# EXPERT FACILITY ACTIVITY NO: EFS-JO-2/WP1

# SOCIO-ECONOMIC IMPACT ASSESSMENTS OF GROUNDWATER OVER-ABSTRACTIONS IN AZRAQ BASIN

## Global report

| Version | Document Title | Author | Review and Clearance |
|---|---|---|---|
| Draft final | SOCIO-ECONOMIC IMPACT ASSESSMENTS OF GROUNDWATER OVER-ABSTRACTIONS IN AZRAQ BASIN | Dr. Amer Jabarin<br>Dr. Marwan Raggad | Suzan Taha |

# THE SWIM AND H2020 SUPPORT MECHANISM PROJECT (2016-2019)

The SWIM-H2020 SM is a Regional Technical Support Program that includes the following Partner Countries (PCs): Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, [Syria] and Tunisia. However, in order to ensure the coherence and effectiveness of Union financing or to foster regional co-operation, eligibility of specific actions will be extended to the Western Balkan countries (Albania, Bosnia Herzegovina and Montenegro), Turkey and Mauritania. The Program is funded by the European Neighborhood Instrument (ENI) South/Environment. It ensures the continuation of EU's regional support to ENP South countries in the fields of water management, marine pollution prevention and adds value to other important EU-funded regional programs in related fields, in particular the SWITCH-Med program, and the Clima South program, as well as to projects under the EU bilateral programming, where environment and water are identified as priority sectors for the EU co-operation. It complements and provides operational partnerships and links with the projects labelled by the Union for the Mediterranean, project preparation facilities in particular MESHIP phase II and with the next phase of the ENPI-SEIS project on environmental information systems, whereas its work plan will be coherent with, and supportive of, the Barcelona Convention and its Mediterranean Action Plan.

The overall objective of the Program is to contribute to reduced marine pollution and a more sustainable use of scarce water resources. The Technical Assistance services are grouped in 6 work packages: WP1. Expert facility,WP2. Peer-to-peer experience sharing and dialogue, WP3. Training activities, WP4. Communication and visibility, WP5. Capitalizing the lessons learnt, good practices and success stories and WP6. Support activities.

## Disclaimer:

This document has been produced with the financial support of the European Union. The contents are the sole responsibility of the implementing Consortium and can in no way be taken to reflect the views of the European Union.

# TABLE OF CONTENTS

1 BACKGROUND ..... 10

2 INTRODUCTION ..... 11

2.1 OBJECTIVES ..... 11

2.2 TARGET GROUP FOR THE ACTIVITY ..... 13

2.3 EXPECTED RESULTS OF THE ASSIGNMENT ..... 13

2.4 Deliverables ..... 15

3 METHODOLOGY ..... 17

4 CHAPTER: SOCIO-ECONOMIC CONTRIBUTION OF AZRAQ BASIN ..... 23

4.1 The farming system of Azraq basin ..... 23

4.2 A comparison between reported water use and actual crop water requirements ..... 30

4.3 Contribution of the Azraq basin to the total national agricultural production and agricultural value in the country ..... 31

4.4 Contribution of the Azraq basin to the total national agricultural EMPLOYMENT in the country ..... 32

4.5 ASSESSMENT OF THE ECONOMIC CONTRIBUTION OF THE INDUSTRIES USING GROUNDWATER IN AZRAQ BASIN ..... 34

4.6 Assessment of the economic contribution of the municipal water using groundwater in Azraq Basin 35

5 SOCIO-ECONOMIC IMPACTS OF GROUND WATER OVER-EXPLOITATION SCENARIOS IN AZRAQ BASIN ..... 35

5.1 Overview of the modelling approach ..... 36

5.2 Estimation of groundwater abstractions under Business as usual scenario, and Plausible trends in sectorial growth ..... 37

5.2.1 Scenario 1 (S1): Business as usual Scenario ..... 37

5.2.2 Scenario 2 (S2): Plausible Sectorial Growth ..... 38

5.3 impact of groundwater over-abstractions on groundwater level and salinity ..... 39

5.3.1 Impact of Scenario 1 on the wells by sector ..... 40

5.3.2 Impact of Scenario 2 on the wells by Sector ..... 41

5.4 socio-economic impacts of groundwater over-abstractions ..... 42

5.4.1 Cases facing the agricultural and domestic sectors ... 42

5.4.2 Summary of the socio-economic characteristics associated with the different cases facing the Farming Systems ... 43

5.4.3 Socio-economic Impacts of groundwater over-abstractions - BAU Scenario: ... 47

5.4.4 Socio-economic Impacts of groundwater over-abstractions: Scenario 2 ... 49

5.4.5 Socio-economic Impacts of the potential reform actions ... 51

5.4.6 Closing illegal wells in the basin action ... 51

5.4.7 Reducing the current abstraction to safe yields ... 53

**6 RECOMMENDED SOCIOECONOMIC MITIGATION MEASURES AND ITS POTETNIAL IMPACTS ... 57**

# LIST OF TABLES

Table 1: List of Deliverables ....15
Table 2: Distribution of the completed questionnaire by Groundwater Basin (Al-Azraq) basin ....24
Table 3: Distribution of socioeconomic and demographic characteristics for the three identified farming systems in Azraq basin ....26
Table 4: Dominant cropping patterns for the three identified farming systems in Azraq basin ....28
Table 5: Crop budgets of the main crops produced in Azraq basin under farm system I for the year 2014 ....29
Table 6: Crop budgets of the main crops produced in Azraq basin under farm system II for the year 2014 ....29
Table 7 Crop budgets of the main crops produced in Azraq basin under farm system III for the year 2014 ....29
Table 8: total production of the three dominant crops in the basin and at the national level in 2014 ....32
Table 9: Daily wages and total labour requirement per dunum of land (2014) ....32
Table 10 Disaggregation of permanent labour in the basin for the year 2014 ....33
Table 11: Disaggregation of temporary labour in the basin for the year 2014 ....33
Table 12: Total production and value of the dominant crops in Azraq basin (Year 2014) ....33
Table 13: Total annual water abstracted by industries in Azraq basin in 2016 (CM) .34
Table 14: Total annual abstracted domestic water in Azraq basin in 2016 (CM) ....35
Table 15: Model results under the selected two scenarios. ....41
Table 16: Summary of the socio-economic characteristics associated with the different cases facing Farming System I (BAU scenario) ....43
Table 17: Summary of the socio-economic characteristics associated with the different cases facing Farming System II (BUA scenario) ....44
Table 18: Summary of the socio-economic characteristics associated with the different cases facing Farming System III (BUA scenario) ....45
Table 19: Summary of the socio-economic characteristics associated with the different cases facing Farming System I (Growth scenario) ....46
Table 20: Summary of the socio-economic characteristics associated with the different cases facing Farming System II (Growth scenario) ....46
Table 21: Summary of the socio-economic characteristics associated with the different cases facing Farming System III (Growth scenario) ....47
Table 22: Estimated socio-economic costs associated with the negative impacts of groundwater abstractions (BAU scenario) ....48
Table 23: Estimated financial costs associated with decline in domestic wells under the BAU ....49
Table 24: Estimated socio-economic costs associated with negative impacts of groundwater abstractions (Growth Scenario) ....50

Table 25: Estimated financial costs associated with decline in domestic wells under the Growth scenario ... 51
Table 26: Expected impacts of closing illegal wells in Azraq basin on farms of system I ... 52
Table 27: Expected impacts of closing illegal wells in Azraq basin on farms of system 2 ... 52
Table 28: Expected impacts of closing illegal wells in Azraq basin on farms of system 3 ... 52
Table 29: Expected reduced impacts of closing illegal wells in Azraq basin on farms of all systems with reference to BAU scenario ... 53
Table 30: Expected impacts of reaching to safe yields in Azraq basin on farms of system 1 ... 54
Table 31: Expected impacts of reaching to safe yields in Azraq basin on farms of system 2 ... 54
Table 32: Expected impacts of reaching to safe yields in Azraq basin on farms of system 3 ... 54
Table 33: Expected impacts of reaching to safe yields in Azraq basin on farms of all systems ... 55
Table 34: Estimated socio-economic costs associated with the impacts of applying closing of illegal wells reform option ... 55
Table 35: Estimated socio-economic costs associated with the impacts of applying the safe yield reform option for groundwater abstractions ... 56
Table 36: Estimated financial costs of 3 options of purchasing the groundwater rights from well-owners (purchasing 100% or 50% or 25% of the rights) ... 59
Table 37:Estimated total investement costs of farms in the Azraq basin ... 60
Table 38: Recommended mitigation measures and its associated "carrots or incentives" and "sticks or penalties" ... 61

# LIST OF FIGURES

Figure 1: The commodity value chain analysis (applicable to the agricultural and industrial commodities)........21
Figure 2: Identified farm systems in Azraq basin........24
Figure 3: PROJECTED WATER DEMANDS (BY SECTOR) AND TOTAL DEMANDS UNDER SCENARIO1 (2017 TILL 2040)........38
Figure 4: Projected water demands (by Sector) and total demands under scenario 2 (2017 till 2040)........39
Figure 5: Needed actions for groundwater wells in 2040 under BAU scenario........40
Figure 6: Needed actions for groundwater wells in 2040 under growth scenario........42

# LIST OF MAPS

Map 1: Groundwater Basins in Jordan:. ........ 11
Map 2: Main cities in Jordan........ 12

# 1 BACKGROUND

The water sector in Jordan faces serious challenges related to water scarcity and the allocation of this precious resource among the different economic sectors. The doubling of population between 2004 and 2015 (9.5 Million in 2015) and urbanization, in addition to the increase in the standard of living, have brought about larger sectorial demands for water. The cumulative impact of all uses on groundwater has resulted in using irreplaceable fossil groundwater at a high cost and over-drafting of renewable groundwater basins at 160% of the safe yield, with subsequent drop in groundwater levels, reduction in or ceasing of spring discharges, saltwater intrusions and deteriorating water quality and the associated socio-economic impacts (from reduced water quality and quantity).

These issues were the main thrust of many on-going and previous initiatives by the GOJ with the support of the donors' community and were addressed in the groundwater by-law of 2001 and its amendments in addition to the Water Strategy "National Water Strategy 2016-2025" and its related policies:

- the Groundwater Sustainability Policy;
- the Surface Water Policy;
- the Water Re-allocation Policy; and
- the Water Substitution Policy,

The above policies laid out the measures and actions required to achieve Jordan's national goals for long-term water security, to improve the efficiency and sustainability of the scarce water resources management and to protect water resources including groundwater with a view to conserve the latter for future generations and using it as a natural reservoir to mitigate the expected drought spells and climate change and other contingencies. The groundwater policy which calls for interalia; enforcement of existing laws, and socio-economic considerations in deciding about the sustainability of irrigated agriculture relying on groundwater, is complemented with the "Water Substitution and Reuse Policy", which promotes the substitution of fresh water in agriculture with treated wastewater in order to enable freeing the fresh water for municipal uses and thus contributing to reducing groundwater abstractions in the aquifers to sustainable levels.

In order to implement the intended reform emanating from the above mentioned groundwater management policy, Jordan requested SWIM-H2020 SM to conduct a "Socioeconomic Impact Assessment for Groundwater Over-abstractions" in the country; within the scope of Expert Facility (EF) Work Package 1 (WP1). The activity is referred to in the EF workplan as "Activity No. EFS-JO-2":

This activity supports the implementation of Jordan's groundwater policy that aims to reduce groundwater abstractions in the highland aquifers to sustainable levels, (focussing on the Azraq basin as a pilot area). The activity will build on the results of two assessments conducted by the USAID-funded "Institutional Support & Strengthening Program (ISSP)":

- Analysis Report of the Socio-Economic Survey of Groundwater Wells in Jordan (December 2014), which provides descriptive analysis of socioeconomic characterization of wells owners and farm operators, the prevailing farming systems and farm equipment's, cropped areas, water usage, labour by nationality, source of energy, farmers' needs etc. The socio-economic survey created an updated body of baseline data (available at the Ministry of Water and

Irrigation) which gave insights into the socio-economic impacts of groundwater use in Jordan; depicted in the analysis report.

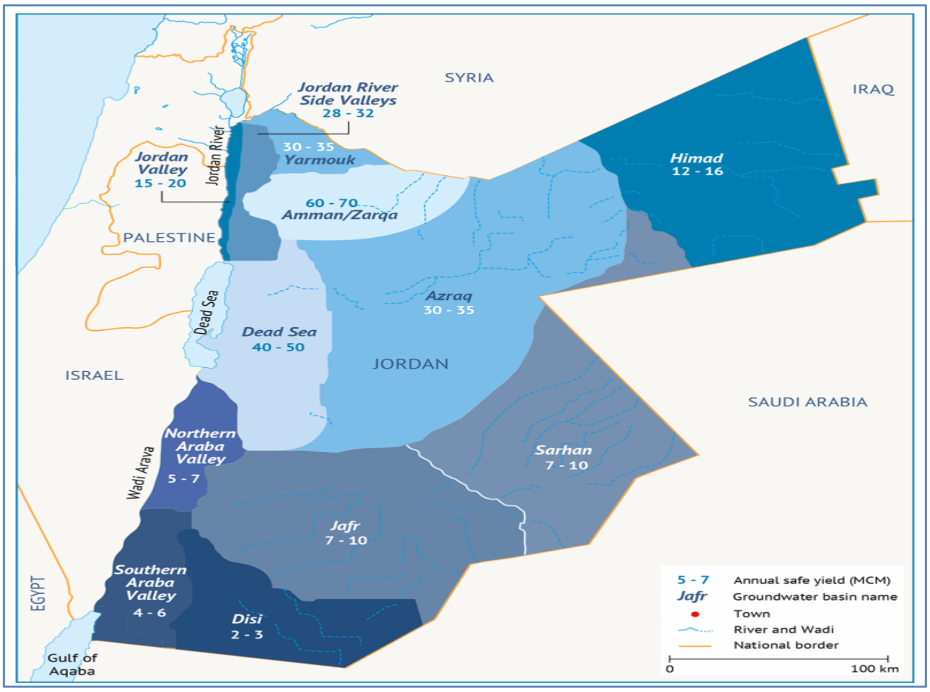
- Water Valuation Study: Disaggregated Economic Value of Water in Industry and Irrigated Agriculture in Jordan (October 2012). The study assesses the value of water across the various sectors of Jordanian society and economy.

# 2 INTRODUCTION

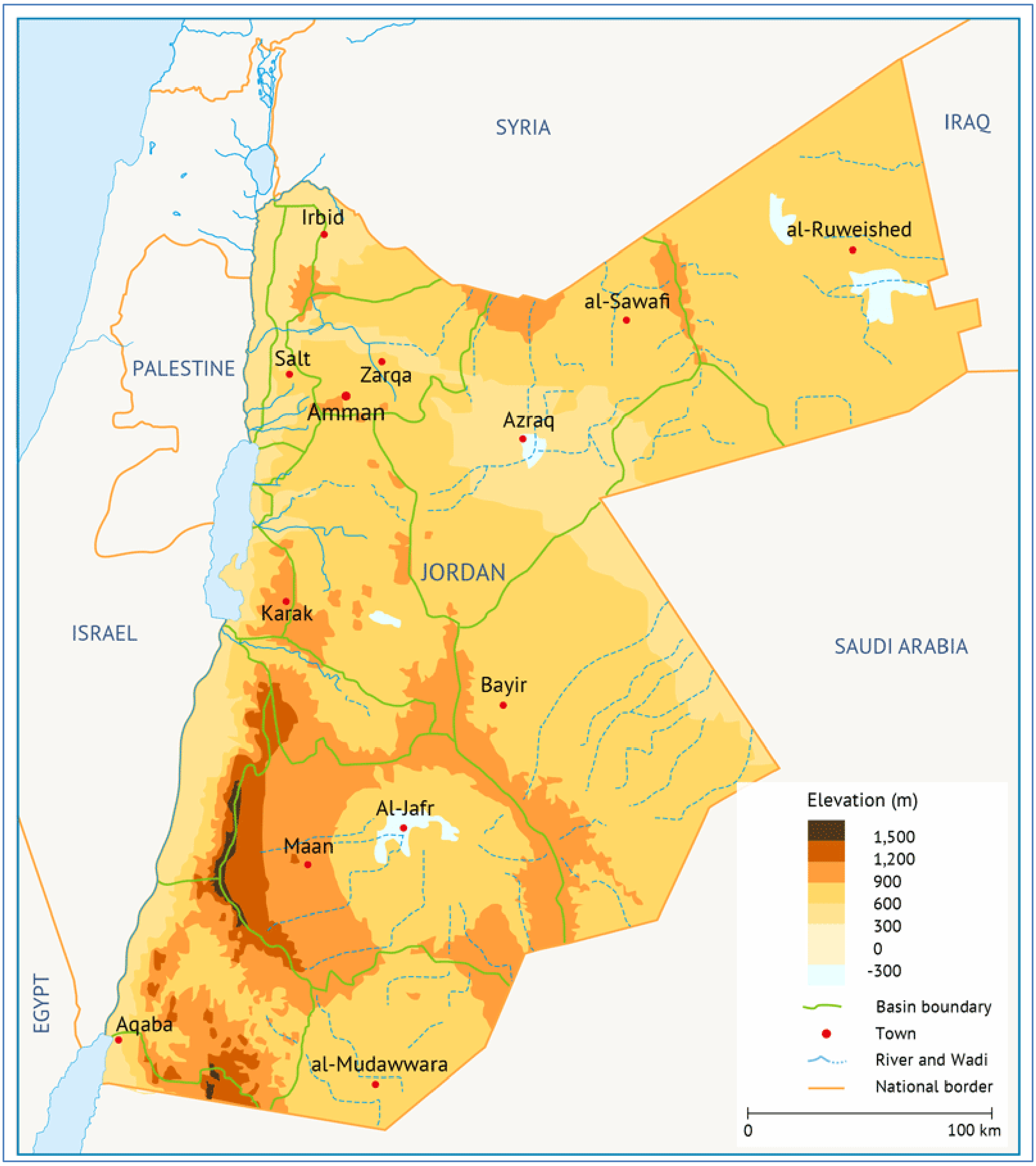
## 2.1 OBJECTIVES

The main objectives of the activity is to support the Ministry of Water and Irrigation (MWI) in the implementation of the ”Groundwater Sustainability Policy” and the “Water Substitution and Reuse Policy” to enable reducing groundwater abstractions in the highland aquifers to sustainable levels, reserve the resource for urban supply and preserve the ability of the aquifer as a buffer against drought-induced surface water shortfalls (focusing on one of the most threatened aquifers suffering from high groundwater over-exploitation; the Azraq basin (Map 1) which will be used as a pilot area for further investigations).

