

Integrated Water Resources Management in the Lower Jordan Rift Valley

Sustainable Management of Available Water Resources with Innovative Technologies



Work package 7, Deliverables D706 and 707

Cost-benefit analysis of alternative IWRM strategies at watershed level and assessment of their financial feasibility

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December 29th, 2013

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Funded by



Federal Ministry
of Education
and Research

Sponsored by the German Federal Ministry of Education and Research (BMBF):
FKZ 02WM1079-1086 and FKZ02WM1211-1212

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Acknowledgements

Appreciations are due to all, who contributed to this study, such as the Palestine Hydrological Group (PHG) in Ramallah (Director: Dr. Abdelrahman Tamimi) and the Palestinian Ministry of Agriculture (Eng. Issam Nofal). The case study at the Jericho area would have been not possible without their readiness to collaborate.

Thanks are also to the Jordan Ministry of Water and Irrigation (MWI) in Amman (Eng. Ali Subah) for the valuable information.

There are numerous institutions both in Palestine and Jordan, who have provided data, amongst them the Municipal of Jericho and the Jordan Valley Authority; many thanks to them.

EXECUTIVE SUMMARY

This report shows the results of the SMART II research activities dealing with the costs, economic benefits, added values and financial implications of IWRM strategies (Deliverables 706 & 707).

In the chapter “Introduction”, the goals of the study and the methodological tools employed will be explained. PART I and II contains the results of the two case studies “Jericho area” and “Jordan Valley”. Financial aspects, discussed in the case studies, will be summarised in PART III. In both case studies, the cost benefit analyses (CBA) plays a key role in appraising water management options and IWRM strategies. This approach addresses the question how water shortage problems can be tackled in an economically efficient way within the planning period from 2012 to 2031. It could be proved that generally the benefits outweigh the costs, resulting in economic values added and increased welfare for the water users. IWRM strategies are defined as combinations of single water management options.

In order to find out the most cost-beneficial IWRM strategies within the planning period, priorities are to be allotted to different water management options according to their economic efficiency. For instance, at the *Jericho east sub-basin* due to its high values added the water reuse option has the first priority, followed by the desalination of brackish groundwater and rainwater harvesting (Table below). This means, that not all the management options are to be realised at the same time. A time-sequence is needed showing the time intervals, within which the options should be implemented in order to minimise the costs and maximise the benefits.

In developing the IWRM strategies the capacities of the new resources are to be taken into account, whereby the size of these capacities should be subject of the management decisions as well. By that, the time-referenced cost-benefit analyses provide *guidelines for water managers, who have to decide in which year and with which capacities water projects should be installed*.

The following overview points out, by which factors the water management process is significantly influenced in the areas of investigation. For instance, the values added of IWRM strategies can be increased, if the cost of projects will be reduced (e.g. lower rates of interest) and the economic benefits will be raised (e.g. higher water tariffs). Capital cost can be lowered by distributing the investments over the planning period. For example defi-

cient networks should not be rehabilitated at the same time, but stepwise in the course of time.

Water demands	Size of population; agricultural production
Water availability	Precipitation; geo-hydrological conditions
Cost of water projects	Investment and operation cost; rate of interest
Value of water	Water tariffs; water profitability in agriculture

