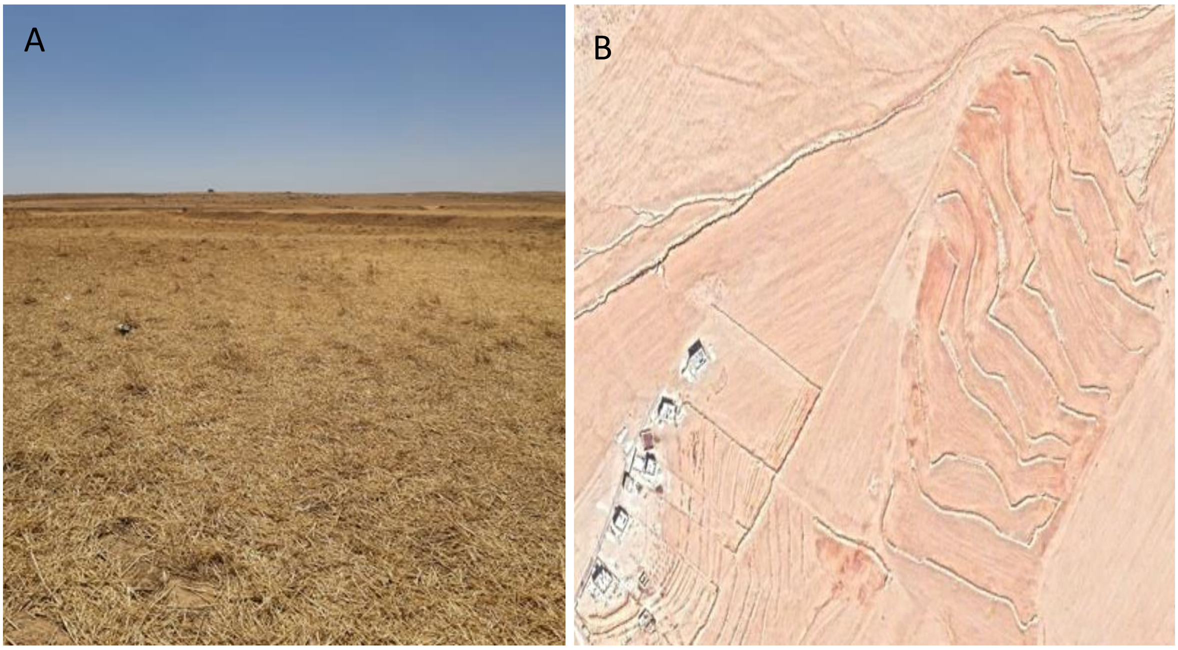


Figure 14: A: Artificial marab at the BRS planted with barley after being harvested; B: Google Earth view of the marab

Many other artificial marab and similar flood harvesting structures are present in desert areas in Jordan. Traditionally, simple marab structures were constructed by farmers/communities.

3.4. Macro Catchment water harvesting

Many people in Jordan already depend on Macro Catchment water harvesting. The dams in the bigger rivers can be called macro water harvesting systems. These will not be considered here since these dams are too big for the program and generally not regarded as RWH interventions. Furthermore, the potential downstream impact of these large dams requires careful analysis.

3.4.1. Sand dam storage

BMZ, the German Federal Ministry of Economic Cooperation and Development, built sand dams in certain places in Jordan. Despite several attempts, it was not possible to reach the different implementing organizations but other interviewees mentioned that these sand dams proved highly effective in the recharging wells. Sand dams (see also textbox 2) can prove to be a sustainable technology for Jordan. The idea behind a sand dam is that sandy ephemeral rivers, particularly in areas with basement rock, can store water in their riverbed sediment the whole year round. A sand dam is a barrier that is built in the sandy riverbed and comes out of the ground only enough to collect the sand. The dam is designed in such way that course sand will accumulate and fill the upstream section. Water will be stored within the sand. Sand dams can play a role in local water provision, in several countries in Africa and the Middle East, sand dams provide drinking water and water for small scale irrigation.

In areas without basement rock or impermeable riverbeds the sand dam can play a role in recharging local groundwater systems. Variations of the sand dam are the subsurface dam or the permeable dam, which are cheaper and more climate resilient, but with less (permanent) storage. The permeable sand dam for instance built with gabion casings and only partially sealed, allows water to trickle down slowly to the downstream area. The subsurface dam is barrier constructed within the existing sediment, without raising above the ground. These are usually constructed in wider, deeper riverbeds with less slope. A subsurface dam does not have to withstand flood flow and can be a simpler structure. When properly sited and constructed it can provide much more storage than a raised sand dam at less cost. It can also be used to recharge groundwater. Because this technology is still in its infant stages in Jordan, we recommend getting in expert organizations for siting, design and construction.

3.4.2. Jessour system

A Jessour is an Arabic term describing the widespread indigenous wall structures built across relatively steep wadis in southern Tunisia. The walls are usually high because the slope is steep. They are made of earth, stones or a mix of both, but always have a spillway, usually of stone. Over the years, as water is stopped behind these walls, sediments settle and accumulate, creating new land for planting, mainly used for figs and olives trees but it can also be used for other crops (Figure 15) (Oweis et al. 2001).

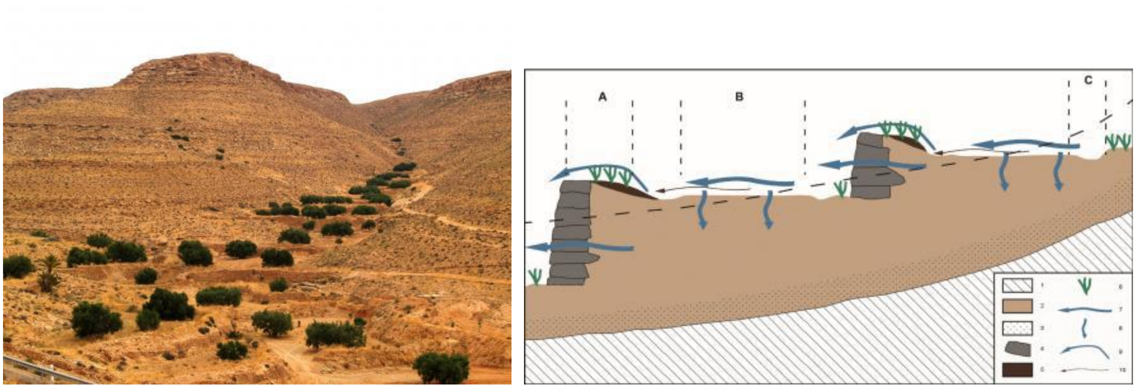


Figure 15: Example of Jessour system from Tunisia (source: N. Blond, 2018)

3.4.3. Managed Aquifer Recharge (MAR)

First, the definition of MAR has to be discussed as there is a variety of interpretations of the concept. In this study we refer to the intended recharge of existing shallow or deep aquifers, and not storage in sand dams or subsurface dams, or diffuse recharge as a co-benefit from soil and water conservation or agriculture. MAR methods include: riverbank filtration, infiltration ponds and injection wells, and uses natural water sources and appropriately treated urban storm water, sewage and other waste waters to increase groundwater storage, protect and improve water quality, and secure drought and emergency supplies. MAR is however not a remedy for water scarcity in all areas. Aquifer conditions must be suitable and (excess) source water must be present. The potential of MAR applications should be preliminarily assessed before field activities initiate. Several studies mention the potential for manage aquifer recharge (MAR), and some specific MAR interventions are possible.

A recent study (Al Absi et al., 2020) provides some general conclusions on MAR potential in Jordan. They are not very positive about the opportunities: "Although managed aquifer recharge has been attempted in Jordan since the early-1960s, most of the recharge dams that have been constructed have failed to reach their objective of infiltrating significant amounts of surface water into the underground, at reasonable costs, and contributing to groundwater recharge in areas where this groundwater can be used downstream for domestic water supply. A countrywide analysis showed that the potential for managed groundwater recharge is low in Jordan" (Al Absi et al., 2020, p.90). The study provides an overview of MAR Facilities in Jordan with nine old recharge dams which are mostly filled up with sediment.

Another recent study (Salameh et al., 2020) provides an overview of MAR potential in Jordan. They indicated high potential areas in the Jordan Valley, Wadi Araba, Jafr and Azraq Basins. The study provides detailed information on the Jordan Valley area. They come to the conclusion that the most favorable sites for MAR schemes are the flat plains in the Jordan and Deas Sea Rift Valley. These plains border the mountain ranges and are underlain by recent coarse alluvial deposits (Abu Habil, Kufranja and Samra Formations). Runoff from the many wadis exiting in the Rift valley or excess water from the King Abdullah canal serve as source water for the schemes. Infiltration can be realized by flooding natural terrain, creating shallow lakes in excavations or using existing gravel quarries.

In the Wadi Araba Basins potential MAR sites are indicated at the alluvial fan deposits in the valley between the Red Seas and the Dead Sea. These are recent deposits from the different wadis coming from the basement outcrop area. In the central flooding areas of the closed basins of Jafr and Azraq. These areas receive a high amount of flood water, which for a large part evaporates. Jafr Depression at times held a large freshwater lake. However, currently, its collected water becomes salty through infiltration into saline groundwater. Thus, MAR processes can be implemented up gradient of the saline water zone. Small dams or weirs can stop freshwater before it reaches the saline zone and provide more time for infiltration. The Azraq enclosed basin has several high potential sites for MAR also before where the collected fresh water becomes salty due to high evaporation rate in the area.

In addition to the Azraq and Jafr central flooding areas, the Qa'as still receive large amounts of floodwater and could also have high potential for MAR, before the water reaches the saline part. The larger areas are indicated in RWH Suitability map (Figure 18). These areas need further exploration for suitability for MAR. The environmental impact of large-scale usage of these flood waters would have to be assessed, the wetlands of the Azraq are commonly known, but an element that is not mentioned in the studies is that the Azraq and many other smaller flooding areas provide seasonal grazing lands, as can be observed from satellite imagery and from the many livestock enclosures surrounding those areas.

One study (Alraggad & Jasem, 2010), describes the MAR potential in the Azraq basin based on a GIS analysis. They indicate high potential in areas, due to the presence of superficial deposits, low slope, aquifer conditions and proximity to water re-sources. An advantage in the Azrag area is the relative shallow depth to groundwater. However, they do not provide practical information on the methods to be used to realize MAR.

In addition to the specific sites and areas of high potential mentioned in literature, we expect that technically MAR could be implemented throughout the country in the areas where aquifers outcrop (see hydrogeological map). Techniques that could be feasible include: instream infiltrations systems such as infiltration dams, sediment dams (sand dams and subsurface dams) and off-stream through infiltration ponds and tube recharge. Additionally, in these areas aquifer recharge can be a co-benefit from soil and water conservation measures. However, a main constrain might be the lack of interest from water users and the government to invest in MAR, and the needed capacity for management of the larger more advanced MAR systems. This could be a reason to look at small scale methods, that can be implemented by farmers and local land owners at catchment scale and have a significant combined impact on groundwater recharge. As many of these techniques are only recently introduced and implemented at limited scale, it is too early to make general conclusions on the potential of MAR in dealing with Jordan's water resources challenges. More research and experience would be needed for this.

3.5. Micro catchment water harvesting

Micro catchment water harvesting is also known as in situ RWH. These techniques regroup several well-known ancestral technologies in Jordan. The following sections provide a summary of these options.

3.5.1. Contour trenches using the Valarani plough

Valarani is the name of an Italian Engineer who creates the Valarani cultivation methods, the method creates a curved dich that can keep moisture for a longer period therefore forming a fertile soil that can be used for planting (Figure 16). While this method is being used successfully in Jordan, the technique is used on small sized area or on research or pilot projects.

The results of these pilot sites show that although it initially seems to increase plant growth, field and satellite imagery observation indicate that many of the valarani disappear after a several years. If the underlaying socioeconomic challenges with rangeland management are not dealt with, this technical and capital intensive intervention does not seem to provide a long-term solution for the Badia. It can be more effective in areas where crop farming is practiced.

Figure 16: Valarani cultivated and planted land

3.5.2. Swales

Some of the permaculture pilot projects reported the use of swales. Swales are large but shallow trenches with a bund on the downstream side. They collect runoff from either the land directly above the swale or from the offtake from small streams or roads. The purpose of the swale is to collect water and sediment and allow it to infiltrate in the soil. This allow the soil to retain humidity and to therefore be more productive. Usually, swales in farms are built parallel, starting from the so-called 'key point' in a valley, with a minor slope away from the valley. These are also called key line swales or key lines. This causes redistribution of the runoff water away from the normal drainage pattern, resulting in more evenly distributed infiltration throughout the field.

3.5.3. Meskat system

Meskat is a term used in Tunisia for an indigenous RWH system supporting mainly olives and figs. This system consists of a catchment, or meskat, occupying the slope adjacent to a flat cultivated area (Figure 17). Usually, it is on gentle slopes in areas with few or no drainage channels.

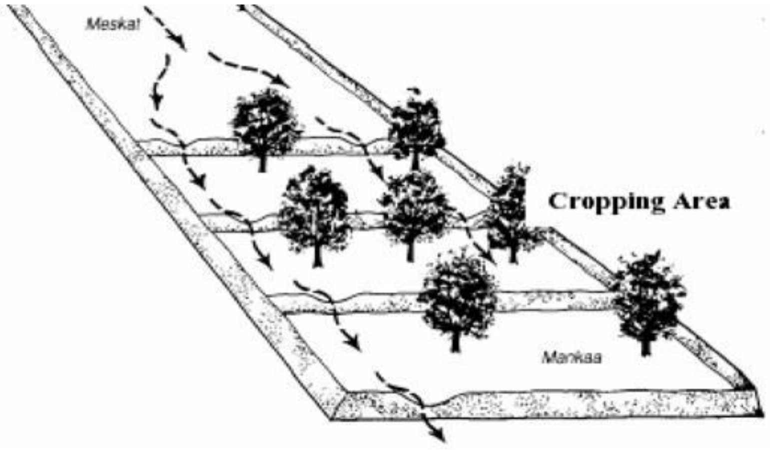


Figure 17: Schematic drawing of meskat system (source: Prinz, 1996 and Oueasser)

Text Box 4: Rock catchment

The textboxes in this section describe these technologies which have not been seen in Jordan much but seem to show potential. One of these can be a Rock catchment. The rock catchment is a very simple principle whereby large storage tanks (100 or 150 cubic meter, sometimes several) collect water from a smooth rocky surface. Depending on rainfall and the size of the rocky surface the size of the collection tank or cistern can be chosen. On the rock there is usually a gutter that directs the runoff into a collection chamber and then into the tank. Potential might exist in the areas where there are smooth rock outcrops facing the prevailing winds.

See: https://qcat.wocat net/en/wocat/technologies/view/technologies_580/

3.6. Rooftop and courtyard RWH

Although the uptake of rooftop RWH might not be feasible in 80% of the country due to low precipitation, rooftop RWH with cisterns can be widely used in areas where there is a minimum of 200mm of annual rainfall.

Unfortunately, in areas where it is possible and viable to use such RWH technology, the high investment cost may reduce the willingness of the population to adopt the practice. Nevertheless, in areas with dramatic water shortages this system provides a good and reliable option. We have seen two variations, rooftop water harvesting in cisterns for general use and cisterns used exclusively for agriculture. Some programs even build cisterns and forbid people to use it for other purposes besides agriculture (ILO). This testifies to the great need for this type of water. In some areas, rainwater is called holy water when harvested. Simple decision tools are available online and in studies for tank size compared to roof size https://www.samsamwater.com/rain/).

Stormwater management in urban areas can be enforced as an obligated inclusion of RWH structure within buildings. This can be in the form of a cistern, but other forms such as above ground tanks are also possible. Such programs were successful for instance in Bangalore India. Setting up such a program requires long term engagement with the municipal government (more than 3 years). In urban areas where flooding is an issue there are solutions like sponge city or resilient city approaches. These approaches use the city and its infrastructure (roofs, roads, parks, drains) as a catchment and adapts to climate extremes (Also see: 5.2.3). Policy work has already started in Amman, but at this scale the impact one wishes to create can take longer than 3 years and might be less interesting for the EKN) https://resilientcitiesnetwork.org/downloadable_resources/Network/Amman-Resilience-Strategy-English.pdf) and could also be looked at in smaller cities.

3.7. Runoff prevention

Most RWH techniques deal with capturing and storing runoff water from smaller or larger catchment areas. However, preventing runoff and enabling direct infiltration is often a way more effective way of capturing rainwater. It increases soil moisture, prevents erosion, and does not need RWH infrastructure. Jordan experiences severe land degradation, non-sustainable land uses (such as improper plowing, inappropriate rotations, destructive grazing of natural rangelands, deforestation, fragmentation of habitats, random urbanization, over pumping of ground water) are the main causes of land degradation in Jordan (Haddad et al. 2015). This has led to soil degradation, reduced infiltration/higher runoff and erosion. There are number of techniques that can be used to prevent runoff and increase infiltration and soil moisture storage. These are:

- Mulching: covering the soil with a layer of (organic) material. Mulching decreases drying of the soil, increases soil moisture retention, increases infiltration capacity, prevents weeds, increases soil life, increases soil structure and fertility.
- Contour ploughing: Traditional contour ploughing by animals is replaced by tractor ploughing along slopes. Contour ploughing is a very effective way of preventing runoff, protecting soils and increase soil moisture and groundwater recharge.
- Permanent vegetation cover.

When calculating volumes of water harvested and comparing it to the cost, these measures are the most cost-effective type of RWH interventions. They can cover large areas, while there is little or no additional cost as they are practices that can be adopted by landowners themselves, because of increased crop production and reduced cost of fertilizer and water. Water harvesting and groundwater recharge will become a co-benefit to the farmers. Increased adaptation of these measures can be a combination of raising awareness, local examples, and policy development stimulating and demanding such practices.

3.8. RWH as part of landscape restoration

The Aligned National Action Plan to combat desertification 2015-2020(Haddad et al. 2015), provides a series of best practices for ***Sustainable Land Management (SLM)***, which includes RWH techniques. These are similar to the ones suggested by FAO, supported by government and non-governmental organizations and have proven to be successful in Jordan. The following are examples of SLM best practices being practiced in Jordan through different projects and programs:

- Through minimum tillage, improved fallows, and promotion of adapted forms of the Conservation Agriculture.
- Restoring overall soil fertility (through increasing organic matter with use of green manure / improved fallows, incorporation in soil of plant residues, animal manure, nutrient replenishment).
- Implementing soil conservation measures (terraces, contour tillage, stone walls).
- Improving water management through water harvesting (for crop, range and forest areas).
- Regeneration of forests, including reforestation of forests, steep slopes or other fragile areas.
- Rehabilitation / re-vegetation of degraded range.

- Restoration of community rangeland governance and management practices, including rotational and seasonal grazing patterns.
- Improving management of ruminant animals including veterinary services and awareness programs on animal diseases.
- Maintenance of stream flow and rehabilitation of water springs.
- Measures to improve livelihoods through sustainable intensification of natural resource use (including introduction of business oriented organic farming in rainfed agriculture, livestock production and non-timber forestry products (e.g., honey production, dairy products, medicinal and herbal plants).

These practices are an integrated part of what is known as Regenerative Agriculture. This is a form of agriculture that is adapted to the local ecosystem and even aims to restore it, while producing food and non-food products. There are many international experiences and some projects and farms using these principles were found in Jordan.

3.9. Rangeland management - Reviving HIMA System

Hima is a traditional institution of tenure which has governed rangeland resources in Jordan and the Arabian Peninsula for over 1400 years. Since then, the community-managed system has evolved slightly to signify the setting aside of land to allow regeneration and sustainable use of natural resources for the benefit of the communities living adjacent to it. The IUCN with the MoA and the Arab Women Organization have identified an opportunity to bridge the policy implementation gap in Jordan through the revival and support of the Hima system, for scale up to the entire Arabian Peninsula. Revival of Hima is carried out by linking communities with local government to legitimize their land management strategies. This enables communities to establish and enforce rules and regulations for rangeland resources, promoting natural re-vegetation and recovery of soil and water cycles. Based on Hima and a preliminary economic valuation conducted by IUCN 2012, the government is revising its rangeland policy.

The Dana Biosphere Reserve provides an example of what is possible with good rangeland management. The overall Dana Biosphere Reserve is divided, based on grazing practices, into three distinct locations: the Core Zone (no grazing), Barrat Dana or Al-Barrah (regulated grazing) and Wadi Araba (uncontrolled grazing or the land of commons). The Royal Society for the Conservation of Nature (RSCN) is interested in the sustainable integrity of the Dana Biosphere Reserve which requires proper management inside the reserve and in the surrounding areas. Although the legislative framework is present, actual application is still incipient and limited to pilot experiences. Therefore, the adoption of a fully integrated land use planning approach (such as the integrated **"ecosystem approach"**) in national programs to combat land degradation needs refinement. In addition, the existence of an adequate and integrated land use planning supporting legislation would also contribute to remove this barrier. Another issue is related to insufficient or inadequacy of law enforcement systems for the application of the legal framework existing in Jordan (From the National Action Plan to Combat Desertification, Haddad et al. 2015).