Map 1: Groundwater Basins in Jordan:.



Map 2: Main cities in Jordan




Building on the results of the two assessments conducted by the USAID-funded "Institutional Support & Strengthening Program (ISSP) Project, the specific objectives of this activity are to:

- Assess the socio-economic impact of groundwater over-exploitation scenarios in Azraq basin (assuming both business as usual (BAU) and likely growth in all sectors (Industrial, domestic, irrigation)), with the associated lowering of water tables, dry-out of shallow aquifers deterioration of water quality, and salt-water intrusion into fresh water layers, taking also into consideration possible influx of new refugees;

- Assess the socio-economic impact of enforcement of groundwater by-laws and the new groundwater policy (such as closing of illegal wells, reduction of water abstraction to safe-yield through restricted water usage (as per the abstraction license).
- Conduct socio-economic analysis of the potential impacts of different measures and actions for the conservation of the aquifers in Azraq basin (including quota reduction, adjustment of water tariff, removal of subsidy on electricity used for water pumping, change in cropping pattern, etc.), on Azraq basin; and
- Assess the socioeconomic impacts of different options to mitigate the impact of reduction in groundwater abstractions including scenarios for alternative income generating activities.

## 2.2 TARGET GROUP FOR THE ACTIVITY

The target group of this activity is the policy and decision-makers who are working in water resources management, as well as water-related sectors, such as the high-level officials and decision makers at MWI, the Water Authority of Jordan (WAJ). The output of this activity can also provide relevant information to the members of the parliament in addition to the Higher Agriculture and Water Committee of the parliament, and the Disaster and Crisis Management Committee.

## 2.3 EXPECTED RESULTS OF THE ASSIGNMENT

As per the Terms of Reference, the expected results per task are listed below:

**Task 1: Develop the methodological approach and identify data and information requirements from MWI.**

- An outline of the methodology with annotated description is submitted for approval.
- Outline of the Final Report
- Data and information requirements from MWI with proposed dates for submission

**Task 2: Assess the socio-economic contribution of Azraq basin in relation to the use of groundwater (Business as usual (BAU), and future) (Assessment by economic sector and totals).**

- Socio-economic contribution of Azraq basin's economic activities, which are using groundwater as a source, is assessed (contribution to the rural, national and sectorial economies, employment, income, food production, and local trade and commodity value chain) and by economic sector with employment and income disaggregated by guest, refugees and local rural people).
- Expected future trend of economic activities and employment opportunities in the economic sectors especially in irrigated agriculture;

**Task 3: Assess the socio-economic impacts of groundwater over-exploitation in Azraq basin - assuming BAU scenario and plausible trends in sectorial growth and possible accommodation of new refugees.**

- Groundwater abstractions under Business as usual scenario, and under plausible trends in sectorial growth are assessed
- The groundwater model for Azraq basin shallow aquifer is updated and the impact of groundwater over abstractions on the depletion of groundwater resources, drying up of wells, and groundwater quality deterioration is simulated using the model (under BAU scenario; and plausible trends in sectorial growth).
- The hot spot areas which will be affected by over-abstractions are delineated and the farms and any other economic activity (domestic and industrial) that are impacted by groundwater abstractions under BAU, and future trends in abstractions are identified, together with the quantified impact of groundwater over-exploitation on the depletion of groundwater resources, drying up of wells, and groundwater quality deterioration in these zones.
- The negative social and economic impacts as a result of depletion of groundwater resources, drying up of shallow wells, water quality deterioration, etc. under BAU groundwater over-abstraction, and future trends in abstractions to meet both “sectorial growths” and “possible influx” of new refugees in Azraq basin are quantified by sector.

**Task 4: Assess the socio-economic impact of enforcement of groundwater by-laws and the new Groundwater Policy on all economic activities (using groundwater in Azraq basin), at the macro and micro levels.**

**Task 4.a:** Groundwater actions for reducing groundwater abstractions in Azraq basin are proposed (for the economic activities that are using groundwater within the hot spots delineated under task 3 above (depending on the degree of decline of GW level and increase in salinity), and the impact of such actions on groundwater levels and salinity is tested using the updated model

**Task 4b:** The socioeconomic impacts of enforcing different measures to reduce over-abstraction in Azraq basin and using suitable socio-economic indicators are assessed for the various sectors, for all the zones delineated under task 3 above.

**Task 5: Propose measures across all sectors to mitigate the socio- economic impacts (resulting from the application of the policy reform options) including alternative income generating possibilities for the selected basin. Assess the socioeconomic impacts of the mitigation measures and recommend plausible ones.**

**Task 5.a:** Options and measures to mitigate the socio- economic impacts of reduction of groundwater over-abstraction (as an outcome of the application of the actions proposed under task 4a above), including alternative income generating possibilities are investigated and plausible mitigation measures are proposed for the farms/business activities affected by the groundwater actions proposed under task 4a above.

**Task 5b**:

- The “Experts’ Group” Meeting is held for discussion and exchange of views on the findings and recommendations.
- Feedback from the “Expert Group” Meeting is integrated into the final report and considered in the recommendations (as applicable).

## 2.4 DELIVERABLES

In accordance with the Terms of Reference, the present intervention is divided into five (5) tasks (See section 2.4 above). Table 1 below lists the required deliverables

Table 1: List of Deliverables

| Task | Deliverables |
|---|---|
| Task 1: Develop the methodological approach and identify data and information requirements from MWI. | - Methodology outline<br>- Outline of the Final Report<br>- Data and information requirements from MWI are submitted with clear indication of the date by which the data/information should be available |
| Task 2: Assess the socio-economic contribution of Azraq basin in relation to the use of groundwater (Business as usual (BAU), and future) (Assessment by economic sector and totals) | Chapter 1:<br>1.1 Analysis of the socio-economic contribution of the various economic sectors in Azraq Basin under the BAU scenario to the rural and national economy, food production and security, local trade and employment, and income generation (Analysis of employment opportunities disaggregated by gender, nationality, foreign labour, remittance transfer, etc.).<br>1.2 Identification of the expected future trends of the economic activities (and resulting water demands), and employment opportunities |
| Task 3.a: Modify existing groundwater model for Azraq basin shallow aquifer and simulate the impact of groundwater over-exploitation on the depletion of groundwater resources, drying up of wells, and groundwater quality deterioration under BAU scenario; and plausible trends in sectorial growth. Delineate hot spot areas which will be affected by over-abstractions and present the findings to MWI for approval and integrate their feedback. | a. Approved methodology for assessing the impacts of groundwater over-abstractions on the depletion of groundwater resources, drying up of wells, and groundwater quality deterioration (under both scenarios): the methodology will be based on modelling the Azraq basin shallow aquifer and testing the impact of groundwater over-abstractions on groundwater level and salinity (under the two scenarios)<br>b. Quantified Impacts of over-abstractions (under both scenarios) per zone type.as input to task 3.c.<br>Both a and b above will be integrated to relevant sections in chapter 2. of the report. |
| Task 3.b: Assess the groundwater abstractions under Business as usual scenarios, and plausible trends in sectorial growth. | Estimates for groundwater abstractions under Business as usual scenario, and under plausible trends in sectorial growth as input to task 3.a. and as part of chapter 2. of the report |
| Task 3.c: Assess the socio-economic impacts of the adverse effects of groundwater over- | Chapter 2<br>2.1. Expected negative socio-economic impacts of BAU of current groundwater over-exploitation in Azraq Basin across the various sectors: agricultural domestic, and industrial |

| Task | Deliverables |
| --- | --- |
| exploitation (depletion, drying up of shallow wells, water quality deterioration) in the Azraq basin - assuming business as usual (BAU) scenario and plausible trends in sectorial growth (including in irrigated agriculture), and accommodation of new refugees (if still judged applicable). The assessment will follow the zones suggested by the GW expert.. | 2.2 Potential impacts of groundwater overexploitation resulting from the expected future trends in the growth of economic activities and respective water demands across the various sectors.<br><br>Chapter 2 of the report will also include the methodology and results of tasks 3.a and 3.b . |
| Task 4a: Develop actions to reduce groundwater abstractions to sustainable levels on the basis of the zoning of the basin into hot spots emanating from task 3.a | - Results of the model depicting the impact of groundwater reform actions on groundwater abstractions, level and salinity<br>- List of farms affected by the proposed actions together with corresponding reduction in groundwater level, salinity increase, total and reduced abstraction, crop type and cropped area)<br><br>- Findings are presented, discussed and integrated into chapter three of the report. |
| Task 4.b: Assess the socio-economic impact of enforcement of groundwater by-laws and the new Groundwater Policy) on all economic activities using groundwater in Azraq basin, for the various sectors . The analysis will be done for the farms/business activities (within the hot spots) affected by the groundwater actions proposed under task 4a. | Chapter 3<br>The socioeconomic impact of enforcement of groundwater by-laws and the new Groundwater Policy (to reduce groundwater over-exploitation of groundwater) on the various sectors in Azraq basin (agricultural, domestic, industry, energy and inter-related sectors)<br><br>Assessment of different options should be based on the implementation of different types of measures |
| Task 5.a: Propose measures to mitigate socio- economic impacts (resulting from the policy reform options emanating from task 4a) including alternative income generating possibilities and recommend plausible measures | Chapter 4<br>Alternative measures to mitigate the socio- economic impacts of reduction of groundwater over-abstraction (resulting from the policy reforms) and assessment of the socioeconomic impacts of those measures for the groups of farms/activities affected by the groundwater policy reform action in the |
| Task 5b: Submit draft final report | |
| Task 5.c: Present the findings of task 5a during the “Experts’ Group” Meeting to be organised by MWI and finalise the report based on the | - “Expert Group” Meeting is conducted, with the all the findings discussed and reviewed by the stakeholders<br>- Brief description of the outcomes of the meeting, integrated into the relevant Chapters of the Report. |

| Task | Deliverables |
|---|---|
| feedback from the experts' panel meeting | |
| Task 5d: Finalise the report based on the feedback from the experts' panel meeting. Submit the model and all relevant files (technical and socioeconomic) to MWI | - Final Report<br>- model and all relevant files/outputs (technical and socioeconomic) |

# 3 METHODOLOGY

The analysis of this study will rely on a comprehensive data sets collected by the USAID's ISSP project for the socioeconomic and water valuation studies (2014). A thorough socioeconomic survey of groundwater wells in Jordan was conducted by the said project for agriculture, industrial, drinking and touristic uses, in order to create an updated body of baseline data and to provide insights into the socio-economic impacts of groundwater use in Jordan. This activity will build on the results of two assessments conducted by the USAID-funded ISSP Project:

a. Analysis Report of the Socio-Economic Survey of Groundwater Wells in Jordan (December 2014), which provides descriptive analysis of socioeconomic characterization of wells owners and farm operators, the prevailing farming systems and farm equipment's, cropped areas, water usage, labour by nationality, source of energy, farmers' needs etc.
b. Water Valuation Study: Disaggregated Economic Value of Water in Industry and Irrigated Agriculture in Jordan (October 2012). The study assesses the value of water across the various sectors of Jordanian society and economy.

The following section shows the proposed methodology for achieving the expected objectives of this activity by task:

**Task 2: Assessment of the socio-economic contribution of Azraq basin in relation to the use of groundwater (Business as usual (BAU), and future) (Assessment by economic sector and totals).**

***The methodology used for task 2:***

The scope of this task according to the TOR calls for assessing the socioeconomic contribution of Azraq basin under 2 scenarios (BAU and future growth). The BUA scenario means that the current practices are expected to continue into the future - regardless of current water resources situation in the basin - which present strong negative impacts on the aquifer. In other words, BAU scenario refers to maintaining the status quo of water pumping levels, cropping patterns, applied technologies of production…etc.

This task of the study was limited to the BAU scenario given that a growth model scenario will require a huge amount of socioeconomic data from different sources which could not be obtained. In addition, the added value of such analysis is limited especially that Azraq basin water resources are at threat of depletion and the economic contribution of Azraq basin will consequently depend on the proposed measures to reduce groundwater over-abstractions as indicated in the last task.

The analysis under this task is undertaken in three parts:

1) Assessment of current socio-economic contribution of Irrigated Agriculture
2) Assessment of current socio-economic contribution of Industrial sector
3) Assessment of current socio-economic contribution of Domestic sector

**1) Assessment of current socio-economic contribution of Irrigated Agriculture**

This task was achieved by applying the following methodology:

a. Conducting descriptive analysis for the current farming systems based on farm categorization. A univariate analysis was conducted (simple descriptive analysis for each of the variables included in the ISSP study such as age, education, gender, nationality, income, family size) no. of family members supported by the farm, proportion of farming income with respect to the total income earned by the family, etc., to estimate means, averages, variation, maximum and minimum values for each variable.

b. Cross tabulation in order to identify the S/E characteristics of each farming system: this analysis was conducted by first categorizing the farm systems in Azraq basin according to the managed farm area in dunums (du) (Small, Medium and Large size holdings, whereby Small Farms (Farming System 1) consist of areas less than 50 dunums, Medium Farms (Farming System 2); between 50 & 200 dunums and Large Farms (Farming System 3); greater than 200 dunums. Based on the categorization of the farming systems, cross tabulation was conducted to obtain an image of the interrelations between the selected socioeconomic variables and the farming systems in order to assess the interactions between them. In addition, the dominant crops cultivated under each farming system were identified

c. Estimating gross margins[1] (by farming system) for the dominant crops to evaluate their likely returns or losses. To estimate the gross margins, crop budgets[2] were constructed for each farming system for the previously identified dominant crops. The required data include:

   i. *Data for Estimating the Revenues:*
      - Crop type
      - Crop Area (du)
      - Crop Output (Kilogram (Kg) per du)
      - Crop Price (Jordan Dinar (JD)/kg)

   ii. *Data for estimating the direct Expenses per crop*
      - Cost of fertilisers(JD/Du)
      - Cost of pesticides JD/du
      - Cost of seeds per dunum
      - Cost of Plastic Mulches per dunum
      - Cost of Water

[1] Gross Margin refers to the total income derived from an enterprise less the variable costs incurred in the enterprise.

[2] Crop budget is on farm management tool that shows the breakdown of costs and returns per one unit of land (du) during a specific period (year 2014) in a specific area (Azraq basin)

  - Water Cost (JD/m3)
  - Water use (m3/du)

iii. *Data for estimating Machinery and Power Expenses*
- Cost of Machinery (including fuel and oil, machine repair, machine depreciation) (JD/dunum)

iv. *Data for estimating Labour Costs*
- *Hired Labour*
  - the daily wage rate of labour (JD/person-day);
  - the number of labour needed (no./dunum)

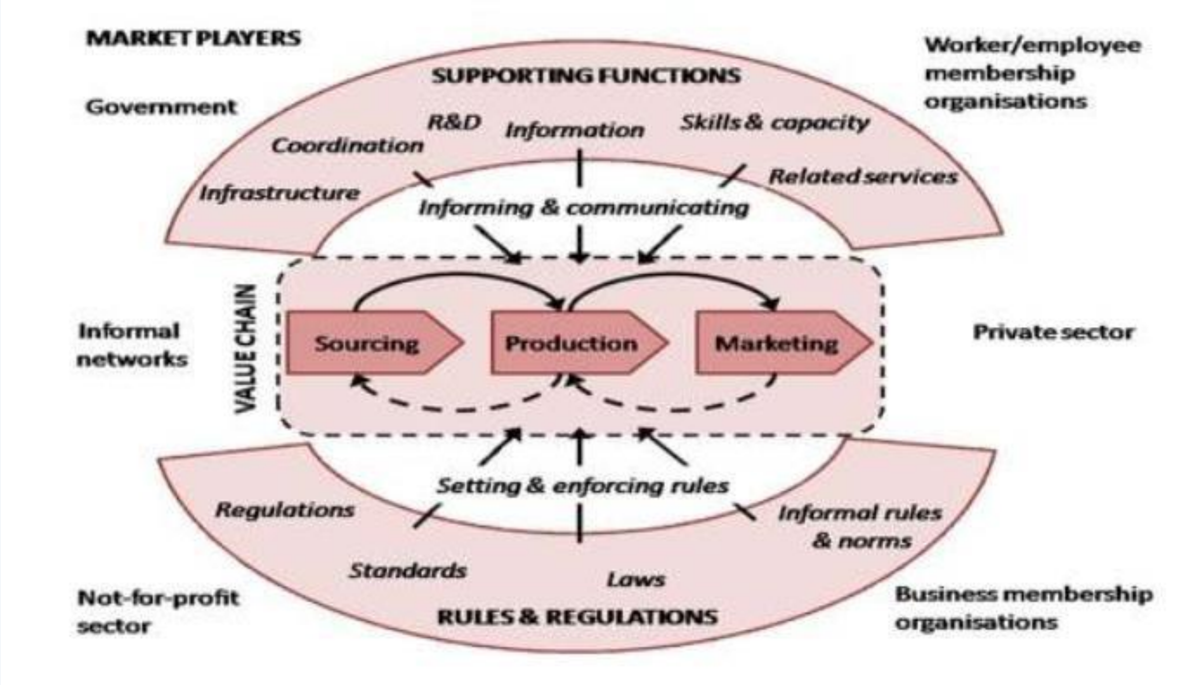
The crops budgets are used to estimate the total costs and returns as well as the gross margins for the dominant crops in the basin; whereby the gross margin (GM) is equal: GM = Total Income – Variable costs. These estimates were used to determine the GM per unit of land,

d. Within the framework of this task, the constructed crop budgets were used to estimate the volume and the value of production of major crops (tons) produced in the Azraq basin and compare it to the national statistics collected by the Department of Statistics (DOS) and the Ministry of Agriculture (MOA) in order to determine the contribution of Azraq basin to the total national agricultural production and agricultural value in the country. Likewise, the crops budgets were also used to estimate the labour requirement per dunum, based on which the total employed labour and its contribution to the national employment can be estimated. Employment was disaggregated by gender, Jordanians and non-Jordanians - using the data collected by the ISSP.

e. The contribution of the agriculture using groundwater in Azraq basin to the total rural economy in the country is difficult to obtain in the absence of official figures on the contribution of the rural economy to the (Gross National Product) GNP. However, DOS maintains records on the distribution of the rural and urban population in the country. Hence, the share of the rural population in the total GDP was assumed to be proportional to the percentage of the rural population to the total population in the country. Furthermore, estimations were made based on the assumption that families which are completely dependent on agriculture in Azraq basin are rural. The number of families that depend fully on agriculture was obtained from the S/E characteristics of each farming system conducted above. The corresponding generated income emanating from the crops budgets calculations was compared with the estimated contribution of the total rural population to the GNP.

