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Farming In The Desert

Analysis of the agricultural situation in Azraq Basin

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Farming In The Desert

Analysis of the agricultural situation in Azraq Basin

Chantal Demilecamps and Dr. Wael Sartawi
2010

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Introduction

In the context of rising water scarcity in Jordan and competition for dwindling water resources, the pressure to reduce water consumption in agriculture is growing, particularly in Azraq groundwater basin which is heavily over-pumped. The Highland Water Forum aims to facilitate the implementation of sustainable groundwater management systems, by enabling water users and decision makers to enter into dialogue and exchange views on Azraq Basin. This should be achieved whilst ensuring there are no adverse impacts on social and economical well being in the area. Therefore, it is key that the situation on the ground be fully understood, which is the objective of this study. Focus was given to the agricultural sector, the largest water user in the Azraq Basin, with a high proportion of abstraction being currently uncontrolled. The suitability of using such a large water quantity for agriculture is indeed regularly questioned, as it is commonly accepted that water profitability is much higher in other sectors. The use of diagnostic analysis that focuses on irrigation water management allows structuring problem analysis, systemising the main types of farms, characterising their strategies, and identifying potential solutions for more efficient water management.

Objectives of the study

• Summarise knowledge about farming evolution and related water issues in Azraq basin.

• Understand and systemise the diversity of farming systems to fully comprehend the situation on the ground and further consider implementing suitable activities to target the water problem in the basin. Results will be used for prospective work.

• Highlight the relation between the different types of farms and their irrigation practices and profitability.

The study presents:

1. Overview of the regional water context and environment.

2. Presentation of the farming activities and the related on-farm water management.

3. Typology of irrigated farming systems (classification and description of systems types and case study example).

4. Outline of current irrigation practices and future trends.

5. Recommendations for future work related to irrigation sector to target sustainable groundwater management in the Highlands.

Methodology and main assumptions

59 field interviews with farmers were conducted in the Azraq basin from September to December 2010 according to the following distribution:

- 14 in North Badia (out of 51 working private agricultural wells),

- 5 in Jiza[1] and 4 in Mwaqqar (out of 16 working private agricultural

[1] *These interviews concern farms located close to the Azraq basin region, but extracting water from the neighbouring water basin. However, data collected during these interviews were considered in our study as farming practices and farmers' strategies are not influenced by the basin which water is abstracted from.*

wells), and

- 36 in Azraq (out of 481 working private agricultural wells).

The farms were randomly chosen on the field in order to cover the whole basin geographically and to reflect the diversity of farming systems by choosing a sample that is representative of all the categories of farms (taking into consideration multiple criteria such as area, soil, type of irrigation network, age of the farm, crops...).
The survey consisted of interviews with farms' managers or farm owners in 59 farms all over the Azraq basin (in Azraq, North Badia and Jiza areas). A questionnaire[2] was developed and used to discuss with farmers the main topics related to farm description and management. The survey was conducted by two experts, one specialised in water management in Jordan, and the other with a vast experience of Azraq region and the specificities and evolution of its agriculture. The total area covered by the survey with the 59 farms visited is 16727 dunums[3] (14775 du of cultivated area).

The questionnaire covered the following items:

1. General information: identity, farm status, agricultural activities (crops, production level), non-agricultural activities.

2. Production system: land tenure and history, water and irrigation, agricultural techniques and inputs, work resource, equipments.

3. Environment and farmer's perception of the water problem.

4. Strategies, trends and future perspectives.

Field data was analysed resulting in the following:

- Farm classification according to structural information and description. The stratification is based on characterisation of the environment (soil, climate, water resource..) and of farms (area crossed with product categories).

- Farm typology with a focus on irrigation, based on the management of the farms, and the role of agriculture in the socio-economic context. It highlights the main objectives for the farms category, the strategies developed (related to assets and constraints), and the adopted management rules (planning and decision rules).

Assumptions:
Efficiency of different irrigation systems[4] :

	Efficiency current system	Efficiency optimised system
Surface irrigation	55%	-
Open tube	65%	70%
Virojet	60%	85%
Dripper (GR)	70%	90%

2 *Cf. Annex 1.*
3 *10 dunums = 1 hectare.*
4 *IOJoV project feasibility study, MREA, 2006.*

I – Azraq Basin: heterogeneity of the physical, hydrological and human characteristics

1.1. General Presentation of Azraq Basin

Azraq basin covers an area of about 12700 km^2 (15% of Jordan superficies)[5]. Azraq basin is a desert, mostly flat to hilly area east of the Highlands. "Highlands" is used in this study to describe the agriculture part of Jordan located on the Eastern Plateau, as opposed to the Jordan Valley. The lowest point of the basin is located at the Azraq depression (Qa'a) with an elevation of about 500 m above sea level. The Qa'a is formed as a single basin and receives water and silt drained by wadis, or water ways, from the surrounding region. This elevation increases to about 900 m in the southern part of the basin. The highest point in Jordan is located at Jabal El-Rimah area with an elevation of about 1234 m[6].
It is called Al-Badia Asharqiya (Eastern desert) and used to be the domain of transhumant and semi settling herders. However, in the last two decades, a large area was cultivated under irrigation, using groundwater.

The Badia region is characterised by a very sparse vegetative cover. According to MWI Land-Use Classification map (1994), 99% of land is urban and bare rock, 0.5% is natural vegetation, 0.3% is irrigated land and 0.03% is rain-fed.

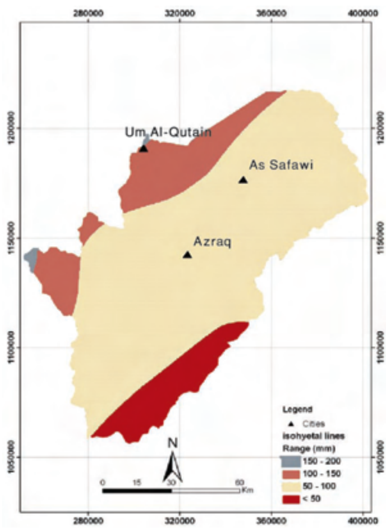


Figure 1: Precipitation in Azraq basin
(long term Isohyetal lines, average on 50 years)

1.2. Variability of agro climatic conditions within a semi desertic region

Climate in Azraq basin is characterised by hot and dry summers, and fairly wet and mostly cold winters.

The mean annual rainfall in the basin ranges from 100 - 150 mm in the west and north, 50 – 100 mm in the middle of the Basin and to less than 50 mm in the south and east[7]. There is no permanent surface water in Al-Azraq basin. Water resources are scarce, fluctuating and uneven both spatially and temporally, with high inter- and intra- annual variations of precipitation.
The effect of climate change, as mentioned by farmers during some interviews, might be a reason for

5 *Wolter, 2009.*
6 *Hydrogeological and Hydrological Investigation for Azraq Basin – NE Jordan, Ibraheem Hamdan, GTZ, 2010.*
7 *Source MWI, 2009.*

the decrease of rainfall in the last 5 years. Over the whole region, irrigation is needed for agriculture.

Most of the soil in the basin is characterised as arid soil, with a high soluble salt content in the subsurface horizons[8]. The predominant soil type is Silty Clay Loam. In Azraq region (East Jordan Limestone Plateau), soil is mostly poor and either clay, Hammada, saline or calcareous. Soils are primarily composed of limestone with flint scattered all over, or covered by basalt pebbles and boulders that resulted from volcanic out crossing centred on Jabal Druze. In the middle of the Badia and to the south of Azraq, soils become saline and contain gypsum[9].

In the North Jordan basalt Plateau, basaltic lava plateau from Jabal Druze soil is developed on parent lava rock and Aeolian silt is likely to have participated in soil formation . Soils are deep to moderately deep, slightly gravely, with a fine silty loam texture in the surface, and subsoil horizons rich in $CaCO_3$. The high silt content of the surface soil, and the absence of suitable organic content makes soils highly susceptible to gully and wind erosion, particularly when disturbed by ploughing or subjected to over-grazing[6]. More details can be found in Annex 2.

1.3. Groundwater resources in Azraq Basin

Azraq Groundwater Basin extends over 19060 km^2: 92% of the aquifer is on Jordanian territory, while 5% exists in Syria and almost 3% in Saudi Arabia[11]. It is composed of 3 aquifers:

1. Upper aquifer complex (good water quality, low drilling cost, renewable water).

2. Middle aquifer complex (more than 600 m deep, low quality due to high dissolved solids concentration, with salinity rates between 600 – 1500 mg/L[12]).

3. Lower aquifer complex (800 to 900m deep, high extraction cost, high salinity).

Infiltration recharge amount for Azraq Basin is about 5.5 MCM, and the underground recharge from rainfall in Syria 18 MCM, so the safe yield amount determined by MWI is 24 MCM.

Two zones in Azraq basin are identified:

- The north part of the basin for basalt aquifer (annual recharge rate around of 11%[13]).

- The south for B4/B5 formation[10] (annual recharge rate around of 3%). In the Azraq area, the B4 aquifer is extensively exploited for domestic and agricultural purposes and water have significantly depleted over the past decade.

	Basalt	B4
Rainfall	400 MCM/y (100%)	250 MCM/y (100%)
Run-off	5.3%	4.4%
Evapotranspiration	82.6%	92.4%
Recharge from infiltration	12.1%	3%

8 Drury, 1993.
9 Atlas of Jordan, Myriam Ababsa, IFPO.
10 http://alic.arid.arizona.edu/jordansoils/_html/land_regions.html#top
11 Dutton & Shahbaz, 2009.
12 Highland Water Forum Secretariat, 2010, Highland Water Forum background.
13 MWI annual report, 2009.

1.4. Three sub regions in Azraq basin

Differences in agro-climatic conditions and in the access to the aquifer led to identify three sub-regions in Azraq basin: Azraq region around the Qa'a depression, North Badia and Jiza. Their main characteristics are summarised below:

	Azraq	North Badia	Jiza
Rainfall	Less than 100 mm	100 – 150 mm	100 – 150 mm
Temperature	Desert climate (hot summer, cold winter)	Semi desertic	Semi desertic
Elevation	500 m	900 m	
Aquifer	B4	Basalt/A7-B2	B4/A7-B2
Average depth of well	75 m	440 m	375 m
Average groundwater level	35 m	350 m	335 m
Main soils[14]	Typical camborthids and calciorthids; Gypsiorthids in some parts. Deep soil. Silty or sandy clay loam	Calciorthids or Xerochreptic paleorthids. Moderately deep soil. Silty Clay Loam	Typical Calciorthids Moderately deep. Silty Clay Loam

II – Historical evolution and dynamics of agricultural development and water management in Azraq Basin

While the first wells were drilled in the 1930s in Azraq, it is only in the 1960s that irrigated agriculture really started developing, based on the introduction of diesel motor pumps. It was part of the state policy to settle Bedouins that used to herd animals in the Highlands by switching to agriculture, based on groundwater exploitation. Irrigated agriculture boomed in the late 1970s and 1980s, when modern irrigation and cropping techniques that were introduced in the Jordan Valley were transferred to the Highlands. Moreover, energy costs decreased, well-drilling techniques improved, and land was cheap, fertile and immune to diseases. In this period, irrigated agriculture in Jordan enjoyed a boom in production and economic profitability and irrigation developed exponentially until the beginning of the 1990s. The Government of Jordan was then tolerant of pumping groundwater in the Highlands, which was consistent with interpreting groundwater as a private good. In the Highlands, investments were private[15], while the involvement of the Government has been much more focus on the development of irrigated agriculture in the Jordan Valley.

[14] *For more information, see Main soils in the project area in Annex 2.*
[15] *Venot, (2007). Irrigated agriculture, water pricing and water savings in the Lower Jordan River Basin (in Jordan).*

2.1. Al-Azraq: from subsistence agriculture for refugees to uncontrolled development of irrigated agriculture

In Azraq, a period of settling waves of Druze and Chechen immigrants took place in 1920s, who were then dependant on livestock breeding in the oases and salt production as well as sustenance agriculture. The first investors and capital holders from other areas in Jordan invested in agriculture in Azraq in the 1970s, mostly planting olive tree farms irrigated with traditional wells and surface irrigation while the road to Iraq was being built.

In the 1980s, with the development of Azraq and the transition from traditional to artesian[16] wells, Azraq underwent the development of large farms. Many farmers were evoked by the speech of His Majesty King Hussein for a green desert as a motivation to invest in agriculture in the region. Moreover, national land regulation dictates that proven activity in an acquired land is sufficient to grant the alleged owner right to this land. As agriculture was found to be the cheapest form of investment to prove ownership of land, the number of farms boomed. The uncontrolled expansion of agriculture driven by land speculation and prospect of cheap land and free water continued in the 1990s. As a consequence of this transition, the oases dried out completely in 1993[17].

The expansion of agricultural land continued in the 1990s with a progressive diversification of crops: introduction of grapes in the late 1990s, pomegranates in the beginning of 2000s, and development of alfalfa in the last few years. Vegetable production was progressively abandoned since the mid 2000s as a consequence of water tariffs, which also resulted in the spread of localised irrigation techniques (micro-sprinklers, open tube and GR).

Water abstraction decreased after 2004 as a result of the steep decline in groundwater levels, the reduced productivity of wells due to the rise of operational costs, salinity problems and lack of profitability. Consequently, some farms in Azraq were abandoned.

Nevertheless, new farms are still being founded despite the prohibition to plant new areas. Indeed, many farmers originating from Bedouin tribes are still planting trees to "claim" their land, with the future perspective of getting the land legalised.

Figure 2. A new olive tree farm planted in 2010 on an illegally acquired land in Azraq.

[16] *It has to be noted that the word "artesian" well is commonly used in Azraq region for wells drilled by a drilling machine, in opposition to manually dug wells. It does not refer to wells from which water naturally comes up the surface, as it is more generally understood in other regions.*

[17] *Azraq water dialogue - Strategic report - History of Socio-economical development.*

Comparing data from different census shows indeed the fast extension of agricultural land in Azraq region (it concerns only the area around Azraq and its different sub regions):

Area (region)	No of farms	Area in 1980 (du)	Average size farm (du)	No of farms	Area in 1994 (du)	Average size farm (du)	No of farms 2009	Area in 2002 (du)	Average size farm (du)
	Data MoA 1980 [18]			Data UNDP 1996 [19]			Data WAJ 2009 [20]		
Al-Awshaq	14	1203	86	38	1751	46	49	2174	44
Ain-El-Beida	9	835	93	20	1338	67	45	3597	80
Al-Dughayla	49	5990	122	80	20451	256	182	26200	144
Al-Ratami[26]	26	426	16	45	2060	46	99	2600	26
Azraq-Al-Janobi	19	315	17	46	837	18	55	980	18
Um-El Massael	0	0		0	0		95	14151	149
Al-Elawat	0	0		0	0		20	1375	69
Um-Swaweneh	0	0		0	0		16	770	48
Total	103	7566	73	191	24686	129	512	51847	101

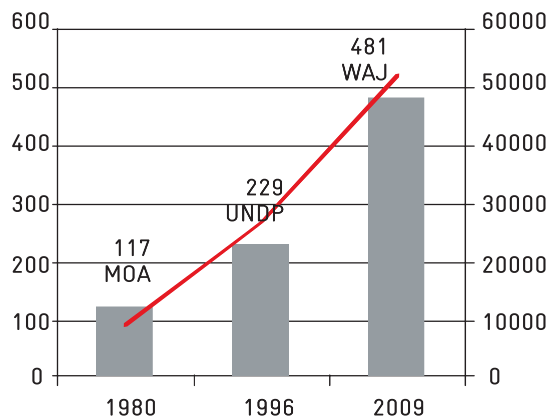


Figure 3. Constant increase of the number of farms and total cultivated land in the Azraq region over the years despite the prohibition of founding new farms (different sources).

In 1980, most wells were still manually operated and only few were artesian wells, most of which existed in Al-Dughayla area. Typically, two-thirds of a farm is planted with trees (mainly olive trees, grapes, pomegranate, and some stone fruit trees). The remaining third of the farm is planted with vegetables (mainly with melon, onion, garlic and winter crops: wheat, barley, as well as some alfalfa). In 1990, both manual and artesian wells were still used. Um-El massael, Al-Elawat and Um-Swaweneh are three locations that were created recently (after 1994) but already represent 30% of the cultivated land in Azraq region.

[18] *Ministry of Agriculture, Annual Report, Wael Sartawi, 1980.*
[19] *The Azraq Oasis Conservation Project: JOR/1992/G311996/.*
[20] *Communication from Mohammad Al-Hawi, Water Authority of Jordan (2010) about data in 2009.*

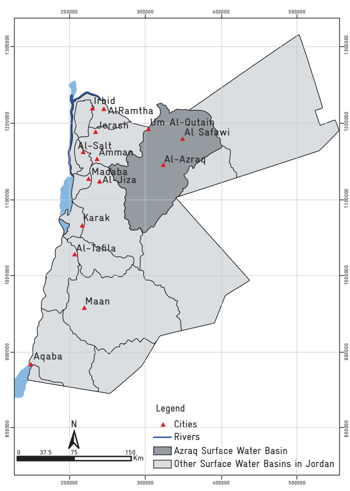
It can be noticed that data from WAJ and MOA are not compliant with each other: while WAJ estimates the total irrigated area to be 51847 du in 2002 (more recent data is not available in WAJ), MoA announces a total area under cultivation of 88028 du in 2010. Today, most wells are artesian wells, only few manual wells are still in use in South Azraq and Al-Ratami.

More details about the historical development of Azraq region were collected by way of interviews with long term Azraq inhabitants in September and October 2010, and are available in Annex 3.
Today, around 15000 inhabitants live in Azraq.