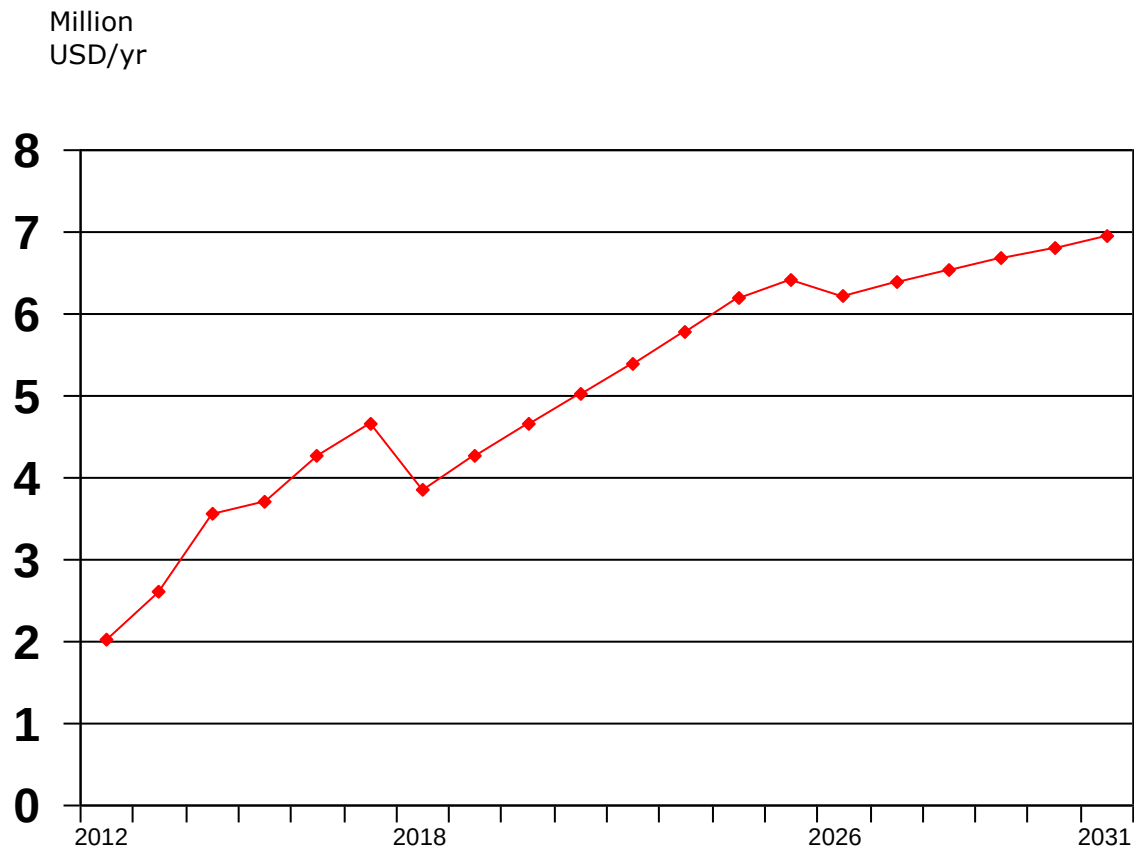
At the sub-areas under investigation, the added values were estimated and the most cost-beneficial IWRM strategies determined within the planning period 2012 and 2031. The figure below shows by example the values added for the *Jericho east sub-basin*.

The fluctuations of the values can be explained by the fact that in the first years the capital costs can be higher than the benefits, because the capacities are not fully utilized: there is no cost recovery, but in the following years the benefits will exceed the costs.

It is important to emphasise, that the influencing factors mentioned above can affect the shape of the curve: for instance, if the water values rise within the planning period, the curve will become steeper.

With special regard to the municipal water users the values added can be raised by higher water tariffs. As mentioned earlier, often the tariffs do not reflect the real cost of water services and understate the willingness to pay of water users. However, the ability to pay of many families in Palestine is lower and may correspond actually to the current water tariffs.

The water profitability in irrigated agriculture can be increased, if more high-valued crops would be cultivated – as suggested recently by the Palestinian Ministry of Agriculture.



At the *Jericho central sub-area*, intersectoral water transfer from agricultural to municipal users is one of the options with relatively high values added: the Jericho municipality wants to increase the water supply and can do that by taking over the water rights in Duyuk Spring of the agricultural users. The cost of the water transfer includes the capital cost for a storage tank and pipe line. Also the expenses are to be taken into account reflecting the income losses of the farmers due to less water availability. As long as the costs of the water rights are lower than the benefits of the municipality, values added will be created and the water transfer will pay.