Some examples of integrated approaches to regenerate degraded land in arid environments include:

- Dana Biosphere Reserve – rangeland management
- Greening The Desert Jordan – Permaculture Example Farm and training centre
- Al-Badya Saudi Arabia – Permaculture in very dry araea
- Famer Managed Natural Regeneration (FMNR) – Approach to rangeland regeneration in the Sahel region
- Landscape approach Ethiopia and Rwanda – Entire regions have been regenerated and re-greened through an integrated landscape approach

- ICARDA Badia Research Site in Southern Amman – Research on Vallarani pits, Marab and other interventions for rangeland restoration

3.10. RWH and Environmental Sustainability

Rain water harvesting whether from rooftops, or within the catchments will have many benefits in Jordan. However, the environment has to be considered during the process of design and implementation. This is needed for the sustainability of the interventions itself, as it should be adapted to the environment, as well as for its impact on the environment. Below is a summary of environmental benefits of Rain Water harvesting (in consultation with Laura Woltersdorf, 2010 and Rockström, J., Barron, J., Fox P., 2002):

- Increases the local provisioning capacity of water for ecosystems: availability and quality of water determines ecosystem health and productivity, both for agricultural and natural systems. This especially true for the highlands in western highlands of Ajloun and Jarash, and in the north western part of Jordan.
- Reduces pressure on ecosystem services by providing additional water supply and reducing demand on surrounding surface and groundwater resources, which will be increasingly exacerbated by climate change. Consequently water over extraction in the landscape and land degradation are reduced and more water for ecosystems is available.
- Reduces the impacts of dry spells with supplemental irrigation and meeting livestock water needs especially in the north eastern part of Jordan. Increased fodder for livestock and poultry, reduces pressure on forests, grazing lands, wetlands like Azraq Oasis and other fragile ecosystems. This helps to improve biodiversity through the improvement of productive habitats, increasing species diversity amongst flora and fauna.
- Erosion control, climatic control, pest and disease control through habitat regulation, water quality control and control of natural hazards. Landscape water balance and water flows: by altering the partitioning of incoming rainfall at the local field scale affecting the amount of water that infiltrates into the soil and the amount that is diverted as surface runoff.
- Short term advantages, based on a single rainfall event, are increased infiltration and storage of water in the soil, as flows of water are slowed. This reduces soil erosion, minimizes incidence of flooding and reduces storm water flow, limiting damage to the landscape and built structures, locally and downstream.
- Longer term advantages, on the scale of days to months, are slower flows of water within the landscape. Longer residence times enable water to be accessed during dry periods, and used for productive purposes, including human consumption, livestock watering and increased crop and vegetation growth.
- Trees and possibly forests safe-guard and generate many ecosystem services for livelihoods and economic goods (Although they ‘consume’ rainfall.
- Reduce evaporation since substantial amounts of surface runoff may be lost during its journey through the catchment through evaporation, before reaching a stable surface or sub-surface freshwater resource.
- Increasing the residence time of runoff flow in a watershed may have positive environmental as well as hydrological implications downstream
- Improved rainfall infiltration recharges shallow groundwater sources and springs. On a large scale it might contribute to the regeneration of landscapes by increasing biomass for food, fodder, fiber and wood for human consumption. In good rainy seasons many springs

in Jordan which have been dried for some time were revived and provided water to serve the regeneration of landscape.

- Rainwater harvesting can help communities adapt to droughts and declining availability of drinking water.
- Improved water provisioning through irrigation of crops with harvested rainwater in rainfed agriculture enhances local food security. Crop yields increase significantly especially due to the second crop planted during the dry period, made possible through water storage. This is beneficial for household food supply and income. The increased storage of water often enables in particular women to increase small-scale gardening activities. Planting of higher value crops has had an impact upon the amount of food available for domestic consumption (Barron, J. (ed.), 2009a, b,c).
- Reduce energy requirements and carbon dioxide emissions, compared to conventional water supply technologies due to reduced pumping requirements.
- Increase the aesthetic use of water. At the landscape scale, water features are often protected and given specific values by local communities by enhancing vegetation

Environmental risks and potential disadvantages:

Rainwater harvesting can also cause undesirable decreases in runoff and streamflow and major impacts on low flows, depending on the adoption rate of rainwater harvesting. Thus, negative impacts need to be considered for sustainable catchment management. Below is a summary of these disadvantages:

- Impact on downstream surface and ground water and possible water uses downstream.
- Increased water availability might increase water demand and use.
- Especially in rangeland water availability attracts livestock which might cause overgrazing in the local environment and cause conflicts with farmers.
- When badly implemented interventions might fail or break, which can increase flash floods periodically, cause erosion, or even landslides.
- Non-functional interventions can also cause pollution and they de-motivate local communities and undermine support for future interventions.
- Need of purification of the water. Variable rainfall may result in poor crop water availability, reducing rain fed yields.

Regardless of the potential disadvantages from RWH it remains a highly viable solution to provide an additional water sources for Jordan. More considerations on environment for this program are provided in section 6.3.1.5.

4. Water harvesting potential put in place

4.1. RWH suitability map

To be able to make an assessment of RWH suitability on National level, an evaluation of existing maps, literature and data on RWH suitability was made. Some existing information and map layers were found, especially by JVA and NARC. The Water harvesting map layers provide by NARC only include a few RWH technologies and have limited detail, the NARC maps form a general description of where Contour, Marabs and Valerani techniques for water harvesting can be implemented in Jordan. It was unclear how the suitability layers related to the physical landscape, or what the suitability indication is based upon. JVA developed a Water Harvesting Projects map (Annex B), but this only provides existing and proposed sites of surface water reservoirs (ponds and dams). These maps were used as input for the assessment. However, no comprehensive RWH suitability map on National scale was found, ready to use for the evaluation purpose of this study, so a new map was developed.

Based on the assessment of the biophysical context and review of existing interventions and literature, an interpretation was made on general RWH suitability in Jordan. This is represented in a RWH suitability map (Figure 18), a larger size map is included in Annex C. The aim of the RWH suitability map is to show the different options that are possible in the different environments/zones. It does not provide an overall judgement on suitability of RWH, because there are options everywhere, and the purpose of the map is to show that potential. The map represents suitability zones which are mainly based on climate zone (Aridity Index) and slope, further details are based on hydrogeology and flooding. For each zone an indication is provided of interventions or management strategies for RWH that are likely to be suitable within this zone. The categories include sustainable land use (with a focus on agricultural practices), SWC and off-stream and in-stream interventions for water storage. The interventions that are listed within these categories for each specific zone are generally matching the environment/landscape. This does not mean that within the zone interventions can placed anywhere, but rather that there is a high likelihood of feasible sites/areas within this zone.

The RWH suitability map was used for the basin assessment within this study. It can be used for general scoping of RWH suitability on basin level or in target areas. However, due to the lack of detailed GIS data in this scoping study, it might not be accurate enough for local planning. It should be noted that the suitability is a first indication only, further assessment of the local situation is required for confirmation of feasibility of specific interventions and actual site location. More information on the focus basins and feasible interventions for implementation as part of the planned program on RWH is provided in Chapter 5.

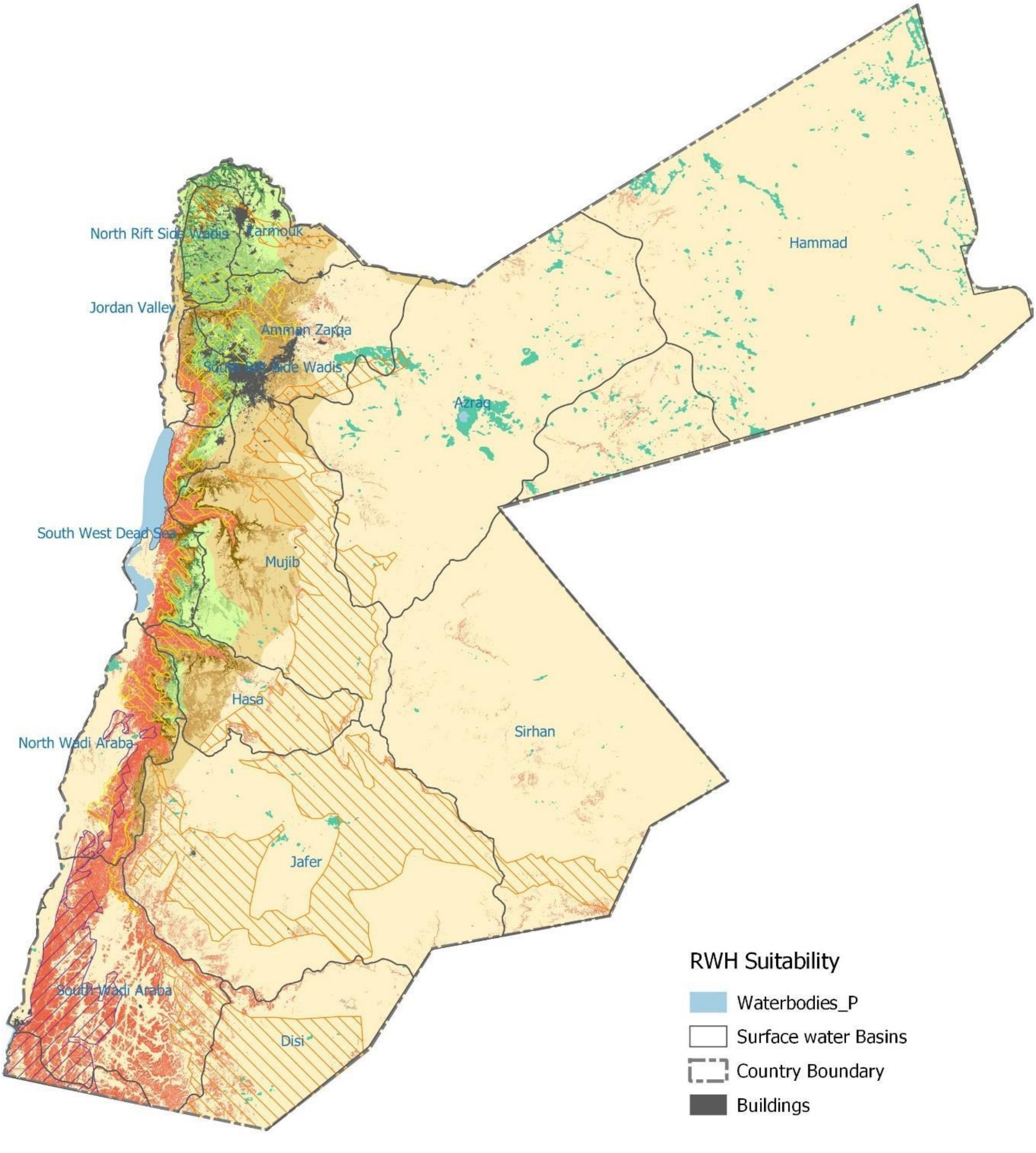


Figure 18: Jordan RWH Suitability, legend on next page

Zone characteristics			Suitable RWH strategies and interventions		
No,	Climate (Aridity Index)	Details and slope	Sustainable land use	Interventions for SWC and local runoff harvesting (in-situ recharge enhancement)	Interventions for centralized storage and wadi flow harvesting
D2	Desert zone (AI < 0.15)	Gentle slopes (<15%)	Seasonal grazing; No groundwater-based irrigation	Rangeland management; Protection of trees along wadis	Off stream: desert ponds, lined ponds (long-term open water storage should be avoided due to high evaporation), spate irrigation, cisterns, MAR; In-stream: subsurface dams for groundwater recharge/MAR, floodwater diversion weirs, marab, wadi bed cultivation
D2		Steep to very steep slopes (15-40%)	Seasonal grazing; Seasonal farming in flooding areas; No groundwater-based irrigation	Rangeland management; Hillside runoff systems: planting pits, small runoff basins, half-moons, contour ridges, 'meskat' system	Off-stream: hillside dams, rock catchments, cisterns; In-stream: cascading check dams, gabion dams, sand-dams for flood buffering and MAR, wadi bed cultivation, Jessour structures
L1	Low rainfall zone (AI = 0.15-0.2)	Gentle slopes (<15%)	Controlled grazing; Farming with drought resistant (permanent) crops; Seasonal farming in flooding areas; No groundwater-based irrigation	Rangeland management: protection of trees, area closures; Tree planting as windbreaks and for SWC; On slopes: contour bunds, tied-ridges, swales, grass-strips, contour ploughing, etc.	Off-stream: desert ponds, lined ponds, cisterns, spate irrigation, floodwater spreading, MAR; In-stream: subsurface dams for groundwater recharge/MAR, floodwater diversion weirs, marab, wadi bed cultivation
L2		Steep slopes (15-40%)	Rangeland; Silvopasture; Farming with drought resistant (permanent) crops	Rangeland management: protection of trees, area closures; On-farmland: stone bunds, tied ridges, trenching, swales, terraces; Hillside runoff systems: planting pits, small runoff basins, half-moons, contour ridges, 'Meskat' system, and no-till practices	Off-stream: hillside dams, rock catchments, cisterns, MAR; In-stream: cascading check dams, gabion dams, sand dams for flood buffering and MAR, valley dams, wadi-bed & wadi-bank cultivation, Jessour structures.
L3		Very steep slopes (>40%)	Forest; Silvopasture; Tree crops	Tree protection; Area closures; Tree planting; In farm land: stone structures above ground for soil stabilization	Valley dams; Rock catchments; check dams
A1	Rainfed agriculture zone (AI >0.15)	Gentle slopes (<15%)	Rainfed agriculture with supplement irrigation; Agroforestry; Horticulture with irrigation from RWH, surface water or waste water reuse	Tree planting as windbreaks and for SWC; Wadi bank cultivation using floodwater; On gentle slopes: contour bunds, tied ridges, swales, grass-strips, contour ploughing, etc.	Off-stream: ponds, lined ponds, cisterns, MAR; In-stream: sand- and subsurface dams for flow buffering and MAR, check dams or weirs feeding irrigation systems and/or ponds
A2		Steep slopes (15-40%)	Slope adapted agriculture; Agroforestry	On farmland: contour bunds, stone bunds, tied ridges, swales, trenching, contour tree lines, terraces, hillside runoff systems: planting pits, small runoff basins, half-moons, 'Meskat' systems, and no-till practices; Rangeland management	Valley dams; Hillside dams; Rock catchments; MAR; Wadi-bank cultivation using floodwater; Flood buffering and MAR: cascading check-dams, gabion dams, sand-dams, etc.; Check dams or weirs feeding irrigation systems and/or ponds
A3		Very steep slopes (>40%)	Forest or forest plantations; Silvopasture; Rangeland	Forest protection; Tree planting; Rangeland management; In farmland: stone structures above ground for soil stabilization	Valley dams; Rock catchments; Check dams
F1	Flooding areas in Low Rainfall/Desert zone (mud flats with seasonal vegetation and salt flats or Qa'a)		Wetland; Seasonal grassland; Seasonal farming in flooding areas where there is no negative impact on (seasonal) wetlands and grazing areas.	Strongly depends on the nature of the flooding area, is there (seasonal) vegetation or no vegetation? Wetland protection (when vegetation); Grazing management; On farmland: flood recession cultivation, bunds, marab	Floodwater spreading for MAR; Floodwater storage in desert ponds or infiltration ponds; Marab; High potential for MAR; In saline areas water should be captured before reaching the salt flat
G1	Hydro-geology: Basement Complex		See underlying layer	High potential for sand-dams and subsurface dams and shallow groundwater storage in top soil and streambeds (alluvial sediments); No potential for deep groundwater recharge	
G1	Hydrogeology: Aquitards		See underlying layer	Potential for shallow groundwater storage through sand-dams and subsurface dams; Low potential for MAR of deep aquifers (unless through tube recharge)	
G3	Hydrogeology: Aquitards/Aquifers		See underlying layer	If aquitard: potential for shallow groundwater storage through sand-dams and subsurface dams; Low potential for MAR of deep aquifers (unless through tube recharge)	
W4	Permanent open water bodies			Protection of floodplains and buffer zone/ riverine buffer with protection of riverine vegetation	Riverbank infiltration; Floodwater spreading
U1	Built-up area's			Urban water management; Increased tree cover	Roof rainwater harvesting; Infiltration ditches; MAR

AI = Aridity Index; SWC = Soil and water conservation; MAR = Managed aquifer recharge

4.2. Water demand and supply

While the country has been in water deficit since the 1960's, the gap between water demand and supply is continuously increasing. The total available water per capita is 88% below the international water poverty line of 1,000 m3 per year. The total water use in 2018 was 15% higher than that of a decade previously (Al Absi et al., 2020). The total municipal water use is expected to increase to about 730 MCM in 2020 according to Jordan's water strategy, and is expected to increase to 778 MCM in 2025. By 2040, it is expected that the country will only be able to meet 34% of the municipal water demand. The municipal sector is however only the second largest water consumer (Al Absi et al., 2020). It is the agricultural sector that consumes the largest amount of the resource due to its irrigation schemes. In 2015, 51% of the total water supply was allocated to this sector. The industrial sector uses around 4% of the national water resources. Industrial water use increased sharply up to around 50 MCM in 2015. The projections by the MWI predicted industrial water use at 70 MCM in 2025.

While the country experiences water deficit, this deficit is felt differently depending on the governorate. There is an unequal distribution and allocation of domestic water per governorate (Al Absi et al., 2020). For example, the highly populated Irbid governorate experiences the lowest share of domestic water (52 l/c/d) while to the Ma'an governorate uses the largest amount of domestic water (132 l/c/d), despite its comparatively low population density. To get a clear overview, this information is represented in a map (Figure 19). The Irbid governorate is partially located within the Jordan Valley basin. Within this basin, there is an overall water shortage because of the numerous dams present on the river and its tributary, probably preventing higher use of water for domestic purposes.

Another striking example is the Amman governorate that is partially located within the Amman/Zarqa basin. This basin comprises the most densely populated area in Jordan. Around 65% of the country's population and more than 65% of its industries are located within this basin. This is why the urban water supply is in a poor shape. The population in refugee camps experience permanent water shortages and floods are a common occurrence throughout the basin.

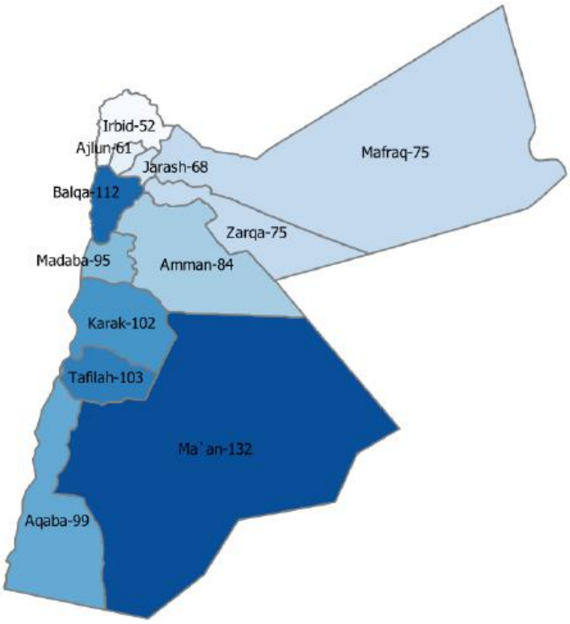


Figure 19: Average water domestic water consumption l/c/d per Governorate (2018). Administrative water losses have been deducted (data retrieved from Al Absi et al. (2020))

In order to be able to assess the water demand for domestic and agricultural purposes on Basin level a map was developed (Figure 20). This map provides the agricultural areas per climate zone and the domestic water coverage, as indication of where there is a potential demand for RWH. Agriculture has different potential and different needs depending on the climate zone. The climate zones were based on the Global Aridity Index. Aridity is usually expressed as a generalized function of precipitation, temperature and reference evapotranspiration (ET0). An Aridity Index (UNEP, 1997) can be used to quantify precipitation availability over atmospheric water demand. This is more representative than precipitation alone, as it indicates the actual water demand for agriculture. Agriculture within the Hyper-Arid zone can use up to double the amount of irrigation water to grow crops than in the semi-arid zone, due to the lower rainfall and higher evapotranspiration. Therefore, agriculture in the arid zones has lower priority and irrigation should only be used from renewable water sources that do not compete with other water needs.

Domestic water coverage is per governorate expressed by the Per Capita share in 2018. It is linked to the populated areas to provide an indication of where people live and their access to water. The actual water use is lower than represented, due to the high percentage of water losses. In addition, the water consumption data is an average on governorate level and local differences are not included. Nevertheless, the current water coverage provides a good indication of the areas where there is need for additional water supply for domestic purposes. This map was used for evaluation of basins and areas within basins to identify areas of water need. This is further discussed in the Basin Evaluation.