2.2. North Badia and Jiza area: an entrepreneurial, market-oriented agriculture succeeds traditional animal breeding

In the 1960s, the Water Authority of Jordan (WAJ) developed settlement programs for Bedouins by switching from animal husbandry to irrigated agriculture, focusing on subsistence and fodder crops. Even if it seemed to have failed in most cases, many Bedouins adopted the idea and began to drill wells and engage in farming activities, often keeping part of their herd too. The first farmers grew mostly olives and fodder crops[21]. This region was therefore one of the first parts of Jordan to develop bore-hole irrigation and clearing of stones and boulders from the land surface was carried out to prepare land for vegetables under drip irrigation.

This was the origin of a modern market-oriented agriculture developed by small to medium entrepreneurial farmers, supplying growing cities and exporting their surplus produce around the Middle East. Until the 1980s, tariffs and subsidies for farming activities contributed significantly to the growth of Jordan's agricultural sector. Thanks to subsidised electricity and diesel used to run wells pumps, as well as subsidies for some field crops and stone fruits (such as peaches), profit margins were guaranteed for most farmers. A feature of irrigation in this area is the rapid build-up of salinity which resulted in many abandoned farms across this region[22].



21 Van Aken, 2007. Historical trajectory of a river Basin in the Middle East – the Lower Jordan River Basin (in Jordan)
22 http://alic.arid.arizona.edu/jordansoils/_html/land_regions.html#top

III – Awareness about water overexploitation: progressive setting of a regulated water management framework

3.1. Competition over limited water resource: a threat to the sustainability of Azraq Basin (context and general consequences of overexploitation of water)

The absence of a specific policy that mitigates agricultural expansion and land exploitation has led to a dangerous spread of agricultural investments and a sharp increase in groundwater exploitation over the past three decades. In addition, water was pumped for urban consumption. In 1963 and 1970, small quantities of Azraq's groundwater were pumped to Irbid. In 1980, water used for agriculture was confined only to the springs which flowed naturally near the surface[23]. At that time, the wetland of Azraq oasis was covered with water on a total area 6 km^2. In 1981, Amman Water Sewerage Authority (AWSA) began pumping water to Amman at a rate of 1.5 MCM/y. In 1982, AWSA drilled 15 wells in northern parts of the Azraq Oasis in order to meet the domestic water needs of Amman and Zarqa (average well abstraction 17 MCM/y). Today, the total number of agricultural wells is 865, with 481 working artesian wells and a few manual wells[24], mainly in Ratami. Azraq Basin currently provides 25% of Amman's potable water. The total abstraction from the basin almost tripled in 20 years: it increased from 21.6 MCM/y in 1983 to 58.5 MCM/y in 2004. This over-exploitation led to a drop in the water table by 0.3 to 0.8 meter per year, (some wells are reported to have dropped by 20 meters), increasing water quality problems due to dramatic salination of the aquifer or pollution, and to the drying up of the wetlands[25].

Today, the problem of groundwater overdraft remains with over abstraction reaching 215% of the safe limit (definition):

- Safe yield being 24 MCM/y.
- Abstraction reaching 51.16 MCM/y[27] in 2009[26] (27.5 for agriculture, 22.9 for governmental drinking water wells for drinking water and 0.76 for other purposes).

Illegal abstraction from the Azraq basin, which is the abstraction from wells that are registered as "illegal wells", amounts to 13 MCM/y. The situation in North Badia is completely different as 90% of the farms have their wells registered[28].

23 *Wael Sartawi, MoA, 1980.*
24 *WAJ Azraq, 2009.*
25 *Van Aken, 2007. Historical trajectory of a river Basin in the Middle East – the Lower Jordan River Basin (in Jordan).*
26 *Data WAJ 2009.*
27 *WAJ Azraq estimations, 2009.*
28 *Source: Highlands Farm Survey, 2008, Internal Report, Water Focal Point.*

Exploding water abstraction in Azraq area: towards an environmental disaster

Azraq wetland formerly comprised a large area of permanent spring-fed marshes and pools, and a seasonally flooded wetland (Qa'a Azraq), fed by two groups of fresh water springs supplied by the upper of three aquifer systems underlying the Oasis. Extensive shallow wetlands used to host a variety of plant communities and migrating birds. In 1977, Azraq Oasis was included in the Ramsar list of wetlands of international importance.

Before 1970, water usage in Azraq area was confined only to the springs which were flowing naturally. The delicate balanced between water abstraction and preservation of the wetland was already highlighted by Nelson (1973) "The fear is that if too much water is withdrawn the effect on the wetland will be large and irreversible by the time it becomes apparent. Equally important, underground changes due to altered levels might lead to contamination of pure water with brine, thus ruining both the habitat and any practical utilization scheme ". Development of agriculture in Azraq area had already been mentioned, and it was advised not to proceed: "Large-scale irrigation and reclamation of area around Azraq [...] is far from desirable. It would be impossible [...] without creating great pressure on the wetland which would eventually destroy it. The Azraq area is in any case unsuitable for agricultural development by irrigation. Most of the soil is too much salty to make leaching practicable except by using large amounts of water".

But in the early 1970s, 54 private wells were dug for irrigation purposes (abstracting 2 MCM), in spite of the prohibition that was decided in 1971 to stop unlicensed digging. Unlicensed digging continued, the number of wells increased and reached 254 manual wells and 73 artesian wells in 1984 (abstraction amounted to 8 MCM).

The 4 springs progressively stopped feeding the oasis, and in 1992, the entire oasis dried out.

Table 1. Azraq water budget 2009, WAJ.

Type of Well	Total number of wells	Consump-tion (MCM)	Non working Wells	Working Wells
Legal agricultural well	304	6.3	59	245
Illegal agriculture well	561	13.2	325	236
Private governmental well	13	0.7	3	10
Governmental well for drinking water	20	16.9	4	16
Wells for herds in remote areas	11	?	5	11
Total	909	37.1	391	518

Table 2. Wells in North Badia (WAJ, 2009): only 51 wells abstract water from Azraq aquifer.

Type of Well	Total number of wells	Non Working Wells	Working Wells
Legal agricultural well	345	56	289
Illegal agriculture well	6	3	3
Private governmental well	11	-	11
Private agricultural wells with permits	5	-	5
Governmental well for drinking water	1	-	1
Wells for factories, universities, productive wells	26	-	26
Wells for construction, livestock or for other uses	13	-	13
Total	407	59	348

3.2. Consolidation of Water Management Policies

From 1962 until 1992, licenses were given by the government for drilled wells in Mafraq and Jiza regions. Two thirds of the licenses specified the maximum amount of water for abstraction (allowable abstracted amount); usually 50000 and 70000 m^3/y (and sometimes 100000 m^3/y after 1990). But faced with overall scarcity of water, the drawdown of aquifers and the decline of water quality, several measures were taken by the Government to decrease groundwater abstraction.

In 1992, the drilling of wells was frozen whereby no licenses were given to new wells.

In 1998, the Groundwater Management Policy was promulgated.

In 2002, the Ministry of Water and Irrigation (MWI) of Jordan issued Underground Water Control bylaw No. (85) to control private agricultural abstraction. This bylaw introduces a system of quotas combined with taxation of any use exceeding the quota. Although this bylaw is very generous in terms of the water quantities and tariff, it is considered the first real attempt to tackle the groundwater situation. Ground water Decree in the year 2002 allows for tariff exemptions (in all areas apart from Azraq) up to 150000 m^3/y. In Azraq every individual well has a so-called "specified quantity" that corresponds to approximately 250 m^3/du. Special tariffs are applied in Azraq. Illegal wells also have a different tariff and they pay from the first cubic meter.

In 2003, the Regulation No. (76) amended the Groundwater Control Regulation. It created a new category for wells with brackish water: the higher the salinity, the cheaper the water.

In 2004, the first bills corresponding to water consumption were sent to the farmers. No one paid.

In July 2009, WAJ distributed water bills (4.5 Million JD for 2003 - 2010) in the Azraq region but some farmers still refuse to pay their bills.

In February 2010, the Ministry of Interior Affairs gave the order to destroy all illegal farms (farms built on illegally acquired lands) which were younger than 2 years. They make up between 1'000 and 2'000 du. The selection of farms to close down was made by a committee comprised from Badia Police Armed Forces and representatives from the Ministry of Interior Affairs and the Department of Land and Survey.

In March 2010, WAJ redistributed water bills in the Al-Azraq region. Most of these bills were based on estimations (depending on the farm size and the kind of crops planted) because the wells had no meters.

In December 2010, a new Amendment to the Groundwater Control Regulation draft is issued by MWI and awaits approval from the Prime Minister Cabinet. It consisted of increasing water tariffs for drinking and agricultural water. It also included a fixed free quota of 50000 m^3 in Azraq.

Evolution of water tariffs for licensed[29] wells:

Quantity of water pumped	According to 2002 bylaw	According to 2004 amendment	According to 2010 amendment
0 - 50000 m^3	Free	Free	Free
50000 - 150000 m^3	Free	Free	0.010 JD/m^3
150000 - 200000 m^3	0.025 JD/m^3	0.005 JD/m^3	0.010 JD/m^3
more than 200000 m^3	0.06 JD/m^3	0.06 JD/m^3	0.10 JD/m^3

[29] *With former abstraction licenses*

Water prices for wells with abstraction permits:

Quantity of water pumped	According to 2004 amendment (as licensed wells)	According to 2010 draft Amendment
0 - 25000 m^3	Free	Free
25000 - 100000 m^3	Free	0.010 JD/m^3
100000 - 150000 m^3	Free	0.100 JD/m^3
150000 - 200000 m^3	0.005 JD/m^3	0.100 JD/m^3
more than 200000 m^3	0.060 JD/m^3	0.100 JD/m^3

Water prices for wells with no abstraction license or permit:

Quantity of water pumped	According to 2002 bylaw	According to 2010 draft amendment
0 - 100000 m^3	0.025 JD/m^3	0.050 JD/m^3
100000 - 150000 m^3	0.030 JD/m^3	0.070 JD/m^3
150000 - 200000 m^3	0.035 JD/m^3	0.100 JD/m^3
more than 200000 m^3	0.070 JD/m^3	0.100 JD/m^3

Water prices for brackish water wells:

Quantity of water pumped	Salinity according to 2002 bylaw	According to 2004 amendment	According to 2010 amendment
0 - 50000 m^3		free	free (1500 - 2000 ppm)
more than 50000 m^3	more than 1500 - 2000 ppm	-	0.015 JD/m^3
50000 - 150000 m^3	1500 - 2000 ppm	free	0.020 JD/m^3
	more than 2000 ppm	free	0.010 JD/m^3
more than 150000 m^3	1350- 1500ppm	0.015 JD/m^3	-
	1500 - 2000 ppm	0.010 JD/m^3	-
	more than 2000 ppm	0.005 JD/m^3	0.015 JD/m^3

Special case in Azraq: water prices for wells with abstraction permits:

Quantity of water pumped	2004 amendment	2010 draft amendment
0 – permitted quantity	Free	
0 - 50000 m^3		Free
permitted quantity-100000 m^3	0.020 JD/m^3	
50000 - 100000 m^3		0.020 JD/m^3
more than 100000 m^3	0.060 JD/m^3	0.100 JD/m^3

3.3. Limited awareness about water shortage within farmers and resistance of the water bylaw

Based on the interviews with farmers, it can be said that most farmers are not aware of groundwater depletion, or at least not relating the problems they are facing to the excessive use of water in agriculture. 35% of farmers consider there is absolutely no problem. Despite the Groundwater Control Bylaw No. 85 (2002) and its amendments about taxation of water used for agriculture, the legal instrument seems to be ineffective. Indeed, as long as no clearly defined procedures and means are deployed on the field to enforce the rules, the law does not offer sufficient control over water abstraction. Water fees seem to play no role in the cost calculations of the farmers. These fees are far below the other farm costs, especially energy and other inputs[30] (fertilisers, pesticides, etc.). This appeared clearly during our survey on the whole Azraq basin, as farmers, when asked about their water bill, they answered with the cost of their electricity bill, suggesting that water is not considered in costs calculations of the farm.

3.3.1. The challenging behavioural change in Azraq

In Azraq, 40% of farmers noticed a drop down of the water level of at least 1 to 3 m (the current average is -1 m/y); even some long time settled farmers could testify to a drop in the water level of around 20 meters (5 farms out of the 36 visited).

Salinity of abstracted water is rarely mentioned as a problem by farmers, even if analysis from WAJ in 2002 showed that most wells had saline water. 26 out of 36 wells have a salinity more than 1000 ppm, reaching up to 2150 ppm! Some of the farmers admit to water salinity in order to be able to distinguish their well as a brackish well used for agriculture, to which the lower tariffs being applied (according to Regulation No. 76 (2003)). Most wells in Azraq region could be included in the category of brackish water wells. Soil salination is much more often mentioned. Some farms have also seen the flow (m^3/hr) of their wells decrease and have difficulty in getting a drilling license for a new well since they refuse to pay their outstanding water bills.

Generally, as groundwater is still easily accessible in Azraq area (around 35 m deep), most farmers consider the water resource abundant ("it is like a sea down there" as some farmers mentioned, meaning the groundwater) and attribute the drying up of the Azraq wetland to the over abstraction of

[30] *Highland farm survey 2008 – internal report – water focal point – Department of Land and Irrigation (MOA).*

drinking water to Amman. They consider that the "special case for Azraq" (the clause in bylaw 85 that specifies a price for private agricultural wells within Azraq) in the water bylaw is unfair, and most refuse to pay their water bill: 12 out of the 36 surveyed farms have not paiyed their bills, most of which are large, recent farms. 5 farms did not provide information about their water bills, as the persons met during the interviews were the managers of the farms who are not responsible of paying the water bill, as bills are received by the owner. Among the 24 farmers who pay their water bill of the surveyed sample, there is a variability of the share of water costs out of global production costs of the farm: water accounts to 1 to 5% of the total production costs for 47% of the farmers; to 5 to 15% for 23% of the farms and, to 15 to 30% for 29% of farmers.

In addition to this, many farms contain illegal wells: there are 26 legal wells and 16 illegal wells within the surveyed farms. In the farms with illegal wells, the wells are not equipped with water metres to control water abstraction (even if most of them are numbered by WAJ); the bill is calculated based on the estimation of WAJ based on the cropped areas and the crop types. Some legal wells even are not equipped with water meters. Some farmers highlighted some inaccuracies in these estimations, as well as some inaccuracies in the procedure for land and well legalisation. For permitted wells, 250 m^3/du is not sufficient to sustain a farm, and all farms consume more than their free quota of water, except for 2 nearly abandoned farms.

Control over water abstraction has been quite limited in Azraq since the beginning of the development of agriculture, therefore it is now difficult for WAJ to apply the regulation and collect fees. Most farmers consider water to be a

Figure 4. Illegal well in Azraq: no meter is installed.

Figure 5. Meters installed on legal wells are used to calculate water consumption.

free resource, and argue that they already pay for energy, and that all water-related infrastructures are private investment (motor, pumps, drilling of the well(s), casing, connection to electricity when relevant), they should not pay for water over and above. But more than water fees, farmers worry over the price of energy. The share of energy costs out of the total production costs is always higher than that of water: 9 to 22% of total production costs are to be charged to energy for farms connected to electricity, and from 40 up to 82% for farms using diesel.

3.3.2. A more stable situation in North Badia and Jiza

In North Badia and Jiza, the situation is completely different. Nearly all wells are legal. In North Badia, most farmers consider that there is no specific water problem in their area, but are aware of the global water problem in Jordan. Only 3 farmers mentioned a water problem, as the water level dropped from 2 to 13 m in their wells. But the situation is much more worrying in Jiza, particularly Mwaqqar area. In Mwaqqar, the water table level has dramatically dropped in the last 10 years: water level dropped down by 35 meters since the founding of one of the farms visited (in 25 years), by 60 meters in another farm (in 20 years); another farm notices at present a drop of the water level in its well of 20 meters per year! The wells productivity also decreased for all wells in this area (only 25% of the initial flow for 5 wells). Some wells are therefore not sufficient anymore to irrigate the entire farm (mostly in Mwaqqar area) and farms are just kept surviving until the right price comes and the owners can sell the farms.

Since the year 2004, farmers have been receiving their water bills regularly: all surveyed farms paid their bills. Some farms do not receive any water bill as they consume less than the quota of 150000 m^3 (5 farms in Jiza, 2 farms in North Badia). Most of farmers try to reduce their water consumption; the reason being not to exceed the quota more than to limit water abstraction. Energy costs are always higher than water costs, even if all farms are connected to electricity, due to high extraction costs. For most of the farms, water costs are less than 10% of the total production cost, whereas energy represents on average 20 to 50% of the total production costs.

Some common dysfunctions to the whole basin regarding the application of the water law are listed below:

1. Some farmers have 2 wells on their farms: one well is legally registered in the WAJ official database as a working well, and water is billed to the farmer according to water meter readings for this well (or estimation of the consumption in some farms in Azraq). The second well is registered as non-working, but according to the field data, these wells are often used, at least

during the peak irrigation season (5 months in summer). However, no data about these "non-working wells" is registered by WAJ, and farmers are not billed for the extra water abstracted by these "non-working" but quite active wells.

2. For some farms, there is no consistency between the data registered in WAJ official database which is also used for billing and the water consumption that we calculated based on the data that we received from the field survey (irrigation schedule and flow of emitters, number of working hours of the well and flow delivered by the well...). The information in the WAJ database often underestimates the real consumption. This leads to the conclusion that tampering with the water meter is a common behaviour. This conclusion is further confirmed by the fact that water bill and electricity bill are not correlated, which indeed suggests an underestimation of the water extraction.

3. Some farmers are most probably tampering with the water meters on their farms, hence the full amount of water consumed is not accounted for. Indeed, the comparison between the water bills and electricity bills shows no correlation!