Due to the current water losses of the networks, the values added of the options rainwater harvesting and rehabilitation of groundwater wells are low (Table below). Therefore, measures to prevent water losses should be undertaken first to improve the economic efficiency of these options.

At the *Jericho Shosa / Duyuk and Nueimah sub-areas*, the values added from replacing open channels with a pipeline network are high in comparison with storm water

harvesting. However, even if both options would be implemented, the water needs in irrigated agriculture - the main users – will continuously exceed the water supply in the planning period.

A similar situation can be found at the *eastern Lower Jordan Valley*, where the three options discussed are not sufficient to solve the water problem. The water reuse option has the highest ranking, followed by the Kufranjeh dam project and improvements in irrigation technologies (Table below). Further measures, such as water transfers (e.g. Disi conveyance system), artificial groundwater recharge and more reservoirs are required and will lead to probably to considerable values added.

The following table gives an overview of the estimated added values per m³ at each of the sub-areas.

Water management options at different sub-basins	Values added (USD/m ³)	
	Agriculture	Municipality
<i>Jericho east sub-basin</i>		
• Desalination of brackish water	0.76	
• Rain water harvesting	1.11	
• Wastewater reuse	2.06	
<i>Jericho central sub-basin</i>		
• Rain water harvesting *)	-0.033	
• Rehabilitation of groundwater wells	0.05	
• Intersectoral water transfer		0.23
• Rehabilitation of networks		-0.57 – 0.42
• Demand management		0.07 – 0.37
<i>Jericho Shosa / Duyuk and Nueimah sub-basin</i>		
• Rain water harvesting	0.66	
• Replacement of open channels	1.01 – 1.11	
<i>Lower Jordan valley eastern sub-basin</i>		
• More irrigation efficiency	0.16	
• Kufranje dam	0.84	
• Wastewater reuse	1.07 – 1.2	

*) Minus value mainly due to water losses

Not surprisingly, the values added vary considerably because of the different local conditions. Moreover, the calculations are often based on uncertain data. Nevertheless, the table

provides a first idea on their ranges: Wastewater reuse, replacement of open channels and rain water harvesting are obviously the best choices.

However, how should the costs and benefits of IWRM strategies be distributed to ensure their financial feasibility?

Both the 'water user pays principle' and 'polluter pays principle' should be applied. According to these principles the costs of both water supply and sanitation have to be paid fully by the users. Usually, projects are financed by charging the water users, such as farmers, citizens and entrepreneurs. All the costs of water projects should be taken into account in water pricing as far as possible. Otherwise, the water users would not get the right information about the financial requirements of IWRM strategies. In special cases, however, they cannot fully afford the costs. Other funds are required, such as governmental, private or international donors.

With special regard to the costs of wastewater reuse in irrigated agriculture – one of the most cost-beneficial options at the Lower Jordan Valley -, there are two different views: The total cost of wastewater treatment or only the extra cost of higher quality standards for using the effluents (together with the costs of storage and conveyance) should be taken into account. The value added of water reuse in the first case is lower than in the second case.

It can be expected, that the incomes particularly of farmers will rise inducing them to join the water reuse projects and to contribute to the costs. An example can be found at the Jericho east sub-area. The financing of such projects can be facilitated if farmers with high income gains would contribute to the cost as far as possible. Negotiations appear to be the best way to find an agreement about the cost sharing. In case, the municipality cannot afford the cost, the national government or / and international donors should support the project. This is always justified, if considerable values added can be expected, which include not only the gains in agriculture but also the benefits of municipal water users. Even in cases where the economic values added are low, the financing of projects can be worthwhile due to their positive environmental impacts (e.g. restoration of groundwater levels, less water pollution, etc.).

As outlined in the Jordan Valley case study, the financing scheme can influence the annual costs. For instance, at the Built Operate Transfer (BOT) approach applied increasingly for public infrastructures, the concession right is granted to private contractors to invest and to operate the water project within a certain period. If BOT is applied, the annual capital cost will be significantly higher compared with the estimated value used in the CBA.