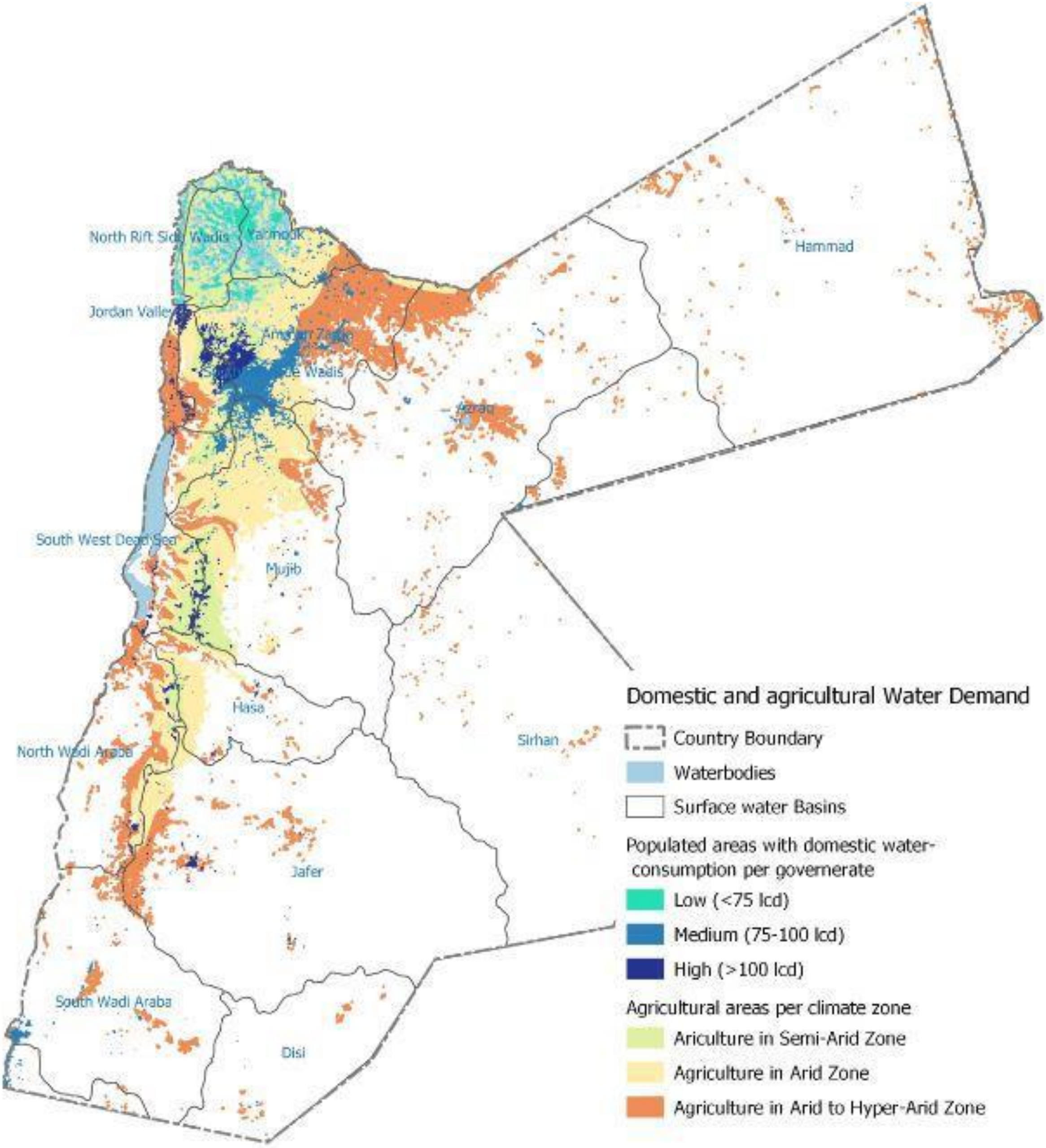


Figure 20: National domestic and agricultural water demand

5. These basins and RWH interventions show the best promise

The previous chapters took stock of the hydrology, geohydrology in the catchments and groundwater basins. We also discussed the stakeholders, capacities and the available and potential technologies. In this chapter we provide our evaluation of the basins and RWH technologies or approaches that show promise. The most feasible basins for the follow-up program are identified through multi-criteria selection process. Within these basins the most suitable interventions for a RWH program are recommended and technical information on implementation is provided.

5.1. Basin evaluation and selection

The focus of the study will be refined based on the initial quick scan of the RWH situation in Jordan. The study was supposed to come up with maximum of three focus basins for a refined analysis and selection of feasible interventions for a follow-up program on RWH.

5.1.1. Summary of basin assessment

A strategic evaluation of all 15 surface water basins was made and recorded in the Basin Evaluation Table (The full table separately provided in Excel). A summary is provided below.

- Yarmouk: Many wadis contribute to the river which then flows into the Jordan River. However, currently it has only <25% of historical flow and effluents of agriculture, industries, and waste water treatment plants reach the river. The basin consists of a mixed land use with agriculture, forest and urban spaces. Some water is stored for agricultural purposes but there is limited excess water available for RWH. There is a need for shift towards crops and agricultural practices that need less irrigation. There is potential for terraces and other hillside adapted agriculture interventions.
- Jordan Valley: The Jordan valley is a wide stretch of plain alluvial deposits along the Jordan River, dominated by intensive agriculture depending on irrigation. It is highly populated along the sides of the valley. There is a water shortage in the Jordan river caused by high numbers of big dams in every tributary. There is locally high potential for MAR using water from outside the valley. In the valley itself there is limited runoff and limited variety in options for RWH, although a lot can be gained from increased water use efficiency.
- North Rift Side Wadis: Consist of many separate sub-catchments, draining towards the Jordan River/Dead Sea. Recently there has been a decrease in flow of the wadis. The area receives relative high rainfall but much of the water is lost as runoff, while groundwater is used to maintain high value agriculture and crops that need much irrigation. There is a need for shift towards crops and agricultural practices that need less irrigation. Aljun Forest Reserve provides opportunities. There are many examples of terraces and RWH/SWC on hillsides present in this basin.
- South Rift Side Wadis: In the North similar to NRSW, the South and South-West are much drier and sparsely populated. There are steep slopes with relatively high annual rainfall which causes high runoff that can be available for RWH. There is a good potential for other interventions too.
- Amman/Zarqa: Although it is the second largest river in the country, recently its natural flow has dropped. However, at present 70% of river flow is treated waste water, which doubled the total discharge. Due to low water quality, at present it can only be used for irrigation of certain crops. It is the most densely populated area in Jordan. The feasibility of RWH varies across the basin due to the variation in landscape and rainfall.
- Dead Sea Side Wadis/South West Dead Sea: Consists of many sub-catchments discharging towards the Dead Sea. Simlar to South Rift Side Wadis, but mostly drier. The steep slopes

towards the Dead Sea are bare and sparsely populated. Large variety of interventions possible within small area. There is a potential for cascading check dams/stone dams to store sand/sediment to buffer flood flow, wadi-bed/bank cultivation, floodwater spreading, terracing, slope adapted agriculture.

- Wadi Mujib: The basin is large with high variety in landscapes, climate and potential for RWH. In the mid-lower catchment, the main wadis are too large for instream RWH and small and large dams are present. There is a saline baseflow in lower reaches of the basin. The southern part (wadi Mujib) has many existing and proposed interventions by JVA.
- Hasa: Drains towards the Dead Sea. Arid climate, and mostly sparsely populated. There are deep incised wadis are very suitable for earth dams and potential for cascading check dams/stone dams to store sand/sediment to buffer flood flow, locally wadi-bed/bank cultivation, floodwater spreading, terracing, slope adapted agriculture. This will also be the place of very ancient RWH practices. It has many existing and proposed interventions by JVA.
- Wadi Araba North: Arid climate with variable landscapes and geology. Scattered Towns and Villages are present. The basement rock areas have a potential for sand dam and subsurface dam. Other water harvesting methods like floodwater spreading, regreening, agroforestry, grazing management are possible too. It has many existing and proposed interventions by JVA.
- Wadi Araba South: The basin has mostly a hyper-arid climate and is sparsely populated except for Akaba. The basement rock areas have a potential for sand dam and subsurface dam. It has no proposed interventions by JVA.
- QA Disi and Southern Desert: Possibly some potential in the flood zones (mudflats) but the catchment has very low rainfall, is remote and mostly uninhabited, therefore the potential is low.
- Jafer: Althoug being mostly hyper-arid, there appears to be potential to recharge water before the runoff reaches the evaporation flatlands. The potential could be Managed Aquifer Recharge, but this needs more study. The road that moves from Al hasa to south could function as a dam (road water harvesting).
- Wadi Sarhan: The basin is sparsely populated with very erratic rainfall and limited variation in topography, therefore, there is limited variety in potential for RWH technologies.
- Azraq: The basin has an arid to hyper-arid climate, but a lot of agricultural activity is going on, mostly depending on groundwater based irrigation. Managed Aquifer Recharge potential is mentioned in several reports but there is a lack of good examples. Floodwater naturally spreads in many of the so called Qa'a areas, but these are often not bare salt flats, but seasonal grazing areas. There is potential for a variety of RWH interventions in agriculture including floodwater spreading.
- Wadi Hamad: The climate is arid but some potential is there, but variety in RWH options is limited. Mainly hafirs, floodwater spreading and wadi bed cultivation is present and has potential. However, due to erratic rainfall, efficiency might be low.

5.1.2. Summary of basin weighting and ranking

Selection criteria were developed that indicate the feasibility of the Basins for a program on RWH. A paired comparison method used to test the weight of each criteria. The method depends on comparing each criteria to the others, giving a score from 0 to 2 for each criteria compared to the other (0 means less priority than the other criteria, 1 means equal priority, 2 means higher priority). Table 5 provides the selection criteria and the total score and resulting weight for each criteria.

Table 5: Criteria of selection of the suitable basins to implement a RWH program

Criteria	Total score	Weight
High domestic water need	12	9%
Limited alternatives and/or high pressure on other water resources from agriculture and other water uses	15	11%
Social and cultural acceptance, RWH traditionally practiced	6	5%
Local capacity in line with the complexity of O&M of the intervention	8	6%
Financial feasibility, good cost-benefit ratio	8	6%
Is there potential and variability of options for in situ RWH (SWC in agriculture)?	14	11%
Is there potential and variability of options for in-stream RWH (without effecting downstream dams)?	14	11%
Is there potential for domestic RWH (scattered buildings? High prices)	13	10%
Is there potential for area conservation (reforestation, rangeland management)	13	10%
Is there potential for groundwater recharge?	12	9%
Presence of existing programs to latch onto	8	6%
National focus area	9	7%

5.1.3. Ranking & conclusions

Al 15 basins were evaluated on each criteria to come up with a priority ranking (Table 6). The basins were provided with a score from 0 to 3 for each criteria. The scoring was multiplied with the weight factor resulting in a weighted score. The Mark provides the total weighted score of all the criteria per basin. The Mark was used to rank the basins.

Table 6: Results of the evaluation and ranking of the basins

Basin	Mark	Rank
Yarmouk	2.17	3
Jordan Valley	1.68	8
North Rift Side Wadis	3.86	1
South Rift Side Wadis	2.59	2
Amman/Zarqa	2.05	6
Dead Sea Side Wadis/South West Dead Sea	1.58	10
Wadi Mujib	1.73	7
Hasa	1.17	11
Wadi Araba North	2.16	4
Wadi Araba South	1.58	9

QA Disi and Southern Desert	0.90	14
Jafer	1.10	12
Wadi Sarhan	0.81	15
Azraq	2.11	5
Wadi Hamad	1.10	12

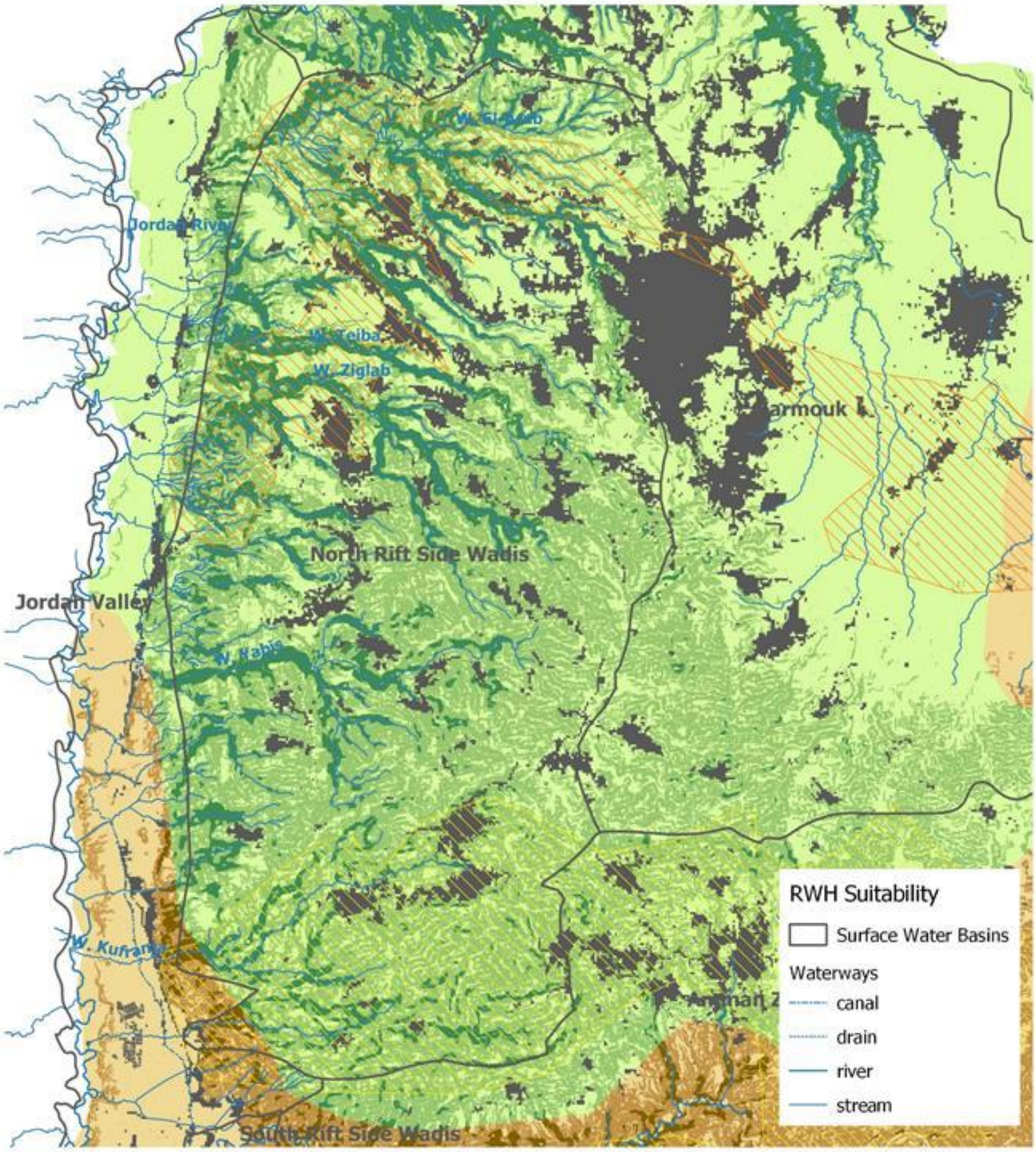
In order to have the challenges and opportunities for RWH in Jordan represented in this study and the follow-up program, the selected basins should include a variety in climate, environment and suitability for different RWH interventions. The highest ranking basin is North Rift Side Wadis (NRSW), this was the first recommended basin and was selected as focus basin. Since the NRSW basin is within the high rainfall zone, a second basin was selected that represents the Badia and desert environment. Within this environment the highest ranking basin is the Azraq Basin. Based on the basin analysis and discussions with EKN Amman, we concluded that these two catchments showed most promise for the scaling up and introduction of RWH structures. The following sections provide more detailed information on these basins and on the opportunities for RWH.

5.2. North Rift Side Wadis Basin (NRSW-Basin)

The North rift side wadis drain towards the Jordan River and the Dead Sea, where some dams have severely reduced the flow of the wadis towards the Jordan River. The water flow towards the Wadi El-Arab was reduced from 30 MCM/year to 5.5 MCM/year. Wadi El-Arab dam has 20 MCM storage capacity. Wadi Ziglab has a spring flow and river flow of 5 MCM/year. Wadi Ziglab dam has a total capacity of 4.3 MCM. In addition to these predicaments the groundwater also retreated considerably.

Land degradation and resulting declining production is a severe problem in the northern, middle and southern Highlands, which form the base for agricultural production in Jordan. In the NRSW-Basin these problems are abundant. Water shortages are strongly related to these problems. While most land degradation is caused by unsustainable agricultural practices, a transition to sustainable farming practices also holds the solution to the land degradation and water related problems. This should be part of an integrated landscape approach, because isolated RWH interventions are a ‘drop in the ocean’, but an integrated catchment approach with a variety of RWH technologies can be a core component of landscape restoration. A variety of interventions is possible in the upper, middle and lower catchment and there are many farming communities with a proven commitment to sustainable land management. Meanwhile, cities are experiencing flooding problems and shortages of domestic water at the same time. These problems are interlinked with the situation in the surrounding agricultural areas, while interventions in farmlands could benefit urban water challenges, there are also options for urban RWH that can be part of a catchment approach. The catchment also has potential for upscaling of an existing roof-RWH program.

Figure 21 provides a section of the RWH suitability map for NRSW-Basin. As the figures shows, there is a large variety in RWH options due to the strong variability in topography and relative high rainfall, while there are people living throughout the Basin. For implementation of a RWH program, one of the wadi-catchments or sub-catchments could be selected. This selection should be based on a detailed assessment of the suitability of RWH interventions, but more importantly on socioeconomic factors. There are several areas where farmers have shown their interest in such interventions. Paragraph 5.2.4 provides more information on potential areas for implementation of a RWH program in NRSW-Basin.



Zone	Zone	Details and slope	Sustainable land use	Interventions for SWC* and local runoff harvesting (in-situ recharge enhancement)	Interventions for centralised storage and wadi flow harvesting
A1	Rainfed agriculture zone (AI >0.15)	Gentle slopes (<15%)	Rainfed agriculture with supplement irrigation; Agroforestry; Horticulture with irrigation from RWH, surface water or waste water reuse	Tree planting as windbreaks and for SWC; Wadi bank cultivation using floodwater; On slopes: contour bunds, tied ridges, swales, grass-strips, contour ploughing, etc.	Off-stream: ponds, lined ponds, cisterns, MAR**; In-stream: sand- and subsurface dams for flow buffering and MAR
A2		Steep slopes (15-40%)	Slope adapted agriculture; Agroforestry	On farmland: contour bunds, stone bunds, tied ridges, swales, trenching, terraces; Control hillside runoff systems: planting pits, small runoff basins, half moon, 'Meskat' system, and no-till practices	Valley dams; Hillside dams; Rock catchments; MAR; Wadi-bank cultivation using floodwater; Flood buffering and MAR: cascading check dams, gabion dams, sand dams, etc.
A3		Very steep slopes (>40%)	Forest or forest plantations	Forest protection, tree planting. In farm land: stone structures above ground for soil stabilisation	Valley dams; Rock catchments; Check dams
G3	Hydro-geology: Aquitards/Aquifers		See underlying layer	If aquitard: Potential for shallow groundwater storage through sand-dams and subsurface dams; Low potential for MAR of deep aquifers (unless through tube recharge)	
U1	Built-up area's			Urban water management; Increased tree cover	Roof rainwater harvesting; Infiltration ditches; MAR

Figure 21: RWH suitability in the NRSW-Basin

5.2.1. Integrated approach for farmland restoration

There are many terraced areas in the NRSW basin. Some farmers have already used this practice for a long time by themselves. Thirty five years ago the MoA started funding projects targeting the implementation of terraces. An example of such a project is the long-term Yarmouk Basin Development Project and Zarqa Basin Development project. This project aims at allowing land-owners to access funds for terraces, cisterns (pear shaped with a cover, usually about 50 m3), and trees. Unfortunately, while there are many applicants, the funding are limited.

The Jarash, Irbid and Ajlun governates are typical areas where such interventions can be applied successfully. Traditionally, local farmers have planted grapes, olives, almonds, without the use of irrigation, except during the first years of the crops. Although there is a good potential for such RWH technologies and these technologies are part of the local agricultural traditions, only few people currently invest in more sustainable agriculture in the high rainfall areas. This could therefore be a great entry point for a program on RWH technologies, where farmers can be selected based on their own expressed interest. Additional methods for RWH could be added to existing practices in agriculture. There is also potential for instream interventions and MAR. In addition to the runoff harvesting techniques, standard SWC practices such as soil management, cover crops, contour ploughing, mulching, etc., should be promoted to prevent runoff and increase infiltration.

An interesting example of RWH/SWC integrated in a farm is Taybeh Organic Farm. It is located in Wadi Rajeb within the NRSW-Basin. They are a good example of the potential of commercial regenerative farming, with many RWH solutions practiced, including water diversion from the Wadi. More information on some of the suitable interventions is provided in the following sections.

5.2.1.1. Terraces

The use of terraces is very conventional in Jordan. Terraces are constructed to reduce erosion, to remove excess surface water, and to retain the maximum amount of moisture for crop production. Thus, it is both a soil and water conservation measure. In mountainous areas, farming of hillsides would be nearly impossible without terraces. Within dry regions, terraces increase plant available water storage.