3.4. The spread of electricity as a source of energy

In our sample in North Badia and Jiza, all farms [31] are connected to the electric grid; in Azraq 20 farms are connected to electricity whereas 16 farms use diesel-powered pumps on the sample of farms surveyed. Indeed, farms that are still powered by diesel cannot be connected to the electric grid unless their well(s) are legalised, which is not legally possible unless land is legalised and all outstanding water bills are paid. Calculated extraction costs[32] are:

Area	Source of energy	Abstraction Costs
North Badia	Electricity	0.143 JD/m^3
Jiza area	Electricity	0.154 JD/m^3
Azraq	44% diesel + 56% electricity	0.104 JD/m^3
	Electricity	0.034 JD/m^3
	Diesel	0.175 JD/m^3

31 *Except one small remote farm in Jiza area.*
32 *According to field data (annual energy bill divided by annual volume of water abstracted).*

IV – Current agricultural setting in Azraq Basin

4.1. Three sub regions with specific cropping patterns

Most farms in Azraq basin are specialised farms: few farms combine field crops with animal husbandry (9.4%); most field crop farms are highly specialised trees or seasonal crops (62.5% tree farms, 28.1% seasonal crop farm)[33]. The predominant crop in the Highlands is olive trees (51%)[30].

According to data collected during our 59 field surveys, Azraq area, North Badia and Jiza area have specific cropping patterns[34]:

- In North Badia, stone fruits represent 44% of the planted area, with farmers mastering high technology and having good marketing know-how level. 32% of the land is planted with vegetables, mainly tomato, melon and water melon, and cabbage in winter in open field. Some vegetable farms are associated with an olive orchard or stone fruit orchard. Farms are scattered, mainly at short distances from villages. Vegetable farms are using the land only for a year, then rotating at a 5 year interval, as there is no pressure on land. Indeed, large superficies of land are not planted, and there is no competition between agricultural land and land for housing. It is easy for any investor to find a local land owner ready to rent out his land.

- In Jiza area, 54% of the land is planted with olive trees, but this area is highly specialised in intensive horticulture, specially cauliflower, mostly open field, with some greenhouses. Small farms tend to diversify with livestock (chicken or cows). Farms are scattered over the landscape, with horticultural farms closer to the Highway and tree farms further to the East.

- In Azraq, the dominant crop is definitively olive tree (75% of the planted area[35]). Some farms newly planted alfalfa as a cash crop, or diversify with grapes or other fruit trees. Vegetables cultivation has nearly stopped. Few farms are trying to get income by developing animal breeding. Farms are located around Al-Azraq depression (Qa'a), with new farms developing to the North and the East of the Qa'a, mostly along service roads.)

33 *Highland farm survey 2008 – internal report – water focal point – Department of Land and Irrigation (MOA).*
34 *According to data collected during our 59 interviews, which represents a total of 14,775 du planted.*
35 *According to data collected during our field interviews, considering the 36 farms visited in Azraq region.*

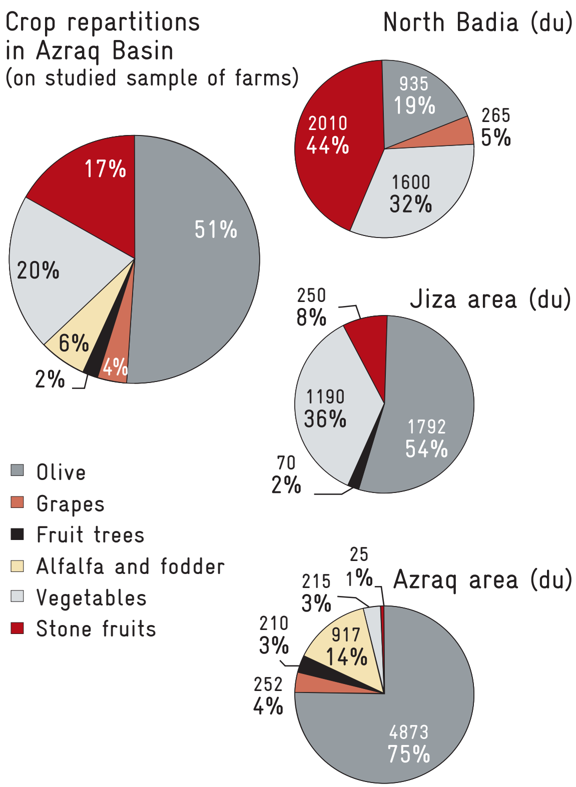
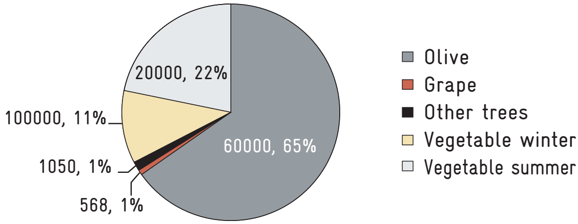


Figure 6: Repartition of irrigated crops in Azraq Basin according to the data collected during our 59 field surveys.

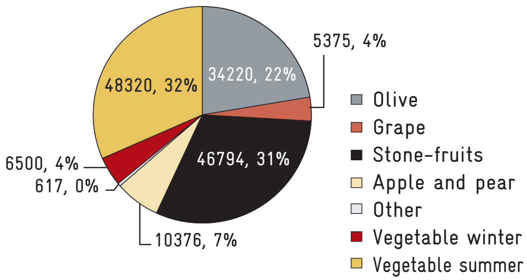
To test the representativeness of our sample, we can compare our data with the crop repartition according to the data of the Ministry of Agriculture[36] (MOA) (cf. Figure 7 below) and to the results of previous studies. It shows that our sample is quite compliant with the data of MoA; our random sampling allowed covering the diversity of farms on the Basin, and can therefore been considered as representative of the reality of cropping patterns and farms in the different sub region. However, in North Badia, our sample slightly overestimates stone fruits compared to vegetables; in Jiza, our sample is slightly under-representing olive trees plantation in favour of Stone fruits (stone fruits are not listed in MOA database in the first place); in Azraq, grapes are combined with fruit trees in the category Other fruit trees, and farms that are planted with alfalfa might be underestimated by MOA, as plantations are really recent and expand quickly.

[36] *This data cover the total area managed by each branch of MoA, which is more than the Azraq Basin in Jiza and North Badia governorates. Moa Annual Report 2008.*

Repartition of irrigated crops in Jiza
(Data MOA 2010 - in dunums)



Repartition of irrigated crops in North Badia
(Data MOA 2010 - in dunums)



Repartition of irrigated crops in Azraq
(Data MOA 2010 - in dunums)

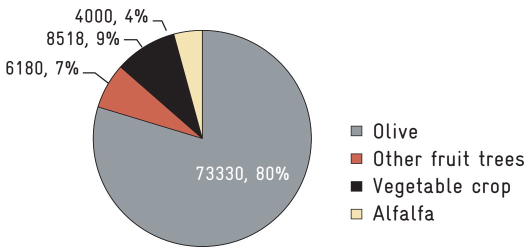


Figure 7. Repartition of irrigated crops according to MoA data 2010 in the three areas.

4.2. Repartition of irrigation systems

There is no detailed data about irrigation systems used in each farm available neither at MOA nor in WAJ, so we could not test the representativeness of our data by comparing it to another data source.

According to data collected in the surveyed farms, most farms adopted localised irrigation:

- in North Badia and Jiza, 100% of farms use localised irrigation. Irrigation systems used are quite homogeneous: GR (drip irrigation) on vegetables and some stone fruit trees, and virojet (micro sprinklers) on trees (olives and some stone fruits). Average efficiency of irrigation is estimated to be 67% in North Badia and 66% in Jiza area.

- in Azraq region, 92% of the planted area is irrigated with localised irrigation. 30% of the farms - mainly small farms of less than 50 du – still have part or the totality of the farm irrigated with furrow irrigation, but it concerns a limited area. Irrigation systems used in Azraq are much more diversified than in North Badia and Jiza: virojet, GR and open tube on olive trees, virojet on fruit trees (pomegranates, date palms and pears), GR on grapes and vegetables, sprinklers and central pivot on alfalfa, and surface on co planted farms[37].

[37] Cf Figure 5.

Average efficiency of irrigation is estimated to reach 63% in Azraq area[38].

The development of localised irrigation systems started in the 1980s and early 1990s when modern irrigation was introduced, starting in the Jordan Valley and then transferred to the Highlands during the "Super Green Revolution"[39]. "The Super Green Revolution" is a term developed by El Musa (1994) to describe the fast growth of agricultural sector based on the adoption of innovations such as localised irrigation systems in the 1980s. Modern irrigation was indeed quickly adopted in vegetables and stone fruit trees farms, but many olive orchards remained with surface irrigation until 2004, when the motive for switching to localised irrigation was triggered by WAJ distributing the first water bills.

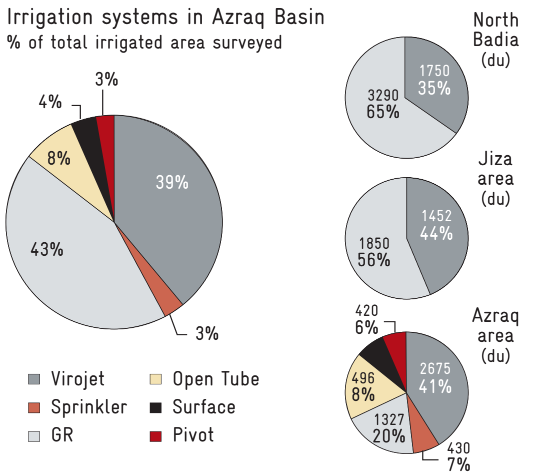


Figure 8. Repartition of irrigation systems in Azraq Basin according to the data collected in 59 field surveys.

Despite widespread use of localised irrigation, most farmers do not use the full potential of their modern irrigation techniques (with the exception of the stone fruits farms with high technology in North Badia). Efficiency of irrigation networks is not maximal; as design is not optimal (efficiency of irrigation application is very low). In addition, knowledge of workers on the farms about irrigation is limited: pressure and flow, as well as irrigation uniformity, are notions that are not mastered. Irrigation is monitored by eye (full basin under the tree, colour of the soil when it is wet...). Filtration systems are often in bad conditions (rusted screens filters), when not absent. For small farms, irrigation material is of poor quality, as they cannot afford buying high quality brands. There is indeed no agricultural extension, and farmers are willing to be better informed about good irrigation practices and conservation methods.

The choice of irrigation system is more the result of the influence of the neighbouring farmers than the result of an educated choice.

Figure 9. Olive tree irrigated with Open Tube: water application with this management is similar to surface irrigation.

38 *According to the percentage of the different irrigation systems and the assumed irrigation efficiency for each, as indicated p.4.*

39 *El Musa, 1994.*

4.3. Stratification of interviewed farms

In the survey sample, combinations of crops and trees, as well as main farms sizes differ between the 3 sub-regions:

North Badia	0 - 49 du	50 - 149 du	150 - 299 du	300 - 600 du	> 600 du
Olives				1	
Stone fruit trees		1		2	
Stone fruits + grapes+ olives				2	
Stone fruits (and olives or grapes) + Vegetables as cash crop				2	1
Vegetables			1	1	
Vegetables + diversification (stone fruit trees and/or olives)			1	2	

Jiza area	0 - 49 du	50 - 149 du	150 - 299 du	300 - 600 du	> 600 du
Olives		1		1	1
Olives + livestock	2				
Vegetables			1		
Vegetables + olives					1
Vegetables + olives + livestock					1
Stone fruits + grapes + olives				1	

In North Badia and Jiza, large farms are predominant, with most farms extending between 300 to 600 du in North Badia, and very large farms (> 600 du) in Jiza associating horticulture with olive, but also smaller farms (0 to 150 du) of olive trees, diversifying in livestock for the smaller (< 50du).

Azraq area	0 - 49 du	50 - 149 du	150 - 299 du	300 - 600 du	> 600 du
Olives	1	6	2		2
Olives + diversification with fruit trees (grapes and/or palm trees and/or pomegranates and/or other fruit trees)	8				
Olives + specialisation in grapes or pomegranates		2	1		
Olives (+ grapes or almond) + livestock		1	1	2	
Olives + alfalfa as cash crop (+ fruit trees and/or vegetables)		3	2	2	
Olives + fodder + livestock (+ fruit trees)		1		1	
Vegetables			1		

Farms are more diversified in Azraq, where the variation of their areas is higher. An additional category of small farms (< 50 du, mainly olive trees co-planted with date palms, pomegranates, and grapes) is represented. Most farms that are specialised in olive trees have an area of 50 to 150 du.

Alfalfa is planted as cash crop, as a plot in large and recent farms, or as an inter crop between olive trees in older and smaller farms.

V – Typology: description of farming systems

Thanks to long interviews with farm managers and owners, data could be collected and cross checked during the interviews, asking for the same data in different ways. However, validity and reliability of the data collected during our field interviews can still be questioned sometimes, as it is difficult to get accurate data from some farmers, especially regarding profit and water consumption. Nevertheless, as a result of the care taken to evaluate the accuracy of the data, the data collected can be considered to be close to reality.

Structural costs (depreciation reserve) have not been taken into consideration in the calculation of profit, since it was difficult to get relevant data about initial investments. Only production costs are considered here to evaluate profitability of the farms.

Some farms, considered as "special cases" in their type, have not been considered in the calculation of averages. An example of these "special cases" could be a farm where, because of an inheritance and waiting for a final compromise between heirs, is just kept in a surviving status, with minimal water consumption, hence no production and no income.

5.1. In Azraq region

Most people in Azraq started their farm attracted by cheap land and water, without real economical feasibility study for their project, nor environmental analysis (soil and water test), and no real knowledge about farming. Most farms have been profitable until beginning of 2000s, as labour wages were cheap (70 JD/month for an Egyptian worker compared to 180 JD/month today), energy was cheap (6 JD/barrel compared to 120 JD/barrel today), production inputs were cheap (fertilisers were subsidised by MOA[40]), whereas in parallel the price of olive oil did not increase according to inflation (around 50 JD/tanakeh during the last few years[41]). But today, 60% of farms make no profit (400 out of 700 farms[42]). Most farmers do not have a real accountancy; their objective is just to sustain the farm. Small farms are often run closely by the owner, while recent big investment farms are run by hired managers. Amongst these recent investment farms, half of the farmers that founded farms in Um Al Masael did not originate from a farming family and so do not have a long experience in farming, but still 90% have some knowledge about farming. The minimum area that a farm should be in order to sustain a household would be around 150 du[43] (considering a farm planted mainly with olive trees, with possible diversification to grapes or fruit trees).

[40] *The strategy of MoA in the 1980s – 1990s was to support the agricultural sector, through subsidising fertilisers, renting tractors at cheap price. Today, no more subsidies are provided to farmers, and support to agriculture does not seem to be a priority anymore, despite 2009 having been declared to be "Year of Agriculture" by the King.*

[41] *A tanakeh is equal to 16 kg of olive oil.*

[42] *According to one of the farmers' estimation.*

[43] *According to a farmer living from the revenue of his farm only.*

Land tenure in Azraq region

Lands in Azraq have been easily accessible through the tradition of "wa'd el jad", which is the Bedouin right to informally sell tribe-owned land. Tribes claimed hundreds of dunums in Azraq, and Sheikhs of these tribes in their turn sell this "tribe-acquired" land according to wa'd el jad by means of an informal piece of paper (Hijjah) to tribe members (or whom ever they wished for that matter). After some years (usually 10 years) of provable cultivation by the buyer (has to be trees, as vegetable cultivation – an annual or biannual culture at most - is not considered as a long term investment on the land), this person can go to the authorities and can have the property put in his name after paying the sale price set by the government as well as a "penalty".

Price of the land used to be around 15 to 20 JD/du (without a well) in 1970's, 40 to 50 JD/du in 1980-1990's, and is around 150 to 300 JD/du since 2000 in Azraq[44].

Three committees mandated with the task of legalising land have been created to study, for a limited period, the demands of land legalisation in 1988, 1996, 2010.

Many farmers originating from tribes still trade with land in an uncontrolled system of non registered land, and the problem of extension of illegal agricultural land is still not resolved.

[44] According to our survey.

5.1.1. Family farming

<table>
<tr><th>Farming system</th><th colspan="2">Small olive tree farms
Family farms + absentee owner and recreational farms</th></tr>
<tr><td>Average superficies</td><td colspan="2">Average size of the farm is 40 du (range: from 10 du to 85 du)</td></tr>
<tr><td>Picture</td><td colspan="2">
Co-Planted olive farm with surface irrigation in Al Ratami</td></tr>
<tr><td>History of farms and owner's origin</td><td colspan="2">These farms are old investments (from 1970 - 1980s), from original refugees, or from people who invested for their retirement, following the advice of a relative or friend that had already invested in Azraq. Most people are from Druze (Al-Ratami and Al-Aoshaq) or Chechen (in South Azraq) or Palestinian origin (farmers of Palestinian origin own the larger farms in this category), in Al-Aoshaq and Ain el Beda). South Azraq was first developed, followed by al Aoshaq and Dgheile in the 1970s, and Ain el Beda and Al Ratami in 1980s.</td></tr>
<tr><td>Ownership</td><td>The owner is the manager. The family lives on the farm.</td><td>Owner resides in another city in Jordan and checks on farm management by phone. Owner's family visits the farm on weekends, or during holidays.</td></tr>
<tr><td>Type of crops</td><td colspan="2">The main crop is olive, often co-planted with fruits trees (date palms, pomegranate, and grapes). Fruit trees production is used at home or as giveaways to relatives (including livestock sometimes). The only income is from olives.</td></tr>
<tr><td>Legal status</td><td colspan="2">Lands and wells are legal (land is owned by tabo – or legal contract), except in Al Ratami where MoA reclaimed some land as rangeland and refuse to legalise the farms planted on this land.</td></tr>
<tr><td>Use of water</td><td colspan="2">Type of wells:
Most farms had traditional wells (less than 10 m deep) until the 1980s, then they drilled artesian wells as abstraction of large water quantities for Amman started and had an impact on the water table level. Some farms in South Azraq and Al Ratami are still using manual[45] wells.

Awareness:
Farmers are aware of the water problem as they have been farming for a long time, and all of them noticed a big drop of the water table level and reduction of the flow delivered by the well.