**f.** The commodity value chain analysis (applicable to the agricultural and industrial commodities) is used to identify the added value of the different segments of the chain (See figure below). Value chain analysis is a method of achieving economic growth and reducing poverty that focuses on linking enterprises of all sizes of farmers into local, regional and/or global value chains, while ensuring an enabling environment and access to the resources needed to take advantage of and benefit from these market opportunities. The term Value Chain refers to the fact that value is added to preliminary products through the combination of other resources (for example tools, manpower, knowledge and skills, other raw materials or preliminary products). As the product passes through several stages of the value chain, the value of the product increases. Figure1 below sketches the value chain approach and aspects to be considered. The value chain approach to economic development and poverty reduction involves addressing major constraints and capitalizing on opportunities faced by the different actors, mainly, input suppliers, producers, processors, traders and other businesses at the different market levels and segments of the value chain. Conducting a value chain analysis involves a wide range of activities to identify how to improve access to necessary inputs, develop the capacity and skills of human resources, improve working conditions and productivity, strengthen the delivery of business and financial services, enable the flow of information, facilitate improved market access, or increase access to higher-value markets or value-added products. The value chain analysis also aims at identifying opportunities and constraints of a particular local/regional sector and analyses its market integration. **This clearly indicates that the value chain analysis requires lots of data collection using sophisticated tools for the different actors involved in each of the identified value chains for the different crops produced in the Azraq basin, and time and resources way beyond those allocated within the study, and is beyond the scope of this study. The available literature shows that there are no analytical and detailed value chain studies conducted in Jordan, except a brief report on olive oil value chain in Irbid. However, it should be mentioned here that the ISSP water valuation study included a descriptive value chain analysis section based on secondary data published by DOS, MOWI and MOA. The water valuation study conducted a simple value chain analysis for Medjood dates in the Jordan Valley, tomatoes and strawberries. The study did not include any recommendations on how to increase the total value that could be obtained from each of the three products through specific interventions over the different segments of the chain. In other words, the study did not conclude what are the specific actions that should be taken at the levels of producers, transporters, processors, aggregators, input suppliers, retailers and consumers to increase the value of the final product, which is the aim of the value chain analysis.**

Figure 1: The commodity value chain analysis (applicable to the agricultural and industrial commodities)




Source: Springfield Centre

2) **Assessment of the economic contribution of the industries using groundwater in Azraq Basin**

For the industrial sector assessment, the consultant collected/investigated industrial projects in the Azraq basin utilizing the ground water in their activities. The major water consuming industries were requested from MWI, together with their water use. Further data were officially requested (through MWI) from the industries to provide information about the total returns and the total number of employees (disaggregated if possible by nationality) for each industry. Based on the available data, analysis was limited to the largest single industry in the basin (the cement factory).

3) **Assessment of the economic contribution of the municipal water using groundwater in Azraq Basin**

The amount of water for local Municipal uses and that transported to Amman and/or other governorates is needed in order to estimate the population benefiting from its water. The contribution of any additional water transferred to other sectorial uses was not evaluated due to the unavailability of data. Potential socioeconomic impacts of municipal water may include better living standards, improved aesthetics, sanitation and many other impacts which are really hard to estimate/evaluate within the scope of this study since it requires the availability of many datasets and modelling efforts.

## Task 3: Assess the socio-economic impacts of groundwater over-exploitation in Azraq basin -assuming BAU scenario and plausible trends in sectorial growth and possible accommodation of new refugees

***The methodology used for task 3:***

Task 3 is intended to assess the socio-economic impacts of groundwater over-exploitation in Azraq basin -assuming BAU scenario and plausible trends in sectorial growth. The task was achieved first through the development of the two abstraction scenarios and testing them using a groundwater model developed especially for simulating the impact of ground water abstraction on both groundwater level and salinity. The activities/wells (domestic, industrial and irrigation) that are impacted by the drop in water level and the increase in salinity were identified. In the case of irrigated agriculture, the impacted farms were identified and use was made of the cross-sectional data collected by the ISSP project to conduct a descriptive statistical analysis of the socio-economic data associated with the impacted farms Likewise, the municipal and industrial wells that are affected, and those which would be affected in the future, assuming as per the requested TOR two scenarios of groundwater over-exploitation (business as usual scenario (BAU), and increase in over-abstractions) were identified. The results of the statistical analysis were tabulated to show the potential impact of the considered scenarios.

**Task 4: Assess the socio-economic impact of enforcement of groundwater by-laws and the new Groundwater Policy on all economic activities (using groundwater in Azraq basin), at the macro and micro levels.**

***The methodology used for task 4:***

Based on the results of the analysis in task 3, the study assessed the socio-economic impacts of enforcement of groundwater by-laws and the new Groundwater Policy on the main economic activities. As in task 3, this task was achieved through conducting also a descriptive statistical analysis of the cross-sectional data collected by the ISSP project and the results of the groundwater model. Two potential reform options were assessed: 1) closing all illegal wells; and 2) reduction of water abstraction to reach safe yield. The two options were examined for the three identified farming systems by estimating economic indicators such as the expected total loss in investment and the loss of expected gross margins of farms.

**Task 5: Propose measures across all sectors to mitigate the socio- economic impacts (resulting from the application of the policy reform options) including alternative income generating possibilities for the selected basin. Assess the socioeconomic impacts of the mitigation measures and recommend plausible ones.**

***The methodology used for task 5:***

The results of task 4 drove the identification of plausible measures to mitigate the impacts of the two proposed reform options. The study recommended a set of incentives and disincentives (penalties) that could support the implementation of the socio economic measure as per chapter 6.

# 4 CHAPTER: SOCIO-ECONOMIC CONTRIBUTION OF AZRAQ BASIN

## 4.1 THE FARMING SYSTEM OF AZRAQ BASIN

This analysis is based on the field survey conducted by ISSP back in 2014 that covered all of the ground water basins in Jordan, including Azraq. The conducted socioeconomic survey in the Azraq basin by the ISSP covered a total of 334 agriculture sites (including 361 operating wells out of 425 wells recorded under the responsibility of the Azraq Basin Office). The covered sites consisted of 313 sites having single wells, 20 sites having 2 wells and 1 site having 8 wells each.

The collected data by the ISSP project covered a wide spectrum of socioeconomic data including: wells coordinates, ownership and partnerships, operating conditions, legal status, volumes of water abstraction and metering, land area managed, crop patterns, irrigation techniques, marketing information, family involvement, educational level of farm managers, sources of finance in relation to the needed facilities, energy source and consumption, temporary and permanent labour, relations between water users and other stakeholders, water quality and quantity, and the future of the farm (in the case of agriculture) as seen by the operators.

This section provides a socioeconomic analysis based on establishing clusters of farming systems with similar characteristics in Azraq basin. The categorization of the farming systems is based on FAO[3] definition that states: *a farming system is defined as a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a farming system can encompass a few dozen or many locations.*

The analysis was conducted to identify key economic and social variables related to different farming systems prevailing in the Azraq basin. The farming system is one method of categorization. Data can always be categorized according to specific interests. Cross tabulation was then applied to obtain an image of the interrelations between selected variables to assess the interactions between them. For this report, the variables selected stem from the purpose of the study, that of providing a policy tool to help Jordan deal with groundwater abstractions. The key variable used in the analysis is the managed farm area at each farm. Three distinct clusters were identified as the farming systems:

a. System 1: covering managed areas of less than 50 dunums (small farm category),
b. System 2: covering managed areas between 50 dunums and 200 dunums (medium farm category), and
c. System 3: covering areas larger than 200 dunums (large farm category).

Analysis was made for these clusters in relation to several indicators such as socioeconomic and demographic characteristics, farm and well characteristics, dominant crop patterns, financial indicators, labour and gender indicators, and economic efficiency.

[3] http://www.fao.org/farmingsystems/description_en.htm

## Distribution of the farm sizes based on the clusters of farming systems

Table 2 shows the detailed breakdown of the "managed farm size". The distribution is based on the ranges of the farm sizes of the 333 respondents in Azraq Basin out of the visited 361 farms by the ISSP numerators.

Table 2: Distribution of the completed questionnaire by Groundwater Basin (Al-Azraq) basin

| Managed Farm Size in Dunum | System | Number of farms in the basin | % of farm size within the groundwater basin | % of the farm size within all basins |
|---|---|---|---|---|
| <= 50.00 | System 1 | 159 | 48% | 40% |
| 50.01 - 100.00 | System 2 | 54 | 16% | 24% |
| 100.01 - 150.00 | System 2 | 28 | 8% | 20% |
| 150.01 - 200.00 | System 2 | 21 | 6% | 17% |
| 200.01 - 250.00 | System 3 | 15 | 5% | 22% |
| 250.01 - 300.00 | System 3 | 9 | 3% | 12% |
| 300.01 - 350.00 | System 3 | 7 | 2% | 21% |
| 350.01 - 400.00 | System 3 | 7 | 2% | 14% |
| 400.01 - 450.00 | System 3 | 6 | 2% | 19% |
| 450.01 - 500.00 | System 3 | 4 | 1% | 15% |
| 500.01 - 600.00 | System 3 | 5 | 2% | 24% |
| 600.01 - 700.00 | System 3 | 2 | 1% | 13% |
| 700.01 - 800.00 | System 3 | 6 | 2% | 30% |
| 800.01 - 900.00 | System 3 | 2 | 1% | 40% |
| 900.01 - 1000.00 | System 3 | 0 | 0% | 0% |
| 1000.01+ | System 3 | 8 | 2% | 26% |
| | | 333 | 100% | 26% |

Figure 2 indicates that the average size of the area managed by almost one half of the interviewed farms is less than 50 dunums (small holders); i.e. belonging to farming system 1. The Figure also shows that the medium farm size represents 31% and the large farms represent 21% of the total surveyed sites/ farms.

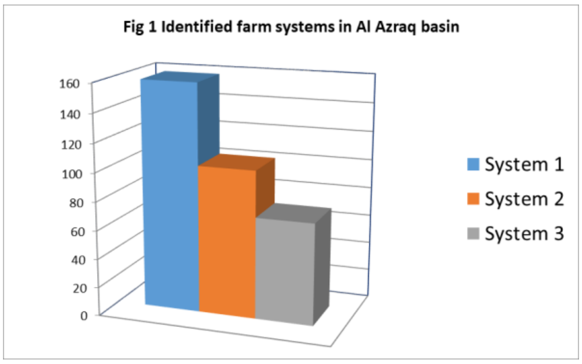



Figure 2: Identified farm systems in Azraq basin

## Socioeconomic and demographic characteristics

A cross tabulation analysis was conducted to identify the socioeconomic characteristics of each of the above identified farming system in the basin. The results of the analysis show the interrelations between the selected socioeconomic variables and the farming systems that should help in assessing the interactions between them. Table 3 shows the distribution of the following socioeconomic indicators amongst the three identified farm sizes.

- **Farming system I (small size holdings):** the majority of the farm owners or managers are older than 46 years of age (59%), their level of education is high school or less (73%), there are only 3 female managers among this group, about one-fourth of the managers are non-Jordanians (mainly Egyptians), 65% of these farms have no family members living on-farm and only one-fourth rely heavily on the income generated by the farming activities.
- **Farming system II (medium size holdings):** 90% of the owners/managers are older than 31 years, the level of education of 71% is Tawjihi (high school) or less, no female farm managers among this group, non-Jordanian managers represents close to one fourth (22%), the majority of these farms support on average 1-5 family members, and about one fourth of the owners rely heavily on farming income.
- **Farming system III (large size holdings):** 93% of the managers are older than 31 years, the level of education of 59% is Tawjihi or less, no female farm managers, almost one-fourth of the managers are non-Jordanian, 95% of these farms support on average 1-5 family members, and 58% of the owners rely heavily on farming income.

**Concluding remarks of the market system analysis:** The results of the analysis of the socioeconomic characteristics of the three clusters in Azraq Basin indicates that **as the farm size increases**, the farms in this basin tend to be **more agribusiness oriented, support more family members and higher reliance on the farming income while smaller farms tend to be more as hobby farms**. **Non-Jordanian farm managers run about one-fourth of all farm systems**.

Table 3: Distribution of socioeconomic and demographic characteristics for the three identified farming systems in Azraq basin

| Indicator | Farm System I (<50 dunum) | Farm System II (50-200 dunum) | Farm System III (> 200 dunum) |
|---|---|---|---|
| | 159 Farms (48%) | 103 Farms (31%) | 71 Farms (21%) |
| **Age** | • 10% < 30 year<br>• 31% 31-45 year<br>• 39% 46 – 60 year<br>• 20% > 60 | • 10% < 30 year<br>• 34% 31-45 year<br>• 36% 46 – 60 year<br>• 20% > 60 | • 7% < 30 year<br>• 34% 31-45 year<br>• 36% 46 – 60 year<br>• 23% > 60 |
| **Education** | • 47% < Tawjihi<br>• 26% Tawjihi<br>• 25% University<br>• 2% > University | • 45% < Tawjihi<br>• 26% Tawjihi<br>• 28% University<br>• 1% > University | • 45% < High school<br>• 14% High school<br>• 27% college<br>• 14% > college |
| **Gender** | • 156 males<br>• 3 females | • 103 males<br>• 0 female | • 71 males<br>• 0 female |
| **Nationality** | • 123 Jordanian<br>• 33 Egyptian<br>• 3 Syrian | • 81 Jordanian<br>• 21 Egyptian<br>• 1 Syrian | • 55 Jordanian<br>• 14 Egyptian<br>• 2 Palestinian |
| **Number of family members supported** | • 79% support 3-5<br>• 21% support less than 3 | • 94% support 1-5<br>• 06% support none | • 31% support 1-5<br>• 64% support >5<br>• 5 % support None |
| **Farming income proportion** | • 26% > 80% of total income<br>• 23% 20-80% of T. income<br>• 51% < 20% of T. income | • 23% > 80% of total income<br>• 25% 20-80% of T. income<br>• 52% < 20% of T. income | • 58% > 80% of total income<br>• 20% 20-80% of T. income<br>• 22% < 20% of T. income |
| **Number of family members living on the farm** | • 65% No one<br>• 19% 1-5<br>• 16% 3-5 | • 61% No one<br>• 20% 1-5<br>• 19% 3-5 | • 65 % No one<br>• 18% 1-5<br>• 17% >5 |

**Source: Processed ISSP Data 2014**

**Dominant crop pattern**

The ISSP socioeconomic survey in 2014 showed that there are different types of crops that have been cultivated under irrigation in the Azraq basin. The **total cultivated area** reported by the 331 respondents is **61,117 dunums of which 48,978 is allocated for fruit trees and the remaining 12,140 dunums for vegetables and annual crops**. This section deals with the analysis of the dominant cropping pattern prevailing at the three identified clusters of farms in this basin. Table 4 shows the distribution of the cultivated area under the different crops for the three farm categories. The table reveals the following:

- **Farming system I (small size holdings): the dominant cultivated tree is olive** for both pickling and for oil extracting purposes**. About 85% of the total farmed area is cultivated with olive trees** of which 63% is devoted for pickling and 22% for pressing. Other cultivated fruit trees are grape and pear which jointly form 4% of the farm size. The rest of the farm is devoted to alfalfa and corn;
- **Farming system II (medium size holdings):** As in the case of farming system I, the **dominant cultivated tree here is also olive** for both pickling and for pressing purposes. However, the share of olive trees here is slightly lower at **67% of the total farmed area** of which 47% is devoted to pickling and 20% for pressing. Area allocated to grape trees is 8% and 2% for pear. The rest of the farm's area is devoted to field crops and vegetables. Alfalfa is the dominant annual crop of this category occupying 11% of the farm's size. The remaining area is devoted to tomato and cantaloupe;
- **Farming system III (large size holdings):** The dominant cropping pattern in this cluster is similar to the previous two systems. **The dominant cultivated fruit tree is also olive** for both pickling and for pressing purposes. The devoted area for olive trees is 64% of the total farm area of which 41% is for pickling and 24% for pressing. Area devoted to grape, pear and palm is 12%. The rest of the farm is devoted to alfalfa (10%) barley (3%), and 2% for wheat.

**Concluding remarks:** The analysis of the cropping pattern characteristics of the three identified clusters of farms indicates that as the farm size increases, the allocated area for olive production slightly decreases. **Large farms tend to diversify crops production especially grape which is considered as a relatively high-value product.** This **conclusion supports the remark in the previous two sections that as the farm size increases, farms become more business oriented**.

Table 4: Dominant cropping patterns for the three identified farming systems in Azraq basin

| Indicator | Farm System I (<50 dunum)<br>159 Farms (48%) | Farm System II (50-200 dunum)<br>103 Farms (31%) | Farm System III (> 200 dunum)<br>71 Farms (21%) |
|---|---|---|---|
| Main fruit trees (% of the total cultivated area in du) | • 63% Olive<br>• 22% Olive for pressing<br>• 3% Grape<br>• 1% Pears | • 47% Olive<br>• 20% Olive for pressing<br>• 8 % Grape<br>• 2 % Pears | • 41% Olive<br>• 24% Olive for pressing<br>• 7 % Grape<br>• 3 % Palm<br>• 2% Pears<br>• 1% Pomegranate |
| Main vegetables and field crops (% of the total cultivated area in du) | • 4% Alfalfa<br>• 2% Corn | • 11 % Alfalfa<br>• 2 % Cantaloupe<br>• 2% Tomato | • 10 % Alfalfa<br>• 3 % Barley<br>• 2 % Wheat<br>• 1% tomato |

**Source: Processed ISSP Data 2014**

**Estimated gross margins for the dominant crops in Azraq basin:**

As indicated in the above table (4), the vast majority of the cultivated area in the basin is devoted to fruit trees. **When considering the total fruit areas (not just the main fruit trees shown in table 4 above), one can conclude that** more than 96% **of the cultivated areas are devoted to fruit trees under** system 1, 86% under system 2 and 84% under system 3).

**The two major fruit trees dominating the cultivated crops under the different farm systems are:** 1) Olive trees for both pickling and oil production; and 2) grapes. The remaining cultivated area with mainly vegetable crops, fodder and field crops (Alfalfa, barley, tomato, wheat and cantaloupe) is about 6% for farm system 1, 15% farm system 2 and 16% farm system 3.

The gross margins (by farming system) was estimated for the dominant crops to evaluate their likely returns or losses. To estimate the gross margins, the different elements of the crop budgets established during the ISSP project for the year 2014 were updated for each farming system for the previously identified dominant crops.