The payback period (amortisation) is, for instance, 20 years and shorter than the supposed usable lifetime (depreciation).

By means of cost benefit analyses the most economically efficient sequence of IWRM strategies in the course of time can be identified (as done in the case studies at the Jericho east and central sub-areas). Such an optimal sequence ensures that the values added will be maximised over the years resulting in less financial requirements for the planned projects.

Follow-up research projects should address the costs and economic benefits of environmental regulations. Furthermore, it should be investigated how changes in precipitation, population and other socioeconomic factors (e.g. crop prices, water tariffs, rates of interest, etc.) affect the values added (“scenarios”). Financial aspects should be analysed in greater detail. Last but not least, the applicability of the WEAP model for CBA studies should be explored in more in-depth analyses.

In the annex of this report, the reader will find a synopsis of all the WP7 socioeconomic studies performed in SMART II (a separate document).

Abbreviations, acronyms and definitions

CBA	Cost-benefit analysis
GW	Groundwater
IWRM	Integrated Water Resources Management
IWRM strategy	Combination of different water management options
KAC	King Abdullah Channel in Jordan
MCM	Million Cubic Meter
MWI	Ministry of Water and Irrigation in Jordan
Net benefit	Difference between benefits and costs of water management options for individual water users, such as agriculture, industries and municipalities
PHG	Palestinian Hydrologic Group in Ramallah
Scenario	IWRM strategy influenced by various external factors, such as precipitation, population growth and crop prices
Value added	Sum of net benefits for water users, such as agriculture, industries and municipalities
Water management option	Measure to change water utilization, such as water re-use, desalination of brackish water and rainwater harvesting
Water productivity	Increase of agricultural yields per additional cubic water for irrigation
Water profitability	Increase in farmers' incomes (profits) per additional cubic water for irrigation
WEAP	Water Evaluation and Planning System
WWTP	Wastewater treatment plant

INTRODUCTION

1. Purpose of the report

This report will provide the results for both the SMART II deliverable 706 “Cost-benefit analysis of alternative IWRM strategies at watershed level” and deliverable 707 “Assessment of the financial feasibility of IWRM strategies”.

2. Goals, subjects and methodologies of the research activities

The **cost-benefit analysis (CBA) of IWRM strategies** at watershed level addresses the socioeconomic dimensions of water management in the Lower Jordan Rift Valley. Other studies of work package 7 (in total 11) deal with advanced IWRM technologies, including decentralized wastewater treatment and reuse, artificial groundwater recharge and desalination of brackish water (701-705; 707-711). The institutional and political challenges in tackling water problems and resolving water-related conflicts (709-710; 712) have been analysed as well. Various methodologies were applied, such as the cost-effectiveness analysis (705), cost-benefit analysis (D704) and the multiple criteria analysis (711). The synopsis in the Annex of this report contains a summary of the results from the WP7 studies.

This report focuses on the **values added of alternative IWRM strategies** for different water users - agriculture and municipalities - in terms of costs and economic benefits. It intends to provide advices how to identify appropriate water management strategies from the viewpoint of economic efficiency and financial feasibility. Climate changes (e.g. decline of precipitation), population growth, changes in pricing structures (e.g. agricultural products) and legal rules (e.g. restrictions of farming practises in water protection areas) are to be considered in follow-up studies. **The areas of investigation - two case studies - are the Jericho area in Palestine and the eastern Lower Jordan River Valley (JV)** (Fig. 1).

In both case studies, alternative IWRM strategies will be appraised in terms of costs, benefits, and values added. Different water resources (groundwater desalinated brackish water and treated wastewater), infrastructures (water conveyance networks, res-

ervoirs and wastewater treatment plants) and water demands (such as agricultural and domestic users) are considered.