Water bill:
Farms are equipped with water meters. Most farmers pay their water bills (75% of farmers pay). WAJ takes real water readings of the water meters. Water cost is the lowest production cost.</td></tr>
</table>

[45] *Manual well (manually dug wells) are also sometimes referred as traditional wells or Arabic wells*

<table>
<tr><td>Use of water</td><td colspan="5">Irrigation system:
Some farms are still with surface irrigation (1/2 of the farms have at least part of the land irrigated with surface irrigation): they know the advantages of localised irrigation but cannot invest in the irrigation material for the whole farm. Others adopted localised irrigation: they switched 5 years ago, when they received the first water bill, and when the price of energy increased (in some farms, trees are still suffering from the change).

Water consumption and irrigation practices:
Water consumption is on average 1160 m^3/du/y, with a distinction between localised irrigation (mostly open tube) using around 900 m^3/du/y with, and surface irrigation using around 1300 m^3/du/y. There is a high demand for technical extension, mostly concerning irrigation techniques, but also for some other techniques like pruning.

Most of the farmers are connected to electricity; but 1/3 of the visited farms is still using diesel pumps and cannot sustain nor invest in a generator. Energy costs represent an average of 19% of the production costs for farms connected to electricity, and 52% for farms using diesel.</td></tr>
<tr><td rowspan="2">Labour</td><td colspan="5">Labour cost is often the highest production cost on the farm. The production is either picked by seasonal workers, or sold on the trees (dhaman[46]).</td></tr>
<tr><td colspan="2">Family and one permanent Egyptian worker.</td><td colspan="3">Trusted Egyptian manager working for a long time on the farm.</td></tr>
<tr><td>Equipments and inputs</td><td colspan="5">Farms have minimal equipment, sometime an old tractor dating from the time the farm was first established, but some were relying on the tractor rented from MoA and are requesting today that MOA keeps providing this service. Managers try to limit expenses by using the minimum quantities of agri-inputs.</td></tr>
<tr><td rowspan="4">Repartition of production costs</td><td>Average costs = 170 JD/du</td><td>% water cost</td><td>% energy cost</td><td>% labour cost</td><td>% input cost</td></tr>
<tr><td>Average for all farms</td><td>8%</td><td>28%</td><td>39%</td><td>23%</td></tr>
<tr><td>working on diesel</td><td>3%</td><td>52%</td><td>28%</td><td>18%</td></tr>
<tr><td>working with electricity</td><td>10%</td><td>19%</td><td>46%</td><td>25%</td></tr>
<tr><td>Profitability [47]</td><td colspan="5">Farmers have a low investment capacity and ability to modernise. The first investment has been covered at the beginning, as farms have been profitable until the 2000s, but now farmers are losing money or can just break even.

Profit hardly reaches 100 JD/du, but most of the farmers are just sustaining or even losing money (on average profit is 9 JD/du). Some look forward to selling the land, whereas others are attached to their farms and do not consider it.</td></tr>
</table>

46 *Dhaman: traders come to visit an olive tree farm just before harvesting time, estimate the production of olives still on the trees, and propose a global price to the farm's owner to buy the production. If the owner accepts,the trader brings some worker, paid by him, who will harvest the fruits.*

47 *Some other references about annual return quoted from Economics Study for Water reuse for agriculture and/or forestry in the Amman Zarqa Highland. Final draft. Willis W. Shaner. MWI. USAid, ARD. November 2000 are given for comparison purposes. Net annual returns to fruit production = 225JD/du (once full production is reached), to combined summer and winter vegetables = 325JD/ du. Rq: according to Eng. Yassan Nazzal, 358 JD/du for grapes, 49 JD/du for olives.*

	The main income for the family often comes from the farm. Some owners receive a retirement pension or have a child sending money. The household sometimes lives below the poverty line[48]. For some families salt production is still a complementary income.	Income of the farm is not important for the owner, who has another source of income (e.g., a shop in Azraq, a small business like a transportation company…).
Remark	Some farms have been abandoned due to changes in water tariffs (in South Azraq); the future of some farms is threatened (Al Aoshaq, Ain El Beda) due to high price of diesel (but electricity is coming), the added cost of water, or because farm are affected by the water level drop. There is a growing problem of land division due to inheritance: some farm shares are abandoned when family members cannot reach an agreement, therefore land is progressively divided.	
Representativeness of our sample	15 out of the 36 surveyed farms in Azraq belong to this type (42%), which would mean that 250 farms in Azraq belong to this category. It is representative of the reality, as there are many small farms in South Azraq, Al Ratami, Al Aoshaq. In total, it would represent 11% of irrigated agricultural land in Azraq[49].	

5.1.2. Specialised Professional investors:

Most of these farms were created in the 1990s and planted with olive trees, some also planted fruit trees but were not successful: in the 2000s, some planted grapes to diversify; while only 3 years ago, some farms started to plant alfalfa. It is not combined with livestock. The oldest farms are in Al Aoshaq, few in Ain el Beda, while the more recent farms are in Um al Masael. Farms extend to the maximum area that can be irrigated by the well(s). Many farms still don't have legal land and/or well. Many are in the process of legalisation as a prerequisite to be connected to the electricity network. They are managed by a full time manager, mainly of Egyptian origin. Some have good technical knowledge.

[48] *Poverty is described as the percent of the population living on less than $2.15 a day at 1993 international prices (Development Data Group, The World Bank. 2002. World Development Indicators 2002).*

[49] *According to MoA (data 2010), the total cultivated land under irrigation in Azraq is 88,028du.*

Farming system	Professional farms – Specialised olive tree farm
Average area	High variability of farm sizes, ranging from 70 to 1000 du. On average 200 du.
Picture	 Olive trees irrigated by Open Tube in Al Aoshaq
History of farms	These farms were created in the time period from 1980 until 2000. They are spread in al Aoshaq, Ain el Beda, Al Alewat and Um al Masael.
Ownership	There is a close follow up of the farm by the owner who often visits his farm. It is managed by a full time manager of Egyptian origin or a relative of the owner's.
Type of crops	Olive trees
Legal status	Most have acquired the land by hijjah but then legalised their land.
Use of water	Irrigation systems and practices: Localised irrigation system (open tube or virojet) is used in all farms, but irrigation practices are not always scientific. Average water consumption is 905 m^3/du. Many of these farms are planted in very saline soil, so trees are also irrigated in winter to leach the soil. Water bill: Most of them do not pay their water bill (57%). Water is not even considered among farm costs. It is the minimal costs among production costs.
Source of energy	Half of the farms are connected to electricity and the other half are working with diesel pumps. Energy costs represent on average 27% of all production costs (37% for farms using diesel, 18% for farms connected to electricity).
Workers	Permanent Egyptian workers (1 for 100 du on average). Farm labour is the highest cost on the farm. Half of the farms (the oldest) supervise the harvest with their permanent labour and extra seasonal workers; the more recent farms sell the production as dhaman.
Equipments and inputs	Most farms are equipped with a tractor and accessories for spraying. The cost of inputs is relatively limited as olive are not subjected to many pests, but management on olive trees is relatively intensive, with fertigation and 2 [pesticide] sprays per year.

Repartition of production costs	Average costs = 145 JD/du	% water cost	% energy cost	% labour cost	% input cost
	Average for all farms	2%	27%	43%	28%
	working on diesel	0%	37%	35%	28%
	working with electricity	3%	18%	52%	27%
Profitability	On average, profit reaches only 20 JD/du. Two types of farms were observed in this farming system; the first type of farms is the productive type that is capable of making a profit of around 100 JD/du. The second type of farms are not fully productive and are in deficit of about 40 JD/du. These farms are either still immature trees (juvenile olive trees that have not reached their maturity hence peak production yet) or suffer from high salinity, leading them to drop their fruits before the fruits reach the mature stage[50], which greatly interferes with the profitability of the farm. 60% of owners have another income, but 40% live from the revenue from the farm.				
Remark	Most farms were planted in stages, as a progressive investment on land; extending planted area according to investment capacity.				
Representativeness of our sample	19% of the surveyed farms belong to this category (7 out of 36). It is estimated that this is representative of the farms in Azraq. It means that 114 farms from the total farms in Azraq belong to this category, covering 22800 du or 26% of the total irrigated area in Azraq.				

Farming system	Professional farms - Olive trees withdiversification to grapes or other fruit trees (pomegranate, almond…)
Average area	Average area is 240 du (range from 130 du to 300 du)
Picture	 Olive trees irrigated with subsurface irrigation network in Um Al Masael
History of farms	Farms have been planted in stages. Olive trees were planted first then grapes or pomegranates (or other fruit trees) were planted later on in the early 2000s to diversify the incomes of the farms.

[50] cf. Picture in Annex 4.

<table>
<tr><td>Ownership</td><td colspan="5">Often, owners are also the managers on the farm, living on the farm or in the city of Azraq, or spending at least some days of the week on the farm. They are the most professional of the farmer types in Azraq, and have good technical knowledge. They also follow closely the marketing of their products.

Most of them originate from the area and come from families who have always practiced farming.</td></tr>
<tr><td>Type of crops</td><td colspan="5">Fruit trees or grapes are planted as plots, no co-planting is observed. Grapes and pomegranates are more intensively grown than olive trees are.</td></tr>
<tr><td>Legal status</td><td colspan="5">Most of these farms have a legal well, but surprisingly[51], not all farms have legal land.</td></tr>
<tr><td>Use of water</td><td colspan="5">Irrigation systems and practices:
It is in these farms that examples of water-saving initiative can be seen. For olives, sub-surface irrigation systems are installed, saving up to 2/3 of water compared to traditional localised irrigated olives. Mainlines are buried, and the trees are irrigated by open tube or virojet. In the case of grapes, GR is often used.
The average water consumption is 390 m^3/du/yr. This is most probably underestimated, as it is less than the theoretical water requirement of olive trees[52].

Awareness and water bill:
Farmers are aware of the water resource limitation.
60% of farmers pay their water bill.</td></tr>
<tr><td>Source of energy</td><td colspan="5">40% are still working with diesel pumps (energy accounts for 47% of production costs when using diesel, 22% when using electricity), but are trying to get connection to electricity. The rest are connected to electricity.</td></tr>
<tr><td>Equipments and inputs</td><td colspan="5">These farms are well equipped with farm machinery and equipment (tractors, sprayers…); some even have refrigerated trucks to send produce (grapes) to the Amman Central Market. As there is good technical management, the price of agro-inputs is limited to 12% of total production costs on average.</td></tr>
<tr><td>Workers</td><td colspan="5">2 to 3 permanent employees or family members work on the farm.
The harvest of olives is done by seasonal workers hired and supervised by the manager (not dhaman).</td></tr>
<tr><td rowspan="2">Repartition of production costs</td><td>Average costs = 145 JD/du</td><td>% water cost</td><td>% energy cost</td><td>% labour cost</td><td>% input cost</td></tr>
<tr><td>Average for all farms</td><td>11%</td><td>34%</td><td>49%</td><td>12%</td></tr>
<tr><td>Profitability</td><td colspan="5">With good management, profit can be relatively high when farms are fully productive (130 JD/du/yr on average).
Some farms have developed strategies (through projects) to get a higher added value from their production. One farms was Global Gap certified, and another was organic farming certified.
On our sample, 60% of owners have another income apart from the farm.</td></tr>
<tr><td>Remarks</td><td colspan="5">Some farms changed the crop varieties or abandoned part of their fruit trees as it needs too much water.</td></tr>
<tr><td>Representativeness of our sample</td><td colspan="5">14% of the surveyed farms in Azraq belong to this type (5 out of the 36), which would mean that 84 farms in Azraq belong to this category. We think it is representative of the reality. In total, it would represent 20000 du, namely 23% of irrigated agricultural land in Azraq.</td></tr>
</table>

51 *Having a legal land is a legal condition to legalise the farm’s well.*
52 *Water requirements for olive trees are estimated to be around 700m^3/dunum/year according to Irrigated agriculture, water pricing and water savings in lower Jordan River Basin, JP Venot, 2007.*

Farming system	Professional farms. Olive tree + alfalfa (+ fruit trees)
Average area	Average size of the farm 270 du (from 100 to 440 du)
Picture	 Alfalfa is planted as a cash crop in many farms
History of farms	These farms are recent investments. They were started after 1995, in Um Al Masael mostly. Trees were planted first (olive trees, sometimes fruit trees), but as farms were not profitable, some started to diversify in beginning 2000s (with grapes, other fruit trees..) and finally adopted alfalfa in 2009-2010 as a cash crops, to cover the monthly costs of the farms until the rest of the farm is fully productive. Many farmers just follow the practices of their neighbours.
Ownership	Most of the owners originate from Amman, and started farming in Azraq as an investment, without having real technical knowledge about farming.
Type of crops	Olives, some fruit trees or grapes not yet productive, alfalfa.
Legal status	Most farms have neither legal land nor legal wells. The main motivation behind legalising their lands is to be able to connect to the electric network.
Use of water	Wells, irrigation systems and practices: Most of these farms have more than one well (2 to 4). All farms are big water consumers (on average 1040 m^3/du/y), since water requirements are high for alfalfa (around 1600 m^3/du/y). Alfalfa is irrigated with sprinklers, or with central pivot systems for larger areas (with a current trend to be extended). Awareness and water bill: Some do not pay their water bill (37% of the sample from this type of farms) but as most farms are in a process of legalisation with the goal to be connected to electricty, they care about paying their bills. Indeed, they can not be connected to electricity unless all water bills are paid. Water consumption is estimated by WAJ, as the wells have no meters. Farmers do not care about water scarcity, arguing that water problem is due to withdrawing water to Amman.
Source of energy	Cost of energy is huge for farms working on diesel (around 71% of total production costs) and farmers are urging to connect to electricity.

Equipments and inputs	Most farms are well equipped, with even specific accessories for alfalfa. Some have invested in central pivot irrigation systems for alfalfa.				
Workers	At least 2 permanent workers on the farm + daily workers hired for each cut of alfalfa.				
Repartition of production costs	Average costs = 240 JD/du	% water cost	% energy cost	% labour cost	% input cost
	Average for all farms	4%	47%	25%	25%
	working on diesel	1%	71%	15%	13%
	working with electricity	4%	53%	15%	28%
	High production costs are due to very high cost of pumping of large quantities of water using diesel pumps and high use of agro-inputs used on alfalfa.				
Profitability	Economical results are very different from farm to farm. Most of these farms are generally in deficit. However, they make profit from alfalfa, they harvest up to 10 cuts per year and make around 60 JD/du per cut (production costs not deducted). A successful farm earns around 85 JD/du/year considering all crops on the whole farm (as income, production costs not deducted). All owners are entrepreneurs and have other investments in other sectors.				
Remarks	According to bibliography, the yield of alfalfa in Azraq is very low (1/3 of maximal yield, which is around 6 tons of dry alfalfa/du/yr according to one of the farmers), might be due to very high water salinity.				
Representativeness of our sample	22% of the surveyed farms in Azraq belong to this type (8 of the 36), which would mean 133 farms in Azraq belong to this category. We think this type slightly over estimates the reality[53]. Indeed, with this proportion, it would represent in total 36000 du, or 40% of the irrigated agricultural land in Azraq.				

Our sample underestimates the number of farms that specialise in vegetable[54]. Indeed, we visited only 1 farm planted with vegetables. Most vegetable farms in Azraq are planting for early production in March or April, under mini tunnels. They plant only one rotation each year, and the farms were not planted during the period of the interviews.

Farms types and their main characteristics in Azraq are summarised in the table below:

Production systems	Average size	% of nb of Azraq farms	% Total irrigated area in Azraq	Average water consumption	Average yearly profit
Small olive tree farms (with fruit tree intercropping)	40 du	42 %	11 %	1160 m^3/du/y -Surf: 1300 m^3 - OT: 900 m^3	9 JD/du/y
Professional olive tree farms	200 du	19 %	25 %	905 m^3/du/y	20 JD/du/y 100 if productive
Professional olive tree farms with diversification (grapes, pomegranate...)	240 du	14 %	22 %	390 m^3/du/y	130 JD/du/y
Olive tree farms with diversification to alfalfa	270 du	22 %	39 %	1040 m^3/du/y	variable 85 JD/du/y
Vegetable farms	170 du	3 %	3 %	1400 m^3/du/y	Not enough data

53 According to MoA data in Azraq (2010), only 4% of the irrigated area is planted with alfalfa.
54 MoA in Azraq (data 2010) estimates that area planted with vegetables represent 9% of total irrigated area.

5.2. In North Badia and Jiza

In North Badia, there is not much land pressure, so vegetable farms change their plots every year, to avoid salinizations of soils and contaminations (by fungi or nematodes) and never return to the same land before 5 years. So farms have their own well, or rent a well. Land is always rented for vegetable production (the owner of the well being often different than the owner of the land), but most of the time, land is owned for tree farms. Indeed, investment on vegetables is 1 year, on stone fruit trees it is on a longer term (on average 15 years).

Farming system	Stone fruit trees entrepreneurs
Average superficies	Farm area is on average 320 du (from 140 du to 440 du)
Pictures	 Peach trees in a farm in North Badia
History of farms	These farms have been created by investors. The land and well are the property of the owner, or rented for a 15 year contract.
Ownership	Owners are managing many projects, other stone fruits farms in North Badia, or vegetable farms in the Jordan Valley or in Jiza. The farm is managed by an engineer, and the owner is involved in the marketing of products.
Type of crops	Stone fruit trees: nectarine, peach and apricot. For some farms, the strategy is to diversify with early, mid season and late varieties; for others, they try to cover the more profitable market opportunities, with early varieties only.
Legal status	Land and well are legal
Use of water [55]	Reasonable, as they want to minimise the energy bill. In addition to the manager, there is often an engineer dedicated to irrigation, or the manager has very good technical knowledge about the water requirements of the trees. Cost of water is less than 10% of the production costs. Average water consumption is 1295 m^3/du/y. Two lines of GR for each row of trees is the most common irrigation system.
Source of energy	All farms are connected to electricity. Energy costs represent around 15% of the total production costs.
Equipments and inputs	All equipments are available on the farm: modern tractor and sprayers, sorting and grading facilities, trucks to transport the fruits to Amman.