The revised crop budgets were also based on current prices of inputs and outputs that were obtained from DOS, MOA and the Agricultural Credit Corporation (ACC) The following summary of the crop budgets were based on the data reported in 2014 by farmers of Systems 1, 2 and 3 . The averages were based on the farmers who reported complete datasets. Some of the interviewees by the ISSP team did not provide the whole needed data for constructing complete budgets, consequently, they were excluded. Tables 5, 6 and 7 contains the crops' budgets together with the gross margins per dunum (JD/Du) and the total gross margin of the cultivated areas (JDs) for systems 1, 2 and 3 respectively.

Table 5: Crop budgets of the main crops produced in Azraq basin under farm system I for the year 2014

| Cultivated Crop Type | Yield kg/du | Price JD/kg | Revenue JD/Du | Cost JD/Du | Gross Margin JD/du | Total Area Du | Total Gross Margin (JD) |
|---|---|---|---|---|---|---|---|
| Olive | 521.05 | 0.85 | 443 | 202.00 | 241 | 391 | 94,069 |
| Olive for pressing | 424.70 | 0.85 | 361 | 202.00 | 159 | 128 | 20,352 |
| Barley | 400.00 | .32 | 128 | 100.00 | 28 | 91 | 2,548 |
| Grape | 290.76 | .80 | 233 | 305.00 | 72- | 44 | 3,185- |
| Cauliflower | 6000 | .15 | 900 | 680 | 220 | 136 | 29,920 |
| Alfalfa | 185.88 | .40 | 74 | 364.06 | 290- | - | - |

**Source: estimated based on the ISSP survey4**

Table 6: Crop budgets of the main crops produced in Azraq basin under farm system II for the year 2014

| Cultivated Crop Type | Yield kg/du | Price JD/kg | Revenue JD/Du | Cost JD/Du | Gross Margin JD/du | Total Area Du | Total Gross Margin (JD) |
|---|---|---|---|---|---|---|---|
| Olive | 488.27 | .80 | 391 | 220.00 | 171 | 5465 | 932,474 |
| Olive for pressing | 551.50 | 0.80 | 441 | 220.00 | 221 | 2310 | 510,972 |
| Alfalfa | 444.21 | .40 | 178 | 238.96 | 61- | 1237 | 75,792- |
| Grape | 1500.00 | .80 | 1,200 | 398.10 | 802 | 947 | 759,399 |
| Cantaloupe | 1482.25 | .28 | 408 | 354.00 | 54 | 255 | 13,673 |
| Arecaceae (Palm) | 250.00 | .30 | 75 | 1471.69 | 1,397- | 241 | 336,603- |
| Tomato | 438.75 | .33 | 145 | 272.33 | 128- | 235 | 29,973- |
| Pear | 624.71 | 1.00 | 625 | 570.55 | 54 | 205 | 11,105 |
| Pomegranate | 660.71 | .51 | 337 | 325.58 | 11 | 163 | 1,855 |
| Watermelon | 250.00 | .13 | 31 | 320.00 | 289- | 160 | 46,200- |
| Corn | 160.00 | .33 | 53 | 100.00 | 47- | 100 | 4,720- |
| Wheat | 160.00 | .40 | 64 | 103.00 | 39- | 50 | 1,950- |
| Eggplant | 354.00 | .15 | 53 | 155.00 | 102- | 47 | 4,789- |
| Onion | 610.00 | .13 | 76 | 155.00 | 79- | 25 | 1,969- |
| Apricot | 800.00 | .80 | 640 | 883.33 | - | 21 | - |
| Garlic | 500.00 | .60 | 300 | 30.00 | 270 | | - |

**Source: estimated based on the ISSP survey[4]**

Table 7 Crop budgets of the main crops produced in Azraq basin under farm system III for the year 2014

| Cultivated Crop Type | Yield kg/du | Price JD/kg | Revenue JD/du | Cost JD/du | Gross Margin JD/du | Total Area (Du) | Total Gross Margin (JD) |
|---|---|---|---|---|---|---|---|
| Olive | 522.48 | .80 | 418 | 220.00 | 198 | 18740 | 3,710,262 |
| Olive for pressing | 468.22 | 0.80 | 375 | 220.00 | 155 | 10994 | 1,699,386 |
| Alfalfa | 700.00 | .40 | 280 | 309.07 | 29- | 4762 | 138,438- |
| Grape | 1500.00 | .80 | 1,200 | 630.00 | 570 | 3234 | 1,843,380 |
| Arecaceae (Palm) | 62.60 | .55 | 34 | 554.40 | 520- | 1461 | 759,676- |
| Barley | 266.67 | .32 | 85 | 31.20 | 54 | 1315 | 71,185 |

4 There are no farm-gate prices for the Azraq basin published by DOS so the figures of the ISSP as reported by the Azraq farmers were used

| Cultivated Crop Type | Yield kg/du | Price JD/kg | Revenue JD/du | Cost JD/du | Gross Margin JD/du | Total Area (Du) | Total Gross Margin (JD) |
|---|---|---|---|---|---|---|---|
| Wheat | 150.00 | .22 | 33 | 32.25 | 1 | 1125 | 844 |
| Pear | 519.00 | .70 | 363 | 828.93 | 466- | 726 | 338,046- |
| Corn | 937.50 | .14 | 128 | 247.14 | 119- | 675 | 80,337- |
| Pomegranate | 1000.00 | .50 | 500 | 358.57 | 141 | 651 | 92,070 |
| Tomato | 1146.56 | .43 | 490 | 260.00 | 230 | 585 | 134,826 |
| Eggplant | 1234.00 | .36 | 444 | 200.00 | 244 | 449 | 109,664 |
| Cantaloupe | 1036.20 | .25 | 261 | 231.67 | 29 | 350 | 10,310 |
| Watermelon | 1083.33 | .30 | 325 | 146.67 | 178 | 170 | 30,317 |
| Apricot | 2000.00 | .65 | 1,300 | 424.83 | 875 | 136 | 119,023 |
| Pistachio | 450.00 | 4.00 | 1,800 | 700.00 | 1,100 | 135 | 148,500 |
| Cauliflower | 1400.00 | .11 | 154 | 250.00 | 96- | 100 | 9,600- |
| Broad bean | 3000.00 | .45 | 1,350 | 58.00 | 1,292 | 80 | 103,360 |
| Beans | 100.00 | .55 | 55 | | 55 | 40 | 2,200 |
| Peach | 1000.00 | | - | 412.50 | 413- | 36 | 14,850- |
| Almonds | 100.00 | .50 | 50 | 2000.00 | 1,950- | 30 | 58,500- |
| green cherry | 2000.00 | .65 | 1,300 | 200.00 | 1,100 | | - |

**Source: estimated based on the ISSP survey**[4]

## 4.2 A COMPARISON BETWEEN REPORTED WATER USE AND ACTUAL CROP WATER REQUIREMENTS

The ISSP socioeconomic survey back in 2014 covered eight groundwater basins in Jordan, including the Azraq. The enumerators have visited 361 registered farms in the Azraq basin, however only 333 farmers responded to the survey questionnaire. As indicated in the survey analysis report of the socioeconomic impact assessment that was conducted by the ISSP and submitted to the MWI the total amount of abstracted water by the respondents was way below the expected volumes. The report states: *"According to the completed questionnaires, the total annual abstraction of water by the three farm systems amounts to 6.434 million cubic meters. This amount of water was used by 333 farmers to irrigate a sum of 61,067 dunums of which 48,978 is allocated for fruit trees and the remaining 12,140 dunums for vegetables and annual crops. This means that the average volume of water used per dunum is 105 cubic meters which is way below the water requirements, thus suggesting lower reported values of pumped water. Table 8 shows the cultivated area of the main vegetable crops and fruit trees in the 333 farms that completed the questionnaire distributed by clusters. The table also shows the crop water requirement per dunum in Azraq basin as estimated by the MOA (due to the unavailability of the crop water requirement for some of the crops, the researcher used the minimum water requirement for the same or similar crops cultivated in other basins in the uplands). As estimated in the table, the total amount of water required to irrigate the sum of the 61,067 dunum cultivated by the 333 farms is 44 million cubic meters which exceeds the total amounts of water reported by the farmers in the questionnaire by more than seven times"*

Table 8 Estimated actual volume of water required for irrigating the cultivated areas in Azraq basin for the three systems in the year 2014

| Main cultivated crop | Area (Dunum) and Water Requirement (CM) by System | | | | | | Water Req CM/Du | Total Water Req (CM) |
|---|---|---|---|---|---|---|---|---|
| | Small | | Medium | | Large | | | |
| | Dunum | CM | Dunum | CM | Dunum | CM | | |
| Olive | 2211 | 1,746,532 | 5465 | 4,317,666 | 18740 | 14,804,600 | 790 | 20,868,798 |
| Olive for | 758 | 598,820 | 2310 | 1,824,900 | 10994 | 8,685,260 | 790 | 11,108,980 |
| Alfalfa | 145 | 112,710 | 1237 | 964,860 | 4762 | 3,714,360 | 780 | 4,791,930 |
| Grape | 113 | 41,625 | 947 | 350,390 | 3234 | 1,196,580 | 370 | 1,588,595 |
| Arecaceae (Palm) | 86 | 76,950 | 241 | 216,900 | 1461 | 1,314,900 | 900 | 1,608,750 |
| Barley | | - | | - | 1315 | 749,550 | 570 | 749,550 |
| Wheat | | - | 50 | 32,500 | 1125 | 731,250 | 650 | 763,750 |
| Pear | 20 | 9,600 | 205 | 98,400 | 726 | 348,480 | 480 | 456,480 |
| Corn | 65 | 17,160 | 100 | 26,400 | 675 | 178,200 | 264 | 221,760 |
| Pomegranate | 16 | 7,200 | 163 | 73,350 | 651 | 292,950 | 450 | 373,500 |
| Tomato | | - | 235 | 131,600 | 585 | 327,600 | 560 | 459,200 |
| Cantaloupe | | - | 255 | 127,500 | 350 | 175,000 | 500 | 302,500 |
| Eggplant | | - | 47 | 27,025 | 449 | 258,175 | 575 | 285,200 |
| Watermelon | | - | 160 | 80,000 | 170 | 85,000 | 500 | 165,000 |
| Pistachio | 20 | 9,600 | 10 | 4,800 | 135 | 64,800 | 480 | 79,200 |
| Apricot | 6 | 2,880 | 21 | 10,080 | 136 | 65,280 | 480 | 78,240 |
| Cauliflower | | - | | - | 100 | 38,000 | 380 | 38,000 |
| Cactus | | - | 85 | 8,500 | | - | 100 | 8,500 |
| Broad bean | | - | | - | 80 | 35,520 | 444 | 35,520 |
| Lemon | | - | | - | 80 | 38,400 | 480 | 38,400 |
| Crops can not identified | 16 | 6,400 | 50 | 20,000 | | - | 400 | 26,400 |
| Peach | 1 | 480 | 11 | 5,280 | 36 | 17,280 | 480 | 23,040 |
| Decoration | 6 | 2,400 | 40 | 16,000 | | - | 400 | 18,400 |
| Beans | | - | | - | 40 | 9,120 | 228 | 9,120 |
| Cautery | | - | | - | 40 | 4,000 | 100 | 4,000 |
| Almonds | | - | 7 | 3,360 | 30 | 14,400 | 480 | 17,760 |
| Apple | 6 | 1,080 | | - | 20 | 3,600 | 180 | 4,680 |
| Onion | | - | 25 | 15,000 | | - | 600 | 15,000 |
| Lettuce | 10 | 3,000 | | - | | - | 300 | 3,000 |
| **Total** | **3,477** | **2,636,437** | **11,664** | **8,354,511** | **45,934** | **33,152,305** | | **44,143,253** |

**Source: ISSP, SOCIO-ECONOMIC IMPACT ASSESSMENT OF GROUNDWATER WELLS IN JORDAN, AL AZRAQ BASIN, SURVEY AND ANALYSIS REPORT**

## 4.3 CONTRIBUTION OF THE AZRAQ BASIN TO THE TOTAL NATIONAL AGRICULTURAL PRODUCTION AND AGRICULTURAL VALUE IN THE COUNTRY

Within the framework of this task, the relevant data from the constructed crop budgets were used to estimate the volume and the value of production of major crops (tons) produced in the Azraq basin and compare it to the national statistics collected by the Department of Statistics (DOS) and the Ministry of Agriculture (MOA) in order to determine the contribution of Azraq basin to the total national agricultural production and agricultural value in the country. Table 9 shows the total production of the three dominant crops in the basin and the national production of the three crops. The table shows that olive production from the basin represents about 14% of the total national production in the year 2014 while the production of grapes represents about 19% of the national production. The total production of the major fruits and vegetables in the basin of 30.6 thousand tons represents only 1.3% of the total national production of vegetable and fruits.

Table 8: total production of the three dominant crops in the basin and at the national level in 2014

| Main cultivated crop | Area by Cluster | | | Total Area Du | Average Yied Kg/du | Total Production Tons | Jordan National Production | % of National Production |
|---|---|---|---|---|---|---|---|---|
| | Small | Medium | Large | | | | | |
| Olive | 2969 | 7775 | 29734 | 40,478 | 1,038 | 21,391 | 155,763.90 | 13.7% |
| Alfalfa | 145 | 1237 | 4762 | 6,144 | 444 | 2,728 | 277,168.50 | 1.0% |
| Grape | 113 | 947 | 3234 | 4,294 | 1,500 | 6,440 | 34,570.80 | 18.6% |
| **Total** | **3,226** | **9,959** | **37,730** | **50,915** | | **30,559** | **467,503** | **6.5%** |
| **Total National Production of All Veg and Fruits** | | | | | | | **2,384,301** | **1.3%** |

**Source: estimated based on the ISSP survey and DOS**

# 4.4 CONTRIBUTION OF THE AZRAQ BASIN TO THE TOTAL NATIONAL AGRICULTURAL EMPLOYMENT IN THE COUNTRY

According to the most recent published data on labour requirements (ACC[5] 2014), the total annual labour requirements of the four major crops cultivated in Azraq basin are listed in table 9.

Table 9: Daily wages and total labour requirement per dunum of land (2014)

| Crop | Annual Total Labour Requirements (Person Day/Du) | Daily wage (JD/Day) |
|---|---|---|
| Olive | 14 | 11 |
| Alfalfa | 20 | 11 |
| Grape | 7 | 11 |
| Barley | Machinery | Machinery |

**Source: ACC - 2014**

The labour requirements in Person Day/Du (from table 9 above) together with the relevant data from the crops budgets (cultivated area under the corresponding main crops) were also used to estimate the labour requirement per year, based on which the total employed labour and its contribution to the national employment was estimated. Employment was disaggregated by gender, Jordanians and non-Jordanians - using the data collected by the ISSP during 2014. Table 10 shows a detailed disaggregation of the labour in the basin using the ISSP data and the total number of permanent labour which was obtained from DOS records for the same year (2014). Using the data portrayed in table 10, the **number of permanent Jordanian labourers employed in the basin represents 12% of total national** figures while the number of permanent non-Jordanian labourers represents only 4% of the national numbers.

5 ACC Handbook for agricultural costs and returns, 2014, Amman-Jordan

Table 10 Disaggregation of permanent labour in the basin for the year 2014

| Farm System | Permanent Labor Requirement (person) | | | | Total Permanent Labor (person) | | Total Permanent Labor by nationality (person) | | Total National permanent Labor (person)* | | % of Azraq to National per Labor | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jordanian | | Non-Jordanian | | | | | | | | | |
| | Male | Female | Male | Female | Male | Female | JOR | Non-JOR | JOR | NonJO | JOR | NonJO |
| Small | 57 | 9 | 102 | 0 | 159 | 9 | 66 | 102 | 1,411 | 10,068 | 12% | 4% |
| Medium | 50 | 7 | 130 | 0 | 180 | 7 | 57 | 130 | | | | |
| Large | 42 | 4 | 190 | 0 | 232 | 4 | 46 | 190 | | | | |
| **Total** | **149** | **20** | **422** | **-** | **571** | **20** | **169** | **422** | **1,411** | **10,068** | | |

**Source: estimated based on the ISSP survey**
***Source: DOS**

Table 11 shows a detailed disaggregation of the temporary labour in the basin using the ISSP data and the total number of temporary labour which was obtained from DOS records for the year 2014. Using the portrayed data in the table, the **number of temporary Jordanian labourers employed** in the basin **represents 10% of total national figures** while the **number of temporary non-Jordanian labourers represents only 16% of the national numbers**.

Table 11: Disaggregation of temporary labour in the basin for the year 2014

| Farm System | Temp Labour Requirement (person) | | Temp Labour Requirement (person) | | Total Temp Labour (person) | | Total Temp Labour by nationality (person) | | Total National Temp Labour (person)* | | % of Azraq to National per Labour | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jordanian | | Non-Jordanian | | | | | | | | | |
| | Male | Female | Male | Female | Male | Female | Jor | Non-Jor | Jor | Non-Jor | Jor | Non-Jor |
| Small | 171 | 93 | 713 | 22 | 884 | 115 | 264 | 806 | 11,602 | 16,012 | 10% | 16% |
| Medium | 277 | 125 | 891 | 12 | 1168 | 137 | 402 | 1016 | | | | |
| Large | 306 | 189 | 562 | 62 | 868 | 251 | 495 | 751 | | | | |
| Total | 754 | 407 | 2,166 | 96 | 2,920 | 503 | 1,161 | 2,573 | 1,411 | 10,068 | | |

**Source: Based on the ISSP survey and DOS**
***Source: DOS**

As indicated in the proposed methodology, the contribution of the agriculture using groundwater in Azraq basin to the total rural economy in the country is difficult to obtain in the absence of official figures on the contribution of the rural economy to the (Gross National Product) GNP. However, DOS maintains records on the distribution of the rural and urban population in the country. Hence, the share of the rural population in the total GDP has been assumed to be proportional to the percentage of the rural population to the total population in the country.