The values added from IWRM strategies represent generally increases in welfare and improvements in the wealth for communities and the society as a whole. They emerge whenever the economic benefit exceeds the cost of water management measures. Note, that economic benefit for a group (such as higher incomes of farmers) do not necessarily lead to overall values added, for the total cost of a IWRM strategy can exceed the sum of the benefits of the stakeholders involved. In such a case, the IWRM strategy will be definitively *economically* not efficient and would lead to economic losses, even though other benefits occur, such as restoration of aquifers or conservation of aquatic biotopes. In those situations, the community and politicians have to weigh up the economic losses caused by sticking to such a strategy against the benefits that can be achieved instead (**trade-off** between costs and non-monetary benefits).

To simulate alternative IWRM strategies the **WEAP model** was employed. It allows exploring the impacts of water management options (e.g. improved water demand coverage) and – to some extent - to appraise their costs and benefits. For single water management options, the capital costs and operation & maintenance costs (for instance, constructing a new conveyance system) can be estimated. The same applies to the economic benefits by evaluating improvements in water supply. The benefits for municipal users (such as households, business, and public administration) can be calculated by multiplying increases in water supply with the water tariffs. This approach assumes that water prices reflect the readiness of consumers to pay for water services. But it can lead to an underestimating of the benefits, if water prices do not cover the full cost of these services. In the case studies below, however, this approach was carried out only in part by using WEAP due to problems in computing. In follow-up research activities, these problems should be addressed. In appraising IWRM strategies a simplified approach was applied by using the Excel software.

With special regard to agricultural users, the economic benefits were not calculated by using water prices, but by considering the water profitability, defined as increase in farmers' income per cubic meter additional water supply.

Since the investments in water infrastructure are generally of long-term nature (covering often more than 20 years), both the costs and benefits are to be calculated in terms of present and annualised values by using a suitable rate of interest ('discount rate'). The costs and benefits can vary significantly over the years, and it is important to consider at which years such changes occur. By using the **present value analysis** the time streams of future costs and benefits can be diverted ('discounted') each to single numbers. The differ-

ence between both values is the *present* net benefit: if greater than 0, the investment would be worthwhile. If there are several optional water management strategies, the one with the highest *net present value* should be chosen.

Another calculation method refers to the **annualised costs and benefits**. The annual cost is computed by multiplying the present value of investment with the capital recovery factor. By using this factor the yearly amount of money required to return the investment (i.e. initial capital cost) over the project life can be determined. Again, discount rates are used. This method is preferable, if major focus will be put on **water prices**. However, as mentioned already both on the cost and benefit side, not all of the consequences of IWRM strategies can be evaluated in economic terms. Examples are the contamination of aquifers due to using effluents in irrigation or the rehabilitation of groundwater levels. By using limit values, such as environmental standards, the adverse and positive impacts can be assessed. As mentioned above, in special situations, the **trade-offs** between economic values added and ecological impacts can be important.

A further issue in water management are the **financial implications of IWRM strategies**. Here, the economic efficiency is to be distinguished from the financial feasibility. The first term means that an IWRM strategy is economically justified, if its economic benefit exceeds its cost. The second term refers to the question, who pays and who benefits. If the farmers located at a specific basin, for instance, would have to pay the full cost of being provided with treated wastewater, it may be that they cannot afford these payments. Provided the water reuse project is economically efficient, somebody else should share the cost, such as the municipality, the government or/and the water utility. Otherwise the project would not be financially feasible, and cannot be implemented (even though it is economically efficient).

To which extent farmers should share the costs, depends on the economic benefits they enjoy from the water reuse project, such as cost savings in fertilizing, more yields and less expenses for freshwater. Farmers should be encouraged to use reclaimed water through adequate economic incentives; otherwise they would not be ready to join the project (unless they would be forced by law). In special situations, this can be institutionalised by markets, where farmers have to purchase effluents. How much the other cost payers should contribute depends on to which extent they will benefit. For instance, if farmers release freshwater in exchange of treated wastewater, municipalities may enjoy an increase in water availability and thus cost savings in developing new water resources to meet growing domestic demands.