[55] *Economics Study for Water reuse for agriculture and/or forestry in the Amman Zarqa Highland. Final draft. Willis W. Shaner. MWI USAid, ARD. November 2000 gives the following reference: Water requirement for fruit trees 1500m3/du/year, and for vegetable 500m3/du/season*

<table>
<tr><td>Workers</td><td colspan="5">Management by a Jordanian engineer, Egyptian permanent workers (responsible for irrigation, treatment of trees, pruning), local seasonal workers for harvest (mostly local women). Work represents around 55% of the production costs.</td></tr>
<tr><td rowspan="2">Repartition of production costs</td><td>Average costs = 635 JD/du</td><td>% water cost</td><td>% energy cost</td><td>% labour cost</td><td>% input cost</td></tr>
<tr><td>Average for all farms</td><td>8%</td><td>16%</td><td>55%</td><td>20%</td></tr>
<tr><td>Profitability</td><td colspan="5">Investment on the farm is very high at the beginning (trees imported from France, metallic structure for fruit trees, equipments...). For example, a new farm of 150 du planted in 2010 costs 1000000 JD: 700000 JD for buying the land and the well and 300000 JD for the plantation and infrastructure. But the investment can be recovered starting from the second year, and profitability is high from the 4th year when trees are fully productive.
These farms are very profitable, and profit can reach more than 1000 JD/du/y.
Most investors have a second income from another sector or other agricultural projects elsewhere in the country.</td></tr>
<tr><td>Remarks</td><td colspan="5">Most of the fruits are exported to the Arab Gulf countries or on a local high added value market, like main malls in Amman. The European market is difficult to access. Some farms are Global Gap certified.</td></tr>
<tr><td>Representativeness of our sample</td><td colspan="5">This type is only represented in North Badia, not in Jiza. 3 farms out of the 14 interviewed in Mafraq are in this category. It might be over-representing the number of farms (18%), but not the superficies, as the visited farms had quite limited area extension compared to other stone fruits entrepreneurs.</td></tr>
</table>

<table>
<tr><th>Farming system</th><th colspan="2">Mixed family farms – vegetables and trees</th></tr>
<tr><td>Average superficy</td><td colspan="2">240 du stone fruits or olives (on land owned) and 180 du vegetables (on rented land)</td></tr>
<tr><td>Pictures</td><td>
Tomatoes in open field on rented land</td><td>
Stone fruits planted on owned land</td></tr>
<tr><td>History of farms</td><td colspan="2">Most of the owners are settled Bedouins. They used to have livestock, sold part of the herd to invest in cultivating vegetables, buying a well and renting land in the 1980s or at the beginning of the 1990s, sometimes planting a small plot of olive trees close to the well.
In North Badia, they are now progressively converting to stone fruits as the market for vegetables is too fluctuant and stone fruits require less work. In order to invest in stone fruits, they often plant vegetables intercropped between the new trees on the first year.
In Jiza, there are no stone fruit trees but only olive trees.
Most of them still get a significant part of the revenue from growing vegetables, which allows them to cover the costs of the immature trees.</td></tr>
</table>

<table>
<tr><td>Ownership</td><td colspan="5">Owners originate from North Badia. They often manage the farm, or entrust its management to a member of their family.</td></tr>
<tr><td>Type of crops</td><td colspan="5">Vegetables in open field: tomatoes, water melon or melon, cabbage or cauliflower are the predominant vegetables grown. Mostly stone fruits (peach and nectarine) on the owned land, sometimes olive trees or grapes.</td></tr>
<tr><td>Legal status</td><td colspan="5">Land and well are legal</td></tr>
<tr><td>Use of water</td><td colspan="5">Most of them are not aware of the water problem, even if the farm extension is often limited by the capacity of the well. They are big water users (around 1315 m^3/du/year). The same well is used to irrigate vegetables and trees in North Badia, but farms are using two wells in Jiza (average area is higher). They pay their water bills.

GR is used on vegetables, Virojet is used on trees.</td></tr>
<tr><td>Source of energy</td><td colspan="5">Electricity</td></tr>
<tr><td>Equipments and inputs</td><td colspan="5">Well equipped, might be with second hand equipment. No hangar for sorting and grading (often in project).</td></tr>
<tr><td>Workers</td><td colspan="5">Management by the family. Egyptian permanent workers on trees and vegetables. Often Syrian seasonal workers for harvest on vegetables, local women for harvest on trees.</td></tr>
<tr><td rowspan="2">Repartition of production costs</td><td>Average costs = 300 JD/du</td><td>% water cost</td><td>% energy cost</td><td>% labour cost</td><td>% input cost</td></tr>
<tr><td>Average for all farms</td><td>8%</td><td>36%</td><td>18%</td><td>28%</td></tr>
<tr><td>Profitability</td><td colspan="5">The cost for infrastructure is high but less than entrepreneur type farms. Less profitable than entrepreneurial farms, profit is still good for this type of farm (460 JD/du/year), but risky, as market for vegetables is very fluctuant.
For many farmers, it is the main source of income (even if they have a second activity as teacher, driver...).</td></tr>
<tr><td>Remarks</td><td colspan="5">Consequent to the problem of tomato in summer 2010, some farmers are thinking to invest in greenhouses in order to better control pests. The general trend is extension of stone fruit trees plantation and reduction of vegetable planted areas.</td></tr>
<tr><td>Representativeness of our sample</td><td colspan="5">9 out the 14 surveyed farms in North Badia (64%) and 2 out of the 9 in Jiza (22%). We think is a good estimation in North Badia. It can be highlighted that this type of farms tends to be more and more important, as many farmers that used to be pure vegetable farmers tend to convert step by step to fruit trees.</td></tr>
</table>

Farming system	Open field Vegetable farms
Average superficy	160 dunum on average (range from 140 to 200 du).
Origin	 Vegetables open field (cabbage) in North Badia on rented land
History of farms	When Bedouins settled in the 1980s and the 1990s, they invested in open field vegetable farms.
Ownership	Land and well are rented by a farm manager, sharing profit with the well owner, or paying a fixed amount to the well owner.
Type of crops	Summer: Tomato, melon, water melon and lettuce. Winter: Late tomato, cabbage, cauliflower.
Legal status	Legal land and well – often different owners
Use of water	The water bill is paid by the owner, so the only concern of the manager is to limit the water abstraction to limit his electricity bill (electricity bill is paid by wells owner – the manager). Average water consumption is 1600 m^3/du/y. Vegetables are a bit over-irrigated as farmers are intimidated by any water stress that would affect the production, as well as to prevent salinity problems.
Source of energy	Electricity
Equipments and inputs	The manager provides the necessary equipment.
Workers	Mostly from Syrian origin for harvest (for 7 months, around 50 workers), and sometimes permanent Egyptians workers.
Profitability	On average, 370 JD/du
Remarks	In Jiza, these farms tend to diversify with vegetables production under greenhouses. This idea is also developing in North Badia, together with a switch to tree farming.
Representativeness of our sample	With only one surveyed farm of this type in North Badia, and another interviewed one of this type in Jiza, we are sure that this type is under-represented in the survey sample.

Farming system	Large olive tree farms
Average superficy	400 on average (from 100 to 640 du)
Picture	  On his olive tree farm in Mwaqqar area, a farmer built 2 water-harvesting dams to save water
History of farms	Investors from Amman bought land in 1985 to 1995, when land was cheap, in Jiza and North Badia, partly for investment and partly to have a hobby farm. Some owners use their farm as a prestige farm to invite guests.
Ownership	Owners are mostly from Amman, from Palestinian origin.
Type of crops	Olives
Legal status	Well and land are legal.
Use of water	All farmers have noted a reduction in groundwater level. It is especially in Muaqqar area that the drop of the water table (water level and flow (m^3/hr) delivered by the wells) is severe: wells are not sufficient any more to irrigate the farm. It has also to be noted that in this area, there used to be more precipitation, so irrigation was just complementary. A farmer in Muaqqar built a water harvesting system to save water and does not need to pump from his well from March to June (average consumption from the well is therefore only 400 m^3/du/y). Water consumption is on average 570 m^3/du/y for this category. It includes farms that have a water abstraction limited by the low flow delivered by their wells, and farms which wells deliver a high flow (and consume therefore more water, on average 800 m^3/du/y).
Source of energy	Electricity
Equipments and inputs	Farms are fully equipped with tractors and accessories.
Workers	2 to 8 permanent Egyptian workers and extra seasonal labour are hired for the harvest (the production is not sold as dhaman) every year. The management is delegated to a permanent worker on the farm (Egyptian, Sudanese).

Repartition of production costs	Average costs = 130 JD/du	% water cost	% energy cost	% labour cost	% input cost
	Average for all farms	2%	30%	44%	24%
Profitability	Average profit is 60 JD/du, but with a high variability between farms (negative for farms with water problems, 175 JD/du/y for the others). All owners have another source of income; some have other more profitable farm(s).				
Remarks	Farmers who experienced the gradual drying up of their wells tried unsuccessfully to drill new wells. Today, it seems that they keep the trees alive only for the hope of being able to sell the farm (Muaqqar will soon be considered among the suburbs of Amman).				
Representativeness of our sample	1 out of the 14 surveyed farms in North Badia, 4 out of the farms surveyed in Jiza. This is representative of the reality, olive farms are not popular in North Badia.				

Farming system	Small olive tree farm with diversification with livestock (chicken, cow, sheep)
Average superficy	10 du
Picture	 These olive trees are 15 years old but are still very small as they suffer from a deficit in irrigation – Mwaqqar area, no well on the farm
History of farms	These farms have been bought in 1995s either by people from Amman to have a complementary income together with a hobby farm, or by bedouins who wanted to settle. Bedouins kept their herd of sheep and goat and planted a small orchard of olive trees; people from Amman planted olive trees, but realising it was not profitable (cf. water cost) they started cow or chicken farming.
Ownership	Most of the owners hired a permanent worker who is also the farm manager. For Bedouins, the family is living on the farm and managing it.
Type of crops	Olives
Legal status	Land is legal. There is no well on the land.

Use of water	As there is no well on the land, water is bought from neighboring farms for 0.7 JD/m³. As water is very expensive, consumption is reduced to the minimum (180 m³/du/y) and just allows olive trees to give little olives used mostly by the family. Water accounts for more than 50% of production costs.
Energy	Diesel
Equipments and inputs	Equipment is minimum, work is done manually, and there is no tractor on the farm. Farmers minimize the use of inputs to reduce production costs.
Workers	Only one permanent worker, or the family.
Profitability	Not profitable.
Remarks	These farms have suffered from the high increase in water price as they buy from private wells, and most of these farms are now not profitable, even after diversifying. Many farms are now being abandoned.
Representativeness of our sample	No farm of this type is found in North Badia. 2 out of the 9 surveyed farms in Jiza belong to this category. Our sample is greatly under representing this type of farms, but we were confirmed the same model applies for all similar farms.

This typology of farming systems can be used to distinguish the impact of the governmental policy on different types of farms and to assess what could be the farmers' adaptive responses in each case.

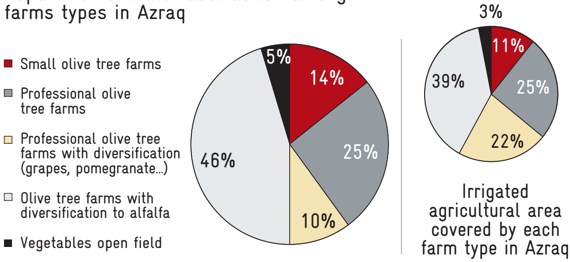
Farm types and their main characteristics in North Badia and Jiza are summarised in the table below:

Farm types	Average Farm Size	% of farms	% Total surveyed area	Average Water Consumption	Average Yearly Profit
Stone fruit tree entrepreneurs	320 du	13 %	12 %	1295 m³/du/y	1000 JD/du/y
Family mixed farms vegetables and trees	240 du owned +180 du rented	48 %	58 %	1315 m³/du/y	460 JD/du/y
Open field vegetable farms	160 du	8 %	4 %	1600 m³/du/y	370 JD/du/y
Large olive tree farms	400 du	22 %	25 %	570 m³/du/y	60 JD/du/y
Small olive tree farms with livestock	10 du	9 %	1 %	180 m³/du/y	No profit

5.3. Repartition of water abstraction by farm typology

In Azraq, based on the estimated total area for each farm type and the average consumption by dunum, the following results have been found:

Repartition of water abstraction among farms types in Azraq

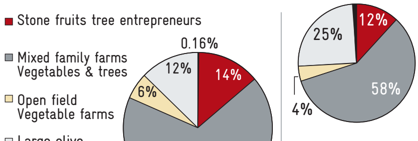


Irrigated agricultural area covered by each farm type in Azraq

These graphs show that some types of farms, especially olive trees farms with alfalfa and professional olive farms, are the main water consumers in Azraq (71% of the abstracted water) even if they represent only 41% of the farms. It should be reminded that it is mainly in these categories that farmers do not pay their water bills. In addition, most farms of the type olive trees with alfalfa are still working with diesel pumps, they are in a way trying to limit their water abstraction to limit the energy bill. Once they are connected to electricity, their pumping costs will drastically be reduced and we fear a high increase in their water abstraction. Highlighted here is the efficiency of water use of professional farms with diversification to fruits, which represent 22% of the irrigated cultivated land but consume only 10% of the abstraction water. It should also be noticed that juvenile olive tree farms, which represent 42% of the farms in Azraq, abstract only 14% of the water in Azraq.

In North Badia and Jiza, the same graphs show the following:

Repartition of water abstraction among farms type in North Badia / Jiza



Irrigated agricultural area covered by each farms type in North Badia and Jiza

Mixed family farms of vegetables and trees are large water consumers, consuming 68% of the total abstracted water while covering 58% of the irrigated agricultural area. In comparison, large olive tree farms achieve more water savings; using 12% of the abstracted water while covering 25% of the area. It can be explained based on the fact that the irrigation water requirement of vegetables and fruit trees are higher than they are for olive trees, and that farmers are often over irrigating their vegetables to overcome the salinisation of soils.

5.4. Evolution trends for farms and irrigation in the current context

Market factors, climatic factors and water availability have a direct impact on strategic planning for farms (when there is one) and on farming practices, so some evolution trends for farms sustainability and irrigation can be expected in the near future.

In Azraq, many farmers are converting to alfalfa at a worrying pace, which could threaten even more the water resource in Azraq if no measure is taken rapidly. We remind here that alfalfa growing using irrigation systems such as sprinklers and central pivot which typically have high water consumption.

Most farmers from the small olive tree farms have financial difficulties as there is very low or no profit at all, which is not enough to sustain their families. Some are deeply indebted, they would accept to sell their lands and wells if they get an interesting offer, but have no other alternative than continue farming at the time being. On the long term, these families would not have any regular income if they leave the farm, as it is their only source of income, and might depend in the future only on governmental support, or even migrate to the cities (Amman, Irbid) to find a job.

Other farms like the professional olive tree farms are not quite profitable and are even sometimes in deficit, but are still planning to continue farming since they do not want to lose the investment they made on the farm and think that the market could be more attractive a few years later. However, even if they do not mention it clearly, they might be interested in selling their land and well if there is an opportunity, as the income from the farm is not essential for them.

In North Badia and Jiza, farmers are more reactive. There is a wide spread trend to switch from vegetables to stone fruits, since the market is risky for vegetables. Some investors who did not come from farming backgrounds tried vegetable farming and abandoned it after just a year because they were not successful. Another trend that could appear next year is the start of greenhouses in North Badia and their expansion in Jiza.

As entrepreneurs of stone fruit tree farms are successful, these entrepreneurs tend to increase their orchards, some by adopting more water efficient techniques and more intensive plantations.

VI – Expected impact of water management changes

As noted by Venot in 2007[56], as a result of little government involvement in the highlands, the lack of enforcement of several limits on abstraction from private wells created a pattern of farmers who ignore the legal boundaries. Even if today most farmers are aware of rules and limits, there are powerful interest groups that are resistant to change. In the highlands where water quality remains high compared to the Jordan Valley, reducing support for irrigation is difficult due to extensive political ties between the farmers and the government. Farming in the highlands has been and still is quite profitable for some investors. These investors want to continue to make profits by irrigating with groundwater. At the same time, the Government is trying through successive laws and bylaws to limit and regulate abstraction of water for agriculture.

6.1. Present cost effectiveness of water use

According to this survey, it appears that on average:

- Most olive trees are irrigated according to their full agronomic requirements[57],

- Stone fruits are irrigated according to their water needs, and

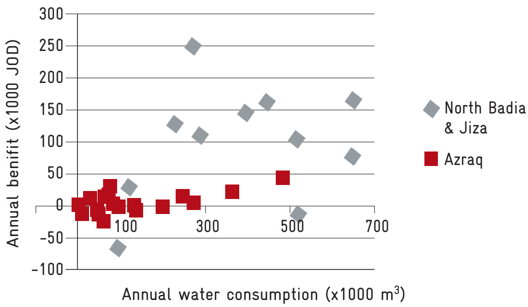
- Vegetables are over-irrigated[58].

Cost effectiveness of water use differs within the Azraq Basin; the general trend being a more cost-effective use of water in North Badia and Jiza than in Azraq area. But no clear trend can be identified from the following graph. It means that in the future, if any project should be based on current water effectiveness, each farm should be studied independently.