**According to the DOS, the agriculture GDP was estimated at 845 million JD in the year 2014 at current basic prices. As indicated in table 12, the total value of the three major crops produced in the Azraq basin is estimated at 23 million JD which represents about 2.7% of the agricultural GDP of Jordan in the year 2014.**

Table 12: Total production and value of the dominant crops in Azraq basin (Year 2014)

| Main cultivated crop | Area by Cluster | | | Total Production Tons | Jordan National Production | Price (JD/kg) | Value of Azraq production (JD) |
|---|---|---|---|---|---|---|---|
| | Small | Medium | Large | | | | |
| Olive | 2969 | 7775 | 29734 | 21,391 | 155,763.90 | 0.80 | 17,112,932.80 |
| Alfalfa | 145 | 1237 | 4762 | 2,728 | 277,168.50 | 0.40 | 1,091,085.60 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Grape | 113 | 947 | 3234 | 6,440 | 34,570.80 | 0.75 | 4,830,187.50 |
| **Total** | **3,226** | **9,959** | **37,730** | **30,559** | **467,503** | | **23,034,206** |

**Source: Based on the ISSP survey and DOS**

Percentage of urban population of total population in 2014 was 82.6%. Given the population statistics of 2014, the total number of rural population in Jordan was 1,134,801. Using the same distribution, the share of the rural population in the total GDP of the Jordan in the same year was 4,324.31 million JD. This means that the contribution of Azraq production in the rural GDP in the year 2014 (JD 23 million/JD 4324 million) is less than one percent (0.53%).

## 4.5 ASSESSMENT OF THE ECONOMIC CONTRIBUTION OF THE INDUSTRIES USING GROUNDWATER IN AZRAQ BASIN

According to the MWI data, there are only four wells for industrial establishments that were included as part of the ISSP survey (Table 13). The total amount of annual abstracted water from these wells is 140 thousand cubic meters representing only 0.2% of the total water abstracted in the basin (table 13). Further information about these establishments and their future plans was hard to obtain. The main industrial establishment that uses more than 50% of the abstracted industrial waters is the North-Jordan Cement company (NCOO) owned by a Saudi holding company. According to 2016 annual report, NCOO employs 154 persons of different disciplines such as engineers, labours, drivers, administrators and technicians. According to the annual report, NCOO has distributed a sum of JOD 11.5 million of profits in the year 2016. Linking the net profits figure to the amount of water abstracted reported by MWI for the NCOO (75,642 cubic meters), it can be concluded that each cubic meter of water has generated a sum of JOD 152. In terms of employment, according to the company budget, a sum of JOD 2,351,153 was paid for salaries and other benefits to the 154 employed individuals in 2016. This means that every 491 cubic meters of water generated one permanent job in this company. Using the same figures, we could say that the returns of each cubic meter of water is JOD 42/ calendar day. In other words, each one cubic meter of water abstracted from the basin has generated 42 JD in the total revenues of the NCOO. The manufacturing GDP for the year 2016 amounted to JD 4573.6 million (DOS, 2017). This means that the amount of profits distributed by NCOO represents only 0.3% of the total manufacturing GDP of Jordan for the year 2016.

It should be noted that the ISSP survey was able to capture only one industrial well in the village of Mkhezan Alshamali used for dairy processing. Very limited data was however collected on this industry.

**Table 13: Total annual water abstracted by industries in Azraq basin in 2016 (CM)**

| ID | Well Name | Total (CM) |
|---|---|---|
| F 4227 | ADAN WATER AND JUICES CO. | 242 |
| F 4380 | ALMASSAR COMPANY | 46,502 |
| F 4274 | NORTH JORDAN CEMENT | 75,642 |
| F 4358 | SAAD MABATI CO. | 17,648 |
| TOTAL | | 140,034 |

Source: MWI, 2016

## 4.6 ASSESSMENT OF THE ECONOMIC CONTRIBUTION OF THE MUNICIPAL WATER USING GROUNDWATER IN AZRAQ BASIN

Table 14 shows the total amount of municipal water produced from the Azraq basin in 2016. According to the MWI, the whole water abstracted from the governmental wells of 26.5 million cubic meter is transferred to Zarqa governorate for domestic purposes. This represents about 28% of the municipal water needs of Zarqa governorate (enough to provide some 392,447 (of the total governorate's population of 1,403,000) with potable water, based on 185 litres per capita per day. As indicated in the methodology section above, the economic contribution of the municipal water was not evaluated due to the unavailability of data. Potential socioeconomic impacts of municipal water may include, but not limited to, better living standards, improved aesthetics, sanitation and many other impacts which are really hard to estimate/evaluate within the scope of this study since it requires the availability of many datasets, socioeconomic surveys and modelling efforts.

Table 14: Total annual abstracted domestic water in Azraq basin in 2016 (CM)

| | |
|---|---|
| Governmental | 26,542,228 |
| Private | 1,537,468 |
| Total | 28,079,696 |

Source: MWI

# 5 SOCIO-ECONOMIC IMPACTS OF GROUND WATER OVER-EXPLOITATION SCENARIOS IN AZRAQ BASIN

A groundwater model was developed to undertake a technical assessment of the impacts of groundwater over-exploitation scenarios on the lowering of water tables in the Azraq Basin, dry-out of shallow aquifers, deterioration of water quality, and salt-water intrusion into freshwater layers, and the identification of the municipal, industrial and irrigation wells that are affected, and those which would be affected in the future, assuming as per the requested TOR two scenarios of groundwater over-exploitation (business as usual scenario (BAU), and increase in over-abstractions).

The technical assessment is undertaken based on mathematical modelling of the Azraq Basin shallow aquifer with the following objectives:

- Quantify the impact of groundwater over-exploitation on the depletion of groundwater resources, drying up of wells, and the salinity of the groundwater resources under BAU scenario, and future trends in abstractions.
- Delineate the hot-spot areas which will be affected by over-abstractions

- Identify the wells (by sector, i.e. industrial, irrigation, domestic) that will be impacted by groundwater abstractions under BAU, and future trends in abstractions, (and the corresponding farms and any other economic activity that are impacted and group them depending on the type and magnitude of impact.
- Assess the impact of policy reform actions (shutting down of illegal wells, reducing quota of over-abstracting wells, etc.) on groundwater abstractions, respective groundwater level and salinity.

## 5.1 OVERVIEW OF THE MODELLING APPROACH

A groundwater model was developed with the aim of measuring response of groundwater system to over pumping under different water development scenarios.

The model concerning this study was constructed using the modular three-dimensional finite-difference groundwater flow code developed by the United States Geological Survey (USGS) commonly known as MODFLOW (McDonald and Harbaugh, 1988, and Harbaugh and McDonald, 1996). The calibrated model was used to forecast the response of the groundwater flow system for the year 2040. This year was selected based on an initial modelling which showed year 2040 as a tipping point in the basin's history. Further details about the model is depicted in the GW technical report

## 5.2 ESTIMATION OF GROUNDWATER ABSTRACTIONS UNDER BUSINESS AS USUAL SCENARIO, AND PLAUSIBLE TRENDS IN SECTORIAL GROWTH

### 5.2.1 Scenario 1 (S1): Business as usual Scenario

This first groundwater abstraction scenario is based on a demand that reflects no growth in industrial and irrigation uses, assuming that irrigation is capped at current abstraction rates. This assumption is based on the analysis of the recorded water abstractions in these two sectors as per MWI records (2010-2017). The following lists the assumptions considered in calculating the future demands

**Domestic Demand:**

1. Population growth of 3%[6]
2. Water supply at 126 Litres per Capita per day
3. Base year: 2010
4. Base year population for Azraq 2007: 13,063 (IUCN and RSCN 2007 updated to 2010)
5. Domestic pumping 14.2 MCM from AWSA well field

**Agricultural Demands**

Agricultural demands were capped at their current uses of 45 MCM/year. Although MWI is advocating reduction of groundwater abstraction to safe yield, records still show fixed abstractions for irrigation purposes.

It is important to note that within the study area, WAJ wells for domestic purposes abstract 14.2 MCM and still the major use type is agriculture consuming more than 70% of total pumped water. This is without including the illegal wells which are not recorded especially in Azraq. According to Albakri 2015[7] estimations based on the use of remote sensing to calculate actual agricultural abstractions indicate an amount of 10-15 MCM of illegal use (non-metered) in Azraq area. To overcome this uncertainty, agricultural abstractions were therefore corrected based on these findings. Records of governmental wells for domestic purposes were however, maintained as per the records of WAJ at 14.2 MCM from AWSA well field.

**Industrial Demands**

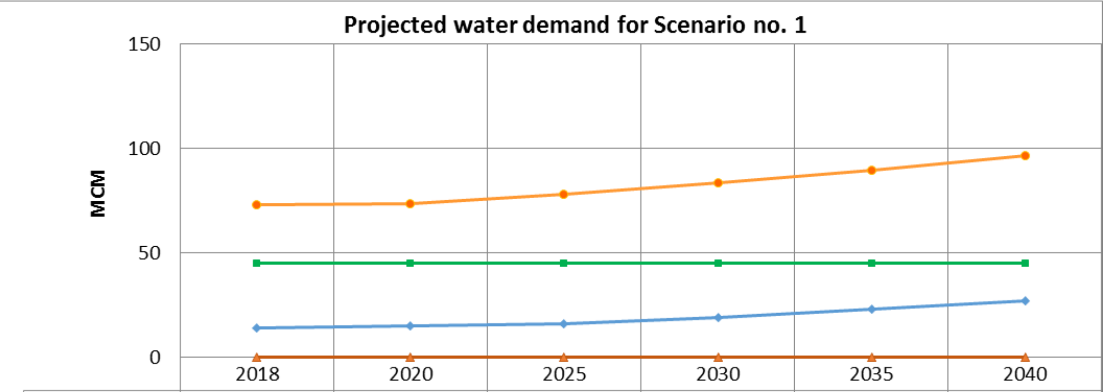
MWI records indicate that industrial pumping is very low (about 0.14 MCM/yr in 2017). This amount was fixed over the modelling period (2017-2040) under scenario 1. No consideration was made for additional industrial activities such as the nuclear power plant.  The latter was considered in scenario 2.

Figure 3 – shows the sectorial demands from 2017 till 2040 and total demands under scenario1

6 Population growth was calculated by DOS 2016 to be 2.8% based on last 10 years records. As Azraq is a rural area, population growth rate was assumed higher (3%)

7 Albakri 2015: Mapping irrigated crops and estimation of crop water consumption in Azraq basin. A report for regional coordination on improved water resources management and capacity building. MWI, Amman – Jordann.

Figure 3: PROJECTED WATER DEMANDS (BY SECTOR) AND TOTAL DEMANDS UNDER SCENARIO1 (2017 TILL 2040)




| | 2018 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| Domestic | 14 | 15 | 16 | 19 | 23 | 27 |
| Agriculture | 45 | 45 | 45 | 45 | 45 | 45 |
| Industrial | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 |
| Total | 73 | 74 | 78 | 84 | 90 | 97 |

### 5.2.2 Scenario 2 (S2): Plausible Sectorial Growth

The second scenario represents a high demand scenario involving the following assumptions

**Domestic Demand (same as scenario 1):**

1. Population growth of 3%8
2. Water supply at 126 Liters Per Capita per day
3. Base year: 2010
4. Base year population for Azraq 2007: 13,063 (IUCN and RSCN 2007 updated to 2010).
5. Domestic pumping 14.2 MCM from AWSa well field.

**Agricultural Demands**

Although MWI records show fixed groundwater abstractions for irrigated agriculture in Azraq area over the time period 2006 – 2015, **remote sensing studies (MWI 2013 and 2017) indicated a yearly increase in agricultural area of 2%.** This growth was considered to apply in the future under this scenario.

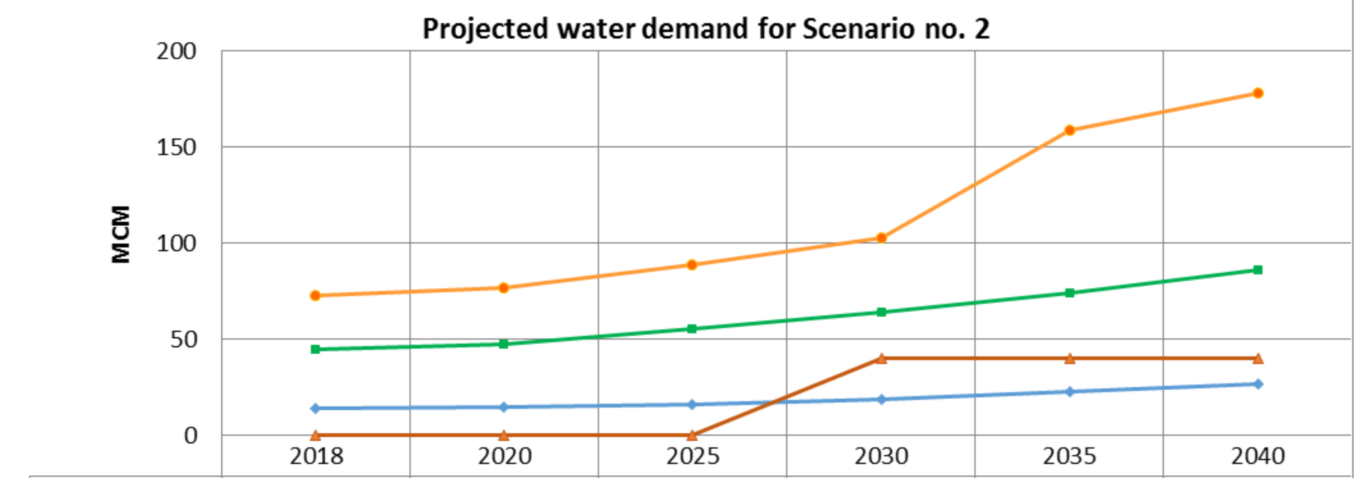
**Industrial Demands**

Within the development plans of the energy sector in Jordan, a nuclear plant is proposed to be constructed west of Azraq city (Qasr Amra area). The total water demand for this plant is estimated around 40 MCM. The plant is located in an area with groundwater as the only source. Due to slow progress on this track, it was assumed that the plant will be under operation by the year 2030.

Figure 4 shows the sectorial demands from 2017 till 2040 and total demands under scenario 2.

8 Population growth was calculated by DOS 2016 to be 2.8% based on last 10 years records. As Azraq is a rural area, population growth rate was assumed higher (3%)

Figure 4: Projected water demands (by Sector) and total demands under scenario 2 (2017 till 2040)




| | 2018 | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| Domestic | 14 | 15 | 16 | 19 | 23 | 27 |
| Agriculture | 45 | 48 | 55 | 64 | 74 | 86 |
| Industrial | 0.15 | 0.15 | 0.15 | 40.00 | 40 | 40 |
| Total | 73 | 77 | 89 | 103 | 159 | 178 |

## 5.3 IMPACT OF GROUNDWATER OVER-ABSTRACTIONS ON GROUNDWATER LEVEL AND SALINITY

The scenarios presented above were tested using a groundwater model developed especially for simulating the impact of ground water abstraction on both groundwater level and salinity (see technical groundwater report).

It should be noted that in order to identify the wells that will dry up, use was made of the aquifer map that was prepared by BGR in 2013, which depicts the bottom of the aquifer. It was assumed that after this depth, the well will get dry and cannot be deepened (refer to technical report).

As for groundwater salinity, time series salinity measurements taken for the monitoring wells during the period 1984-2015 was used to identify trends in salinity during that period. In addition, data available from USGS 2013 and El Naqa 2010 were used to fill the gaps and identify zones of higher salinity. The latter study, which reported the saline water intrusion affecting AWSA well field (not related to any private wells) was considered in our model to validate the impact of salinization on AWSA well field. The annual increase in salinity, thus identified was applied to the projection period. Interpolation of salinity values was done using natural neighbourhood model, based on which groundwater salinity zones were defined.. The salinity thresholds after which crop yield reduction will occur, were obtained from FAO standards and averaged for the main crops in Azraq Basin (Olives, alfalfa, fruit trees, vegetables).

Generally, the model showed under the two scenarios dry cells (dry aquifer) in the Western parts of the area by the year 2040 which is expected due to low saturated thickness as reported by BGR 2013. The highly affected area will be the area between North Azraq and South Azraq. Wells in the eastern parts of the area are expected to last longer due to higher saturated thickness and higher groundwater flows from the North. AWSA well field is not under high risk of being dry. This is due to the high recharge rates from the North and the high aquifer yield in the area.

In addition, the model showed high groundwater salinization rates in the central part of the basin where farm areas are concentrated; mostly due to high return flows dissolving Calcite and Gypsum from the soil profile to the groundwater.

## 5.3.1 Impact of Scenario 1 on the wells by sector

**Domestic wells:**

Domestic supply in Azraq Basin is mainly from AWSA well field drilled in the Basalt limestone aquifer with a high capacity. This area is exposed to recharge coming from the north and hence drawdown is lower.. It is expected that the water level will decline 23 m in AWSA well field by 2040 which is still considered a productive level ( see figure 5.3 ). However, it will have implication on pumping costs.

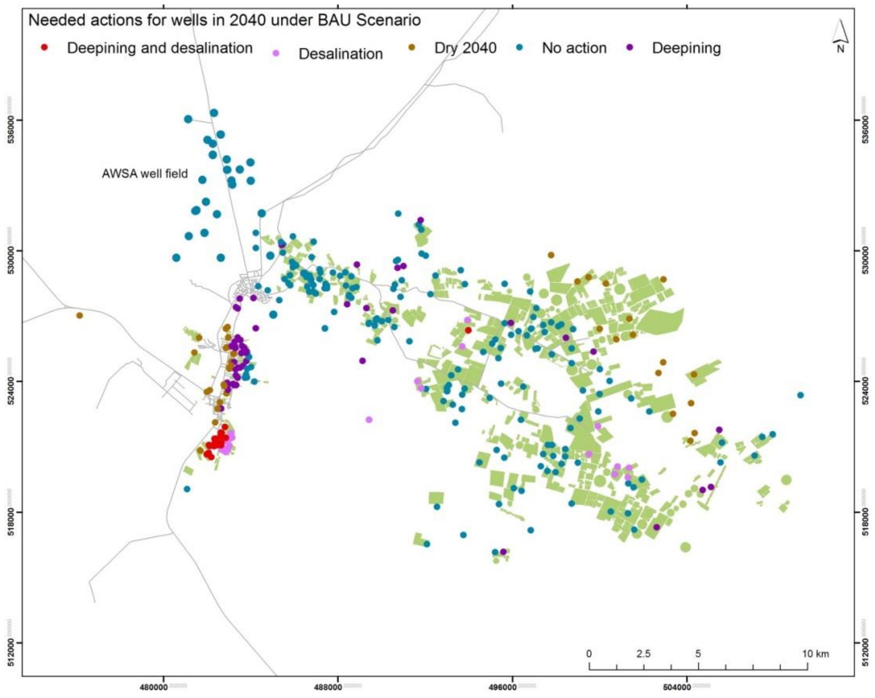
**Agricultural wells:**

Agricultural wells in the eastern parts of Azraq city will be the most affected due to lower saturated thickness of the aquifer in that area in addition to poor well finishing. .It is expected that the water level will decline 27 m The model findings under BAU scenario showed that 78 wells will need deepening while 49 wells need groundwater desalination to sustain the agribusiness. It also showed that 36 wells will be totally dry due to the elevated aquifer bottom west of the oasis and east of Azraq city (see table 14)

**Industrial wells:**

Industrial use of groundwater is located at the western parts of Azraq basin. Due to high saturation thickness of the aquifer in that area and low pumping rates, Industrial well will not be affected under this scenario

**Figure 5: Needed actions for groundwater wells in 2040 under BAU scenario**



Annex 1 lists all the wells by farming system that will be either abandoned, or will require deepening and/or desalination by 2040, as a result of the abstractions assumed under scenario 1. Due to the large amount of data (the ISSP data obtained from MWI) that needed to be processed, the information about those same wells, together with the prevailing main crops was prepared and summarised for each type of farming system (See tables 16, 17 and 18 corresponding to scenario 1).