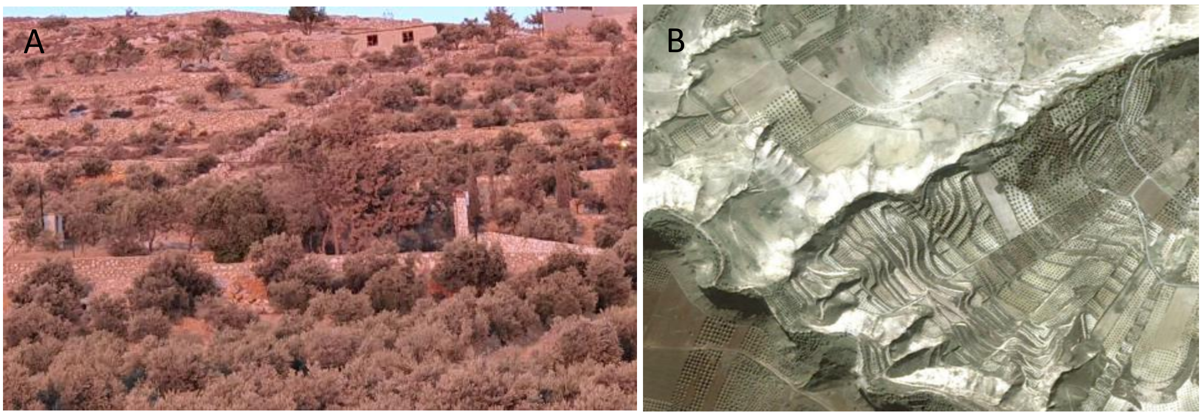


Figure 22: A: Typical stone terraces in Jordan; B: Example of an area with & without terraces and other RWH interventions in the in NRSW-Basin (source: Google Earth)

Proposed approach: Programs around terracing need to consider labor and the business case of improved land. Implementing organizations should start with a demand mapping to understand if farmers have interest to do terracing. Then in areas where the demand is present there are several ways in which people can be motivated to do terracing. The implementing team will need to make an informed decision on which approach can deliver most benefits, this decision should be based on what farmers describe as the main reasons for not (yet) doing terracing.

1. Direct incentive: Investing to pay casual laborers to build terraces can be a problem for farmers. It is our understanding that previous programs on terracing have worked with local

finance institutes to receive loans for terracing. This system should be preferred since it creates optimal ownership with the end user. Another approach that has worked in other areas are so called conditional incentives. For instance, a farmer is rewarded seedlings, or a group of farmers receive access to drinking water or such like incentives, but only after they have done the terracing.

2. Production benefits: When the kind of crops which people can grow on land that is terraced become more profitable the decision is made easier to invest in terracing. This means for instance that projects working on the olive or almond value chain can create a stronger demand for such crops, or help farmers with seedlings, transport, local processing industries etc. The improvement of the supply chain can be like a conditional incentive to persuade farmers to build terraces. This method is based on some of the examples from Ethiopia where farmers had terraces but neglected them because there was no market for their crops and the other example from Kenya where people picked up terracing because their crops gave them a good income and they could increase productivity of their land.
3. Labor availability: It is our understanding that besides water programs there is a clear demand for programs that deliver labor opportunities. Terracing usually requires a lot of work and can best be done by groups of 10 or more people. By forming work teams that can be trained and become skilled local capacities are strengthened and treatment times for land become shorter. More information on cash for work opportunities in Jordan is provided in 6.2.8.

Outcome of a proposed program:

- Production of farmland increases due to adoption of in situ water harvesting techniques.
- Erosion and runoff decrease in the intervention area, increased infiltration and recharge. When properly constructed and maintained, terraces can reduce rainfall runoff to almost zero. The actual volume of water harvested per m2 of terrace would depend on rainfall and current runoff ratio.
- Methods for popular adoption of terraces are tried and implemented.

Example BoQ of terrace construction

Table 7 represents the BoQ and cost estimate of typical 1000 m^2 (one Donum) terrace using stone walls.

Table 7: The BoQ of a one donum terrace

Item	Unit Cost (EUR)	Quantity (meter)	Cost (EUR)	Picture
Construction of stone walls by building of stone over each other's without grout or wire mish	15	200	3000	

Construction of stone walls by building of stone over each other's with grout	20	200	4000	
Construction of stone walls by building of stone over each other's with wire mish boxes	20	200	4000	

Procurement plan for terrace construction

In case the procurement of terrace needs to be realized via an agency, it is worth noting that contractors are available in all Jordanian governorates. Contractors classified as grade 6 (General works) according to the classification of the Ministry of Public Works and Housing are eligible to do such work. Therefore, an open competition for grade 6 contractors could be a very good procurement method. In this case, a profit margin of 15 to 25% shall be added to the above-mentioned cost estimates.

In case the procurement needs to be done by the beneficiary, they will be in charge of the fund and may enter in different contact for different activity (e.g., digging, plastering). It is also possible that the beneficiary performs some work themselves (e.g., ancillary work, material transportation).

Time Schedule

Around 10 working days are sufficient for the construction of a 200 m^3 of terrace.

Net present value (NPV)

The calculation of the NPV can be done for each project depending on the land use and the planting type. Terraces are a long term intervention, with a life span of more than 50 years if well maintained.

5.2.1.2. Cisterns

While there is a local demand for cisterns and the technical capacities are present, the bottleneck factor seems to be the financing of the technologies. Cisterns are highly valued by the users and give good water year-round. Building on the program of MWI there can be a follow up that takes on the lessons learned. This program should not focus on presenting the technical opportunities, rather it should explain how these technologies can be scaled up using the private sector. We see there is potential to work on innovative financing and technological development around cisterns implementation.

Proposed approach: Programs should again start with a demand analysis at farm level and then debate with different finance organizations. It would be wise to pick up where the IWMI program left, engage with different finance organizations. Local governments can play a role in this program also, for instance in signing of agreements on collateral or giving more authority to the signing of the loans.

Outcome of a proposed program: Access to cisterns is made affordable. Improved access to renewable water supply.

BoQ of cisterns

The BoQ with cost estimate for typical 40 m^3 and 65m^3 cisterns are shown in Table 8.

Table 8: Comparison of the BoQ with cost estimate for a 40m3 & 65m3 cistern

Item	Cost for a 40m cistern (Eur)	Cost for a 65m cistern (Eur)
Digging	800	1200
Construction of Concrete ring (1m height & 1m diameter)	100	100
10 cm thick blinding concert	20	20
Plastering of walls	200	300
Steel Door	50	50
Pump with connections	100	100
Total	1270	1770

Procurement plan for cistern construction

In case the procurement of cisterns needs to be realized via an agency, it is worth noting that contractors are available in all Jordanian governorates. Contractors classified as grade 6 (General works) according to the classification of the Ministry of Public Works and Housing are eligible to do such work. Therefore, an open competition for grade 6 contractors could be a very good procurement method. In this case, a profit margin of 15 to 25% shall be added to the above-mentioned cost estimates.

In case the procurement needs to be done by the beneficiary, they will be in charge of the fund and may enter in different contact for different activity (e.g., digging, plastering). It is also possible that the beneficiary performs some work themselves (e.g., ancillary work, material transportation).

Time schedule

Usually, 20 working days are sufficient for the construction of a 40 m^3 cistern (Table 9).

Table 9: Working schedule for the construction of a 40m^3 cistern

Activity	Working Days																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Digging	■	■	■	■	■	■	■													
Blinding								■												
Plastering									■	■	■	■	■	■						
Concrete ring															■	■				
Steel door																	■	■		
Pump and connections																			■	■

Net present values

Net present values calculated in Table 10 are based on the following assumptions:

- Life of the cistern is 30 years (it is usually more as Roman cisterns are still used).
- Operation (Electricity) cost is 30 Eur/Year in the first ten years increased to 40 Eur/year in second 10 years and to 50 Eur/Year in the third 10 years.
- Benefit are 120 Eur/year, means 3 Eur/ m^3 , and it is less than providing water by tankers which currently cost 4 to 6 Eur, the figure is also less than the cost incurred by WAJ to provide water to high lands.

Table 10: Net present values of the construction of a cistern in Jordan

	NPV	Years																													
		2021	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	2050
Capital Costs*	-1210	-1270	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O&M Costs*	-565	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-40	-40	-40	-40	-40	-40	-40	-40	-40	-40	-50	-50	-50	-50	-50	-50	-50	-50	-50	-50
Revenues*	2105	0	120	120	120	120	120	120	120	120	120	150	150	150	150	150	150	150	150	150	150	200	200	200	200	200	200	200	200	200	200
Totals*	358	-1270	90	90	90	90	90	90	90	90	90	110	110	110	110	110	110	110	110	110	110	150	150	150	150	150	150	150	150	150	150

**Rates in K in EUR; Discount rate of 5%*

5.2.1.3. Regreening, agroforestry and rangeland management

RWH programs can be strengthened by an additional focus on regreening and landscape restoration. Many of the slopes of the hills between the plateau and the valley are not covered with vegetation and farmland generally has low tree coverage, except for monoculture plantations. This situation therefore leads to high level of runoff and low soil fertility. The reason behind the lack of vegetation can be the soil nutritional status, deforestation, overgrazing by livestock, or a combination of factors. The Aljun Forest Reserve and some other patches of forest show what the landscape can potentially look like. There have been many tree planting projects in Jordan, often with a limited success on the long term. Nevertheless, a variety of proven successful strategies can be followed in order to increase tree coverage and forest growth. For regreening or landscape restoration projects to be sustainable they have to address the underlying issues that led to deforestation and land degradation. Often this is within the socioeconomic context, interventions have to be imbedded in this and provide the right incentives, to make a lasting impact. A proven strategy is to incorporate a variety of trees in farming models, through agroforestry systems. Farmers can be stimulated to plant trees in various ways, but most importantly, there should be an economic benefit. Regreening programs would have to be combined with improved rangeland management practices, as uncontrolled grazing by livestock is a challenge to many farmers and a reason for many regreening attempts to fail.

Proposed approach

Every region has different methods and ways towards regreening, there is not one size fits all. Unless there is an implementing organization which already knows exactly what to do, a better approach would be to set up a variety of pilot sites at sites of individual owners and collaborate with the owners so that they have the feeling the interventions are their idea. We have heard of several pilot sites where local owners were only excluded from the site, but by seeking collaboration the owners can ensure long term sustainability. An approach to this can be by making the owners 'employees' of the program, by paying them to be part of the program, try out ideas discussed with experts. Thereby the owners become the champions of the approach and can make the case towards others. Piloting things without the owners, or by excluding local users runs the risk of alienating the people around the project. Around the world there are thousands of pilot sites which show very good results at a technical level. For farmers these sites are less inspiring, often because of the high investment cost there have been (for instance, getting a bulldozer to build swales is quite an investment), but also because the site does not belong to one of their peers but to people from outside.

Agroforestry

A simple strategy to increase tree cover could be to stimulate farmers to plant trees around the perimeter of their land as a live fence. Such fence would also promote sustainable water management, would act as a windbreak, would provide some green manure (depending on the species) and could also provide some additional income. An interviewed farmer said it would be interesting to have a policy that demands farmers to plant indigenous trees around the farm. There are many valuable indigenous trees, such as Wild Pistachio, Carob Tree (very common), and other trees for green manure, which are known by the local communities and could easily trigger the interest of the local farmers.

Additionally, agroforestry practices within the farmland could be promoted. Farmers could be supported with the design and implementation of productive polyculture tree systems combined with (other) RWH interventions. A combination of commercial trees with (indigenous) trees that provide other benefits, such as green manure, fodder, shelter, improved soil, and additional products could be promoted. An agroforestry system itself would create a major increase in infiltration, through canopy interception and increased infiltration capacity of the soil. Additional RWH interventions can be incorporated in the system such as tree lines combined with contour trenches or swales and ponds. A clear business case can be developed for such a system, for example with the use of the Farm Tree Tool (https://farmtreeservices.com/).

When dealing with degraded lands on slopes, the site needs to be made erosion proof, meaning that from the upper side of the slope, runoff should be avoided/controlled. This could be in the form of a cut of the drain (deep trench) but more effective, especially on slopes above 5% is to create permanent vegetation strips. This can be realized through so-called enclosures (fenced areas) of about 7 to 12 meters wide with along the contour lines. It can be optional to plant trees, particularly when native species do not easily propagate by themselves these can be supported. Then a well-known method is by doing planting pits filled with humus so the tree or bush gets to a flying start. If gullies have formed on the land, gully plugs can be put in place.

Land ownership

At a local level the success of tree planting activities is always about ownership of the trees and their initial irrigation (if needed) and/or grazing restrictions. Site selection needs to be done at local level with the local government to find out: is the local land common property or individual. If common property, what users are there, if individual, can the owner be approached and asked to collaborate.

Regeneration on common lands: The main group to approach will be the people who graze their animals on the common but eroded lands. If they have no other opportunities, then a stepwise approach can be done where each year a small section of the land is excluded from grazing and allowed for regeneration. When done with trees that can also provide fodder there will be benefits.

Individually owned lands: Owners can be approached and for instance asked to do cost sharing. If the program supports with fencing or with seedlings for wind breaks etc then the owner will see the benefits.

Outcome of a proposed program

Degraded lands regenerated through land management practices, increased production, increased resilience, reduced dependency on groundwater. The agricultural and forested landscape would slow down and/or reduce the runoff, recharge aquifers and increase springs flow.

5.2.2. In-stream water management and MAR

In addition to the above-mentioned intervention strategies in the upper- and middle catchment, there is potential to continue the catchment approach in the smaller ephemeral streams and rivers. RWH and buffering can be implemented in the local drainage channels and small streams through gully plugs, a bit further downstream weirs can be constructed. The gully plugs and weirs could be linked to small irrigation channels, swale systems or ponds. These interventions can increase in size when implemented downstream. The proposed dams can be can constructed from locally available rocks and should not be impervious, but rather, should slow down the water flow so that sediments are trapped. Potentially, part of the soil accumulated upstream of the stonewall can be cultivated, using the Jessour system. When series of cascading check dams are constructed, this has a significant impact on water buffering. In larger streams larger sediment dams and small valley dams can be constructed. It should be noted that constructing gully plugs, without dealing with the runoff problem first, is often unsuccessful. The structures can wash away, the gully widens or replaces, because the same volumes of water have to be discharged. So a catchment strategy should start with the cause of the problem i.e. high runoff from poorly managed soils on slopes in the upper catchment, before going to in-stream interventions.

There is potential for MAR on the lower slopes towards the Jordan valley within NRSW Basin, as described before in the section on MAR. Considering the prevailing aquifer characteristics (limestone and alluvial aquifers with sufficient hydraulic conductivity), MAR is considered a feasible option. Strong periodic rainfall runoff, especially from urban areas in the highlands, could be used to feed the MAR schemes. However, given the steep topography, the karstic aquifers would not provide appropriate long-term storage but discharge the water soon afterwards Wolf et al. (2004). Improved SWC in farmlands and the cascading instream interventions can contribute considerably to recharge of aquifers. This will also depend on the nature of the geological formations in the implementation area.

Proposed approach: A catchment-based approach should always start with a hydrological and environmental assessment. This assessment should give insight on the water balance: the rainfall-runoff situation, evapotranspiration, recharge and hydrogeology, and stream flow. It should indicate what the impacts are from scenarios of interventions on the environment and water users.

A water demand analysis combined with the RWH suitability analysis the team can find sites with the local community where both seasonal water can be retained or recharged and where a selected number of participants can set up small agricultural schemes, or improve existing schemes, or get access to drinking water.

Outcome of a proposed program:

- A catchment approach to water harvesting is implemented
- Water that would otherwise have disappeared with flash floods is diverted or recharged
- Reuse options for shallow groundwater are implemented
- Erosion is reduced

5.2.3. Urban RWH – Sponge City Approach

In the north-eastern part of Jordan there is a high risk of flooding due to stormwater (Figure 23) (World Food Programme (WFP), 2019). It is well known that Amman suffers from flooding in the downtown area. Other cities such as Irbid also face a similar problem. According to the Reliefweb.int the towns of Amman and Irbid are susceptible to floods. While most of the flood zones of Amman are located outside the NRSW catchment, the floods in the city of Irbid falls within the catchment area. It would therefore be interesting to investigate the opportunities for urban water management such as the concept of the sponge city.

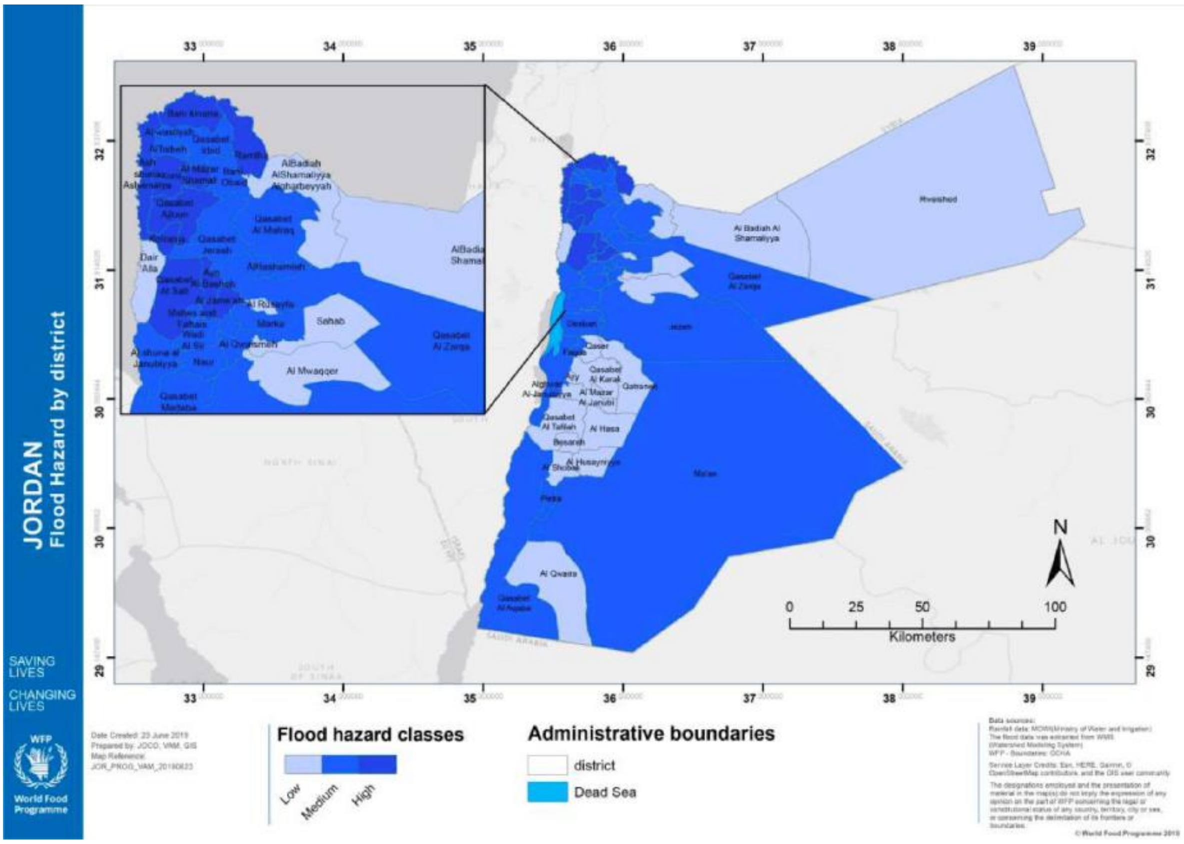


Figure 23: Flood hazard map for Jordan (source: WFP, 2019)

The so-called Sponge city approach uses the already available urban infrastructure as catchments. For instance, side drains or parks can be used as recharge pits. This would serve a triple purpose: (i) Water can percolate in the soil rather than remaining stagnant above the soil surface; (ii) Water can replenish groundwater reserves rather than be lost as floodwater; (iii) Water can moisturize parks and road drains to allow trees to grow, thereby cooling the city.

Proposed approach: The work is best done by a consortium that has specialists in:

- working with local governments and policy
- understanding urban drainage and geohydrology
- building with nature

We must stress that collaboration with municipalities or town governments can be a tedious process that might take several years. From experience we know that these programs require a lot of patience since the stakeholders are comprised of organizations that tend to be reluctant to change the local drainage system. Ideally, an organization with experience, preferably even local experience, would handles the liaison with the authorities and builds in a go- or no-go moment. When local authorities cannot be persuaded within a year, it is more judicious to relocate or cancel the program. If local authorities can be persuaded there needs to be a study on the urban drainage and the recharge or retention potential. This means a full analyses of the urban rainfall-runoff situation, where it flows, where there are bottlenecks and where it can be potentially stored and infiltrated. In an Urban environment, water quality is an issue and should be part of the analysis.

There are dozens of small scale technical options for roof water harvesting, road water harvesting, recharge pits etc. Describing the options here would need an additional 10 pages. We expect that this program needs more than 4 years to develop and it seems likely the option will not be pursued because of this.

Outcome of a proposed program:

- Areas within the selected town or city redesigned with water recharge and retention options
- Floodwater streams reduced through green infrastructure
- Local governments involved in sustainable water management practices

Experience in other countries shows that urban water management is a complex process, which needs time and much stakeholder interaction. In three years' time, for an amount of roughly 200,000 to 300,000 Euro, an organization can start with mapping the hydrology, determining the options, and establishing continued interaction with all the stakeholders. Requesting permission and permits to set up a demonstration (a few swales, roadwater drainage recharge options, infiltration pits). These demonstrations can be used in trying to bring the stakeholders on board in a more encompassing plan and possibly at year 3 implement a bit larger project such as a small recharge park or such like.