In this example, the **cost sharing** will be worthwhile for the municipality, provided the benefit exceeds the total cost of the project. If a water utility provides reclaimed water to the farmers and belongs to the municipality (i.e. it is a public company), cost sharing will not cause serious problems, provided the municipality can actually fund it. In contrast, private utilities should have sufficient economic incentives to join the project. Negotiations between all the parties involved appear to be most appropriate way to find an agreement on the distributions of the costs and benefits. Important financial implications of IWRM strategies will be highlighted (PART III).

The outcomes from the case studies are based on data with **uncertainties**. The sources were local statistics and interviews, secondary literature and partly approximations. Thus, the case studies provide reasonable estimations rather than exact calculations.

The main purpose of this study is to present a **methodological framework** for assessing IWRM strategies from the socioeconomic point of view. The methodologies developed for both case studies may be applied for other water basins.

There is a further research project using the WEAP model, the **Multi-Year Water Allocation System (MYWAS)** (Huber-Lee 2011). It is designed to be applied in Palestine and later in Jordan in the near future. It aims to provide advices how to economise the use of scarce resources. A key role plays the scarcity value of water, which often differs from the tariffs. It is influenced both by the production cost and the water demands. Where water resources are abounding, no water scarcity values exist. MYWAS is based on the WAS approach (Water Allocation System), developed jointly by water experts in Israel, Jordan and Palestine between 1992 and the beginning of 2000 (Fisher, F. M., Huber-Lee et al. 2005). Currently, MYWAS is being tested at the areas of Hebron, Bethlehem and Jericho in the Southern West Bank, It can be considered as a further promising economic tool for appraising alternative IWRM strategies at watershed level.

The following main differences between WAS / MYWAS and the CBA approach should be pointed out: (1). WAS / MYWAS applies functional relationships between the water price and water demands of domestic, agricultural and other users (price–demand curves), whereas we assume generally there are *no significant impacts of changes in prices on the water supplies and demands* of specific users. (2). WAS / MYWAS determines the water prices and water values (shadow values) within a water allocation optimization model (GAMS), whereas we refer to *existing water tariffs for municipal and agricultural users*. In order to find out the most cost-beneficial IWRM strategies, we use water tariffs for municipal users and the water profitability for agricultural users. These differences in determining water values will certainly result in different net benefits and added values result-

ing from various water management strategies. (3). In WAS / MYWAS the *optimal* water demands and supplies are being computed, whereas we deal them as *exogenous variables* (determined by the unmet demand of specific water users). (4). WAS / MYWAS computes for different users the economic impacts of changes in water supply on the basis of endogenously determined water prices and shadow values, whereas we analyze the *impacts of increases in water availability on the net benefits of different users at given unit water values* (cf. 2. above). (5). WAS / MYWAS analyses for confined areas with a given water infrastructure the *system-wide impacts* of new projects (e.g. a projected conveyance system), as it deals many variables as determined endogenously within the model, such as water prices, opportunity costs and shadow values (cf. 4. above), whereas we focus on the *direct impacts* of IWRM strategies on the water users in terms of costs, benefits and added values, even if there are different users involved (notably in the case of interregional or intersectoral water transfers, such as between farmers and municipal users).