## 5.3.2 Impact of Scenario 2 on the wells by Sector

**Domestic wells:**

Under this scenario, AWSA well filed will face salinization of few wells; namely F 1028, F 1029 and F 1042. Historical records of the three wells were used to forecast the salinity in 2040 which was found to go beyond drinking standards. As for well productivity, this scenario showed a dramatic drop in groundwater level in AWSA area by 2040 (more than 35 m). In this case pumps would need to be deepened and some wells will require rehabilitation.

**Agricultural wells:**

Under this scenario, the agricultural sector will be highly deteriorated as there will be a total loss of 43 wells and deepening of 88wells The model also indicated an elevated salinity in more than 97 wells which would need to be desalinated, and a decline in water level in the order of 40 m by 2040

**Industrial wells:**

This scenario added 40 MCM of industrial use for the nuclear plant by 2030. As the exact location of the plant's wells is not known, the total pumping of 40 MCM was assumed to be supplied through the addition of 100 wells within the proposed vicinity of the of the nuclear plant at a pumping rate of 50m$^3$/hr per well. It was assumed that by 2040 the wells of the nuclear plants will be fully operational with proper site selection

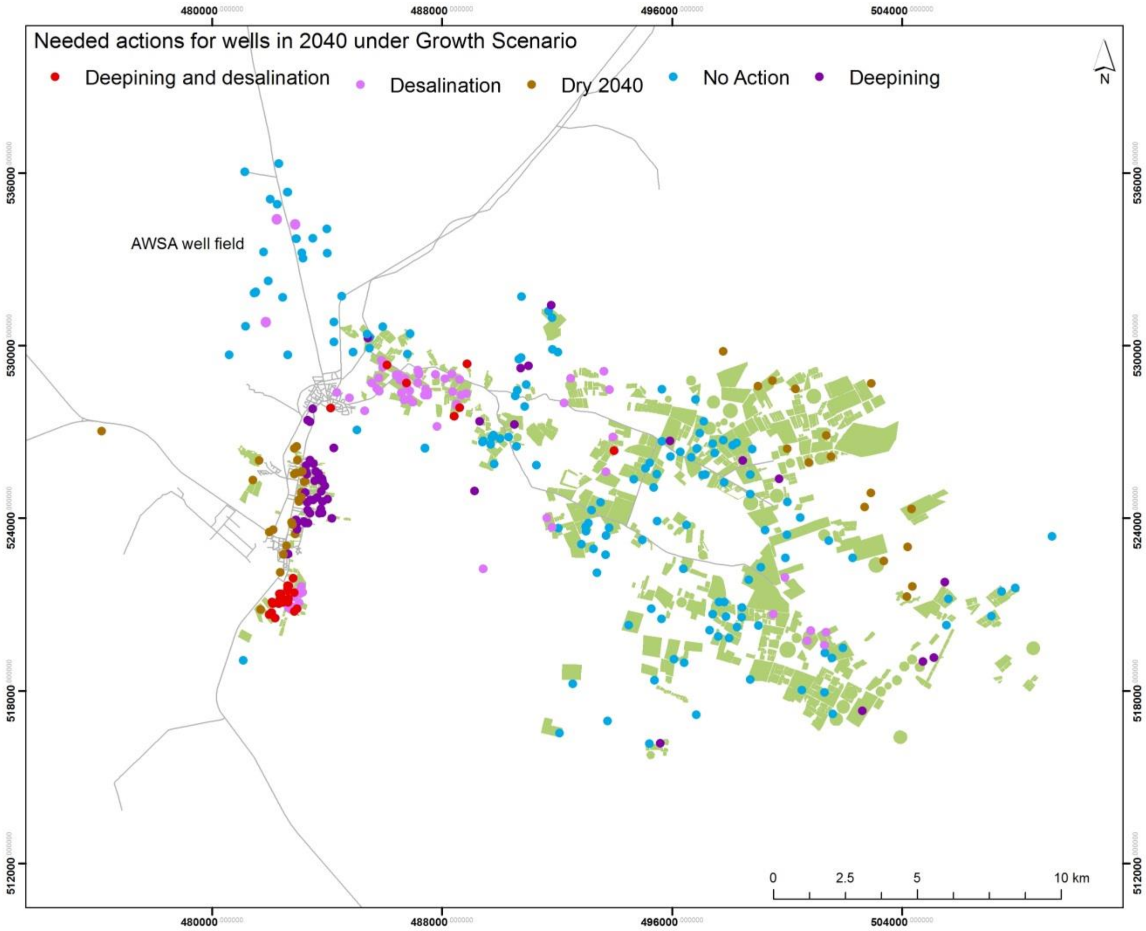
It should be noted that considering the vicinity of the proposed plant location, no salinity measurements could be obtained due to lack of monitoring wells in the area. Therefore, the future changes in the groundwater salinity could not be modeled. In general, the proposed location of the nuclear plant falls within an area with elevated groundwater salinity (> 1000 mg/l).

**Table 15: Model results under the selected two scenarios.**

| In the year 2040: | BUA Scenario | Growth Scenario |
|---|---|---|
| Wells that needs to be deepened | 78 | 88 |
| Wells that needs desalination (FAO standards) | 45 | 97 |
| Wells that will be abandoned | 36 | 43 |
| **Total** | **159** | **228** |

Annex 2 lists all the wells that will be either abandoned, or will require deepening and/or desalination by 2040, as a result of the abstractions assumed under scenario 2. Due to the large amount of data (the ISSP data obtained from MWI) that needed to be processed, the information about those same wells, together with the prevailing main crops was prepared and summarised for each type of farming system (See tables 19, 20 and 21 corresponding to scenario 2).

Figure 6: Needed actions for groundwater wells in 2040 under growth scenario




## 5.4 SOCIO-ECONOMIC IMPACTS OF GROUNDWATER OVER-ABSTRACTIONS

### 5.4.1 Cases facing the agricultural and domestic sectors

The estimated ground water abstraction up to the year 2040, given the assumptions under both scenarios mentioned above resulted in the following cases facing mostly the agricultural sector and its three faming systems in Azraq Basin:

1. Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated;
2. Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned;
3. Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned; and
4. Wells that will be abandoned in the year 2040 due to water dry out.

For the domestic sector, the water level is expected to decline 20 – 30 m in AWSA well field under scenario 1, whereas **under scenario 2,** the said well field will face salinization of few wells; namely F 1028, F 1029 and F 1042. Under the same scenario (scenario 2), a dramatic drop in groundwater level of more than 35 m is expected in the well field by 2040, suggesting the need for deepening the pumps in all wells and for rehabilitation of some wells.

## 5.4.2 Summary of the socio-economic characteristics associated with the different cases facing the Farming Systems

Linking the socioeconomic data for Azraq basin (obtained from the ISSP socioeconomic database[9]) with the list of the wells that are expected to be either abandoned, deepened and/or desalinated by 2040 (based on modelling the abstractions under the two scenarios and simulating its impacts on groundwater), it was possible to synthesise a tabular summary of the socio-economic characteristics associated with the different cases that will face the agricultural sector under each system of faming. **For the BAU scenario,** the results are presented in tables 17 through 19, for farming systems 1, 2 and 3; respectively. The tables show the expected cases that will result if the current (status-quo) situation continues until the year 2040 without any interventions from the government. For instance, by the year 2040, a total of 36 wells will totally dry out under the three systems, while a sum of 123 wells will need either deepening and/or desalination to continue functioning. The tables also show the vast majority of cultivated lands are used for olive production (more than 80%) which is considered as a large long-term investment that will be lost once these wells are dried out or the water levels are sharply declined, as expected.

**Table 16: Summary of the socio-economic characteristics associated with the different cases facing Farming System I (BAU scenario)**

| BUA Scenario Options (System 1) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned; | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned; | Wells that will be abandoned in the year 2040 due to water dry out; |
|---|---|---|---|---|
| Current Number of wells | **64** | **57** | **35** | **19** |
| Total size of the farm (dunum) | 4990 | 1233 | 4476 | 7480 |
| Total cultivated area (dunum) | 1823 | 856 | 600 | 247 |
| Total amount of annual pumped water (m3) [10] | 818218 | 399906 | 189785 | 93636 |
| Well types (Artisan) | 86% | 7% | 6% | 90% |
| Well types (Shallow) | 14% | 92% | 94% | 10% |
| Well depths | less than 30m =34%, 30-50 m =31%, 50-150=28% and more than 150 m = 3% | less than 30m =65%, 31-50 m =30%, 50-150=5% | less than 30m =67%, 31-50 m =26%, 50-150=7% | less than 30m =44%, 30-50 m =39%, 50-150=11% and more than 150 m = 5% |

9 As indicated in section 4, the database covered a wide spectrum of socio-economic information for the surveyed agricultural sites including the well ID

10 These are the reported pumped water volumes by the farmers, which were found to be much lower than the water requirements

| BUA Scenario Options (System 1) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned; | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned; | Wells that will be abandoned in the year 2040 due to water dry out; |
|---|---|---|---|---|
| Well salinity | Less than 1000 = 21%, between 1000-1500 =18% and above 1500 = 48% | Less than 1000 = 46%, between 1000-1500 =18% and above 1500 = 36% | Less than 1000 = 41%, between 1000-1500 =30% and above 1500 = 29% | Less than 1000 = 25%, between 1000-1500 =38% and above 1500 = 37% |
| Well capactiy (m3/hr) | Less than 10m/hr = 20%, 11-30 m3/hr = 58% and more than 30 m3/hr= 22% | Less than 10m/hr = 22%, 11-30 m3/hr = 63% and more than 30 m3/hr= 15% | Less than 10m/hr = 16%, 11-30 m3/hr = 72% and more than 30 m3/hr= 12% | Less than 10m/hr = 17%, 11-30 m3/hr = 67% and more than 30 m3/hr= 16% |
| Main crops | Olive 87%, alfa alfa 4%, Grape 4%, Others 5% | Olive 88%, alfa alfa 5%, Grape 3%, Others 4% | Olive 78%, alfa alfa 6%, Grape 3%, palm 6% | Olive 70%, Grapes 7%, Others 23% |
| % Jordanian Farmers | 64% | 88% | 72% | 95% |
| % Non-Jordanian Farmers | 36% | 12% | 28% | 5% |
| Farmer's Gender (Male) % | 100% | 100% | 100% | 100% |

**Table 17: Summary of the socio-economic characteristics associated with the different cases facing Farming System II (BUA scenario)**

| BUA Scenario Options (System 2) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out; |
|---|---|---|---|---|
| Current Number of wells | **77** | **12** | **8** | **6** |
| Total size of the farm (dunum) | 16150 | 3770 | 1841 | 1270 |
| Total cultivated area (dunum) | 8527 | 1310 | 1026 | 803 |
| Total amount of annual pumped water (m3)[9] | 2037560 | 131760 | 187560 | 92490 |
| Well types (Artisan) | 3% | 100% | 100% | 100% |
| Well types (Shallow) | 97% | 0% | 0% | 0% |
| Well depths | less than 30m =10%, 30-50 m =26%, 50-150=53% and more than 150 m = 11% | less than 30m =13%, 30-50 m =50%, 50-150=37% | less than 30m =37%, 30-50 m =37%, 50-150=26% | less than 30m =20%, 50-70 m =40%, 70-130=30% and more than 150 m = 0% |
| Well salinity | Less than 1000 = 54%, between 1000-1500 =20% and above 1500 = 26% | Less than 1000 = 43%, between 1000-1500 =33% and above 1500 = 24% | Less than 1000 = 33%, between 1000-1500 =50% and above 1500 = 17% | Less than 1000 = 0%, between 1000-1500 =66% and above 1500 = 34% |
| Well capactiy (m3/hr) | Less than 10m/hr = 6%, 11-30 m3/hr = 47% and more | Less than 10m/hr = 10%, 11-30 m3/hr = 40% and more | Less than 10m/hr = 0%, 11-30 m3/hr = 71% and more | Less than 10m/hr = 0%, 11-30 m3/hr = 75% and more |

| BUA Scenario Options (System 2) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out; |
|---|---|---|---|---|
| | than 30 m3/hr= 47% | than 30 m3/hr= 50% | than 30 m3/hr= 29% | than 30 m3/hr= 25% |
| Main crops | Olive 87%, alfa alfa 4%, Graps 4%, Others 5% | Olive 70%, alfa alfa 8%, Graps 9%, Others 14% | Olive 75%, barley 5%, Graps 5%, Others 15% | Olive 60%, Graps 7%, Palm 6% Others 27% |
| % Jordanian Farmers | 79% | 75% | 63% | 83% |
| % Non-Jordanian Farmers | 21% | 25% | 37% | 17% |
| Farmer's Gender (Male) % | 100% | 100% | 100% | 100% |

**Table 18: Summary of the socio-economic characteristics associated with the different cases facing Farming System III (BUA scenario)**

| BUA Scenario Options (System 3) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Current Number of wells | **49** | **9** | **2** | **11** |
| Total size of the farm (dunum) | 57480 | 13518 | 674 | 19176 |
| Total cultivated area (dunum) | 24405 | 11362 | 640 | 12227 |
| Total amount of annual pumped water (m3) [9] | 1796335 | 187250 | 50400 | 555144 |
| Well types (Artisan) | 96% | 100% | 100% | 82% |
| Well types (Shallow) | 4% | 0% | 0% | 18% |
| Well depths | Not Available | Not Available | Not Available | Not Available |
| Well salinity | Not Available | Not Available | Not Available | Not Available |
| Well capacity (m3/hr) | Not Available | Not Available | Not Available | Not Available |
| Main crops | Olive 54%, alfa alfa 9%, Graps 10%, Others 27% | Olive 63%, alfa alfa 24%, Graps 4%, Others 9% | Olive 56%, Palm 14%, Graps 13%, Others 17% | Olive 90%, Graps 2%, Pomegranate 1% Others 7% |
| % Jordanian Farmers | 71% | 88% | 100% | 90% |
| % Non-Jordanian Farmers | 29% | 12% | 0% | 10% |
| Farmers' Gender (Male) % | 100% | 100% | 100% | 100% |

A similar summary was also synthesised for the socio-economic characteristics associated with the different cases that will face the agricultural sector under each system of faming, but this time under the second scenario using the same ISSP database for Azraq basin. The results are also presented for the three farming systems in tables 20 through 22 (farming system 1, 2 and 3; respectively). The tables also show the expected cases that will result until the year 2040 if more stress is imposed on groundwater through increased abstractions above its current levels, assuming no interventions from the government. Adding more stress due to increase in agricultural use and possible commissioning of the nuclear power station will put more burden on the basin. Under such scenario, by the year 2040, the number of wells that will totally dry out under the three systems will increase to 43 instead of 36. In addition, the number of wells that will need either deepening and/or desalination to continue functioning will increase from 123 to 185 wells. While the number of wells that are expected to continue functioning without deepening or desalination will decline from 190 wells to 135. As in the BUA scenario, the tables 20 to 22 also show that the vast majority of cultivated lands are used for olive production (more than 80%) which is considered as a large long-term investment that will be lost once these wells are dried out or the water levels are sharply declined, as expected.

**Table 19: Summary of the socio-economic characteristics associated with the different cases facing Farming System I (Growth scenario)**

| Growth Scenario Options (System 1) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Number of wells | **31** | **65** | **62** | **24** |
| Total size of the farm (dunum) | 3966 | 1397 | 5411 | 7650 |
| Total cultivated area (dunum) | 1049 | 1024 | 1287 | 3431 |
| Total amount of annual pumped water (m3) | 367790 | 431184 | 527275 | 220116 |
| Well types (Artisian) | 93% | 90% | 90% | 92% |
| Well types (Shallow) | 7% | 10% | 10% | 8% |
| Main crops | Olive 85%, alfa alfa 6%, Graps 3%, Others 6% | Olive 86%, alfa alfa 5%, Graps 5%, Others 4% | Olive 83%, alfa alfa 6%, Graps 3%, Others 8% | Olive 77%, alfa alfa 9%, Graps 6%, others 8% |
| % Jordanian Farmers | 68% | 83% | 70% | 92% |
| % Non-Jordanian Farmers | 32% | 17% | 30% | 8% |
| Farmers' Gender (Male) % | 100% | 97% | 97% | 96% |

**Table 20: Summary of the socio-economic characteristics associated with the different cases facing Farming System II (Growth scenario)**

| Growth Scenario Options (System 2) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Current Number of wells | **57** | **14** | **31** | **7** |
| Total size of the farm (dunum) | 13817 | 3794 | 5004 | 1510 |
| Total cultivated area (dunum) | 6613 | 1459 | 3198 | 888 |
| Total amount of annual pumped water (m3) | 1472620 | 228390 | 721300 | 94740 |
| Well types (Artisian) | 96% | 100% | 100% | 100% |
| Well types (Shallow) | 4% | 0% | 0% | 0% |
| Main crops | Olive 67%, alfa alfa 10%, Graps 10%, Others 13% | Olive 69%, alfa alfa 8%, Graps 10%, Others 13% | Olive 70%, alfa alfa 10%, pomogrante 13%, Others 7% | Olive 64%, alfa alfa 23%, Graps 6%, others 7% |

| Growth Scenario Options (System 2) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| % Jordanian Farmers | 77% | 79% | 80% | 71% |
| % Non-Jordanian Farmers | 33% | 21% | 20% | 29% |
| Farmers' Gender (Male) % | 100% | 100% | 100% | 100% |

Table 21: Summary of the socio-economic characteristics associated with the different cases facing Farming System III (Growth scenario)

| Growth Scenario Options (System 2) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Current Number of wells | **47** | **9** | **4** | **12** |
| Total size of the farm (dunum) | 56335 | 13518 | 1826 | 19416 |
| Total cultivated area (dunum) | 23550 | 11362 | 1790 | 12467 |
| Total amount of annual pumped water (m3) | 1796335 | 187250 | 50400 | 555144 |
| Well types (Artisian) | 96% | 100% | 100% | 83% |
| Well types (Shallow) | 4% | 0% | 0% | 17% |
| Main crops | Olive 54%, alfa alfa 9%, Graps 11%, Others 26% | Olive 63%, alfa alfa 24%, Graps 4%, Others 9% | Olive 50%, wheat 17%, Graps 5%, Barley 17 Others 11% | Olive 90%, Graps 2%, Pomegranate 1% Others 7% |
| % Jordanian Farmers | 70% | 89% | 100% | 92% |
| % Non-Jordanian Farmers | 30% | 11% | 0% | 8% |
| Farmers' Gender (Male) % | 100% | 100% | 100% | 100% |

## 5.4.3 Socio-economic Impacts of groundwater over-abstractions - BAU Scenario:

### *5.4.3.1 Agricultural Sector*

Based on the above socioeconomic analysis, the following negative impacts of the BAU scenario are identified:

- Additional drilling costs needed to get better water quality and increase wells' production;
- Additional pumping costs as a result of the decline in the groundwater level (applicable for both the wells that need deepening and the remaining wells that are expected to stay operational
- Desalination costs needed to reduce the salinity of the water;
- Loss of agricultural productivity resulting from increased salinity being the main crop in the basin)

- Lost investment cost of the wells expected to dry out by the year 2040;
- Expected loss in the profits generated by the owners of the farms with dried out wells; and due to increase in energy cost.
- Loss of employment (permanent and daily workers) of both males and females.