5.2.4. Potential focus areas/sub-catchments within NRSW-Basin

In order to identify potential focus sub-catchments or villages for the implementation of the program, the related Ministry of Agriculture departments were contacted in the governorates of Irbid, Jerash, Ajloun. They were asked to identify areas with high feasibility for implementing terraces and cisterns, and how those departments see the areas and villages. The priority areas are provided in Table 11. In all of these areas/villages the MoA department got a number of requests to fund the terraces construction and cisterns digging and they indicated high potential for RWH. These areas need to be further investigated during the first phase of the RWH program, to identify an area that is most feasible for implementation of an integrated RWH program on catchment level. This would require a field visit to talk with the local stakeholders and assess the specific areas on suitability for different interventions.

Table 11: Recommended focus areas in NRSW by MoA

Gover-norate	Sub-Governorate	Priority areas/ Villages	Arabic Names of Areas/ Villages	Additional justifications by Contact person to the selected the areas/ Villages
Irbid	Qasaba	Dogara, Mugair, Tugbul, Um ElJadaiel, Kufur Rahata, Marw	دوقرا، المغير، ام الجدايل، كفر رحتا، مرو	
	Bani Kinana	Um Qais, Barashta, Hatem and Aqraba	ام قيس، برشتا، حاتم، عقربا	Existing local contractors for implementation
	Ramtha	Ramth, Turra, Thunnibeh, Emrawah, Shajarah	الرمثا، الطره، ذنيبه، عمراوه الشجره	Existing local contractors for implementation
Jerash	Qasaba	Suf, Kufur Khaal, Balial, Burma, Kushibeh	سوف، كفرخل، بليلا، برمه، خشيبه	Existing local contractors for implementation
Ajloun	Qasaba	Sekra, Wahadneh, Halwa	صخره، الوهادنه، حلاوه، عنجره	Existing local contractors for implementation. Some farmers are welling to implement the cistern and terraces by themselves. Other water resources shortage Need for supplementary irrigation
	Kufranja	Kufranja	كفرنجه	Existing local contractors for implementation. Some farmers are welling to implement the cistern and terraces by themselves. Other water resources shortage. Need for supplementary irrigation

5.2.5. Program scale and cost efficiency in NRSW

A program of 1 to 2 million euro with an integrated approach to waterharvesting can be done within the 3 years' time. The program can combine small scale infrastructural works in agriculture and in-stream structures with landscape restoration. Landscape restoration practices such as agroforestry and rangeland management have a longer turnover time to show results, however, the program can start and look for extension opportunities. Combined in a catchment approach the individual interventions will complement each other and the effects multiply. Peak flow will be reduced, base flow is increased and upstream interventions can recharge downstream interventions. The terraces (and other agricultural interventions) and rangeland rehabilitation will reduce peak flow and erosion and increase base flow. As a result the check dams, gully plugs and other interventions can capture and recharge more water and be more sustainable at same time due to reduced siltation and reduced risk of flood damage.

The total amount of interventions and impact a program can have for a certain budget depends less on the cost of the contractor than on the extent to which a program organization can mobilize participants to help themselves. To give an example with just one technology, terraces, there are a number of straightforward calculations one can make, a budget of 300.000 Euro can do:

- About 10 hectares if fully funded without co-funding or in-kind contributions by beneficiaries
- About 20 hectares if you ask participants to take on a loan and co invest in the work, covering 50% of the cost
- 50 hectares for the same price, if you cut out the contractor, train groups of local youth to do the work and ask the owners of the land to participate in the construction as well as ask people to take on a loan to pay the casual labor you might be able to cover.

The same calculations as with terraces apply with cisterns or check dams or other farm scale interventions, when the cisterns are fully funded a limited number can be implemented by a program. However, because these interventions save people so much time and money on water you could request them to take on a loan for at least 50% of the cost. If people invest themselves, they will also be sure to keep an eye on the quality and do regular maintenance.

The larger communal infrastructure requires the agreement and support of the surrounding villages If at all possible participation should be requested in kind contributions (bringing stones etc). For large structures a village level planning of the water use should be made to ensure that no conflicts will emerge once the water is harvested.

It is likely that the system of just implementing infrastructure without communal or individual investment has contributed to the limited uptake of waterharvesting in Jordan in recent years. The emphasis of a program should be in the inception phase to understand the willingness to pay, loan or participate. If people do not want to pay or participate, they will not maintain or use the infrastructure and programs produce surplus infrastructure. Even more ideal will be a situation where people who are going to be part of the program are involved already in the design phase of the program and can contribute ideas and knowledge about the possible interventions. These processes probably take too much time for the current setup.

Indication of intervention cost efficiency

Table 12 provides an indicative comparison of cost and captured volume per intervention. This is only indicative as most parameters vary per location and intervention. Additionally, benefits of some interventions are not limited to captured water, especially for in-situ measures such as terraces, swc and rangeland management provide additional benefits such as additional income, soil conservation, increased biodiversity, and carbon sequestration.

Table 12: Indicative comparison of cost and captured volume per intervention

Intervention type	Unit Area of land (m2)	Storage volume (m3)	Cost estimate (EUR)	Approx. Volume Captured m3/Year*	Life span**	Approx. Volume Captured over life span	Cost per m3 captured over lifespan	Cost of piped water (EUR)***	Cost of Water by Water Trucking per m3 (EUR)***
Stone wall terraces on steep slopes	1,000		1,200	75	50	3,750	0.32	0.6-1.5	6
SWC measures such as contour bunds in farm land on gentle slopes	1,000		400	50	15	750	0.53	0.6-1.5	6
Promotion of agroforestry and rangeland management	1,000		400	50	30	1,500	0.27	0.6-1.5	6
Instream interventions, check dams		150	1,000	150	10	1,500	0.67	0.6-1.5	6
Cisterns (65 m3)		65	1,770	65	20	1,300	1.36	0.6-1.5	6
Large storage pond or small dam		20,000	75,000	20,000	10	200,000	0.38	0.6-1.5	6

** Simple water budget calculation, based on assumption of agriculture soil with rainfall intensity about 500 mm, and assumed runoff reduction for in-situ measures*
*** Life span based on experience in Jordan. Can vary strongly depending on maintenance, especially for in-situ measures good local ownership and uptake is a precondition*
**** For comparison. Based on current water trucking prices. Piped water prices are only indicative as they depend on volume and piped water is not allowed for agriculture*

Example program on sub-catchment scale in NRSW

A program of 2 million euro in NRSW could target a sub-catchment of one of the wadis of about 20 km2. Assuming good local participation and 50% own contribution, within this catchment the following interventions could be implemented:

- 300 hectares with contour bunds, swales, grass/tree strips, etc. on gentle slopes (600.000 euro)
- 100 hectares with terraces, stone bunds, hillside runoff systems, etc. on steep slopes (600,000 euro)
- 100 cisterns of mixed sizes (80,000 euro)
- 100 gulley plugs and check dams, possibly combined with small floodwater irrigation systems (50,000 euro)
- An integrated agroforestry and rangeland management program on 250 hectares (500,000 euro). There are too many uncertain variables to make an estimation on the output of land under rehabilitation or agroforestry
- Trainings on soil and water conservation, soil management, cover crops, contour ploughing, mulching, composting, etc. (100,000 euro)

The mentioned cost estimates are a lump sum and include cost for local scoping, community mobilization, siting and design and implementation. However, in a program indirect cost for program development and management will have to be taken into account. All interventions are supposed to be locally owned, by individual farmers, groups or communities. Operation and management cost throughout the life cycle are not included, as they are expected to be carried out by the owners.

As mentioned, this is an example, the actual interventions and implementation areas will have to be determined through field work and stakeholder consultation, during the inception phase of the program. More information about this process and program development in provided in Chapter 6.

5.3. Azraq Basin

The Jordanian Azraq basin is situated in the northeastern Highlands of the country, and covers an area of about 700 km². The total area of this transboundary basin is 12,414 km² and extends from beyond the Syrian border in the north to the Saudi Arabian border in the south. Around 94% of the Azraq basin area falls within Jordan and the rest is located in Syria.

The Azraq basin mostly has an arid climate characterized by hot and dry summers and fairly wet and cold winters. The mean annual rainfall ranges from 50 mm/year in the Azraq Oasis area to 500 mm/year in Jabal Al Arab area in Syria, where flood flows originate from. Developments of water resources on the Syrian and Jordan side of the upper catchment have led to decreased flood flows. The Azraq Basin with the internationally recognized Azraq Wetland at the center is a complex and unique hydrological and ecological system. Until the early 1990s this was a huge wetland providing a source of fresh water for many purposes, including a pathway for migratory birds. Man-made and natural impacts caused severe depletion of this basin and the oasis disappeared in the early 1990s (Araggad et al. 2010).

The Azraq basin consists of three aquifer systems hydraulically connected in certain parts: the upper, middle and deeper aquifer systems. The upper aquifer is exposed in the entire basin and consists of four major water-bearing formations: B4, B5, the Basalt (Ba) and the Quaternary formation (Figure 9).

The Azraq City has a colorful history, a mixture of different ethnic groups and diverse economy and complex land ownership. The main communities are Chechen, Druze and Bedouins, which traditionally have different cultures and livelihoods. Even though Bedouins were mostly pastoralists, some of them started farming when agriculture boomed in the basin. Others preferred to work as land brokers. The Chechen and Druze are re-settled from different regions in 1902 and 1920 respectively, they settled in the city center. The Druze were mostly working in the salt industry, before it closed and then moved to agriculture. The Chechen were traditionally farmers and are mostly involved in agriculture, although it is of low productivity in the Qa'a area in the south of the city where they live.

As in other areas in Jordan the transition to groundwater-fed agriculture has led to increased investment in agriculture and expansion of agricultural land. In addition, the groundwater from this basin is the main resource for Amman's drinking water supply. It has become one of the most over pumped basins and currently contains over 400 wells (Haddad et al. 2015). As a result, groundwater levels have severely dropped and water becomes increasingly saline, leading to the almost complete disappearance of the Azraq wetland. While historically the wetland was fed by several permanent springs, currently the water level has dropped over 25 meters below ground level. This situation is causing a serious threat to the livelihoods of the communities in Azraq. The future of agriculture depends on the wetland and groundwater, and this livelihood is currently the main local economic activity.

There are two main areas of interest in the Azraq Basin: (i) The central Azraq wetland and surrounding agricultural sites near the town; and (ii) The upstream areas where flashfloods originate from.

5.3.1. The Azraq small scale farmer MAR systems

The Azraq wetland and the surrounding towns suffer from retreating groundwater (Al-Naber 2016). The farming community relies on wells from shallow groundwater which increasingly turns saline. This can be due to over abstraction but also due to lack of recharge in the wet season. A program that uses recharge measures to bring water into the aquifer to supply the existing wells can be attempted.

Despite the dry climate, precipitation events can be of high intensity causing floods from wadis to the Qa’a area, where water accumulates. As mentioned before, the Qa’a area has a saline soil and is located above a saline aquifer. Water harvesting is one of the options that the MoA in cooperation with the WAJ has introduced in order to collect flood water and prevent surface water recharge coming from wadis to reach the Qa’a and mix with the saline water. Since three dams and several infiltration systems were built in different location in Azraq, the amount of water reaching the Qa'a has decreased accordingly, but has also had a negative effect on the wetland itself, since flood water was also recharging the wetland (Al-Naber 2016). Therefore, any usage of floodwater should be carefully planned so that only water that would otherwise end up in the Qa'a is used, while the wetland is not negatively impacted.

There is still an active recharge in the Azraq area, as groundwater fluctuations due to recharge events caused by rainfall are being observed. This is a good indication for the potential of MAR. There are several options for local MAR systems that recharge the shallow groundwater surrounding the central Azraq flooding areas. These include: infiltration ponds, infiltration ditches and other surface infiltration systems. Since most surface infiltration systems have problems with siltation, another option could be a system that uses tube recharge to get water beyond the upper layers with low infiltration capacity. An example of a relative simple farmer managed system was developed by Acacia Water in the areas with brackish groundwater in Bangladesh (Figure 24). It is also applied in the Netherlands. This system uses storm water collected in a pond and infiltrates it in a shallow (confined) brackish aquifer. However, it is uncertain if this is system is technically feasible and economically more efficient than other options within the Azraq area, because of the high cost in Jordan for well drilling and construction.

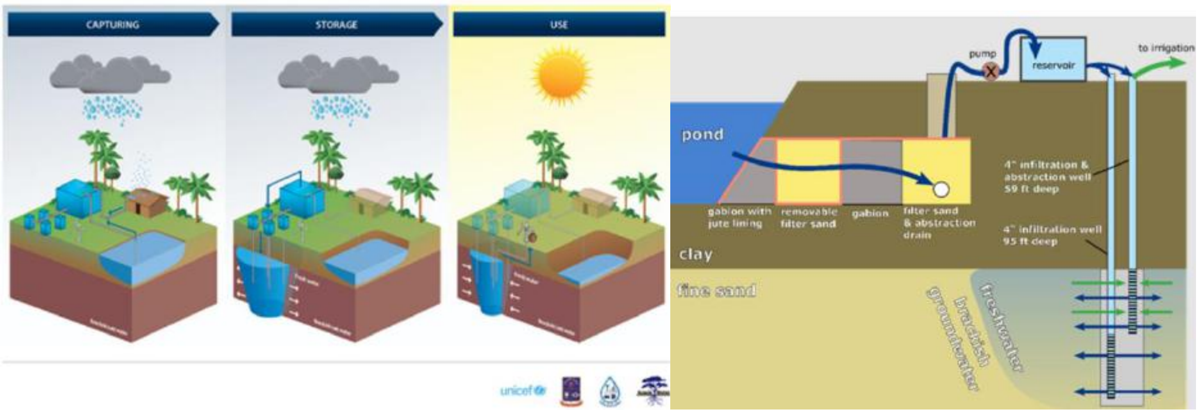


Figure 24: Example of a small-scale MAR system implemented by Acacia Water in Bangladesh (source: Acacia Water, 2015)

Besides the injection wells and storage ponds this area could also be suitable for nature based solutions or other more location specific water harvesting solutions. For instance, giant recharge wells backfilled with stones and topped up with sand that are adapted to slow peak flows will offer opportunities for natural recharge to happen without having to do siltation every year. Water spreading weirs in sandy areas can enlarge the recharge area. If water flows are present within the sediment of large streams, large subsurface dams using local clay can buffer large volumes and increase recharge. Because these are solutions that are so much dependent on the local natural circumstances and hydro(geo)logy an expert organization needs to be involved to see if this can be done or not.

Proposed approach: The proposed project is a balancing act in a zero-sum game. Water is so scarce that modifications could also create shortages. Therefore this project has no proposed interventions yet but starts with an assessment phase which then needs to be reviewed. The conclusion can be that there are no opportunities to modify and recharge the flow due to damages it might do downstream.

Such an assignment can be done for roughly 100,000 Euro. It will require expert hydrogeologists in combination with agricultural experts and development specialists who understand water management. Local fieldwork will be required, both social and hydrological. If drilling is also needed the costs will probably double. All this has to be conducted in the first phase of the planned program, before actual implementation of the interventions. The types of assessments that should be carried out are listed below.

- Stakeholder assessment is used to gather information such as what farmers are there, what exactly is their experience with this water, which are the other water users (for example pastoralist groups use the floodwater), etc.
- A hydrological assessment of the whole catchment and aquifer system. This assessment will need to show where the water is stored and where potential recharge areas exist.
- An environmental assessment of possible downstream or upstream areas with ecological functions

Only after the interpretation of these assessments can an organization propose a number of sites for MAR. There are opportunities to recharge water for local farmers, but this program should not take place if:

1. Water used to recharge the aquifer was already used by other users.

The water in this part of the Azraq Basin serves many purposes. First it floods large parts of land which are then used for seasonal grazing. Under no condition can aquifer recharge for relatively low profitability in farming be done at the expense of more sustainable and profitable livestock keeping. The second purpose is to flood the wetlands near the town of Azraq. This wetland has a strong ecological function which should not be undermined by upstream water harvesting.

2. The water used by farmers can be used by many instead of a few.

The study should also make it evident who is using this water for agriculture and how much water is used (this is where the WAPOR system of IHE might come in handy). Ideally the water recharge should benefit many and not only a few farmers. This means the program might have to mobilize all the farmers in the area into a water user group that understands that if someone uses large quantities of water, the other users will only have access to fewer resources.

Outcome of a proposed program:

- Water recharged for small scale irrigation, preferably by a farmer led irrigation program
- The water recharged was water that would otherwise have evaporated or turned saline
- In the catchment and aquifer of the intervention all users and uses are known and not deprived

Cost Estimate of infiltration pond and well

An infiltration well needs to have a storage reservoir to buffer the water from which the silt can sink and the water can be injected. Depending on the nature of soil and mobilization distance, the Cost per cubic meter will vary between 3 to 5 Euros. With a normal life expectation of 5 years.

The estimated cost of drilling and installing of a recharge well and abstraction well with a depth between 50 to 100 m is 60,000 to 80,000 Euro (The required drilling depth in Azraq is likely to be less).

Procurement Plan for Construction

In case the procurement of ponds needs to be realized via an agency, it is worth noting that contractors are available in all Jordanian governorates. Contractors classified as grade 5 or more (Excavations and/or road construction) according to the classification of the Ministry of Public Works and Housing are eligible to do such work. Therefore, an open competition for grade 6 contractors could be a very good procurement method.

In this case a typical document that comprise of the following sections could be typically used: Invitation to bidders, General Conditions (possibly also FIDIC short form (Green Book)), Special Conditions, Drawings, Bid Data sheet, BoQ, Agreement forms, Others, if needed.

As a general practice it is preferable to bid in Arabic language to get more and maybe cheaper offers as some eligible contractors sometime have difficulties in translation.

Usually, 90 working days are sufficient for the construction of a 100,000 m^3 storage pond.

Example of a program in the Azraq flooding area

Due to the limited time span of the program, and the piloting nature of the interventions, it is recommended to allocate a smaller budget. A program of 0.5 million euro could target a group of farmers around the Azraq wetland area and combine several technologies. For example:

- Pre-assessment on hydrology, environmental impact and technology feasibility (100,000 euro)
- 2 pilot MAR systems recharging the well area, technology to be determined (200,000 euro)
- 2 interventions for enhancement of natural recharge by floodwater diversion or subsurface dams (150,000 euro)

Since these interventions focus on recharging the existing aquifer, which is already utilized by many wells with water supply systems, the program can target enhancing existing abstractions rather than creating new systems.

5.3.2. Saline agriculture

To provide a future to the agriculture in The Azraq wetland area, and the many other areas with naturally high salinity and/or increasing salinity of the groundwater, saline agriculture could be an interesting option to explore. This could be combined with a MAR project or other interventions and would build on earlier projects of the Dutch water sector and EKN-Amman.

5.3.3. The revival of ancient water spreading techniques on the downslope of Mt. Jabal

The downslope of Mt. Jabal Al ‘Arab draining into the Azraq basin from Syria is the area where the oldest dam in the world was found. It is also the area from which dramatic flooding come flowing down and create destruction. Along the Syrian border at the food slopes of Mt. Jabal Al ‘Arab is an area with a more feasible climate for agriculture, where small scale agriculture is practiced and many small towns/villages are present. This area could serve as a pilot site to investigate whether floodwater spreading weirs or impoundments of floodwater can generate more water for agriculture. This could be combined with tree used as windbreaks and other SWC practices such as contour bunds, tied-ridges, swales, grass-strips, contour ploughing. The use of floodwater should be done in a way that reduces problematic peak flows, but does not prevent the downstream users to access the water that they need. Floodwater spreading weirs or peak flow diversion weirs would fit this environment and could be used for spate irrigation, or feed into channeled irrigation systems.

Proposed approach: There appear to be very little income generating activities in the area and it is likely to be less developed than the other selected catchment. A program could showcase how to work with local users to create agriculture from floodwater. The program approach could be through site selection and community mobilization whereby the role of the community will be to get organized and select a program committee to collaborate with the implementing team. The program committee should be able to exercise authority over the grazing activities of the area and be part of closing off certain sites for grazing. If the people who use the area have no ownership relation to the land or are unable to take ownership of the process because they have no interest in the possible income that could be generated, the project should not take place.

Water-spreading weirs, spate irrigation systems or systems that drain into swales cannot be designed from a desk and need to be carefully set up with an expert organization, the local community and a sound understanding of the water flows. In this area cash crop production could be challenging, but there is potential for fodder making and crops for local consumption.

To the south of the basin, agriculture is replaced by sparse rangeland. Currently it seems that these areas are overgrazed and the soil is left bare. Rangeland management techniques such as controlled intensive grazing and area closures can help to restore some of the rangelands. A temporary break in grazing can help to increase biomass, which can be used as fodder for the local livestock.

There is only one way forward and that is by working with the people that do grazing and make them part of the solution. If pastoralist groups cannot be persuaded to refrain from grazing then the project will only last as long as there is finance to pay for security of the area closure. If there are opportunities to do this in collaboration with pastoralist groups the way forward can be to fence off a large track of land, jumpstart the progress by the valarani plough or manual physical swc interventions and plant preferred grass seeds and trees.

It cannot be expected that this program will provide a solid business case (unless a specific agroforestry/silvopasture system is designed with committed farmers and carefully managed). The overall benefit will be environmental, more biomass, more recharge, less erosion. Another other benefit will be that if it works the site can become a place to visit and duplicate. If sound collaboration can be set up with pastoralist groups the management should be transferred to them as soon as possible.