56 *JP Venot and all; Irrigated Agriculture, Water Pricing and Water Savings in the Lower Jordan River Basin (in Jordan (2007)*
57 *It contradicts JP Venot (2008) and Hanson (2000) who wrote that only 56% of olive orchard water requirements are met, showing that profit maximization is not the strategy on olive orchards for many farmers.*
58 *Also noted by Fitch (2001), who evaluated the vegetable farmers abstract nearly 160% of the net crop requirements*

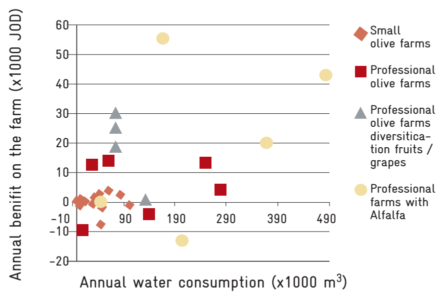
The following graphs show the benefit according to the total water consumption on the farms. Only farms with a complete set of data (consumption and benefit) could be represented, and farms deviating too much from the norm were removed. The trend was then identified per

Water effectiveness in Azraq Basin



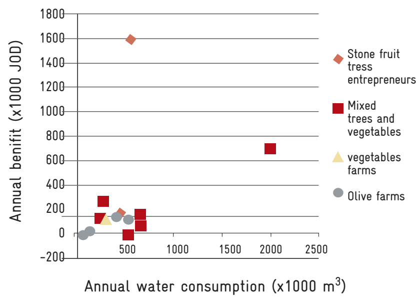
farming system in the different regions. In Azraq, there is a clear trend for the "small olive tree farms" type where Profit = 0.005*water consumption (R^2=2.10^{e-5}), which signifies a very low water effectiveness. For "Professional olive tree farms" type, Profit = 0.03*water consumption (R^2=0.007), which indicates that water effectiveness is higher than that for the previous type. For "Professional olive tree farms with diversification" and "Professional farms with alfalfa" types, no trend could be identified. Variability between farms is too high (respectively, R^2 = 0.92 and R^2 = 0.15).

Water effectiveness in Azraq



In North Badia and Jiza, the variability between farms of the same type is high, and the sample more limited, so no trend could be identified for any type.

Water effectiveness in North Badia & Jiza



By improving on farm efficiency, it would be possible to decrease the amount of water pumped. However, olive tree farms are unlikely to reduce their water consumption. Indeed, many orchards in Azraq are planted on saline soils, therefore trees are also irrigated in winter (monthly water quantity used being approximately 1/2 of monthly quantities used in summer) to leach soils and keep salinity away from the tree roots. This water has null cost-effectiveness!

6.2. Potential impact of increase of water tariffs

As there is no real awareness of the water problem among farmers, the main effective argument to intice farmers to save water is economical gain. Indeed, most farmers will be motivated for any change only if they foresee in this change a possible reduction of their water or energy bill.

We have seen during our interviews that the initial bylaw (85) in 2002 had an impact on reducing water abstraction for existing farms. Indeed, when farmers in Azraq received their first water bill in 2004, many of the farmers who were still using surface irrigation invested in the optimisation of their irrigation systems, switching partly or fully to localised irrigation (mostly to open tube). In North Badia and Jiza, most farmers were already using localised irrigation, as pumping costs are high, and some tried to reduce their consumption in order to remain within the free quota of 150000 m^3/y.

As described before, the water cost (for farms which are paying their water bill) is low compared to all other costs on the farm, with variability among farm types. In Jiza and North Badia, the water consumption per dunum is high, but there is a good profitability of this water, so even with a price increase of water, farmers might continue with the same practices. For example, the new bylaw Amendment of 2010, for entrepreneurial stone fruits trees farms, will see their water bill increase by around 80%, but will have a decrease of their profit of only 3.5%. For mixed farms vegetables and fruits, it is difficult to estimate since many farmers are tampering with their water meter, so we can not anticipate their reaction, but it could be that their water bill increases by 80%, which would decrease their profit by 2.5%.

In Azraq, the situation is different. Small olive tree farms will benefit from the new bylaw, as they will get 50000 m^3/y for free, which is the average consumption of this type of farm, so the water bills of many farms will be zero (average bill is around 600 JD/y) so their profit will increase from 9 to 24 JD/du/y. On professional olive farms with diversification with fruit trees, irrigation practices have already been optimized and farmers are on average consuming less than 100000 m^3, so their water bill will remain the same. It is to be highlighted that the bigger water consumers in Azraq, meaning the new "farms that partly grow alfalfa" and the "professional olive trees farms", are not paying their water bills[59]. So any increase in water price will not have any impact

[59] Percentages of farms not paying their water bills, accordind to farms categories are: 50% of farms partly planting alfalfa, 15% of small olive tree farms, 57% of professional olive tree farms, 40% of professional olive tree farms with diversification

on them, unless there is a real effort for effectively implementing the existing bylaw. A campaign of water meter installation in all farms (even on illegal wells) and water meter maintenance (some farmers complain about paying the annual maintenance fee of 80 JD without receiving any assistance for water meter maintenance, even when required if the water meter has stopped, working slowly, leaking....) is also needed for achieving better equity between farmers. Implementation of the special tariff for brackish water seems not to be effective yet, although many farmers would have their wells in this category in Azraq (high water salinity). All farms that do not pay their water bills (35% of the farms), will of course not be affected by the new Amendment 2010 unless there is a real willingness of WAJ to apply the law, by activating a real water police which would frequently control in all farms that all water quantities abstracted from private agricultural wells are indeed recorded by the water meters.

The threat is also that the farms that are still limiting their water consumption because they are working with diesel pumps, and are these days trying to be connected to electricity. Once switched from diesel to electricity, the energy bill will be reduced; water bill will still remain a relatively low cost compared to other production costs, so price of water should not really influence the farmer strategy to limit his water abstraction. As noticed on the field, the main criteria that limits water abstarction is the cost of energy, so most farms would be more influenced in their water abstraction by an increase of energy price than water price.

As it was already analysed for the bylaw no.85 of 2002[60], substantial increase in volumetric charges would not result in major water savings but would further decrease the income from low value or extensive crops. It is therefore essential that negative incentives be accompanied by positive measures offering attractive alternatives (market opportunities, subsidies for modernisation, technical advice, etc.) and exit strategies with compensation.

[60] *Ground water depletion in Jordan Highlands: can pricing policies regulate irrigation water use?, jean Philippe Venot, Francois Molle, 2008*

VII – Project proposals for reducing agricultural water abstraction in Azraq Basin

The high level of specialisation means that policies for changing water use practices need to be differentiated. While, for example, olive trees are not profitable before 7 years, and stone fruit trees are an investment of about 15 years (might be profitable from the second year, commonly from the third or fourth year), one-year horticulture cropping patterns or alfalfa can be adjusted or reduced within a short time and without losing the invested capital. Therefore, seasonal crop farms can and will react more directly to economic incentives, while tree farms will keep on working even if benefits are temporarily negative. Also, farmer's emotional attachment might be different. While trees, especially olive trees, have a high cultural and emotional value and many of the tree farms are also for the purpose of recreation, the case for seasonal crops is less sentimental[61].

Therefore, any project proposition should consider improving existing practices on tree farming, or develop in parallel a high added value activity (but it would result in extra water use), whereas alternatives (more water efficient or cost effective crops..) can be proposed to short time investment crops (vegetables and alfalfa).

A description of project ideas follows, as well as a prioritisation of these projects according to farm categories.

When organising any training or awareness session, organisers should be aware that many farms, at least in Azraq region, are managed by Egyptian workers that are not permanent on the farm and can leave a year later. A way has to be found to ensure sustainability of knowledge transfer.

7.1. Projects for the preservation of the water resource

It has been proven, in the Jordan Valley for example[62], that simple changes of the existing irrigation networks and irrigation practices can result in improving irrigation efficiency at farm level (around 15% of irrigation efficiency), and therefore in water savings at the level of the basin[63]. It is possible to fine-tune irrigation through:

• Improved design of farm irrigation

network to raise the efficiency of water application,

• Use of higher quality emitters and improved filtration system,

• Better on - farm operation,

• Use of skilled, well-trained labour, and

• Better monitoring of soil water reserves.

61 *Highland farm survey 2008 – internal report – water focal point – DLI*
62 *IOJoV project (Irrigation Optimization in the Jordan Valley), JVA, financed by AFD, 2008 - 2011*
63 *Reference of water saving in the Jordan valley refers to a pressurized network, where efficiency of distribution at the level of the main distribution network has to be considered also to evaluate the efficiency at basin level. For Azraq basin, as water is directly abstracted from wells, there is no water loss in the distribution network, so we could consider that if all farms are involved in a project of optimization, it could save 15% at the basin level.*

7.1. 1. – Technical assistance for irrigation optimisation at the farm level

A detailed study to collect data about the existing situation of irrigation systems and practices in the Azraq Basin is necessary before planning any project for irrigation optimisation (c.f. Baseline study, as detailed in Extra studies required).

Provision of technical support to the farmers located in the Azraq basin could include:

- Organise farmer trainings (field days) and farmer meeting in order to raise awareness about irrigation techniques and possible water savings, through discussion between farmers, as well as through knowledge transfer (introducing notions of evapotranspiration, soil moisture holding capacity of the soil, structure of roots, soil profiles…).

- Evaluate irrigation networks performance for interested farms, and provide recommendation for improvements (by optimising the current irrigation system[64], or by switching to a more efficient irrigation system). Assist the farmers to optimise the on-farm irrigation networks (adapted design of the irrigation system)[65].

- Train the farmers on the newly optimised irrigation practices:

Irrigation scheduling according to crop / age of planting / planting season / soil characteristics / irrigation network (when to start irrigation, how to manage irrigation during the season, when to stop irrigation). Organise trainings and guidelines (through MoA or NCARE if possible for sustainability, or the cooperative if created). Introduce the use of tensiometers (simplest and cheapest soil moisture monitoring system).

This might include the creation of pilot farms (farms of leading farmers) to demonstrate good irrigation practices (measuring flow and pressure, flushing procedures, monitoring of irrigation, planning of irrigation schedule…).

- Provide subsidies for modern water saving irrigation materials. Subsidy mechanism should be carefully studied (percentage of subsidy according to farmers' category, according to old / new irrigation system, or revolving fund…)

7.1.2. – Technical assistance for better fertilisation practices

Fertilisation programs are most of the time quite empirical (except in high-tech stone fruit tree farms). Some farmers are using some chemicals without knowing their precise impacts, and calculation of quantities used is not related to elements availability in soil (it can be highlighted here that nearly no farmer is using soil tests to get more information about his soil, in spite of the low cost of the test[66]). It seems that over-fertilisation is

64 *In a farm in Al Ratami, by switching from surface to open tube irrigation, water use was reduced and production on olive trees doubled!*
65 *This might suppose the creation of a mechanism for subsidy, to help farmers in investing in more water saving irrigation material.*

common on vegetables (in North Badia and Jiza), and sometimes occurs in stone fruit tree farms as well as in few olive tree farms. In Azraq some farms, while only using manure, get the same production that other farms get using chemical fertilisers. Therefore the use of chemicals can be reduced.

Some fertilisation programmes based on soil quality, water quality, crop and stage of the crop have been developed and successfully implemented by GIZ in the Jordan Valley (Use of reclaimed wastewater in agriculture in the Jordan Valley). Similar references[67] (with special highlight on the use of brackish water) could be developed for the Azraq basin area, and an awareness campaign and technical trainings organised for farmers.

Training programmes about fertilisation should target the reduction of chemicals use, the increase of organic matter rate in the soil, in order to limit contamination and salinisation of ground water, as well as salinisation of soils.

A project of organic farming, mostly on olive trees, has been raised, however it seemed illogical to develop organic farming (a concept that promotes sustainability) for orchards irrigated from an overexploited aquifer (a completely unsustainable activity).

7.1.3. – Action research projects for water saving techniques and preservation of water quality, adapted to Azraq Basin conditions

Action research is an interactive inquiry process that balances problem solving actions implemented in a collaborative context with research to understand underlying causes enabling future predictions about changes (Reason & Bradbury, 2002). In other words, action research consists of identifying a problem, implementing a pilot research project together with concerned stakeholders on the field, and valorising the results of this pilot experiment to plan a better adapted strategy on a larger scale.

Some pilot projects for water conservation techniques have been suggested by innovative farmers, who have tested new techniques or practices on their farm and had seen an improvement (reduction of water use, or better yield), but have no concrete scientific data/ evidence of water-savings. The implementation of small action research projects on farms of motivated farmers (reference situation as usual to be compared to plot testing the innovation) would enable the creation of reference and showing to other farmers the results on the field. It comprises the selection of farms, bibliography and preparation of an experimental protocol, installation of necessary

66 *NCARE did such a test in Balqa for 25JD.*
67 *Results from the proposed study for crop suitability map about soil quality and crop requirements would be an asset for implementing an efficient fertilization program.*

equipment, field measurements campaign (reference plot and innovative plot), statistical analysis of field data, and extension through creation of guidelines and open gate visits on the experimental plot for other farmers.

A list of field observations and related identified project are listed below.

Water savings through choosing adapted crops and adopting adapted farming practices

1. Worrying extension of alfalfa in Azraq (Um al Masael and South Azraq), a high water requiring crop

⇨ Use of polymer for alfalfa cultivation[68].

⇨ Develop guidelines and technical recommendations for alfalfa cultivation, based on field experiments.

⇨ Experiment more water-saving fodder crops (e.g. sorghum..) to substitute alfalfa[69].

2. Some farms complain that they bought their olive trees without knowing the specificities for each variety, and today have a big difference in terms of yield between varieties.

⇨ Experiment with olive tree varieties best suited for the area.

3. Many olive trees are not pruned to ensure optimal production (structure of the tree is not optimal, some old olive trees orchard are grown as in a forest..).

⇨ Demonstration of the impact of rejuvenation pruning of trees on production, impact of good pruning techniques on young olive trees to build the architecture of the tree and favour better production and limit water consumption.

Water savings through adapted irrigation practices

1. 3 farms in Azraq reported that by using sub surface main lines and secondary lines for their irrigation networks, they can cut down their water consumption by half.

⇨ Installation of sub-surface main lines and sub main lines in irrigation networks.

2. Many farms facing problems of soil salinisation and difficulty to leach soils.

⇨ Build simple drainage systems to limit salinity (2 m deep trench down the slope to drain excess water).

3. Most farmers monitor irrigation by eye.

⇨ Pilot project for irrigation monitoring with tensiometers.

[68] *WaterWorks Crystals® is a completely non-toxic superabsorbent cross linked polymer, capable of absorbing up to 400 times its weight in rain or irrigation water, and a percentage of water-soluble nutrients and fertilizers, making almost 100% of that water and nutrients available to plant roots.*

[69] *Check experiments done by ACSAD*

Water savings through adoption of simple innovations

1. Use of tuff as mulch (thickness 5 cm, as a strip under stone fruit trees) in a farm in North Badia, is reported to allow water savings up to 25% according to an experiment that one farmer conducted on part of his farm.

⇨ Use of tuff as mulch under stone fruits and olive trees.

2. One farm in Azraq reported that by preparing its own compost from farm waste (weeds, branches after pruning, cow manure) and incorporating it 50 cm deep before planting the trees, he could save up to 45-50% of water as it attracts the trees to develop deeper roots that grow to deeper soil layers, and soil retains more humidity.

⇨ Production of compost from farm waste and incorporation of compost to soil preparation[70].

7.2. Projects to change the cropping pattern: towards more water-efficient crops

Water consumption versus possible economic return for many tree crops, field crops, and vegetable crops have been studied: the conclusion was that there needs to be a policy shift to water thrifty and salt tolerant crops in the context of water scarcity, in order to support a water saving policy[71]. But based on our field interviews, we saw that:

1. In Mafraq, there is a trend to switch from vegetables to fruit trees, not for water saving purposes, but to save work and get better profitability.

2. In Azraq, most farmers are reluctant to switch to new crops since olive trees are a long term investment. They would not remove their trees. They are not interested in palm trees, and do not have enough technical and market knowledge about pomegranate to switch to this crop.

Would farmers remove existing trees if they are proposed an interesting alternative for another higher added value crop? Is the change of cropping pattern a good alternative? As it is commonly agreed that the expansion of farms should stop in order to limit water abstraction, is it not risky to propose income generating crops for farmers who might be tempted to increase their cultivated land instead of replacing existing not water effective crops?

In any case, planning, funding, education, marketing, technical know-how and the will to execute any water conservation policy need to be addressed in more details before implementing any conservation policy. If it is decided to encourage farmers to change their crops, these crops should be selected according to economical feasibility (detailed market study), suitability to the local environment (soil, water, climatic conditions) and water conservation potential.

[70] *Also refer to 7.3.A – Compost Plant Project*
[71] *A water for peace strategy for the Jordan River by shifting cropping patterns, Said A. Assaf, 2007*

7.2.1. – Proposition of crops more suitable to environmental conditions

Based on bibliography, we can highlight that some crops seem to be well adapted to water thrifty conditions. Almond has very low water needs and is a marketable product[27] (water requirements estimated in the Jordan River Basin are 380 m^3/du for soft shell almonds, 350 m^3/du for hard shell almonds, while olive trees need 400 m^3/du in the same conditions). The desert- type jojoba trees have the lowest water needs amongst all trees (300 m^3/du).

Table 3: Crop water requirements, according to different bibliography sources

Crop	Mafraq regionm[72] (Eastern desert area) m^3/du	Total water needs in the Jordan River Basin[73] m^3/du
Tomato	750	
Cauliflower and cabbage	500	
Other vegetables	750	
Watermelon	415	550
Sweet melon	580	450
Average on vegetables	600	
Olive	690	400
Apple	1060	
Peach	1000	
Grape	1040	
Other stone fruits	1045	400 (apricot)
Other deciduous trees	1000	
Average on orchards (olive excluded)	1030	
Date palm		1500
Jojoba		300
Almond (soft shell / hard shell)		380 / 350
Alfalfa		400
Vetch		325

72 *Net crop water requirement (in m3/du/year) in amman Zarqa basin (adapted from Fitch 2001). The net requirement is the total crop requirement divided by an estimated 80 percent efficiency for drip irrigation in the Amman basin. In Irrigated agriculture, water pricing and water savings in lower Jordan River Basin, JP Venot, 2007*

73 *Total water needs, or rainfall requirements for economic production. In A water for peace strategy for the Jordan River by shifting cropping patterns, Said A. Assaf, 2007*

Jojoba trees, that have been introduced in 1982 in the West bank (there is also a demonstration farm in the Jordanian eastern desert close to the airport and a trial of re-introduction of jojoba by IUCN project in Azraq), are highly successful, and are producing the high value jojoba crop oil (several times the price of olive oil). It is also been proved that jojoba can grow and produce fairly well using 2500 ppm water salinity.