Table 22 shows the estimation of the socio-economic costs associated with the negative impacts of groundwater abstractions under the BAU scenario under each farming systems. **This includes employment losses of 1.2 Million on both temporary and permanent labour.** The table shows that the total losses will amount in 2040 to a sum of JD 10.7 million at the current prices. The largest two portions of the losses are the costs of desalination and the loss in investment.

Table 22: Estimated socio-economic costs associated with the negative impacts of groundwater abstractions (BAU scenario)

| Item | BAU Scenario Options (System I) | BAU Scenario Options (System II) | BAU-Scenario Options (System III) | Total |
|---|---|---|---|---|
| Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | 64 | 77 | 49 | 190 |
| Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned; | 57 | 12 | 9 | 78 |
| Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned; | 35 | 8 | 2 | 45 |
| Wells that will be abandoned in the year 2040 due to water dry out; | 19 | 6 | 11 | 36 |
| Temporary Labor Requirement (person year)/ well | 6.28 | 12.67 | 15.76 | |
| Permanent Labor Requirement /(person year)/well | 1.06 | 1.82 | 3.32 | |
| Total Lost Temporary labor in abandoned wells/ person year | 119.32 | 76.02 | 173.37 | 987,547* |
| Total Lost Permanent labor in abandoned wells/person year | 20.14 | 10.89 | 36.56 | 180,851 * |
| Total cost of lost labour (JD) (total labour requirement*JD 2,678)..(1) | 373,474 | 232,745 | 562,193 | 1,168,411 |
| Total drilling needed for deepening (m) | 1500 | 1100 | 890 | 3490 |
| Total desalination needed MCM | 3.1 | 4.3 | 3.9 | 11.3 |
| One-time Cost of needed drilling (@ JD100/m) …(2) | 150,000 | 110,000 | 89,000 | 349,000 |
| Annual Cost of total needed desalination (@ JD 0.3/cm)…(3) | 930,000 | 1,290,000 | 1,170,000 | 3,390,000 |
| Total pumping in MCM based on actual water requirement | 2,636,437 | 8,354,511 | 33,152,305 | 44,143,253 |
| Cost of extra pumping per CM due to 27m decline (0.27kwh*0.094JD/kwh)…(4) | 66,913 | 212,037 | 841,406 | 1,120,356 |
| Average Investment Costs in JD/Farm (ISSP) | 69,918 | 91,446 | 25,5243 | |
| Expected loss of investment in JD due to well dry out (5) | 1,328,442 | 548,676 | 2,807,673 | 4,684,791 |
| **TOTAL ECONOMIC LOSSES IN JD DUE TO BAU SCENARIO in 2040 (1+2+3+ 4 + 5)** | **2,848,829** | **2,393,458** | **5,470,271** | **10,712,558** |

*This value was estimated by multiplying the annual salary of the laborer (JD 2,678) by the number of lost permanent and temporary jobs due to the expected abandoned wells.
** Each 10 meter decline in groundwater level adds 0.1 kWh/m3. As the decline in agricultural area is 27 meter then each cm will require 0.27 kwh.

**According to NEPCO, cost of each kWh for water pumping is JD 0.094

### 5.4.3.2 Domestic Sector

Table 23 shows the estimation of the financial costs associated with the negative impacts of groundwater abstractions under the BAU scenario for domestic purposes in the basin. The table shows by the year 2040 under BAU, 2 wells will need deepening and desalination. The table also shows that the capital costs in 2040 at the current prices for deepening the wells are JD 37,500 under the BAU. However, the recurrent annual cost of the negative impacts of the decline in water level (related to the increased energy for pumping) is about JD 562 thousand under BAU.

Table 23: Estimated financial costs associated with decline in domestic wells under the BAU

| **No. Wells Impacted by Scenario** | **BAU** |
|---|---|
| No. Wells for Abandonment | 0 |
| No. Wells for Deepening | 2 |
| No. Wells for Desalinization | 2 |
| **Total amounts** | **BAU** |
| Deepening m | 150 |
| Desalinization m3 | 850000 |
| **Financial Estimates** | **BAU** |
| Cost of Deepening (JD 250/m) | 37,500 |
| Total domestic pumped water (M3)* | 14,200,000 |
| Annual Cost of Energy for 23 m decline JD** | 307,004 |
| Annual Cost of Desalinization (JD 0.3/m3) | 255,000 |
| **Total annual recurrent costs (JDs)** | 562,004 |

* This is based on MWI. Indicating no intentions to drill more wells to augment the supply to meet the increasing demand at BUA and growth scenarios
**Each 10 meter decline in groundwater level adds 0.1 kWh/m3. Considering 23 m decline in AWSA well field then each CM will require 0.23 K/hr

**According to NEPCO, cost of each kWh for water pumping is JD 0.094

## 5.4.4 Socio-economic Impacts of groundwater over-abstractions: Scenario 2

### 5.4.4.1 Agricultural Sector

Table 24 shows the estimation of the socio-economic costs associated with the negative impacts of groundwater abstractions under the growth scenario for each farming system. The table shows that the total losses will amount in 2040 to a sum of JD11.6 million. The largest two portions of the losses are also the costs of desalination and the loss in investment.

Table 24: Estimated socio-economic costs associated with negative impacts of groundwater abstractions (Growth Scenario)

| Item | Growth Scenario Options (System I) | Growth Scenario Options (System II) | Growth Scenario Options (System III) | Total |
|---|---|---|---|---|
| Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | 31 | 57 | 47 | 135 |
| Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned; and | 65 | 14 | 9 | 88 |
| Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned; and | 62 | 31 | 4 | 97 |
| Wells that will be abandoned in the year 2040 due to water dry out; | 24 | 7 | 12 | 43 |
| Temporary Labor Requirement (person year)/ well | 6.28 | 12.67 | 15.76 | |
| Permanent Labor Requirement /(person year)/well | 1.06 | 1.82 | 3.32 | |
| Total Lost Temporary labor in abandoned wells/ person year | 150.79 | 88.69 | 189.13 | 428.61 |
| Total Lost Permanent labor in abandoned wells/person year | 25.36 | 12.71 | 39.89 | 77.95 |
| Total cost of lost labor (JD) (total labor requirment*JD 2,678)..(1) | 471,732 | 271,544 | 613,300 | 1,356,576 |
| Total drilling needed for deepening (m) | 1500 | 1100 | 890 | 3490 |
| Total desalination needed MCM | 3.1 | 4.3 | 3.9 | 11.3 |
| One-time Cost of needed drilling (@ JD100/m) …(2) | 150,000 | 110,000 | 89,000 | 349,000 |
| Annual Cost of total needed desalination (@ JD 0.3/cm)…(3) | 930,000 | 1,290,000 | 1,170,000 | 3,390,000 |
| Total pumping in MCM based on actual water requirement | 2,636,437 | 8,354,511 | 33,152,305 | 44,143,253 |
| Cost of pumping assuming cap kept at 45 million/m3 and cost of pumping per cm 0.094**…(4) | 66,913 | 212,037 | 841,406 | 1,120,356 |
| Average Investment Costs in JD/Farm | 69,918 | 91,446 | 25,5243 | |
| Expected loss of invetement in JD due to well dryout (5) | 1,678,032 | 640,122 | 3,062,916 | 5,381,070 |
| **TOTAL ECONOMIC LOSSES IN JD DUE TO BAU SCENARIO in 2040 (1+2+3+ 4 + 5)** | **3,296,677** | **2,523,703** | **5,776,621** | **11,597,002** |

*This value was estimated by multiplying the annual salary of the laboror (JD 2,678) by the number of lost permanent and temporary jobs due to the expected abandoned wells.
** Each 10 meter decline in groundwater level adds 0.1 kWh/m3. If the decline is 20 meter then each cm will require 0.2 kwh.
**According to NEPCO, cost of each kWh for water pumping is JD 0.094

### *5.4.4.2 Domestic Sector*

Table 25 shows the estimation of the financial costs associated with the negative impacts of groundwater abstractions under the Growth scenario for domestic purposes in the basin. The table shows by the year 2040 under the Growth scenario, 4 wells will require deepening and 2 will require desalination. The table also shows that the capital costs in 2040 at the current prices for deepening the wells are JD 75,000 under Growth scenario. However, the recurrent annual cost of the negative impacts of the decline in water level is JD 722.2 thousand under this scenario.

Table 25: Estimated financial costs associated with decline in domestic wells under the Growth scenario

| No. Wells Impacted by Scenario | Growth |
|---|---|
| No. Wells Abandonment | 0 |
| No. Wells Deepening | 4 |
| No. Wells Desalinization | 2 |
| **Total amounts** | **Growth** |
| Deepening m | 300 |
| Desalinization m3 | 850000 |
| **Financial Estimates** | **Growth** |
| Cost of Deepening (JD 250/m) | 75,000 |
| Total domestic pumped water (M3)* | 14,200,000 |
| Annual Cost of Energy for 35 m decline** | 467,180 |
| Annual Cost of Desalinization (JD 0.3/m3) | 255,000 |
| Total annual recurrent costs (JDs) | 722,180 |
| * This is based on MWI expressed intention **not** to drill more wells to augment the supply to meet the increasing demand at BUA and growth scenarios<br>**Each 10 meter decline in groundwater level adds 0.1 kWh/m3, As the decline in agricultural area is 35 meter then each cm will require 0.35 kwh. | |
| **According to NEPCO, cost of each kWh for water pumping is JD 0.094 | |

## 5.4.5 Socio-economic Impacts of the potential reform actions

Two reform options were examined in this study based on consultation with the MWI and the review of the groundwater strategy: 1) closing illegal wells in the basin and 2) reducing the current abstraction rate to the levels of the safe yield 24 MCM/yr through a set of measures that include increasing irrigation efficiency (see section 6). It should be noted that safe yield of Azraq basin is in the order of 24 MCM/yr while the total pumping in 2017 is around 73 MCM/yr. In order to reduce abstraction to the safe yield, this suggests cutting down on abstraction by 49 MCM mostly from irrigated agriculture. Irrigated agriculture currently consume 45 MCM without including illegal wells estimated at 10 MCM/yr.

Reduction to safe yield is assumed to be undertaken in gradual steps with an annual reduction of 5% decrease every year starting from 2020. As for the closing of illegal wells, it was assumed that this action will be completed by 2025.

## 5.4.6 Closing illegal wells in the basin action

Tables 26 through 28 show the impacts of option 1 on the three identified farming systems in the basin.

Compared to the BAU scenario, explained above, it is very clear that closing the illegal wells in the basin will result in many positive impacts for all farm systems in the basin. For instance, in the case of small farming systems (System I), the number of wells that will not be abandoned by year 2040 and do not need to be deepened or desalinated will increase by 21 wells. This means that the total cultivated area that could be put aside is increased to 1,856 dunums and a sum of 213,976 cubic meter of water would be saved. In addition, the number of wells that would need to be deepened will decrease by 20 wells and the number of wells that will require desalinization will also decrease by 3 wells. The analysis shows also that the number of wells that will be abandoned in the year 2040 due to water dry out will decrease by 6 wells.

Table 26: Expected impacts of closing illegal wells in Azraq basin on farms of system I

| Scenario Options (System 1) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Current Number of wells | **85** | **37** | **32** | **13** |
| Total size of the farm (dunum) | 6846 | 864 | 4438 | 5899 |
| Total cultivated area (dunum) | 2104 | 621 | 562 | 147 |
| Total amount of annual pumped water (m3) | 1032194 | 211821 | 122114 | 57801 |
| Well types (Artisan) | 86% | 97% | 97% | 85% |
| Well types (Shallow) | 14% | 3% | 3% | 15% |

Table 27: Expected impacts of closing illegal wells in Azraq basin on farms of system 2

| Scenario Options (System 2) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Current Number of wells | **85** | **9** | **5** | **3** |
| Total size of the farm (dunum) | 17814 | 3450 | 1327 | 440 |
| Total cultivated area (dunum) | 9498 | 1131 | 652 | 385 |
| Total amount of annual pumped water (m3) | 2127830 | 103080 | 134160 | 84300 |
| Well types (Artisan) | 98% | 100% | 100% | 100% |
| Well types (Shallow) | 2% | 0% | 0% | 0% |

Table 28: Expected impacts of closing illegal wells in Azraq basin on farms of system 3

| Scenario Options (System 3) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Current Number of wells | **55** | **7** | **2** | **7** |

| | | | | |
|---|---|---|---|---|
| Total size of the farm (dunum) | 68155 | 8550 | 1324 | 12826 |
| Total cultivated area (dunum) | 32619 | 6505 | 590 | 8920 |
| Total amount of annual pumped water (m3) | 2085055 | 224950 | 18000 | 261144 |
| Well types (Artisan) | 96% | 100% | 100% | 71% |
| Well types (Shallow) | 4% | 0% | 0% | 29% |

Table 29 shows the expected reduction in the impacts on all farming systems in the basin as a result of applying the option of "closing of illegal wells" when compared with the respective impacts under the BAU scenario. The table shows that this option will result in not abandoning an additional 35 wells at the basin level; bringing the total number of wells under this category to 225 compared to 190 under the BAU scenario. In addition, it will result in reducing the number of wells that will be utilized only by deepening and desalination by 25 and 6 wells, respectively. This action will also result in reducing the number of wells that will be abandoned due to dry out by 13 wells.

**Table 29: Expected reduced impacts of closing illegal wells in Azraq basin on farms of all systems with reference to BAU scenario**

| **All Systems** | **Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated.** | **Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned** | **Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned** | **Wells that will be abandoned in the year 2040 due to water dry out** |
|---|---|---|---|---|
| Current Number of wells | 35 | -25 | -6 | -13 |
| Total size of the farm (dunum) | 14195 | -5657 | 98 | -8761 |
| Total cultivated area (dunum) | 9466 | -5271 | -462 | -3825 |
| Total amount of annual | 592966 | -179065 | -153471 | -336879 |

## 5.4.7 Reducing the current abstraction to safe yields

Tables 30 through 32 show the impacts of reducing the rate of water abstraction which includes improving the water use efficiency for the three identified farming systems in the basin.

Compared to the BAU scenario, explained above, it is very clear that reducing the rate of abstraction should have better positive impacts than closing the illegal wells in the basin. For instance, as indicated in table 30 in the case of small farming systems (System I), the number of wells that will not be abandoned by year 2040 and do not need to be deepened or desalinated will increase by 39 wells to reach to 103. This also means that the total cultivated area that could be put aside would increase by 8,914 dunums and an additional 356,998 cubic meter of water would be saved. In addition, the number of wells that would need to be deepened will decrease by 23 wells and the number of wells that will require desalinization will also decrease by 6 wells. The analysis shows also that the number of wells that will be abandoned in the year 2040 due to water dry out will decrease by 15 wells. Tables 31 and 32 show the same trend of impacts for systems II and III.

Table 30: Expected impacts of reaching to safe yields in Azraq basin on farms of system 1

| Scenario Options (System 1) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Current Number of wells | **103** | **34** | **29** | **4** |
| Total size of the farm (dunum) | 13904 | 3453 | 3242 | 114 |
| Total cultivated area (dunum) | 2398 | 549 | 459 | 35 |
| Total amount of annual pumped water (m3) | 1175216 | 156021 | 91832 | 1899 |
| Well types (Artisan) | 86% | 97% | 93% | 100% |
| Well types (Shallow) | 14% | 3% | 7% | 0% |

Table 31: Expected impacts of reaching to safe yields in Azraq basin on farms of system 2

| Scenario Options (System 2) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Current Number of wells | **95** | **4** | **3** | **1** |
| Total size of the farm (dunum) | 21226 | 1260 | 430 | 115 |
| Total cultivated area (dunum) | 106864 | 505 | 360 | 115 |
| Total amount of annual | 2292440 | 54870 | 93060 | 9000 |
| Well types (Artisan) | 98% | 100% | 100% | 100% |
| Well types (Shallow) | 2% | 0% | 0% | 0% |

Table 32: Expected impacts of reaching to safe yields in Azraq basin on farms of system 3

| Scenario Options (System 3) | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Current Number of wells | **56** | **10** | **3** | **3** |
| Total size of the farm (dunum) | 68279 | 12556 | 3700 | 8020 |
| Total cultivated area (dunum) | 34069 | 6565 | 1300 | 7100 |
| Total amount of annual | 2033155 | 351250 | 88500 | 143544 |
| Well types (Artisan) | 97% | 90% | 67% | 67% |
| Well types (Shallow) | 3% | 10% | 33% | 33% |

Table 33 shows the expected reduction in the impacts on all farming systems in the basin as a result of applying the option of "reducing the abstraction rates to safe yields" when compared with the respective impacts under the BAU scenario. The table shows that this option will result in not abandoning an additional 64 wells at the basin level bringing the total number of wells under this category to 254, compared to 190 under the BAU scenario. In addition, it will result in reducing the number of wells that will be utilized only by deepening and desalination by 30 and 10 wells, respectively. This action will also result in reducing the number of wells that will be abandoned due to dry out at the basin level by 28 wells.