Outcome of a proposed rangeland management program: The easiest and cheapest possible actions are explored to reduce overgrazing. Areas start to produce more biomass which is then put under rangeland management systems that reduce the erosion and increase infiltration and groundwater recharge. Increased income from livestock and productive trees and other products from rangeland areas.

Example of a program in the on the downslope of Mt. Jabal

In costing this intervention the limiting factor is time, since the type of interventions are less straight forward than in the NRSW Basin. Also the capacity of the community to contribute and adopt the interventions is uncertain, particularly if they are not the owners of the land or have no intention to work on agriculture. If the program could take 6 years the implementing team could build up experience with the local community and different interventions and replicate the best methods and techniques. This would increase cost efficiency and sustainability of the interventions and a larger budget could be spent in an effective way. Since the program time be limited to 3 years a budget of 0.5 million could potentially cover 2 villages, or a 5 to 10 km2 headwater catchment with 2 to 4 larger instream interventions and several agricultural program sites as well as rangeland management interventions (also see the example program in NRSW Basin). The difficulty will be in understanding what people need, how to help them with tailor made solutions for agricultural water and to show the possibilities and opportunities in such a way that people can pick up the benefits.

6. Formulating a RWH program in the Focus Basins

The previous Chapter described the specific program components within the focus Basins and specific target areas. This Chapter provides information on how to formulate a RWH program. It looks at the main stakeholders to be considered, potential implementing partners, the main components of such program, sustainability considerations and roles and responsibilities of different organizations that could be involved in implementation.

6.1. Stakeholders to be considered for the program implementation

6.1.1. National governmental agencies

The Ministry of Water and Irrigation (MWI)

The MWI is responsible for developing water policy and for water master planning, as well as administrative restructuring of the water sector. The MWI is the official body responsible for the overall water supply and wastewater system, planning and management, the formulation of national water strategies and policies, research and development, information systems and procurement of financial resources. The MWI is responsible for coordination among the MWI, WAJ, and JVA. Though both WAJ and JVA predate the MWI, both are affiliated with the Ministry, and their quasi-separate status represents an attempt by the government to separate functions of water service delivery from those of regulation and oversight.

The Water Authority of Jordan (WAJ)

The WAJ is an autonomous corporate body, with financial and administrative independence but linked to the MWI. The government scrutinizes it through the Central Audit Bureau and the Bureau of Supervision and Inspection. WAJ is responsible for municipal water supply and wastewater services as well as for water resources planning and monitoring, construction, operations, and maintenance. The organizational structure of the Authority is highly centralized. The utilities in each governorate are responsible for operating and maintaining the water and wastewater systems, dealing with subscribers' issues, and project supervision. Most of them enjoy some autonomy, though key tasks are managed centrally, including financial and human resource affairs, capital investment, water quality monitoring, and planning. The Project Management Unit of WAJ is managing the transition period with support from an international aid agency.

The Jordan Valley Authority (JVA)

The area of JVA's responsibility extends from the Yarmouk River in the North to the Red Sea in the South. The Eastern extension of the area is limited by the 300 m contour line north of the Dead Sea and the 500 m contour line south of the Dead Sea. The Jordan Valley Authority is responsible for the social and economic development of the Jordan River Valley, including the development, utilization, protection and conservation of water resources. The King Abdullah Canal serves as the backbone of the JVA water distribution system north of the Dead Sea and is used to irrigate farm units. Beside this, JVA is responsible for dams and hafirs only in other parts of the country.

Ministry of Agriculture (MoA)

The MoA is responsible for a wide variety of tasks, ranging from managing public lands to regulating hunting to protecting soil resources. The ministry's stated goals with respect to water are to maximize production of food and agricultural outputs, achieve sustainable use of natural agricultural resources without harming the environment, and improve irrigation water use efficiency at the farm level. The MoA is also invested in maximizing productivity, in which water plays a large role. The MoA researches efficient crop rotation patterns and varieties of crops which are most water-efficient, as well as other issues contributing to water productivity. They will be an important stakeholder and partner in the implementation of RWH programs with farmers.

Ministry of Health

The Ministry of Health provides a similarly broad array of services. Its water responsibilities are to monitor the quality of drinking water resources and inspect any potential source of pollutants. The Ministry regulates all potable water regardless of its source. It has overall responsibility for examining and permitting any imported or produced potable water including the processes of treatment, transmission, distribution, and storage of potable water to ensure its quality.

Ministry of Environment
The Ministry of the Environment is the newest ministry in the government. Its mandate is to maintain and improve the quality of the Jordanian environment by sustaining and conserving Jordan's environmental resources and contributing to sustainable development. Its connection to water policy is less developed, but it has dealt with several cases of poor water quality and over-use of water negatively effecting the environment.

National Agricultural Research Center (NARC)
This center is mandated to implement agricultural scientific research and technology transfer at the national level.

Royal Hashemite Court
The Royal Hashemite Court, part of the executive branch, helps create and fund water policies.

Universities
At present, there are 11 governmental and 20 private universities in Jordan Universities are responsible for a large portion of government funded research on water issues. Furthermore, faculty members of universities serve on governmental committees such as the Royal Water Committee. Finally, universities train the next generation of water experts that will serve in government ministries, firms, and NGOs, and so exert significant indirect influence on those institutions.

Municipalities
IWMI stressed that to implement more demand driven programs the collaboration with the municipalities is critical. More than the national agencies, the municipalities will know better what the local demand and capacities are and can really facilitate the implementation of the program. Although we tried to enter in contact with VNG International, due to holiday period, it was not possible to get an interviewee from the relevant person. While VNG International is not a water organization, they do take on water related assignments and can be crucial to facilitate dialogue with the local governments.

6.1.2. The NGO sector

Water User Associations
The government hopes to gradually reduce its role in water distribution and replace the current system with Participatory Irrigation Management, where farmers take on the responsibility of managing water delivery to their farms. If the system is successful in pilot areas it will be extended to all irrigation systems (Water Authority of Jordan, 2008). Currently, some farmers in the Jordan Valley participate in the management of Jordan's irrigation systems through Water User Associations or Farmers Committees. These groups have been helpful in locating and reporting system leakages, managing irrigation lines, and representing farmers to the Jordan Valley Authority. Moreover, these groups are increasing the level of trust between farmers and the Jordan Valley Authority.

ACTED
This organization has experience with implementation of water infrastructure mainly in and around the refugee camps. Some of their work can be considered innovative and of interest to the program. ACTED developed a project that proposed to connect RWH ponds to runoff from refugee camps. As an NGO, their work is situated between humanitarian aid and development work, which might make them less experienced with long-term infrastructural water solutions requiring environmental, social and financial sustainability. For instance, the proposed innovation would make a lot of sense socially and environmentally, but it would stop with the end of the program.

INWRDAM

INWRDAM (INTER-ISLAMIC NETWORK ON WATER RESOURCES DEVELOPMENT AND MANAGEMENT) focuses on policy and applied research and conducts dialogues through which it seeks to advance ideas and concepts to inform policy making and program formulation processes towards shaping the contours of water resources development and management. The experience of INWRDAM is in the field of development and management of water resources. In pursuit of this, it seeks to generate ideas and policy directions through intensive stakeholder dialogue, studies and research on a continuing basis. INWRDAM has been involved in many projects related to rainwater harvesting in the badia region and rural areas. It has built strong relationships with local farmers and local governments toward having a strong partnership for managing the harvested water in hafeirs in the badia region.

Mercy corps

Mercy Corps is a global non-governmental, humanitarian aid organization operating in transitional contexts that have undergone, or have been undergoing, various forms of economic, environmental, social and political instabilities. Mercy corp seek improvements in livelihoods, and deliver durable development to their communities. Mercy Corps has been operative in Jordan since 2003 are active in Jordan's water sector. Key efforts include making infrastructure investments throughout northern Jordan. Reservoir rehabilitations and expanding water supply for both the Jordanian host communities and the Syrian refugees. In addition, through the expanded revolving loans program, loans managed by partner CBOs are disbursed for water-saving investments at the Jordanian household level, water catchments and greywater treatment systems in order to relieve pressure on municipal water networks. Finally, Mercy Corp has established a community grants program to fund water-saving investments in over-burdened public institutions used by both Jordanians and Syrians. Examples include schools and medical centres. Like the revolving loans program, the grants has expanded the water supply and modelled technology and raised awareness of conservation in local communities. Based on interviews and the consultants' experience, Mercy Corps might not have the full technical know-how to design and implement a catchment based RWH program themselves.

6.1.3. Knowledge partners

IWMI

Interviews with IWMI took place with Nafn Amdar who is currently also enrolled as PhD at IHE Delft. IWMI implemented several water-related programs that took a more integrated and holistic approach than many of the other examples seen. For instance, the program on cisterns was not only focused on building the infrastructure. It also included loan schemes, training and employment IWMI would also be able to work more at catchment level with the right knowledge partners.

ICARDA

Particularly through their Badia Research Site (BRS), ICARDA delivered a lot of knowledge on the benefits of different water technologies. Th organization would be a relevant knowledge partner since the programs they developed were designed to show the technical potential of RWH. During the interview, it became clear that ICARDA had in mind the cost benefit analysis of RWH. In this way, they can render RWH a viable alternative for agricultural production of, for instance, fodder. Their interventions on the BRS are research oriented with a strong technical and physical focus. They have challenges with the socioeconomic components on their test plots, leading to challenges with sustainability of some of the interventions. The question they are currently investigating is whether technical and machine input-based solutions are the key to restoring degraded rangelands. A RWH program targeting a large community would work if ICARDA can be linked to a strong local NGO, specialized in understanding rangeland management, community demand, willingness to invest etc.

IHE Delft

IHE is currently working on several programs taking place in Jordan, particularly on the topic of water governance. Within the broader organization there are specialist people working on RWH and MAR at catchment level. It is important to note that IHE is a knowledge institute that should be linked to an organization implementing and working at municipal or village level on the local demand and participation. Also the practical design and implementation of RWH interventions at catchment scale would need collaboration with an organization more specialized in that.

Wageningen University & Research (WUR)
WUR programs focused farming and to some extent on high capital investment in farming looking for optimal water use in a water scarce environment, both water quality and quantity. This approach is valid in its own right and has its place in the MACS. Based on our research and interviews with a variety of different stakeholders (including the interviewee from WUR), we understand that the scaling options of this approach are not ideal and the agricultural economy and policy environment works against water saving opportunities. We see more opportunities for catchment approaches to water harvesting, household solutions and rainfed agriculture in a program that is to highlight the opportunities for waterharvesting.

6.1.4. Companies

A variety of different companies work with international lenders, NGOs, and the Jordanian government to help plan, design, and implement major infrastructure developments in the country. Consulting companies consist of both Jordanian companies and international companies, but international companies normally partner with Jordanian ones on projects.

Acacia Water
Acacia Water has done some projects with RWH and especially MAR in the region. There main expertise is hydrogeology, but they have a strong vision for sustainable development of the water sector and are able to deal with integrated water resource development projects. They are part of the 3R consortium and are experienced with RWH in other parts of the World, from scientific research to hands on implementation. Acacia Water is positive about a RWH program in Jordan, and they think there is a good possibility to showcase what is possible with RWH within the agricultural sector starting with some practical examples. However, they stressed that it is a complex setting and that there should be room for an in-between phase between scoping study and full proposal, to allow for project design. Within the project there should be space for the process and flexibility to adapt to the local context. Acacia Water indicated that they generally prefer to be a partner in the programs they are involved in, instead of being a sub-contractor. They often bring in the practical know-how but also the overview and integration. As sub-contractor their influence on the process is often limited, which complicates the activities and the sustainability of the outputs in their view.

Nectaerra
Nectaerra has done some work in Jordan with saline agriculture, and they are currently looking at options to be involved in regenerative farming. They are actively working on projects in Iraq and Egypt. These projects aim at training and designing sustainable commercial farming systems (regenerative agriculture). It includes alley cropping systems with trees for biomass and windbreaks and RWH. In Egypt, they also work on several projects on saline farming, agroforestry, and RWH for commercial farming systems. There main expertise is hydrogeology, but Nectaerra has a high interest and vision for regenerative agriculture and smart water use in the dry areas. They could provide technical know-how as well as coordination of the design and implementation process of interventions. Therefore, Nectaerra would be a good partner if Regenerative Agriculture or agroforestry would become an important part of the program.

MetaMeta
Although currently, MetaMeta has no programs in Jordan, this Dutch organization is specialized in innovative RWH solutions. Like RAIN and Acacia Water they are part of the 3R consortium and can play a role in the development and implementation of appropriate solutions. They have a lot of practical experience in RWH, catchment approaches and agriculture. Also there approaches and activities are characterized by a high level of environmental awareness and stakeholder participation.

Regenerative agricultural farms and organizations

Although some of these farms sometimes appear like NGOs and often do not make much profit, they might be private sector entities to consider. Regenerative agricultural farms like Regamena, Carob Farm and Greening The Desert-Jordan are sites of RWH innovation where flood water harvesting or swales and application of organic manure are aimed at doing what RWH is supposed to do: keep water in the system and make optimal use of what you have. From these farms and the experience there follows the capacity to develop RWH structures. For instance, during the interviews, it appears that these three regenerative farms aim at implementing small scale RWH structures based on real demand with locally available resources. The Greening The Desert project has a demonstration site and education center on permaculture in Jordan. They also have a high-level of expertise on RWH integrated in farming systems.

A relatively large commercial and organic farm with a strong regenerative vision is Taybeh Organic Farm. It is located in Wadi Rajeb within the North Rift Side Wadis Basin. They are a good example of the potential of commercial regenerative farming, with many RWH solutions practiced, including water diversion from the Wadi. Another interesting private sector organization of Dutch origin is Groasis. In addition to their technical tree planting solutions (the plant cocoons) for dry areas, they are experienced in the sector of regreening and tree planting in Jordan. Also Menaqua uses cocoon technology; they offer high impact solutions for water scarcity, environmental and economic issues. Lately they signed an agreement with MoA; Menaqua supports the process of rehabilitation of the forest area and degraded land in Jordan though smart and sustainable tree-planting initiatives, aiming to assist in the restoration and rehabilitation of degraded land in Al-Haysha forest area by planting 1200 forest trees using the cocoon technology. Another expert worth involving in any regenerative program with a RWH component is Thomas Fernley Pearson, ecologist, permaculture, and RWH specialist.

6.1.5. Local organizations

The consultant performed some interviews with possible Jordanian implementing partners that maybe capable to implement within consortiums, all of them show their high interest and capability to perform such projects. Table 13 provides an overview.

Table 13: Local organisations

Partner Name	Core Business	Description	Consultant Initial Appraisal
Engicon **http://www.engicon.com/**	Consultant and Water Projects Operator	Classified as class A Engineering Consultant, with long experience in water sector, also Enicon owned a daughter company specialized in the field of operation and maintenance of water utility.	Engineering: Excellent and Can be done by the organization Procurement: Can be done by the organization Social Part: Organization will need to hire expert or sub-contract Capacity building: Can be done by organization
ECO Consult	Consultant	Consultancy firm Highly committed to sustainable development with environmental focus and experience in the water and agriculture sector. This can be a feasible partner when it comes to environmental scoping.	Engineering: May need to hire experts or firm Procurement: Can be done by the organization Social Part: Organization is professional in social part Capacity building: Can be done by organization
JOHUD Jordanian Hashimite Fund for Human Development	NGO https://www.johud.org.jo/	One of the biggest local NGO with long experience in development	Engineering: May need to hire experts or firm Procurement: Can be done by the organization Social Part: Organization is professional in social part Capacity building: Can be done by organization
Future Pioneers **http://future-pioneers.org/**	NGO	One of the biggest and active local NGO with long experience in development	Engineering: have enough capacities Procurement: Can be done by the organization Social Part: Organization is professional in social part Capacity building: Can be done by organization
Princess Alia Foundation	NGO	One of the NGOs working in natural conservation	Engineering: May need to subcontract Procurement: Can be done by the organization

http://princessalia foundation.org/	Social Part: Most probably that organization can cover the social part Capacity building: Can be done by organization

6.2. Recommendations for the main components of the RWH Program

Combined with the different proposed programs and sites we believe that the following aspects of RWH need particular attention in the ToR and grantmaking process.

6.2.1. Inception Phase

Throughout the study it became clear that working in the water sector in Jordan is a complex matter. Much has been done by many different organizations, often based on international funds, but much has failed or never went beyond pilot scale. Awareness and motivation to change are issues on all levels and although many good policies are in place, implementation and enforcement are often a challenge, as acknowledged in the different sectoral reports. Therefore, starting a RWH program is not a straight-forward matter of selecting technologies and locations and implementing them. To be able to make a difference, this program will have to find the right local entry point and the right niche to operate in. On a conceptual level this has been covered in this study by strategic selection of specific focus areas and identifying most promising intervention strategies and technologies (as described in Chapter 5). However, conceptual feasibility and hotspot identification is not the same as selecting an actual implementation site. To get to an implementation site of a specific intervention, there is local siting to be done, for example: field evaluation, local stakeholder interviews, topographic surveys, geophysical surveys, test pits, assess.1ing environmental impact, establishing appropriate ownership and management systems, etc. This is something that has to be done for each intervention during the inception phase, before actual implementation.

A major component for sustainability will be finding the right local project owners (communities, farmers, households, businesses, etc.) for each intervention. The program and eventually the RWH systems will have to be adapted to their needs, capacity, and preferences. In addition, the actual RWH interventions will have to be selected and designed based on a thorough assessment of the local environment. For example, the local soil type and availability of materials, should change the design of a terrace, check dam or irrigation method. Local traditions in construction should be followed as much as possible to increase ownership and potential for upscaling.

The first year would be research and inception whereby researchers visit many different sites to understand the needs of farmers and their reasons to do terracing or not to do it. Depending on the willingness to invest money and labor the project can set up loan and participation systems whereby farmers can get a loan to build terraces and cisterns. Also, the feasibility of rangeland management and agroforestry requires a lot of time and patience. If landownership arrangements and user rights are not treated with due caution the intervention will not be sustainable. It is essential to involve all the users of the land (crop farmers, pastoralists, etc. etc.) and make sure all benefit or at least see the benefit. Enclosures and reforestation in the long run creates more biomass, which will also increase the potential for grazing. Degraded lands regenerated through land management practices, increased production, increased resilience, reduced dependency on groundwater. The agricultural and forested landscape would slow down and/or reduce the runoff, recharge aquifers and increase springs flow.

The second and third year would be implementation of the proposed program and phasing out or working on extension.

Implementing such a program will require a strong consortium of implementing partners, which have to build a working relation together and with local stakeholders. Therefore, we strongly recommend starting this program with an Inception Phase that allows implementing partners to do the local research required to meet the above-described criteria, and fine-tune their proposal for implementation based on that. A high level of flexibility and adapting to ongoing insights and local context will be essential throughout the program.

Developing a highly detailed ToR with specific technical requirements at this stage can hamper the process of adapting the interventions to the local context and to new insights during the process. Much of the required knowledge and expertise for this process will be brought-in by the Implementing Partners, including the Dutch organizations specialized in RWH. They should therefore get the opportunity to provide input on the design of the program. A separate Inception Phase during which the detailed proposal can be developed/refined could enable the contractors to co-design the program and provide the required flexibility in the process. The ToR for the program, including inception phase, could focus on the main objectives and the framework, leaving the specific outputs to be determined during the Inception Phase, with room for adjustments during the implementation process.

6.2.2. Technical implementation

Implementation of basic structure such as ponds, terraces and cisterns can easily be done by engineers from the ministry or some NGOs. From the interviews, it appeared that ICARDA and some of the permaculture farmers as well as government engineers were also capable of building more innovative RWH structures (such as the Marab, the swales, floodwater distribution). However, it was also found that these organizations tend to focus primarily on research and technology and less on local demand and scaling through the participants.

6.2.3. Hydrological modelling and geohydrology

During this scoping assignment, it was observed that detailed data on groundwater levels, well abstraction, wellfields, surface water reservoirs and surface water flows are present within Jordan. Only part of this data could be collected as getting access to most of this data proved difficult within the timeframe of this study. Within the government and several expert organizations there is ample knowledge available. However, during the research, it became apparent that there is a large gap between theory and practice. Therefore, while the catchments are clearly delineated and thoroughly understood very limited information was retrieved on organizations working on:

- RWH at catchment level: working from an upstream/ downstream perspective where excess floodwater is used for irrigation or upstream distribution to keep water in the upstream environment and reduce flooding downstream.
- Water recharge for shallow and deep aquifers while taking into account the water balance of the catchment.

The local water system should be understood before designing a RWH program. Therefore, the program should start with a hydrological analysis and land use analysis. A simple hydrological catchment model could help understand the water system and to identify the impact of RWH interventions on the water system, such as: runoff, infiltration, soil moisture, recharge, streamflow, and downstream water systems and users. This information should also be used for the design of the water harvesting interventions within the program, especially those harvesting runoff water from larger catchments.

In the process of getting RWH on the agenda, raising awareness of the need for alternatives, and showcasing the potential of RWH, it is important to be able show the facts. The hydrological model could help to provide these facts and make a case for RWH.