Some other crops grown in Azraq basin are much more water requiring.

Bibliography indicates that date palms water requirements are much higher than olive trees requirement (1500 m^3/du for dates instead of 400 m^3/du for olives in Jordan River basin[74]), so this recommendation of MoA to plant palm trees in Azraq can be questioned.

Water conservation may also be realized by growing vegetable crops under plastic greenhouses, compared to the same vegetables grown and irrigated in open field. The great difference in infrastructure cost for providing water to the crops produced in a greenhouse with that in an open field is offset by the greater production inside greenhouses. However, it seems very difficult to develop greenhouses in Azraq as they are damaged by strong winds.

Table 4: Water needs of crops under irrigation in greenhouses versus open field, in m^3/du[75]

Type of vegetable	Water needs for vegetables inside a greenhouse	Water needs for vegetables inside a greenhouse
Tomatoes	600	1000
Cucumbers	850	1200
Green beans	750	900
Peppers	600	800
Thyme	300	350

Some salt resistant crops might also be successfully grown, if combined with good irrigation practices (the following data should be tested in Azraq basin conditions).

74 *A water for peace strategy for the Jordan River by shifting cropping patterns, Said A. Assaf, 2007*
75 *A water for peace strategy for the Jordan River by shifting cropping patterns, Said A. Assaf, 2007*

Table 5: Water salinity levels used for irrigation of certain salt tolerant crops in the Jordan River Basin[28]

Salt tolerant crop	Salinity in total dissolved solids (ppm)
Cactus (prickly pears)	2500
Jojoba	2000
Melons (cantaloupe)	1500
Tomatoes	1200
Alfalfa	1100
Hard seeds almond	800
Olives	800
Citrus	500

All these data should be checked in Azraq basin conditions:

- Real crop water requirements in Azraq basin, for existing crops (olive tree, grapes, pomegranate, date palms) and for potential new crop (jojoba, almond trees).

- Salt tolerance for theses crops, in real conditions in Azraq basin.

Based on field interviews, we can say that most farmers have a general idea of the more water consuming crops. For example, they know that water requirements for dates palms > for pomegranates > for olives, so farmers are quite reluctant to adopt palm trees.

Some farmers are interested in developing pomegranate production, if they receive suitable technical assistance. Pomegranates are resistant to salinity and tolerant of drought conditions but require appropriate moisture for optimal yield. Pomegranate trees need more care than olive trees, and water requirements are higher than those of olive trees, but profit is higher. Market opportunity should be carefully studied before proposing a project.

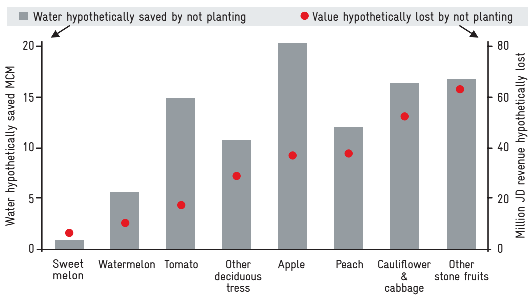
7.2.2. Proposition of crops according to water productivity

There is a high variability in terms of water productivity between crops. This should also be taken into consideration before developing any incentive to change the cropping pattern. Data found in bibliography should be updated with current prices of agricultural products on the market. Some data is reproduced below, for information.

Table 6 : Water productivity in agriculture in the Highlands[76]

Major crops in the highlands	Productivity (gross margin of water – JD/m³)
Olive	0.05
Tomatoes	0.11
Cauliflower	0.12
Apple	0.14
Peach	0.24
Grapes	0.39
Watermelon	0.46
Sweet melon	0.49

(Based on a general farm model for the Amman – Zarqa Highlands)[76]



Sources: Values are from Agricultural statistics 2002 (DOS). Water uss are from Fitch, 2001, appendix.

Figure 10: Revenue lost and water saved if the area set for various crops falls within the Highlands in 2002

7.3. Projects for alternative source of water

Building of water harvesting infrastructure (dams on temporary wadis, cisterns at the farm scale or at a larger scale…) seem not to be relevant in Azraq (according to farmers) as wadis do not convey water because earth dams have already been built upstream. Possibility for water harvesting (at the scale of the farm, or at a larger scale) should however be checked in Azraq, as well as in Mafraq and Jiza[77]. If some relevant locations are identified, a subsidy mechanism should be set.

For grey water treatment and reuse of treated waste water, cost of infrastructure would be very high as farms are located far from the Azraq village. It would mean costs for building the treatment plant and installing pipes on long distances to deliver water to the farms. In addition, as Azraq is not a highly populated area, the volume of treated waste water is not important, and the profitability of such a project should be carefully studied.

76 *Source: James Fitch (USAid, 2001), Siegfried Holtkemper (MWI, 2003).*

77 *A farm in Muaqqar area, that build two water harvesting dams indeed saves 3 months of water pumping from his well (he can irrigate from April till end of June from the dams).*

7.4. Other projects

7.4.1. Compost plant project

Humus contributes to soil fertility by retaining plant nutrients through adsorption. It also acts as a binding material in the soil, thus improving soil structure. It is responsible for making silt less susceptible to erosion, and it increases the water holding capacity and cation exchange capacity of soil[78]. So incorporating compost in soil would reduce irrigation needs (as water retention capacity increases) and reduces groundwater pollution by chemicals and heavy metals (as cation will be adsorbed by the humic complex).

Based on one farmer's experience, incorporating compost in a 15 to 20 cm trench and planting vegetable in it would save 70% of water; incorporating humus at a 50 cm depth under the tree, in a circle under the canopy, would save up to 45 to 50% water (as trees would develop deeper roots and go to deeper and wetter soil layers). This information should be checked through conducting scientific experiments.

Based on the concept of a non-profit company for services,
a system of gathering of farms residues (residues from olive trees pruning, weeds, animal manure, ..) could be organised, and then residues would be processed at the compost factory. This small project (estimated at 50000 JD - 100000 JD for land, machines and technician) would provide a local and cheap source of environmentally friendly fertilisers. It should in parallel include a component of demonstration plot and technical advice to farmers who for most of them, trust chemical fertilisers[79].

7.4.2. Establish a cooperative

Despite the wide spread reluctance of farmers to create any association or cooperative, we support the idea that a cooperative dealing with trading of inputs, boxes, equipments at fair price, renting equipments belonging to the cooperative (tractors, sprayers...), as well as marketing olive products with a better market knowledge (based on a market information system) would be a useful tool for farmers. But while many small farmers in Azraq are in favour of such organizations, the managers/owners of the large commercial farms in North Badia and even in Azraq declared that they would not participate in such an institution (and these big farmers are commonly leaders in such projects).

7.4.3. Income-generating projects

We report here some projects that have been mentioned by farmers during our surveys. Even if they

78 *Brandjes et al., 1996*
79 *A farmer even mentioned that he would not use compost on his farm as it is drying out the soil*

do not contribute to water saving, they would help small farmers (mostly in Azraq) to sustain on their farms:

1. Develop a hyper intensive plot in small family farms to provide the household with a source of income (for example, install a greenhouse for vegetables on a 40 dunum olive tree farm in Azraq to get an income all year long).

2. Livestock mini projects: to diversify income on small farms in Azraq, many farmers would like to develop livestock activity (some sheep, some cows for milk or meat) but do not have the capital to invest.

7.4.4. Others

Some other alternatives should be studied with the objective of water conservation or more generally of natural resources conservation. The development of alternative energies (solar or wind energy) could allow reducing pollution by using diesel for farms working on diesel pumps.

Tending to reduce water use in agriculture, well buy-out is an option often discussed. WAJ would buy wells from farmers. Some unprofitable farms might stop farming, others would buy water from WAJ for irrigation. Willingness of farmers to sell their wells (mostly in Azraq) should be checked.

Large water abstraction by the neighbouring Syrian farmers is often mentioned by the farmers in the Azraq basin as a reason for the water table level draw down. Indeed, no rules have been developed in Syria to limit water abstraction, which creates an inequity between farmers in both countries. Launching a dialogue about cross-borders water rights with Syria and Saudi Arabia is important to work on an integrated water management plan for Azraq Basin.

7.5. Complementary studies

7.5.1. Baseline study about irrigation practices and irrigation efficiency (situation before project)

This proposition aims at having detailed information of the situation before project, as a reference to be used for any future project impact. It can include:

1. A detailed inventory of irrigation systems by farm and by crop in the Basin[80].

2. The relation between irrigation system, crop and water consumption on the farm (statistical analysis of WAJ data as well as field data).

3. The assessment of farmers' irrigation knowledge[81]: questions about flow, pressure, uniformity, filtration system, flushing....

[80] *Some data already exist for North Badia, it needs to be checked for Jiza, there is no such data for Azraq*

4. The assessment of irrigation performance on the farm (design of irrigation network, quality of material, flow and pressure effectively delivered, uniformity, pump efficiency, irrigation schedule).

5. An assessment of farmers' willingness to improve their irrigation network (financial and technical ability of farmers to invest in extra materials needed for improvement). This study should give recommendations about:

a. Detailed training needs (main items to be included in training session).

b. Best way to improve on-farm extension services on the long term.

c. Cost evaluation of materials needed for irrigation optimisation (providing reference for different possibilities of irrigation optimisation changes, such as Surface => Open Tube, Surface => Virojet, Open tube non optimised => Open tube optimised…) and proposition for best mechanism for subsidy (% of subsidy according to farming system or to water consumption, revolving fund, % of farm area subsidised…).

d. Organisation to be set for sustainability (training session organised on project base, one to one training (close follow-up) or one to many (from trainer to farmer, or from farmer to farmer), permanent training centre in MOA, pilot farm created through the project, demonstration plot in the farm of a leading farmer, …).

7.5.2. Comprehensive Market studies

This study should be conducted before viewing a development strategy of any new crop. Farmers might benefit from better knowing the market organisation, market quality requirements, niche markets and other market opportunities both locally and internationlly.

This study should provide an overview of market mechanisms, as well as specific market opportunities for contemplated crops to be supported by the project.

For example, for pomegranate, where are the markets, which product is required (fruits and characteristics of size, color…, or juice concentrate…).

[81] *We want to highlight here that any training program should consider the fact that most workers are Egyptian and not permanent on farms on a long term.*

7.5.3. Crop Suitability and Soil Fertility Mapping using Geographic Information System (GIS)

This kind of study entails combining and analysing agro-environmental, soil information, water information and crops biological requirements for growth[82]. It considers soil samples analyses. An important work has already been done by MOA about description of soil chemical properties, resulting in a description of soil fertility. Overlaying the agro-climatic map with land suitable for farming practice map and soil fertility map, a crop suitability map could be developed.

It would then be possible to propose more accurate recommendations about irrigation practices according to soil types (Guidelines about irrigation practices in saline soils for example).

It would be interesting to establish Information Centers in the MOA branches. They would be a way of sharing the acquired data with farmers, who could come and ask for the any information they need about market, soils, water crop requirements... This database should be kept and updated by the MOA directorates.

It was mentioned previously that data from WAJ and data from MOA are not compatible. For example, there is a large difference between irrigated planted areas between WAJ and MOA. Indeed, WAJ calculations are based on data from 2002.

A coordination project between both Ministries would be interesting to harmonise the common data.

82 *Henry A. Adornad and Masao Yoshida, 2008.*

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ANNEX 1: QUESTIONNAIRE USED FOR FARMERS' INTERVIEWS

Questionnaire for agro economic study of farms in Azraq Basin
Highland Water Forum
September – December 2010

Objective of the study

A - Classification of farms: structural information and description (results, practices)
Stratification based on characterisation of:

1> Environment (soil, climate, water resource, natural reserve, agro Industry Company.
2> Farms (Surface x production categories)

B – Typology of the farms: about functioning of farms, and the role of the farm in the socio economical context of the region, to be used for action planning, by understanding:

Objectives ⇨ Strategy (related to assets and constraints) ⇨ Management (planning and decision rules)
Each type is characterised by similar strategy and objectives

For example, typology about importance of irrigation in farm management, priority on which crops? Irrigation increase or decrease, which strategies and management rules (about assets and constraints, risk management...)

General information

Name farmer and phone:
Location:
Date:
Position on the farm (owner / owner in partnership / member of owner`s family / sharecropper / manager).
Name of owner if different:

Farm status

Farm size:
Well Number:
Status: Rented / Managed by a single owner / Managed by several owners / Managed by a permanent employee (= manager) – Interview with owner/ manager?
Other farms (in region/other part)

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Productions

Crop	Area + Nb trees (spacing rows,trees)	Age	Irrigation system	Production Yield in box/kg...	Destination Sell/ Autocons.	Selling price	Evolution last 5 y + / - / =	Evolution next 5 y + / - / =

Reasons for choice of crops and reasons if change in production:
Rotation:
Soil type:
Animals breeding?
Total gross product:

Family

Number of family members living on the farm:
How long is he a farmer? Is he originally from a farmers family?
Age and education level of farm manager:
Other revenues and activities (professional / social):
Tribe or social group:
Needs of the family and part of agricultural revenue in total family revenue
Perspective of children to take over the farm

Production system

Land

Status of land:
When was did he get the land? How? Price of land? Or rented (since when) at which price?
Why did he choose farming / buy land in Azraq/Mafraq (low land price, availability of water, advise from trusted person, family originally from the place, reimbursement of loan by land..?)
Was the land already planted / with well?
What was his objective? (willing to have land property, for children, investment, hobby farm, speculation?) Future projects (sell/extend...)
How could he invest?

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Water and irrigation

Infrastructure and investment

Well? Legal or not? With license or permit? When was it dug (and legalized)? Depth of the well? Modification in well on the farm (deepened, change location...)?
Pump: power and cost, how many CM/hour?
Watermeter installed?
Cost drilling well
Cost irrigation system and life time
Cost energy (fuel/electricity)

Irrigation knowledge and practices

Crop	Water requirements	Irrigation system (and evolution techniques)	Water applied and irrigation scheduling (nb hours, frequency and months)

Who decided type irrigation system? Previous system? Advantage/ disadvantage?
Who and how was the irrigation network designed?

Knowledge of irrigation techniques (uniformity, follow up pressure at emitters, flow...) Knowledge about conservation methods, effective and efficient irrigation methods? Using the full potential of the irrigation method? Demand of training, advices, water user association.....

Water situation

Total abstraction / year (and previous Years)
Annual bill water (and previous years)

Did he decrease his pumped quantity when high price of diesel? What about electricity price? Does he already think about an other source of power?

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Characteristics of the water resource? Opinion about groundwater situation?
Any problem with water on his farm? Quality of the water, salinity and consequences?

Government might limit allowed quantities of water pumped, or water increase prices: what will he do in a such case, limited quantity of allowed water pumped and/or if water prices increase? Does he have any alternative / idea? Does he know anybody with innovative project to reduce water consumption?

Inputs

Crop	Type of input applied	Frequency (when?)	Quantity	Total price quantity / season or JOD / season

Source of technical advice

Work resource

Nb workers from family

Nb workers from outside (seasonal / permanent?) and salary

Any problem to get enough staff during work peak? (Seasonal installation / removing of irrigation system, Land preparation, Irrigation, Pruning, Fertilisation, Weeding, Flushing...)

Material and equipments

Autonomy with equipments on the farm for farming, sowing, harvesting, storage?

What was the investment for private material?
Cost of equipment rent (if necessary)?

New investment and projects planned?

Financing

Based on loan?

Socio – economical environment

Any production contract
Marketing facility? Criteria to choose buyer? Selling strategy?
Any technical advice for marketing? Need?

Economical results

Gross product
Operational costs
Structural costs

Main constraints

What are his main constraints in terms of farm management? Labour (quantity? quality? For which activity)? Fertilisation technique and Fertilisers? Soil? Disease? Production (quantity? quality? uniformity?)...? Low water resource? Irrigation techniques?

Comments from the farmer, projects, remarks...

Comments from visual inspection:

Uniformity in production? Status of the trees? Diseases? Installation and maintenance? Fertiliser used?...

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ANNEX 2: SOILS OF THE STUDY AREA

(BASED ON FIELD SURVEYS DONE FROM SEPTEMBER TILL DECEMBER 2010)

1 - Azraq Region

1.1 – Fin Silty, mixed, hyperthermic, family of Typic Haplosalids *.

This type of soil occurs on flat to very gently sloping Qa and wide Silty wadis in the Azraq Oasis the soils are formed on unconsolidated alluvium which derived from mixed basaltic limestone origin; these soils found in South Azraq, around the oasis, Part of Al- Rat amah and Al-elawat.

Soil Moisture regime is Aridic with a precipitation between 0-50mm, average soil depth is 110 cm. when dry the surface is extremely hard, presence of salt on the surface are common, strongly to moderately calcareous and very saline with Salic horizon recognised at a depth of 50cm.

The top soils is yellowish brown to brown (10RY 6/4-7.5YR5/6) moderate medium sub angular blocky, texture is Silty Clay (46.1% Clay, 52.4% Silt, 1.5% Sand), and strong reaction with dilute hydrochloric Acid.

The sub soil is brown (7.5YR4/4) moderate fine granular, moderately thick Clay coating Silty Clay Loam, (44.8% Clay,54.9% Silt,0.3% Sand), the soil overall Saline with Ece value of 42.5-109.4 mS/cm, ESP is very high in the subsoil, whilst reaction is slightly alkaline at pH 7.6 with CEC of 19.5-20.6me/100g, while $CaCO_3$ levels is between (26.9-30.7%) inherent fertility would be very low due to high salinities excessive content through the profile ,with Organic Matter at 0.58%, Total-N of 0.06% and available –P about 29.4ppm,

The deep soils are dominants, arrowed the flooded area and the margins of springs.