Table 33: Expected impacts of reaching to safe yields in Azraq basin on farms of all systems

| All Systems | Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned | Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned | Wells that will be abandoned in the year 2040 due to water dry out |
|---|---|---|---|---|
| Current Number of wells | 35 | -25 | -6 | -13 |
| Total size of the farm (dunum) | 14195 | -5657 | 98 | -8761 |
| Total cultivated area (dunum) | 9466 | -5271 | -462 | -3825 |
| Total amount of annual pumped water (m3) | 592966 | -179065 | -153471 | -336879 |

Tables 34 and 35 show the estimation of the socio-economic costs associated with the impacts of applying the two reform options of closing illegal wells and reaching to safe yields groundwater abstractions rates for the three farming systems. These losses also include the monetized employment losses. Comparing the results in the two tables, we conclude that the total cost of reaching the safe yield rates is lower than closing the illegal wells. Table 35 shows that the losses in investment, in addition to the cost of deepening the well and cost of desalination will amount in 2040 to a sum of JD 4.42 million. When compared with the costs associated with the BAU scenario, that adopting this option will result in direct savings in costs that amounts to (10.7-4.4=6.3) million JDs in addition to saved water and improved water quality in the basin.

**Table 34: Estimated socio-economic costs associated with the impacts of applying closing of illegal wells reform option**

| Item | Closing Illegal wells Reform Option Scenario Options (System 1) | Closing Illegal wells Reform Option Scenario Options (System 2) | Closing Illegal wells Reform Option Scenario Options (System 3) | Total |
|---|---|---|---|---|
| Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | 85 | 85 | 55 | 225 |
| Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned; and | 37 | 9 | 7 | 53 |
| Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned; and | 32 | 5 | 2 | 39 |
| Wells that will be abandoned in the year 2040 due to water dry out; | 13 | 3 | 7 | 23 |
| Temporary Labor Requirement (person year)/ well | 6.28 | 12.67 | 15.76 | |

| | | | | |
|---|---|---|---|---|
| Permanent Labor Requirement /(person year)/well | 1.06 | 1.82 | 3.32 | |
| Total Lost Temporary labor in abandoned wells/ person year | 81.68 | 38.01 | 110.32 | 230.01 |
| Total Lost Permanent labor in abandoned wells/person year | 13.74 | 5.45 | 23.27 | 42.45 |
| Total cost of lost labour (JD) (total labour requirement*JD 2,678)..(1) | 255,522 | 116,376 | 357,758 | 729,656 |
| Total drilling needed for deepening (m) | 615 | 276 | 692 | 1583 |
| Total desalination needed MCM | 1.6 | 0.7 | 3.2 | 5.5 |
| One-time Cost of needed drilling (@ JD150/m) …(2) | 92,250 | 41,400 | 103,800 | 237,450 |
| Annual Cost of total needed desalination (@ JD 0.3/cm)…(3) | 480,000 | 210,000 | 960,000 | 1,650,000 |
| Total pumping in MCM based on actual water requirement | 2,636,437 | 8,354,511 | 33,152,305 | 44,143,253 |
| Cost of pumping assuming cap kept at 45 million/m3 and cost of pumping per cm 0.094**…(4) | 66,913 | 212,037 | 841,406 | 1,120,356 |
| Average Investment Costs in JD/Farm | 69918 | 91446 | 255243 | |
| Expected loss of invetement in JD due to well dryout (5) | 908,934 | 274,338 | 1,786,701 | 2,969,973 |
| **TOTAL ECONOMIC LOSSES IN JD DUE TO BAU SCENARIO in 2040 (1+2+3+ 4 + 5)** | **1,803,618** | **854,151** | **4,049,665** | **6,707,434** |

**Table 35: Estimated socio-economic costs associated with the impacts of applying the safe yield reform option for groundwater abstractions**

| Item | Safe Yield Reform Option Scenario Options (System I) | Safe Yield Reform Option Scenario Options (System 2) | Safe Yield Reform Option Scenario Options (System 3) | Total |
|---|---|---|---|---|
| Wells, which will not be abandoned by year 2040 and do not need to be deepened or desalinated. | 103 | 95 | 56 | 254 |
| Wells that could be utilized only if deepened at an additional cost, otherwise it will be abandoned; | 34 | 4 | 10 | 48 |
| Wells that could be utilized only if desalinated at an additional cost, otherwise it will be abandoned; | 29 | 3 | 3 | 35 |
| Wells that will be abandoned in the year 2040 due to water dry out; | 4 | 1 | 3 | 8 |
| Temporary Labor Requirement (person year)/ well | 6.28 | 12.67 | 15.76 | |
| Permanent Labor Requirement /(person year)/well | 1.06 | 1.82 | 3.32 | |
| Total Lost Temporary labor in abandoned wells/ person year | 25.13 | 12.67 | 47.28 | 85.08 |
| Total Lost Permanent labor in abandoned wells/person year | 4.23 | 1.82 | 9.97 | 16.01 |
| Total cost of lost labor (JD) (total labor requirement*JD 2,678)..(1) | 78,622 | 38,792 | 153,325 | 270,739 |
| Total drilling needed for deepening (m) | 615 | 276 | 692 | 1583 |
| Total desalination needed MCM | 1.6 | 0.7 | 3.2 | 5.5 |
| One-time Cost of needed drilling (@ JD150/m) …(2) | 92,250 | 41,400 | 103,800 | 237,450 |
| Annual Cost of total needed desalination (@ JD 0.3/cm)…(3) | 480,000 | 210,000 | 960,000 | 1,650,000 |
| Total pumping in MCM based on actual water requirement | 2,636,437 | 8,354,511 | 33,152,305 | 44,143,253 |
| Cost of pumping assuming cap kept at 45 million/m3 and cost of pumping per cm 0.094**…(4) | 66,913 | 212,037 | 841,406 | 1,120,356 |

| Item | Safe Yield Reform Option Scenario Options (System I) | Safe Yield Reform Option Scenario Options (System 2) | Safe Yield Reform Option Scenario Options (System 3) | Total |
|---|---|---|---|---|
| Average Investment Costs in JD/Farm | 69918 | 91446 | 255243 | |
| Expected loss of invetement in JD due to well dryout (5) | 279,672 | 91,446 | 765,729 | 1,136,847 |
| **TOTAL ECONOMIC LOSSES IN JD DUE TO BAU SCENARIO in 2040 (1+2+3+ 4 + 5)** | **997,457** | **593,675** | **2,824,259** | **4,415,392** |

### 5.4.7.1 Domestic Sector

It is believed that the impact of both reform actions on the domestic sector (AWSA) being upstream the agricultural wells will be not noticed within the time frame under the consideration of the model. For this reason, the socio economic impact on the domestic sector was not discussed under this section.

# 6 RECOMMENDED SOCIOECONOMIC MITIGATION MEASURES AND ITS POTETNIAL IMPACTS

Based on the results and conclusions of the above analysis, the following mitigation measures are recommended. Table 37 shows the recommended mitigation measures and the associated “carrots or incentives” and “sticks or penalties” that are proposed to go with it

1 Government offers incentives or direct payments to farmers to reduce ground water abstractions based on the monitored abstracted volumes of water (payment could be either per dunum that has been set aside or per not pumped m3 of water)

2 Provision of technical and financial support to farmers in the form of subsidized credit for improving the efficiency of the current irrigation systems. The first step is to assess the efficiency of the currently used irrigation system in the farms by specialized experts. Based on the assessment, recommend the most optimal irrigation technology that should be used. In this regards, consideration should be made to the results of the on-going "Water Innovations Technology (WIT)" project implemented by Mercy Corps. This is a 5-year (March 2017-2022) US$ 35M USAID-funded program designed to catalyze a movement for water conservation in Jordan. The WIT program will contribute to the overall objective of conserving water in Jordan, through the adoption and proven water-saving technologies and techniques, by achieving three integrated outcomes: 1) Water conserving technologies and behavior changes are adopted at the agricultural, community and household levels; 2) Access to financing for adoption of water conservation technology is improved; and 3) Institutions strengthened to support water saving technologies. The total saving in irrigation estimated by this project is 18 MCM in Azraq and Mafraq which includes 5-7 MCM to be gradually saved in Azraq over 2018 - 2023. Reduction to be done through:

- Enhancing irrigation efficiency.
- Adopting new cropping patterns.
- Introducing water saving devices and tools in the Agricultural sector

Provision of incentives for the utilisation of more efficient irrigation systems should be conditional on capped irrigated areas. Use can be made of the cost of electricity used for pumping to estimate abstractions and subsequently the actual areas irrigated by the farmers. Another option is to monitor the expansion in groundwater-irrigated areas through satellite imagery. The results from this system need however to be calibrated and validated on the ground. This measure also requires available and trained staff at MWI to process and analyse the images, and personnel in the field to enforce the law.

1 Provision of financial incentives to convert farms to solar farms. The solar farming solution has been investigated through the Highland Water Forum initiative (enlisted in the forum action plan as one of the solution resulting from the consultations). **This measure should be applied carefully to avoid encouraging farmers to pump more water using solar energy produced on their lands.** The offered **financial incentives should be conditional to well closure and abandonment of all agricultural activities on the farm.** In 2015, the GIZ conducted a detailed study on the solar energy farming in the Azraq Basin of Jordan. The study concluded that the solar energy farming could be one of the potential non-water consuming alternatives for farmers in order to reduce groundwater over-abstraction while maintaining their social and economic situation. The study added that because most of the agricultural lands in the highlands are dependent on the already over-exploited groundwater resources, creating new business and investment opportunities will enhance and revive the economy of the rural communities and reduce their reliance on agriculture.

2 Closure of the illegal wells. If the government is willing to compensate the owners of closed illegal wells, then the compensation may include incentives credit to convert to solar farm under the condition of well closure and abandonment of all agricultural activities on the farm;

3 Purchase of groundwater rights. This could be done by paying the farmer a flat rate per each cubic meter purchased by the MWI as per the official well license. The MWI would then pay the farmer the sum of the future value of the purchased water over the next 20 years taking into account the value of money over time (One payment of annuity for 20 years/discounted one payment). Currently, the prevailing price11 of the pumped cubic meter of water is around JD 0.5 which includes the cost of energy. Farmers claim that the cost of energy for pumping is approximately JD 0.1. This means that the cost of a cubic meter without the pumping cost is JD 0.4. Table 36 shows the discounted total cost of purchasing 100% or 50% or 25% of the pumped agricultural water in the basin based on the crop water requirements (table 8 above). A discount factor of 8% was used to estimate the one payment of purchased water over the next 20 years. The table shows that if the government decides to purchase all water rights in the basin (i.e. close the wells), then the total needed cost is about JD 180 million which would save a sum of 44 million cubic meter annually over the next 20 years.

11 This is the prevailing price of water sold between the farmers in the basin. In other words, there is a market for irrigation water. This would be the incentive of the farmers to sell it to the government

Table 36: Estimated financial costs of 3 options of purchasing the groundwater rights from well-owners (purchasing 100% or 50% or 25% of the rights)

| Year | Purchasing all water rights in the basin @ JD 0.4 per cubic meter | Purchasing 50% of water rights in the basin @ JD 0.4 per cubic meter | Purchasing 25% water rights in the basin @ JD 0.4 per cubic meter |
|---|---|---|---|
| 2019 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2020 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2021 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2022 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2023 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2024 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2025 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2026 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2027 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2028 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2029 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2030 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2031 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2032 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2033 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2034 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2035 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2036 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2037 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2038 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2039 | 17,656,101 | 8,828,051 | 4,414,025 |
| 2040 | 17,656,101 | 8,828,051 | 4,414,025 |
| Total cost of the one payment at a discount rate of 8% | **180,105,362** | **90,052,681** | **45,026,341** |

4 A cheaper option that could be considered is the buyout of the whole farms in the basin. Table 38 shows the basic calculations of the total investment costs of 333 farms as reported in the ISSP questionnaire. The table shows the average investment costs under each type of the identified farming system. The table also shows that the total investment costs of all farms of the three different types is about JD 40 million. This figure could be a rough proxy of the total value that the government could pay for buying out all the farms in the basin.

Table 37:Estimated total investement costs of farms in the Azraq basin

| Items | Farm System I (<50 dunum) | Farm System II (50-200 dunum) | Farm System III (> 200 dunum) |
|---|---|---|---|
| | 159 | 103 | 74 |
| Average Investment Costs in JD/Farm | 69,918 | 91,446 | 255,243 |
| Total investment costs in JD per farm type | 11,116,962 | 9,418,938 | 18,887,982 |
| **Total investment costs in JD for all types** | **39,423,882** | | |

5 Improve the cropping patterns and crop diversity in the basin. As indicated in the above sections, the vast majority of cultivated area in the basin is olive trees, which consumes huge amounts of water. A new cropping pattern should be adopted by gradually replacing the current olive orchards with high-value crops that consumes lower amounts of water. This would result in decreasing the volumes of water abstraction and increases the returns per cubic meter of water. The MWI can leverage the outcomes of the on-going USAID funded WIT project currently working on reducing irrigation abstractions in Azraq basin through a set of measures including changing of cropping patterns with a total of 6 million cubic meters of irrigation savings per cubic meter being envisaged.

Care should be taken to ensure that the water saved is not used to irrigate additional areas. Expansion in irrigated areas should therefore be monitored through the indirect control of groundwater-irrigated areas with remote sensing and satellite imagery. As mentioned above, the results from this system need however to be calibrated and validated on the ground. This measure also requires available and trained staff at MWI to process and analyse the images, and personnel in the field to enforce the law.

6 Strengthening of the public participation in the decision making process in the basin to confront the users with the serious consequences of the depletion of the aquifer on their farms and their investments. This should help in the sustainable water management of the basin. Public participation should therefore be continued. The ministry has made big strides in engaging the local communities and the farmers in the past through the Highland Water Forum. Building on that and continuing is very helpful in the ministry's efforts to manage groundwater sustainably. In the GIZ study mentioned above, the GIZ concluded that over the past 4 years, the Azraq basin Committee of the Highland Water Forum worked on developing the first participatory action plan namely “Azraq groundwater Management Action Plan” which was finalized in 2013 and included a number of activities and measures that are expected to reduce the over-abstraction of groundwater in Al-Azaq Basin, if implemented. ;

**Table 38: Recommended mitigation measures and its associated "carrots or incentives" and "sticks or penalties"**

| ***socioeconomic Measure*** | ***Carrot (farmers*** | ***required supporting actions/sticks*** | ***Expected Outcomes*** |
|---|---|---|---|
| *Government offers incentives or direct payments to farmers to reduce ground water abstraction based on the monitored abstracted volumes of water (payment per dunum)* | • *Payment per unit area set aside or water not pumped* | | • *Reduction in abstracted water*<br>• *Increasing/stabilizing farmers income*<br>•<br>• *Reduction in cultivated areas*<br>• *Farmers may improve water-use efficiency*<br>• *Change in the cropping pattern*<br>• *Help in reaching safe yield levels* |

| | | | |
|---|---|---|---|
| *Provision of technical and financial support to farmers. Subsidized credit through ACC for improving the efficiency of the current irrigation systems. The first step is to assess the efficiency of the currently used irrigation system in the farms by specialized experts. Based on the assessment, recommend the most optimal irrigation technology that should be used* | • *Subsidized credit through ACC for improving the efficiency of the current irrigation systems Increase water use efficiency will result in increasing the disposable water for irrigation*<br>• *Increase yields and quality of produce*<br>• *Increase farmer's income* | • *Subsidised credit is not granted unless the farm's irrigated area is capped (to avoid using the saved water in the irrigation of additional areas).*<br>• use the cost of electricity used for pumping to estimate abstractions and subsequently irrigated areas.<br>• Use remote sensing to estimate actual irrigated areas<br>• Field visits for monitoring and enforcement | • *Reduction in abstracted water*<br>• *Reduction in cultivated areas*<br>• *Farmers may improve water-use efficiency*<br>• *Increase in crop yields and quality*<br>• *Change in the cropping pattern*<br>• *Improvement in best management practices* |
| *Provision of financial incentives to convert farms to solar farms powering the national grid* | • *Provide subsidies to Solar farming for augmenting the supply to the power grid.*<br>• *Minimize agricultural risks of production and marketing*<br>• *Increasing/stabilizing farmer's income* | *Such subsidies are not granted unless wells are closed.* | • *Reduction in cultivated areas*<br>• *Positive environmental impact*<br>• *Help in reaching safe yield levels*<br>• *Increase renewable energy supply* |

| | | | |
|---|---|---|---|
| *Closure of the illegal wells and offer some financial incentives to convert farms to solar farms powering the national grid* | • *Financial incentive to convert fast to solar farming.*<br>• *Provision of alternative source of income;*<br>• *Minimize agricultural risks of production and marketing* | • Make inventory of illegal wells<br>• *Apply legal measures and Sanctions* | • *Reduction in cultivated areas*<br>• *Positive environmental impact*<br>• *Help in reaching safe yield levels*<br>• *Increase renewable energy supply* |
| *Government to purchase groundwater rights of legal wells for a period of 20 years (one payment considering future value of money-annuity)* | • *Insuring farmer income for the coming 20 years at no agricultural risk of production and marketing.*<br>• *Minimize agricultural risks of production and marketing* | • *Raise abstraction quotas*<br>• *Freezing of wells deepening*<br>• *Sanctions* | • *Reduction in cultivated areas*<br>• *Reduction in abstracted water*<br>• *Help in reaching safe yield levels* |
| *Improve the cropping patterns and crop diversity* | • *Subsidized credit for new crop variety*<br>• *Increase farmer's income*<br>• *Reduce agricultural risk* | • *Monitoring through satellite images to ensure no expansion in irrigated areas*<br>• *Provision of any incentives or subsidies credits should be linked to capped irrigated areas.* | • *Reduction in abstracted water through introducing low-water requirements crops*<br>• *Reduction in cultivated areas*<br>• *Farmers may improve water-use efficiency*<br>• *Improvement in best management practices* |

| | | | |
|---|---|---|---|
| *Strengthening of the public participation in the decision making process in the basin to confront the users with the serious consequences of the depletion of the aquifer on their farms and their investments.* | • Establishment of Water User Association in the basin<br>• *Support implementing the above actions*<br>• *Reduce agricultural risk* | | • *implementing the socio economic measure with following consequences:*<br>• *Reduction in abstracted water*<br>• *Farmers may improve water-use efficiency*<br>• *Improvement in best management practices* |
| *Other complementary measures may include, improvement of water monitoring and control, and outreach and educational programs to targeted farming community and public in the region* | • | | • *Reduction in abstracted water*<br>• *Farmers may improve water-use efficiency*<br>• *Improvement in best management practices* |