In this study a first general RWH suitability map was made on National level. A detailed map could be made for the target areas. Accurate and high-resolution data sets are available and can be refined through remote sensing and field work where needed. Required datasets include: soil, land cover and use, slope, hydrology and hydrogeology, stream sediment characteristics, existing water sources, rainfall runoff, etc. This data could be used to develop a high resolution RWH suitability map, which can be used on local level for planning purposes. This could help with the planning and implementation of the program itself, but can also function as a tool for upscaling the interventions by other organizations and individual land owners.

6.2.4. Water governance

Several organizations were well equipped to study and advise on water governance. All organizations concluded that the cause of and the solution to the water shortages in Jordan were clear. As said in the introduction, RWH cannot play a role in repairing the water shortages caused by irrigated agriculture because the volumes of water needed are too large. However, implementing water harvesting initiatives can alleviate water shortage problems in many needy areas. The scaling up of the local water harvesting schemes and the replication of them in appropriate areas will resolve many water scarcity problems in the country. The issue here is not the harvesting of large quantities of water, rather it is the capture of quantities that will help cater for the needs of a certain household, community, farmer, etc. The main challenge here might be the creation of a culture that adopts water harvesting as an everyday practice by all to fulfill the saying that "in Jordan, every drop counts".

6.2.5. Policy dialogue and enabling environment for scaling up

The predicament of the water resources situation in Jordan will not have escaped anyone's attention in policy circles. The main question in the policy dialogue and lobby work in the enabling environment will be how sustainable water harvesting solutions can be promoted as an alternative. Awareness of the problems and the alternatives is an important objective. One approach, is by pointing out how irrigated agriculture consumes high volumes of non-renewable groundwater resources. Such a program is already in line with the Delft IHE WAPOR analysis where water use can be measured. If quantifying the overconsumption and pointing to individual users will reduce the abstraction of water, then that will be of great help. Higher prices on water abstraction will also help in making the case for water harvesting.

Policies could be formed to make water users to be more aware of the water situation. Stricter enforcement of groundwater protection regulations and higher prices would be a good first step. Furthermore, land owners could be stimulated to take control of their land and implement RWH interventions and plant trees in several ways. There are examples of different policies and approaches to restore landscapes in such way throughout the world. Some are more top-down such as in China, Ethiopia and Rwanda, others are more focussed on changed awareness on grassroots level, for example the FMNR strategy in the Sahel region or widespread adaptation of regenerative agriculture by farmers in South America. Probably a combination of approaches is needed in Jordan.

Generally, policies and strategies for sustainable water use and alternatives to groundwater are in place. However, the enforcement of regulations and practical adoption of these strategies on the ground by water users and land owners is where the challenge seems to be. This is where the program could make a difference also when it comes to policy dialogue. Programs on waterharvesting can be instrumental in guiding policies in new directions. Experience in other countries has shown that governments can struggle with the complications of Catchment based approaches. Demonstration sites can give content for such approaches and inspire scaling. It would be preferable if the demonstration works at a 'real' catchment scale, so for instance one ephemeral river from upstream to downstream. Many catchment programs have the tendency to say that a certain technology is a catchment technology (such as a sand dam or a floodwater spreading weir). To demonstrate upstream downstream effects on catchment level one or a few of such interventions will not yet be enough. Additionally, showing the business case and other benefits at the level of the user or farm, can be a good starting point for policy dialogue and for convincing other users in order to scale-up the practices.

6.2.6. Capacity building for beneficiaries

As also stated above, in waterharvesting, IWRM and catchment approaches to water resources, capacity development as well as lobby and advocacy has less impact when practical examples are not present. For instance, the ICARDA site with the different waterharvesting technologies will have helped a lot in the recognition of technical opportunities for waterharvesting. Likewise, for farmers, there is seldom a better way than ‘seeing is believing’. As was also stated in chapter 5, capacity development is usually best done by the users themselves. So if a program on terracing for instance, engages farmers as champions who can promote the approach to other farmers, then that will work better than bringing in program staff from the capital to explain. NCAR has already implemented many sessions of the Farmer Field Schools (FFS) with the aim of strengthening farmer’s skills in areas water resources management and soil fertility, etc. These FFS can be an excellent capacity building tool to promote water harvesting among farmers. The way these FFS work is to bring an experienced FFS master trainer from NCAR or other collaborative partners to work with local farmers through a season-long approach adapted to local contexts.

Other capacity building approaches can be achieved through projects implementation by international NGOs such as IUCN and INWRDM. These have been specifically successful in the north east badia were municipalities, farmers, and livestock farmers were trained on many aspects of water harvesting techniques and management for use.

6.2.7. Participatory approaches and scaling

During the interviews with the different organizations, it became apparent that a top-down approach characterized the Jordanian water sector. With large projects like dams, wellfields and water utilities companies, there are few viable alternatives to this top-down approach. While we believe that RWH technologies at catchment level also need a top-down approach, the implementation of structures used by farmers or pastoralists should really look at the users first and preferably engage with them so that they are made part of the program. Programs focused on the best technical solutions will end as pearls in the desert, beautiful in itself but seen by few and not adopted by anyone. The proposed programs on cisterns, terraces and other local infrastructure offers opportunities to work from grassroots up. This will also provide scaling options. It is however our experience that in counties where a top-down approach has been used for a long time, setting up a participatory system will require patience a determination from the implementing partner.

The biggest mistake the program can make is just implementing infrastructure as give-away for a few local participants. This will create jealousy and it will also spoil the field for other interventions. People will just prefer to wait for the free option to come along. It is better take two years to get it right than to rush towards implementation. This will be crucial for future up-scaling of interventions

6.2.8. Cash for Work (CfW) Programs in RWH interventions in Jordan

Interest in cash-for-work (CfW) programs has increased immensely over recent years in Jordan. The total budget of these CfW programs over the last five years has been about EUR 300 million and they have employed at least 70,000 workers during this time – typically for a period of 40-90 working days – in the rehabilitation and cleaning of infrastructure, the collection and recycling of waste, the rehabilitation of eco-systems, the creation of municipal parks, and the intensification of agriculture.

These programs have proven to be a social transfer scheme and an instrument of passive labour market policies – they contribute to multidimensional poverty reduction in multiple ways. Analysis has shown the CfW programs are able to deliver (i) wage employment (that is, work, income and social protection) to vulnerable people; (ii) strongly needed infrastructure such as roads, sanitation, irrigation systems or others, as this is where the labour force is put to use; and sometimes even (iii) skills development among participants if explicitly included in the setting up of the programs (German Development institute, 2020).

In the case of rainwater harvesting the opportunities are great. These can range from cash for digging and constructing wells to building terraces to even levelling the ground for the purpose of collecting rainwater and channelling it to groundwater recharge sites.

One such program was the highlands development project since 1964 which was under the umbrella of the Ministry of agriculture in cooperation with the World food program and later adopted by FAO. The project was designed to target farms in the highland with slope between 8 – 35 % in order to improve the livelihood of farmers in the highlands of Jordan. One outcome of the program was minimizing sediment transport to dams through controlling erosion in runoff. The project included building huge amounts of terraces in steep slope lands and also water harvesting wells in farms. Funding to farmers interventions was usually through giving cash or even some goods that can be sold in the market to get cash in return. The working experience and the new skills learnt through this project were huge and was replicated so many times to create a huge impact in the targeted basins.

Another project that deals with Rainwater Harvesting is that of the German Federal Ministry for Economic Cooperation and Development (BMZ), Cash for Work: Protection of Water Dams in Jordan, which spans from 2017 to 2022 implemented in cooperation with the Jordan Valley Authority. The objective of the project is to implement Labour-intensive measures to maintain the storage capacity of the reservoirs and reduce erosion in the catchment areas of the dams. At the same time, the living conditions of needy Jordanian families and displaced people are improved through temporary employment opportunities.

The Approach is to firstly implement field of action that includes measures to protect against soil erosion such as reforestation and the construction of check dams made out of gabion baskets, terraces, gabion walls, rip rap, and dry stone walls. By creating temporary jobs as part of this field of activity, the project is contributing to improving the household income of Jordanian families and displaced Syrians. Both the reforestation of the riparian areas and the construction of anti-erosion infrastructure in the dams' catchment areas will reduce erosion and the sediments formed in reservoirs during precipitation. This serves to maintain the storage capacity of the reservoirs and ensures that agriculture in the Jordan Valley remains irrigated in the medium and long term. The reservoirs also indirectly supply drinking water for the population. Through the life time of the project, 7,000 people will be employed as cash workers for an average of at least 40 days. Women are mainly employed in tree nurseries and providing supplies for the cash workers on the project sites. The project is also committed to delivering medium and long-term employment prospects, mainly by providing Post Employment Services (PES). These include, for example, further training, job formalization, subsidies for self-employment and advisory services (Cash for Work: Protection of Water Dams in Jordan (giz.de), accessed 18 September, 2021)

Such type of projects can be seen as a good model for the water harvesting initiative and the upcoming program by the Dutch embassy. This program with benefit all members of a community and training may have positive effects for the whole community in the long run.

6.3. Technologies and approaches should be about sustainability

Chapter 3 reviewed the available technologies, also mentions a number of technologies and projects in the text boxes that could be interesting to additionally review. We propose that the main innovative power for RWH in Jordan - or the approach that might create the biggest movement and popular uptake - is not in delivering individual technologies to the landscape. Instead, we believe that many of the technologies would be more efficient, more popular and more visible if put in a scheme that looks at the sustainability clauses as formulated by the Dutch WASH alliance under the so called FIETS sustainability framework (Financial, Institutional, Environmental, Technical and Social).

6.3.1. The FIETS Sustainability Framework

6.3.1.1. Financial sustainability

Several technologies raise the question of their financial sustainability in terms of capital investment and operational costs versus value addition or direct business. For instance, a hafir in areas where there is high evaporation and low population pressure will be a high investment (around 200.000 EU) with very little productivity added. We noticed that in the Badia, the animals have no water shortage in the wet season when the existing hafirs are full, and only in the dry season when the water in hafirs is evaporated. Another problem is the short life-span due to the lack of maintenance, resulting from high maintenance and rehabilitation cost, which are not incorporated in the funding and are not carried by the local users due to lack of financial capacity and/or lack of ownership.

There are other technologies which have relative low implementation costs, but need significant maintenance such as trenches, terraces, tree lines and swales. Such technologies can never be implemented top-down because they demand the users to take up operation and maintenance. Any program implementing such technologies should clearly state to the intended users the amount of money invested in the whole life-cycle of the intervention, the impact it will have on the crops and the positive end balance that should be obtained from this investment. Much depends on the willingness of farmers and other stakeholders to invest in this. There are many examples around the world and in Jordan of farmers doing this themselves, without (financial) support. When implementing these types of interventions as part of a program, the focus would be on the more 'soft' components, such as awareness, community mobilization, training, and enabling environment. As already stated above, the main challenge can be in the lack of interest in on farm measures. When people do not own the land they use or work on, or when the owners have their real income from other sources, dedication to invest time, labor and money will be limited. An additional challenge is the availability of 'free' groundwater from boreholes, which undermines the business case of RWH and other water saving measures. There is no program that we know of that has managed to overcome these challenges.

However, there is a subset of technologies which have relatively high investment cost but very long depreciation periods and operational costs. These are for instance cisterns, sand dams, subsurface dams and bench terraces with stone walls. The advantage for a program is that they have proven sustainable, there is existing capacity to work on them. The challenge is finding sustainable financial solutions and good stakeholder involvement and ownership. For RWH that challenge is always there but there are good local institutions to work with. When done at individual level there can be a loan scheme that helps farmers or households get over the high capital expenditure. When at river basin level the main investment should be by the users in making available labor and materials.

Private sector involvement in rain water harvesting projects and financial sustainability of the interventions

The private sector can and will play a major role in the water sector management in Jordan. To date most of the intervention was large scale and in areas that does not include Rainwater harvesting in rural areas, the badia, or even in urban areas with high rainfall levels. Below is an analysis of examples of private sector participation possibilities in the rain water harvesting field with high financial sustainability and expected revenue for the beneficiaries.

The banking industry can through specific arrangements with the ministry of agriculture and/or the farmers union or any other entity allocate funds (soft loans) with low interest rate which can then made available to small farmers to carry out water harvesting initiatives. This can be implemented in many parts of Jordan. Specific location of interest are areas where livestock owners are located. The north east badia and the southern Amman region are very good location for this initiative. The soft loans will be specifically devoted to water harvesting and landscape restoration practices such as cisterns, ponds, trenches, terracing and tree planting.

A similar intervention can be supported for roof water harvesting by providing soft loan to home owners or big residential compounds in cooperation with municipalities and the local governments. Specific areas for the interventions would be in the northern part of Jordan, especially Irbid, Ramtha, Ajloun, and Jerash where the precipitation rate is high and the quantity of water can be large and economically rewarding.

Another intervention associated with Marabs and Qa'as would be the funding of small farmers nearby to facilitate building storage facilities of water associated with constructing a conveyance system for water to a point where small farmers can then take to their lands or livestock farms in the area.

A similar program was implemented in the past in the industrial sector through the Jordan investment board where coalition of banks supported the implementation of best environmental practices at small and midsize industries in Jordan with soft loans.

Another type of private sector participation in the water harvesting initiatives is to give groundwater well licenses to big land ownerships farmers with the conditions that they can pump quantities of water from aquifers that are equal to the amount that they can harvest from rainfall. This will need some policy and legislative intervention by the water authorities. It will also need creating an appropriate institutional set up to monitor the process.

6.3.1.2. Institutional sustainability

Institutional sustainability means that programs should develop the capacities of the local user groups and preferably even capacitate local municipalities, farm associations, individual users or town authorities to take up the work themselves. Institutional sustainability means that once the program is over, the local institutions who are in direct touch with the users and who will remain in the field, are capable of operation and maintenance and preferably even expanding the technology. From the interviews, it seems like this concept is lacking in many programs. Therefore, the ToR should pay particular attention to this aspect.

6.3.1.3. Environmental sustainability

Programs that are environmentally sustainable take into account the broader resource environment of the technology. This means for instance that a program on RWH which looks at upstream water harvesting always takes into account the environment and downstream users. RWH technologies done in the upstream catchment can have a positive environmental impact when they replenish groundwater resources and reduce flooding downstream. They can also have a negative environmental impact when downstream users are deprived of base or flood flow that they need or water is left to evaporate through large surface water reservoirs or center pivot irrigation in hyper arid lands. It is important to keep in mind that, as a rule, that RWH programs are not environmentally sustainable when they draw from resources that cannot be replenished or when only few users benefit from a resource that is shared by many. Usually when small-scale interventions are made, impact on the basin water balance is minimal, however large interventions or small interventions implemented at large scale can have a significant impact on the water balance. Small scale SWC interventions that restore degraded land and reduce erosive runoff, are rarely have a negative impact, but many positive impacts on water quality, water quantity and water availability.

6.3.1.4. Technical sustainability

As already described above, we noticed that there are many good engineers in Jordan and the technical solutions might not be the biggest challenge. What needs further attention in the program development is what we call appropriate technology. This means that technologies are for people and not people for technologies. If the users of the technology cannot see the benefit of the technology or cannot perform operation and maintenance, then the technology is not appropriate and should not be built. We strongly urge to take this into consideration for the reputation of RWH technologies. In many counties, 'hit and run' programs have been implemented where a certain technology is piloted top-down and then fails as soon as the program stops. Often the blame is put on the users or the technology itself. RWH technologies have the added value that they do not often create a negative impact and often they are so called no regret measures. But if with the same financial mean a different, more appropriate technology could have been implemented then it seems important to focus on this specific technology instead.

6.3.1.5. Social sustainability

Social sustainability refers to the best practices in any kind of program where the implementing organization should take care that program benefits are not only for a targeted well-off community or demographics. Assuming effects of an intervention will trickle down automatically is a myth that has led to larger divisions between social groups in society. The EKN should support programs that have a keen understanding of gender, generation, and ethnic relations in the field and that see it as an obligation to help all people regardless of their social or cultural identity. During the interviews we noticed that Jordan is blessed with highly skilled male and female engineers. Diversity in the program staff will make it easier to approach other groups besides the groups that represent only a very small faction of society that tends to be in charge of the local resources. It is easier but not automatic. If concerns over gender, generation and culture are not firmly imbricated into the program design, program staff tends to go for the easy way and choose for only these people who represent the current powers.

6.4. Specific recommendations for the roles and responsibilities of implementing partners

The consultants have reviewed the Jordanian water sector and the way different Dutch and international parties can provide input on a program on RWH. We have looked for places, people, methods and technologies which can work as an alternative source of water for individual use of Jordanian citizens and farmers. The activities in such program have been elaborated in the previous Chapters, this Chapter provides specific recommendations on implementing partners for the different activities, roles and responsibilities. The implementing partners that are considered most feasible for the activity are indicated between brackets. This should only be considered as an indication, as this eventually will have to be proposed by the organizations themselves, based on their expertise and understanding of the Jordanian water sector and the RWH program.

6.4.1. Required expertise and steps per potential program component

6.4.1.1. Catchment approach

If a catchment approach is considered with a variety of RWH approaches in agriculture and landscape restoration the consortium should have a combination of experience and expertise on:

- Hydrological modelling and remote sensing, mapping (Acacia Water, Nectaerra, IHE)
- Ephemeral rivers and sediment transport (IHE, MetaMeta, Acacia Water)
- Different RWH technologies such as sand dams and subsurface dams and implementation of innovative RWH solutions (MetaMeta, IWMI)
- RWH in agriculture and regenerative agriculture/agroforestry (MetaMeta, Nectaerra, local expert for example Greening The Desert and Groasis or Menaqua)
- Stakeholder, socioeconomic and environmental assessment (MetaMeta, local expert such as ECO Consult)

The program should then start with:

- Stakeholder mapping of the tributaries
- Detailed water demand analysis, particularly looking at small scale irrigation
- Detailed inventory and mapping of most appropriate water harvesting technologies throughout the catchment
- Stakeholder mobilization for discussion on the opportunities. In such meetings the potential participants should be asked if and how they can contribute so that with less input from the program, more can be achieved for the catchment.
- Possibly taking stakeholders to similar sites.

- Co-creating a user group that will monitor the catchment.

6.4.1.2. Roof RWH or individual farmer cistern scheme

If a Roof RWH or individual farmer cistern scheme is proposed the consortium should have experience on:

- Collaboration with local governments (institutional sustainability) (IWMI)
- Collaboration with the financial sector (financial sustainability and leverage) (IWMI)
- Developing innovative financial models around financing water technologies (IWMI)
- Stakeholder, socioeconomic and environmental assessment (MetaMeta, local expert)

The program should then start with:

- Stakeholder mapping of the possible financial institutions who could provide loans
- Detailed water demand analysis at household level, looking at the number of potential clients.
- Stakeholder mobilization for discussion on the opportunities. In such meetings the potential participants should be asked if and how they can contribute so that with less input from the program, more can be achieved. Possibly taking stakeholders to similar sites.
- Developing the capacity of local institutions to run the program once it has picked up with the users.

6.4.1.3. Urban RWH Program

If an urban RWH program is to be considered the consortium should have experience on:

- Working with high level stakeholders towards practical implementation, preferably already in the town selected (VNG International)
- Stakeholder, socioeconomic and environmental assessment (MetaMeta, local expert)
- Understanding urban infrastructure and drainage (Dutch Consultancy specialized on urban water management)
- Creatively use urban infrastructure for water management solutions (Dutch Consultancy specialized on urban water management, MetaMeta)
- Make hydrological maps of the urban environment, groundwater as well as surface water flows (Acacia Water, Nectaerra)
- Be able to work on RWH in roads, parks, drainage channels etc. (MetaMeta)

The program should then start with:

- Stakeholder mapping and understanding the policy environment and have go/no go moments.
- Detailed runoff mapping and land use or drainage channel mapping to see potential sites of recharge and retention.
- Stakeholder mobilization for discussion on the opportunities.
- Possibly taking stakeholders to similar sites, even if this is abroad where there is experience.
- Developing the capacity of local institutions to run the program once it has picked up with the users.

6.4.1.4. MAR intervention

If specific innovative MAR interventions are considered the consortium should have experience and expertise on:

- Hydrological assessment and modelling including floodplains, and remote sensing and mapping (Acacia Water, Nectaerra, FutureWater, IHE)
- Hydrogeological assessment for feasibility of MAR and identifying suitability for MAR technologies (Acacia Water, IHE)
- Design and implementation of innovative MAR solutions (Acacia Water)
- Stakeholder, socioeconomic and environmental assessment (MetaMeta, local experts)

The program should start with:

- Stakeholder mapping of the area
- Detailed water demand analysis, particularly looking at small scale irrigation
- Detailed inventory and mapping of most appropriate water harvesting technologies and specifically MAR technologies throughout the catchment/target area
- Evaluation of appropriateness of specific MAR technologies and environmental impact with a Go/No-Go decision
- Stakeholder mobilization for discussion on the opportunities. In such meetings the potential participants should be asked if and how they can contribute so that with less input from the program, more can be achieved for the catchment.

Conclusions

Jordan is one of the most water scares countries in the world, with rapidly declining fossil groundwater resources. Therefore, the country is highly in need of alternative water resources and more importantly, of finding ways of reducing its water consumption. At the same time, the transition towards more efficient water use and alternative water usage is being hampered by the availability of (low cost) groundwater, especially within the agricultural sector. Although policies are in place and many efforts have been made, groundwater resources are still abstracted legally and illegally for unsustainable irrigation of crops at large scale. The agricultural sector will have to make a rapid transition towards more water efficient practices and towards the use of alternative and sustainable water resources. RWH can be a part of that transition but cannot pretend to give the solution to Jordan's water recourses crisis given the current abstraction rates.