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1.2 – Deep fine mixed calcareous family of Typic Haplocambids*.

Occurs in flat to very gently sloping, Qa wadis and some terraces in the aridic moisture regime, precipitation 50-100 cm,the soil is formed on basaltic alluvium and average soil depth is 96 cm, these soils found in Al-Awshaq which represent the old farm in Azraq.

When dry the surface is hard to very hard, vesicular and often shows polygon formation with common 0.5-1cm wide cracks. Surface gravel cover is variable from nil to 60%, and a gravelly phase is recognized as a soil type.

The topsoils is reddish yellow to strong brown (7.5YR7/6-5/6)strong to moderate coarse to medium sub angular blocky structured, texture is Silty Clay or heavy silty Silty Clay Loam (44.8% Clay, 49.2% Silt, and 6.0% Sand),the topsoil is platy and vesicular breaking to sub angular blocky. Reaction to dilute HCL is strong.

Subsoil is strong brown to yellow red (7.5YR5/6-5YR4/6)weak to moderate, coarse to medium sub angular blocky Silty Clay Loam to Silty Loam, (31.2% Clay, 58.2% Silt, and 10.6% Sand) A few $CaCO_3$ concentration can occurs throughout and few gypsum crystals occur in lower subsoil. Gravels normally absent or very low, the deep subsoil can be massive compacted reaction to dilute HCL is strong.

These soils is very saline and sodic with Ece 43 and 35 mS/cm in top and sub-soils respectively and ESPs of 15 and 50% respectively, Reaction is slightly alkaline with pH 7.4,If reclaimed fertility would be medium to high with CEC of 20-30 m/100g. inherent fertility is low with Organic Matter about 0.1%, total-N<0.1% and available-P about 57ppm, Ca/Mg and Mg/K ratios of 2.7 and >100 respectively indicate a strong k deficiency, $CaCO_3$ contents of about 17% are moderately high and somewhat hazardous and gypsum content of about 3% relatively low but could reduce CEC and AWC, Moisture reserves, if the soil was wetted, would adequate with AWA in the range 110-120 mm/m, low infiltration rates.

ANNEXES

1.3 - Deep fine mixed thermic Family of Typic Calcigypsids*.

Soil occurs in flat to gently sloping pediments and terraces of basalts flows on upland are on the upland area the soils formed from on colluvial and alluvial materials derived from basalts in arid zone with a precipitation is <50 mm , with thermic temperature regime, average soil depth is 90 cm, these soils observed in Ein-AlBida , Um-Elmasael.

The surface is normally hard and capped with high gravels cover.
Topsoil is reddish yellow to dark brown (7.5YR6/6-3/4) slightly gravelly weak to moderately structured sub angular blocky, texture is Silty Clay Loam (33.7% Clay, 50.2%Silt, and 16.1% Sand). With strong reaction with dilute hydrochloric Acid.

The sub soil is yellowish red to strong brown (5YR4/6-7.5YR5/8) week to moderate sub angular blocky structured, Silty clay loam, (27.6% Clay, 42.9% Silt, 29.9% Sand) which become massive with depth and very gravelly layers con occur giving loamy –skeletal textures, the typical profile of these soils shows an average of 38% CaCO3 content. Reaction with dilute hydrochloric Acid is strong to violent.

Over all this type of soils is strongly saline (Ece value of 80 mS/cm) and subsoil is moderately saline (Ece value of 11 mS/cm) whilst pH is slightly alkaline (7.2-7.8) fertility potential based on CEC of 25 - 30 me/100g is considered medium but inherent fertility is very to extremely low with Organic Matter about 0.6%.

Total - N at < 0.1% and available – P at 7.6 ppm, overall gypsum levels are moderately high at 5-15%, Common gypsum crystal occur and give gypsic horizon between 10-50 cm depth, while $CaCO_3$ is about 22%.

Moisture reserves could be considered adequate to low depending on actual gravel content (5-10% sub- rounded basalt gravels, and 10% small soft gypsum crystal)

The deep soils are dominants, whilst gravely and moderately deep soils are common in the area.

1.1.4 - Deep fine mixed thermic Family of Typic Haplogypsids*.

Soil occurs on gently sloping fans below basaltic ridges and above the course of wadi Rajil in its lower reaches to the east of Azraq. These soils observed in Al-Dughyla which represent the Agriculture area in Azraq depression

The soil is formed in alluvial/colluvial material of mixed basaltic limestone origin, moisture regime is aridic (<50 mm precipitation). Average soil depth is 96 cm .and it is found as Lithic Haplogypsids, with soil depth less than 50 cm.

Soil when dry the surface is hard with high basaltic gravels cover, topsoil is strong is very pale brown to yellowish brown (10YR7/3-5/6) structure less to weak single grain loose Sandy Clay Loam(15.2% Clay, 21.6% Silt, 63.2% Sand) with common chert gravels and strong reaction to HCL.

Subsoil is strong brown to very pale brown (7.5YR5/6-10YR8/3)weak to moderate sub angular blocky structured, Clay Loam (31.5% Clay, 45.7% Silt, 22.8% Sand)which can be under lain by massive, hard sand, Gypsum content increases with depth and usually is the cementing agent in the massive horizon. Few to common chert and basalt gravels occur throughout. A gypsic horizon is formed found normally between 35 and 75 cm. Reaction to HCL is strong.

These soils are strongly saline, field estimates show gypsum contents of up to 60-70% in the subsoil. This soil would have very low potential due to salinity and excessive gypsum content, attempts at reclamation by leaching would prove problematic due to likely collapse of the profile as the gypsum in the subsoil dissolved and was removed.

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2 - North Badia Region

2.1 - Deep fine mixed calcareous thermic Family of Xeric Haplocambids*.

This type of soil occurs on gently sloping to undulating basalt flows mainly in the eastern part of Mafraq (North Badia) the soil is formed on alluvial/colluvial material overlying paralithic (weathered) Basalt. Soil Moisture regime is transitional xeric-aridic with a precipitation between 150-200 mm, average soil depth is 80 cm. these soils found in Al-Ashrafyeh and Naïfeh.

Soil when dry the surface is moderately hard to hard, can be slightly capped leading to run-off and surface stone or gravels cover up to 50% of the surface.
The top soils is brownish yellow to strong brown (10RY 4/4-7.5YR4/6) moderate medium sub angular blocky, texture is Silty Loam (28.3% Clay, 56.6% Silt, 15.1% Sand), and strong reaction with dilute hydrochloric Acid.

The sub soil is brown to brownish yellow (7.5YR4/4-10YR6/6) moderate to strong medium sub angular blocky, Silty Clay Loam, (29.4% Clay,54.7% Silt,15.9% Sand). Few $CaCO_3$, occur in subsoil and increase with depth but no Calcic horizon occurs within 100 cm, the soil overall slightly saline with Ece value of 3-5 mS/cm, ESP of up to about 6% in the subsoil whilst reaction is slightly to moderately alkaline at pH 7.9 with CEC of 24-25 me/100g, whilst inherent fertility is low with Organic Matter at (0.81-1.43%), Total-N of 0.1% and available –P about 20ppm, Ca/Mg and Mg/K ratios at 2.5 and 4 and do not indicate any major deficiencies. $CaCO_3$ levels at (15-20%) are moderately high and create some hazard. Moisture reserves would be adequate with available water holding capacity (AWC) in the range 110-130 mm/m.

The deep soils are dominants, but moderately deep soils limited by fresh or weathered basalt or sometimes basalt gravel are common.

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2.2 - Deep fine mixed thermic Family of Xeric Haplocalcid*s.

Soil occurs on gently sloping plains of basalt flows mainly in the easterly parts of the drier xeric to transitional xeric aridic zone with annual precipitation 150-200 mm the soil is formed on basaltic material with upper layers of alluvial/colluvial origin possibly with some Aeolian admixture and lower layers form weathered in-situ basalt, average soil depth is 97 cm. these soils found in Al-Rfaeatt, and Um-Al-Quttan.

When dry the surface is hard to very hard, and usually has moderate to strong capping which leads to significant surface run-off which, in turn can lead to sheet erosion, and can have a very high percentages of basalt stone and boulder cover.

The top soils is strong brown (7.5YR5/6) weak, coarse sub angular blocky or angular blocky Loam to Silty Clay Loam (27.3% Clay, 58.9% Silt, 13.8% Sand). and strong reaction with dilute hydrochloric Acid.

The sub soil is strong brown to brownish yellow red (7.5YR5/6-5YR4/8) with much paler colours often dominating at depth due to the density of the Calcic horizon which generally occurs between 45 and 100 cm. moderate to strong sub angular blocky heavy Silty clay loam, (34.2% Clay, 56.4% Silt, 9.4% Sand) the typical profile of these soils shows an average of 35% $CaCO_3$ content. Reaction with dilute hydrochloric Acid is strong to violent.

Top soil is very slightly saline (Ece value of 2.6 mS/cm) and subsoil is moderately saline (Ece value of 11 mS/cm) whilst pH of about 8.0 is slightly to moderately alkaline, fertility potential is considered medium with CEC OF 17-20 me/100g.

Total-N of 0.1% and available –P about 5.2ppm, a Ca/Mg ratio of 2 is on the low side while a Mg/K ratio in excess of 30 indicates possible K deficiency.

And $CaCO_3$ (35%) content in the subsoil is moderately high and could explain the low available phosphate value, Moisture resources would be estimated at about 110-120mm/m due to the $CaCO_3$ content reducing the available water holding capacity (AWC).

The deep soils are dominants, but minor moderately deep soils exist with depth limited by Lithic, weathered (paralithic) basalt or gravels.

3. Jiza Region

3.1 - Deep fine Silty, carbonatic thermic family of Typic Haplocalcids*.

This soil occur on sloping plains in aridic moisture regime with rainfall in the 100-150 mm zone, parent material is colluvial limestone derived with significant Aeolian additions Average soil depth 83cm. these types of soils found in Hamam Al-Shamut and Al-Hanafeyia.

Soils when dry the surface is hard to moderately hard, and usually has a strong capping-which lead to significant surface run-off which, in turn, can leads sheet and gully erosion.

The top soils is very pale brown to brown (10YR7/4-5/4) yellow to strong moderate medium to fine sub angular blocky structured, texture is Fin sandy to Silty Clay loam or Silty loam (15.8% Clay, 55.6% Silt, and 28.3% Sand), grovel content are common with 5015% chert and reaction with dilute hydrochloric Acid.

The sub soil is dominantly yellowish brown (10YR6/6-10YR5/8) but sometimes strong brown (10YR5/6-10YR5/8) moderate medium sub angular blocky, and sometimes bricking to crumb, gravel content are low in the upper sub-soil but chert and limestone fragments can restrict the effective depth from 45 cm, $CaCO_3$ concentrations are common from relatively shallow depth and Calcic horizon is recognized between 15 and 50cm,in the deep sub-soil texture can be clayey with many $CaCO_3$ and can be compacted. Texture is Silty Clay Loam, (28.8% Clay, 55.5% Silt, and 15.7 % Sand).

Over all this type of soils is strongly saline with Ece about 25mS/cm with high ESP value (about 27%) and reaction is moderately alkaline (pH 7.6-8.3).

Giving an overall classification of saline-sodic, if reclaimed fertility potential would be medium with CEC of 14-15me/100g, inherent fertility would be low considered low to very low due to salinity-sodality and the moderately high levels of $CaCO_3$ with Organic Matter at (0.81-1.43%), Total-N of 0.1% and available – P about 20 ppm, Ca/Mg and Mg/K ratios at 2.5 and 4 and don›t indicate any major deficiencies. $CaCO_3$ levels at (15-20%) are moderately high and create some hazard. Moisture reserves would be adequate with available water holding capacity (AWC) in the

range 110-130 mm/m.
The deep soils are dominants, but moderately deep soils limited by fresh or weathered basalt or sometimes basalt gravel are common.

1.3.2 - Deep fine mixed thermic Family of Xeric Haplocalcids*.

Soil occurs on gently sloping plains of basalt flows mainly in the easterly parts of the drier xeric to transitional xeric aridic zone with annual precipitation 150-200 mm the soil is formed on basaltic material with upper layers of alluvial/ colluvial origin possibly with some Aeolian admixture and lower layers form weathered in-situ basalt, average soil depth is 97 cm. these types of soils found in Al muaqer. When dry the surface is hard to very hard, and usually has moderate to strong capping which leads to significant surface run-off which, in turn can lead to sheet erosion, and can have a very high percentages of basalt stone and boulder cover.

The top soils is strong brown (7.5YR5/6) weak, coarse sub angular blocky or angular blocky Loam to Silty Clay Loam (27.3% Clay, 58.9% Silt, 13.8% Sand). And strong reaction with dilute HCL Acid.

The sub soil is strong brown to brownish yellow red (7.5YR5/6-5YR4/8) with much paler colours often dominating at depth due to the density of the Calcic horizon which generally occurs between 45 and 100 cm. moderate to strong sub angular blocky heavy Silty clay loam, (34.2% Clay,56.4% Silt,9.4% Sand)the typical profile of these soils shows an average of 35% $CaCO_3$ content. Reaction with dilute hydrochloric Acid is strong to violent.

Top soil is very slightly saline (Ece value of 2.6 mS/cm) and subsoil is moderately saline (Ece value of 11 mS/cm) whilst pH of about 8.0 is slightly to moderately alkaline, fertility potential is considered medium with CEC OF 17-20 me/100g.

Overall the inherent fertility is considered low with Organic Matter about 1%.

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Total-N of 0.1% and available –P about 5.2 ppm, a Ca/Mg ratio of 2 is on the low side while a Mg/K ratio in excess of 30 indicates possible K deficiency.

And $CaCO_3$ (35%) content in the subsoil is moderately high and could explain the low available phosphate value, Moisture resources would be estimated at about 110-120mm/m due to the $CaCO_3$ content reducing the available water holding capacity (AWC). The deep soils are dominants, but minor moderately deep soils exist with depth limited by Lithic, weathered (paralithic) basalt or gravels.

*Soils classified according to Keys of soil Taxonomy, Eleventh Edition, 2010.

References:

- Wael Sartawi, 1994,The Soils of Jordan, Semi-Detailed Studies
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ANNEX 3: HISTORICAL DEVELOPMENT OF AZRAQ REGION

The first occupation of the Azraq castle occurred by Druze people coming from Bilad el Sham from 1905 to 1916. Between 1920 and 1925, many Druze flew away from Syria, preparing the Syrian revolution against the French Mandate, leaded by Sultan Al Atrash. They started building their houses around the castle and dug wells (by hand, 5m deep). Salt production started in 1930 on the Qa'a. The village of Druze is founded on salt (Nelson, 1973). Animal husbandry was also important to the Druze village economy. There was little farming. Azraq being on the Haj road, people bartered salt for grains.

Shishan village was founded in the 1920s. In 1927, Chechen people came from Zarqa, Sweileh and Souhneh (close to Amman) and settled on the other side of Wadi Ratame. Shishan are traditionally farmers, and they chose a location close to a water source. Land that was dedicated to them was divided in strips of 8 dunums each, on both sides of the road, where families built their house and grew their garden. They built a canal from the spring of the oases through Wadi Ratami, to develop agriculture, but failed as water was too saline. Part of Shishan stayed raising livestock, others left to Zarqa for farming. Shishan was almost entirely farming and fishing village. They owned a large number of cattle, donkeys and water buffaloes which grazed in the marsh and on the Qa'a.

Bedouins were mostly pastoralists, their flocks appearing from time to time, using Ain el Beda as their watering place, traveling between the hills North of Azraq, Syria, and Saudi Arabia.

In 1934, an agreement was signed between Druze, Chechen and Bedouins to share the land and put an end to land conflicts: Eastern part of Al Aoshaq is for the Bedouins, North and South Azraq as well as Al Aoshaq are for Druze and Shishan.

The development of agriculture started in the 1960s in the Northern part of Azraq, were Druze and Arabs succeeded. Chechen, who were not allowed to develop agriculture (according to Geneva convention), started farming illegally on governmental land, manually digging wells (around 2 meter deep, maximum 10m), planting mainly olive trees, following the Arabs, but also palm trees, grapes , pomegranate and yellow melons, on farms of 3 to 30 dunums. They asked later for legalization of their land. Other farms started in Al Aoshaq.

Motors were introduced in the 1960s, and farms were connected to electricity in 1980s in Southern Azraq. The irrigation systems switched from furrow irrigation to drip irrigation in the 1980s: indeed, the technique had been adopted already in the Jordan Valley, people started being conscious of the water problem, it was easy to manage, and a company opened in Azraq, providing technical advice.

In 1971, the construction of the asphalt road to Iraq attracted people to put a hand on the land, claiming the ownership of the land as it was their traditional grazing land: people from Al Khraysheh tribe in 1970s, from Al Fayez in 1990s. Since the 1980s, tribes started building fence around the land, digging a well and selling the land by Hijjah to outsiders who invested in Azraq. This led to a fast increase of agricultural land. These new investors made a large profit as water and land was cheap.

In the 1970s, an Association was created in Azraq, dealing many different purposes (agriculture,.. but above all salt production…). In 1987, the salt factory opened in Azraq, and economy grew. In the 1980s, the Potash factory was opened in As Safi (Southern Ghors), which broke the salt price, and both factories had to close. In the 1990s, Gulf War I had a negative impact on the local economy. Some few families are still producing wells however (but for only 3 JOD/ton).

In 1993, the pounds dried out, from over pumping, which decreased the water table by 12 meters. Water buffalos breeding stopped, as it was not possible to graze in the mud.

Until 1999, the situation of water was good, but then the level of the water table dropped down, for 3 to 4 years, salination problem force some farmers to abandon their land (as it is forbidden to drill new wells).

ANNEX 4

Due to high salinity of the soils, olive trees are losing an important part of their olives before maturation, causing high losses in the farm income (Al Alewat, Azraq).

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