Jordan has a long history of RWH use and examples of different RWH structures are being found throughout the country, such as cisterns, terraces and water spreading dams. However, the current focus of the MWI/JVA seems to be on large open water storage infrastructure, such as hafirs and dams. Several stakeholders, including the Government itself, expressed concerns about the sustainability and the lack of socioeconomic scoping in the design and implementation of these interventions. Additionally, many of these reservoirs are located in an area with an arid to hyper-arid climate, where evaporation rates can be over 4000 mm per year. Another worrying trend that was observed is that especially within the agricultural sector the use of sustainable practices of RWH and SWC have generally declined, rather than increased over the last decades. Overall, land degradation is a major factor in the issues surrounding the Jordanian water resources. It leads to reduced infiltration and hence reduced recharge, increased problematic flashfloods, increased erosion, reduced productivity, and an increased need for irrigation water.

Many suitable RWH methods and approaches, which could help increase water availability and/or reduce the need for water, were identified during this scoping study. The broad spectrum of RWH technologies were described and their conceptual suitability put in place in a RWH suitability map on National level. This can help to put the potential of RWH on the agenda and inspire to consider alternative options in an integrated approach.

In this scoping study the 15 surface water basins were evaluated and North Rift Side Wadis Basin (NRSW Basin) and Azraq Basin were selected as focus basins for the follow up program envisioned by the ENK. Within the NRSW Basin, an integrated catchment program surrounding farmer communities could be implemented with a variety of interventions. Within the Azraq basin, the main focus could be on the farmer communities surrounding the Azraq wetland and on the challenges the communities face with saline groundwater. The Badia also have serious challenges due to land degradation and limited water resources. Technically, RWH interventions are feasible, but due to the socioeconomic and climatic context, rangeland management approaches with a focus on the 'soft' interventions rather than on physical RWH structures would be most appropriate. However, this might not be within the scope of the program intended by EKN Amman.

During the interviews with the different organizations, it became apparent that a top-down approach characterized the Jordanian water sector. With large projects like dams, wellfields and large piped water systems, there are few viable alternatives to this top-down approach. The implementation of structures used by farmers or pastoralists should use a user first approach and should preferably engage and include them in the program. An important component of the development of a RWH program in Jordan will be finding the right local project owners (communities, farmers, households, businesses, etc.). Programs focused on the best technical solutions will end as pearls in the desert, beautiful in itself but seen by few and not adopted by anyone.

There are many good examples of RWH programs and pilot projects within and outside of Jordan. Before starting new pilot projects, the program could learn from the locally existing examples, extract the success factors and find a way of scaling them and adding additional components. The actual RWH interventions will have to be selected and designed based on a thorough assessment of the local environment. For example, the local soil type and availability of local (natural) materials should change the design and implementation modality of a terrace, check dam or irrigation method. Local traditions in construction should be followed as much as possible to increase ownership and the potential for upscaling. Probably the main innovative power for uptake of RWH in Jordan is not in delivering individual (innovative) technologies. Instead, many of the technologies would be more efficient, more popular and more visible if put in a scheme that looks at the sustainability clauses as formulated by the Dutch WASH alliance under the so called FIETS (Financial, Institutional, Environmental, Technical and Social) sustainability framework.

Implementing such a program will require a strong consortium of implementing partners, with the right expertise and experience. This program would need an Inception Phase that allows implementing partners to do the local research required to meet the above-mentioned criteria, and to use their results to fine-tune their proposal for implementation. A high level of flexibility and adapting to ongoing insights and local contexts will be essential throughout the program.

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Annexes

Annex A – List interviewed stakeholders

List of interviewed RWH stakeholders in Jordan

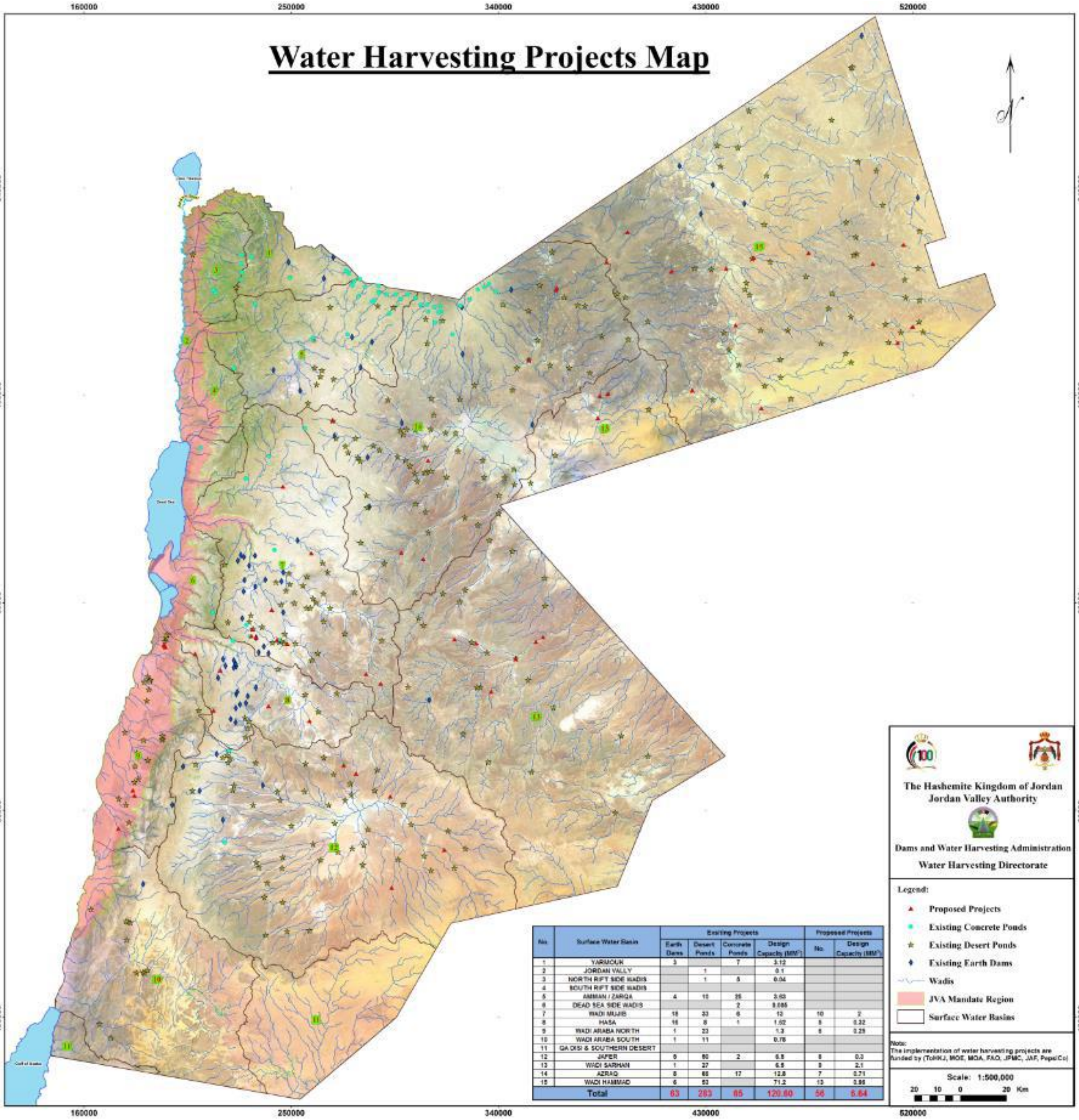
Stakeholder in Jordan	Interviewee
MWI and JVA	To be completed... Eng. Mohammad Doairi/ MWI ASG for strategic planning. Eng. Hisham Hisa/ JVA ASG for Dams and Irrigation. Dr. Adel Obiat/ MWI Strategic Planning Manager Dr. Mohammad Khamaiseh/ Water Harvesting Manager. Eng. Rehab Tarawneh/ MWI
MOA	For Irbid Governorate, Qasaba and Bani Knana Sub-Governorate: Eng. Jihad Obiedat. Mobile: +962 7 9903 8739. For Ramtha Sub Governorate and Jerash: Eng. Kamal Jaradat. Mobile: +962 7 80319542 . For Aljoun Governorate: Eng. Mousa Hadad. Mobile: +962 7 91415065
Mercy Corps and USAID	Raed Nimri (Mercy Corp) Nour Habjocka (USAID).(rnimri@mercycorps.org, nhajoka@usaid.gov)
INWARDAM	Marwan Raqqad
IUCN	Eng. Ali Hayajneh (ali.hayajneh@iucn.org)
NARC	Dr. Nizar Hadad, EnG. LubNA mahasneh
IWMI Egypt	Dr. Amgrad Elmahdi (a.elmahdi@cgigar.org)
ACTED Jordan	Aline Milev (aline.milev@acted.org)
GIZ	Armin Margane
Carob Farm – Regenerative Farm	Rakan Mehyar (racan@carobfarms.com)
ICARDA	Dr. Hassan Machlab
ICARDA/CGIAR	Stefan Martin Strohmeier (s.strohmeier@cgiar.org)
	Mira Haddad (m.haddad@cgiar.org)
Freelance	Mohammed Ayesh
Inter-Islamic Network on Water Resources Development and Management (INWRDAM)	Dr. Marwan Raqqad
National Agriculture Research Center (NARC)	Dr. Nizar Hadad
Engicon	Name: Tariq Zuriqat Position: Managing Director. Mobile: +962 7 96302345

	Name: Bilal Sharief. Position: Projects Director. Mobile: +962 7 96302345
JOHUD - Jordanian Hashimite Fund for Human Development	Name: Mutasim Hiari. Position: Projects Manager. Mobile: +962 7 79669668
Future Pioneers	Name: Obida Hammash. Position: General Manager. Mobile: +962 7 90717686
Princess Alia Foundation	Name: Maysa Al Hwayan. Position: Projects Manager. Mobile: +962 7 96680164

List of interviewed Dutch RWH stakeholders

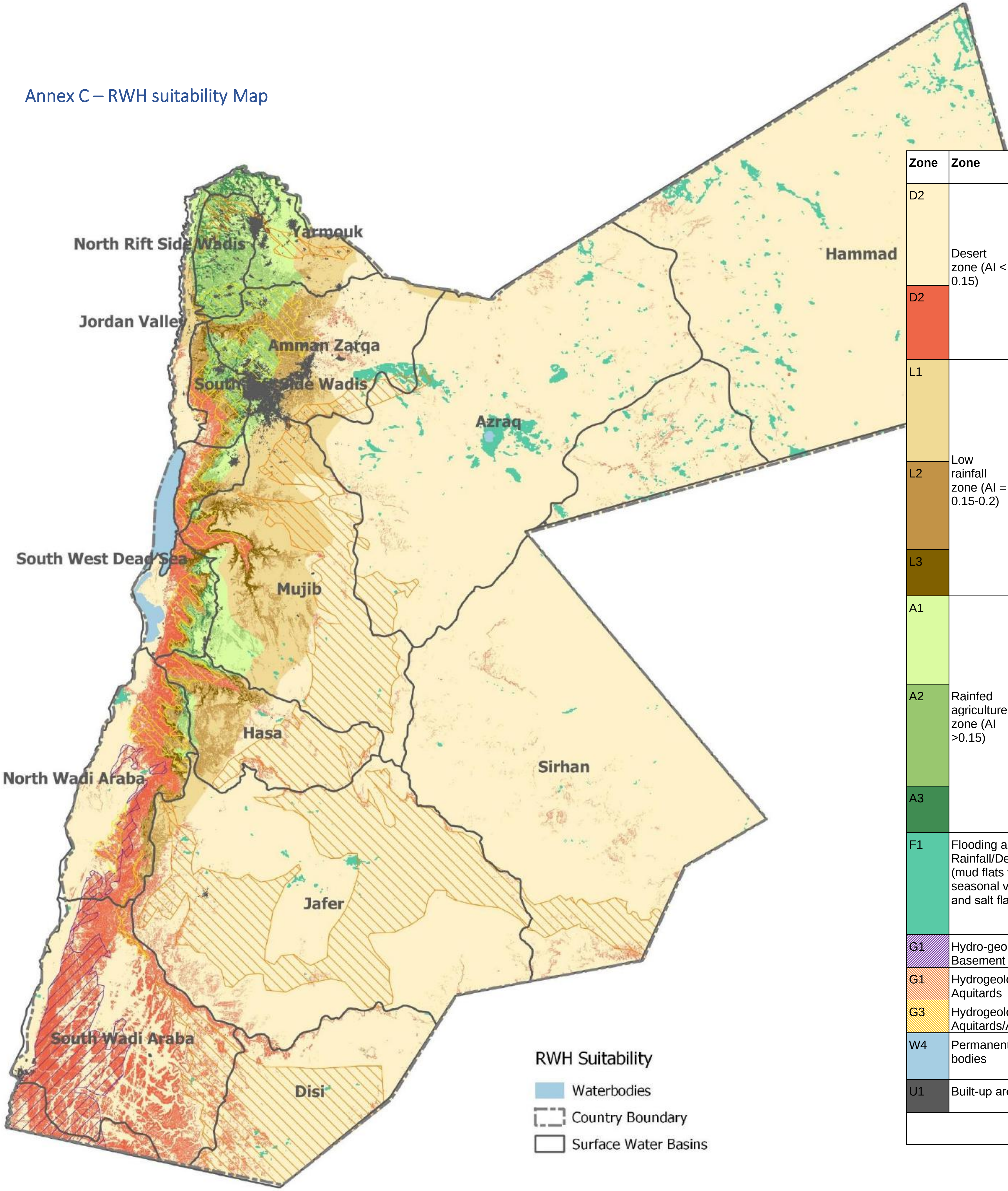
Dutch organization as potential partners	**Interviewee**
IHE Delft	Prof. Marloes Mul (m.mul@un-ihe.org)
	Prof. Annelieke Duker (a.duker@un-ihe.org)
MetaMeta	Frank van Steenbergen
Acacia Water	Stefan de Wildt (stefan.dewilt@acaciawater.com)
	Arjen de Vries (arjen.devries@acaciawater.com)
WUR & RVO GRO	Flip van Koesveld (flip.vankoesveld@wur.nl)
Agricultural Counsellor Egypt & Jordan	Dr. Melle Leenstra
Nectaerra	Rogier van Opstal (rogier.van.opstal@nectaerra.com)
RegaMena	Laura Van Nieuwenhoven
Expert water management Jordan	Winfried Pietersen (winfried.pietersen@pietersenconsult.com)
Embassy of the Kingdom of the Netherlands Kigali Rwanda	Timmo Gaasbeek

Annex B Water Harvesting Projects Map



No.	Surface Water Basin	Existing Projects				Proposed Projects	
		Earth Dams	Desert Ponds	Concrete Ponds	Design Capacity (MM³)	No.	Design Capacity (MM³)
1	YARMOUK	3		7	3.12		
2	JORDAN VALLY		1		0.1		
3	NORTH RIFT SIDE WADIS		1	5	0.04		
4	SOUTH RIFT SIDE WADIS						
5	AMMAN / ZARQA	4	10	25	3.63		
6	DEAD SEA SIDE WADIS			2	0.085		
7	WADI MUJIB	18	33	6	12	10	2
8	HASA	16	8	1	1.02	5	0.22
9	WADI ARABA NORTH	1	23		1.3	6	0.29
10	WADI ARABA SOUTH	1	11		0.78		
11	QA DISI & SOUTHERN DESERT						
12	JAFER	8	60	2	6.8	8	0.3
13	WADI SARHAN	1	27		6.5	8	2.1
14	AZRAQ	8	66	17	12.8	7	0.71
15	WADI HAMMAD	6	53		71.2	13	0.86
	Total	63	283	65	120.80	56	5.64

Annex C – RWH suitability Map



Zone	Zone	Details and slope	Sustainable land use	Interventions for SWC and local runoff harvesting (in-situ recharge enhancement)	Interventions for centralized storage and wadi flow harvesting
D2	Desert zone (AI < 0.15)	Gentle slopes (<15%)	Seasonal grazing; No groundwater-based irrigation	Rangeland management; Protection of trees along wadis	Off stream: desert ponds, lined ponds (long-term open water storage should be avoided due to high evaporation), spate irrigation, cisterns, MAR; In-stream: subsurface dams for groundwater recharge/MAR, floodwater diversion weirs, marab, wadi bed cultivation
D2		Steep to very steep slopes (15-40%)	Seasonal grazing; Seasonal farming in flooding areas; No groundwater-based irrigation	Rangeland management; Hillside runoff systems: planting pits, small runoff basins, half-moons, contour ridges, 'meskat' system	Off-stream: hillside dams, rock catchments, cisterns; In-stream: cascading check dams, gabion dams, sand-dams for flood buffering and MAR, wadi bed cultivation, Jessour structures
L1	Low rainfall zone (AI = 0.15-0.2)	Gentle slopes (<15%)	Controlled grazing; Farming with drought resistant (permanent) crops; Seasonal farming in flooding areas; No groundwater-based irrigation	Rangeland management: protection of trees, area closures; Tree planting as windbreaks and for SWC; On slopes: contour bunds, tied-ridges, swales, grass-strips, contour ploughing, etc.	Off-stream: desert ponds, lined ponds, cisterns, spate irrigation, floodwater spreading, MAR; In-stream: subsurface dams for groundwater recharge/MAR, floodwater diversion weirs, marab, wadi bed cultivation
L2		Steep slopes (15-40%)	Rangeland; Silvopasture; Farming with drought resistant (permanent) crops	Rangeland management: protection of trees, area closures; On-farmland: stone bunds, tied ridges, trenching, swales, terraces; Hillside runoff systems: planting pits, small runoff basins, half-moons, contour ridges, 'Meskat' system, and no-till practices	Off-stream: hillside dams, rock catchments, cisterns, MAR; In-stream: cascading check dams, gabion dams, sand dams for flood buffering and MAR, valley dams, wadi-bed & wadi-bank cultivation, Jessour structures.
L3		Very steep slopes (>40%)	Forest; Silvopasture; Tree crops	Tree protection; Area closures; Tree planting; In farm land: stone structures above ground for soil stabilization	Valley dams; Rock catchments; check dams
A1	Rainfed agriculture zone (AI >0.15)	Gentle slopes (<15%)	Rainfed agriculture with supplement irrigation; Agroforestry; Horticulture with irrigation from RWH, surface water or waste water reuse	Tree planting as windbreaks and for SWC; Wadi bank cultivation using floodwater; On gentle slopes: contour bunds, tied ridges, swales, grass-strips, contour ploughing, etc.	Off-stream: ponds, lined ponds, cisterns, MAR; In-stream: sand- and subsurface dams for flow buffering and MAR, check dams or weirs feeding irrigation systems and/or ponds
A2		Steep slopes (15-40%)	Slope adapted agriculture; Agroforestry	On farmland: contour bunds, stone bunds, tied ridges, swales, trenching, contour tree lines, terraces, hillside runoff systems: planting pits, small runoff basins, half-moons, 'Meskat' systems, and no-till practices; Rangeland management	Valley dams; Hillside dams; Rock catchments; MAR; Wadi-bank cultivation using floodwater; Flood buffering and MAR: cascading check-dams, gabion dams, sand-dams, etc.; Check dams or weirs feeding irrigation systems and/or ponds
A3		Very steep slopes (>40%)	Forest or forest plantations; Silvopasture; Rangeland	Forest protection; Tree planting; Rangeland management; In farmland: stone structures above ground for soil stabilisation	Valley dams; Rock catchments; Check dams
F1	Flooding areas in Low Rainfall/Desert zone (mud flats with seasonal vegetation and salt flats or Qa'a)		Wetland; Seasonal grassland; Seasonal farming in flooding areas where there is no negative impact on (seasonal) wetlands and grazing areas.	Strongly depends on the nature of the flooding area, is there (seasonal) vegetation or no vegetation? Wetland protection (when vegetation); Grazing management; On farmland: flood recession cultivation, bunds, marab	Floodwater spreading for MAR; Floodwater storage in desert ponds or infiltration ponds; Marab; High potential for MAR; In saline areas water should be captured before reaching the salt flat
G1	Hydro-geology: Basement Complex		See underlying layer	High potential for sand-dams and subsurface dams and shallow groundwater storage in top soil and streambeds (alluvial sediments); No potential for deep groundwater recharge	
G1	Hydrogeology: Aquitards		See underlying layer	Potential for shallow groundwater storage through sand-dams and subsurface dams; Low potential for MAR of deep aquifers (unless through tube recharge)	
G3	Hydrogeology: Aquitards/Aquifers		See underlying layer	If aquitard: potential for shallow groundwater storage through sand-dams and subsurface dams; Low potential for MAR of deep aquifers (unless through tube recharge)	
W4	Permanent open water bodies			Protection of floodplains and buffer zone/ riverine buffer with protection of riverine vegetation	Riverbank infiltration; Floodwater spreading
U1	Built-up area's			Urban water management; Increased tree cover	Roof rainwater harvesting; Infiltration ditches; MAR

SWC = Soil and water conservation; MAR = Managed aquifer recharge