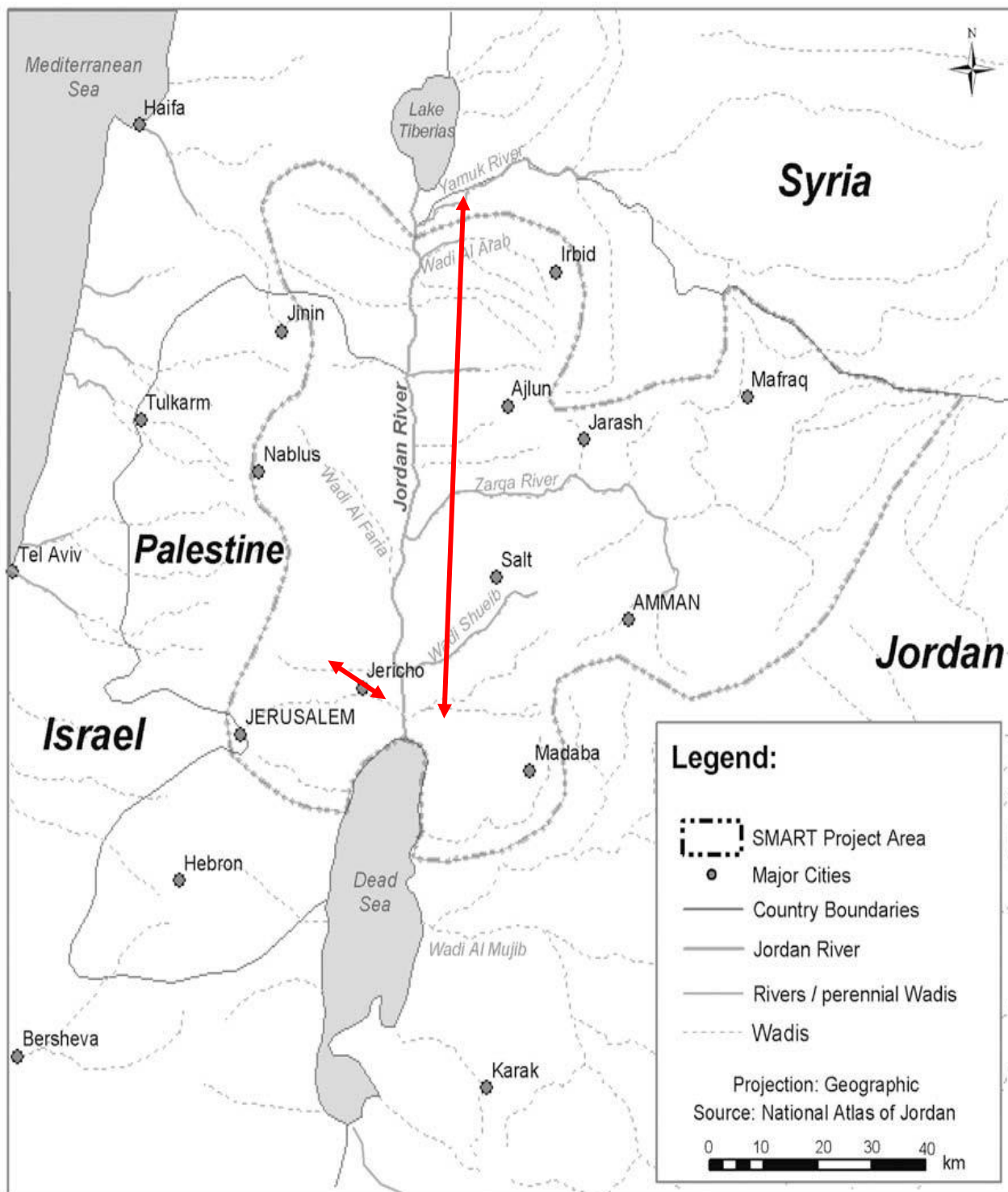


Figure 1: Location of the case studies

PART I. JERICHO AREA

The area of investigation is divided into three sub-areas with different utilization of water resources, infrastructures and water demands: a) Jericho east sub-area, b) central sub-area with the Jericho City and c) Jericho north sub-area (Fig. 2). At each of them with specific problems, water management options have been identified, that are supposed to be appropriate in improving the water situation. Water shortage is currently not the main problem due to the availability of spring waters (e.g. Ein Sultan Spring). However, in the near future water supply problems will emerge. In areas, where agriculturally used land could be expanded, more water will be required. In other areas, growing population and additional commercial activities will increase the municipal water demand. Of special relevance is that in the Jericho area the sanitary infrastructure is poor as no wastewater treatment plants (WWTP) exist. Cesspits are in use, by which the water bodies (groundwater, wadis) are being polluted.

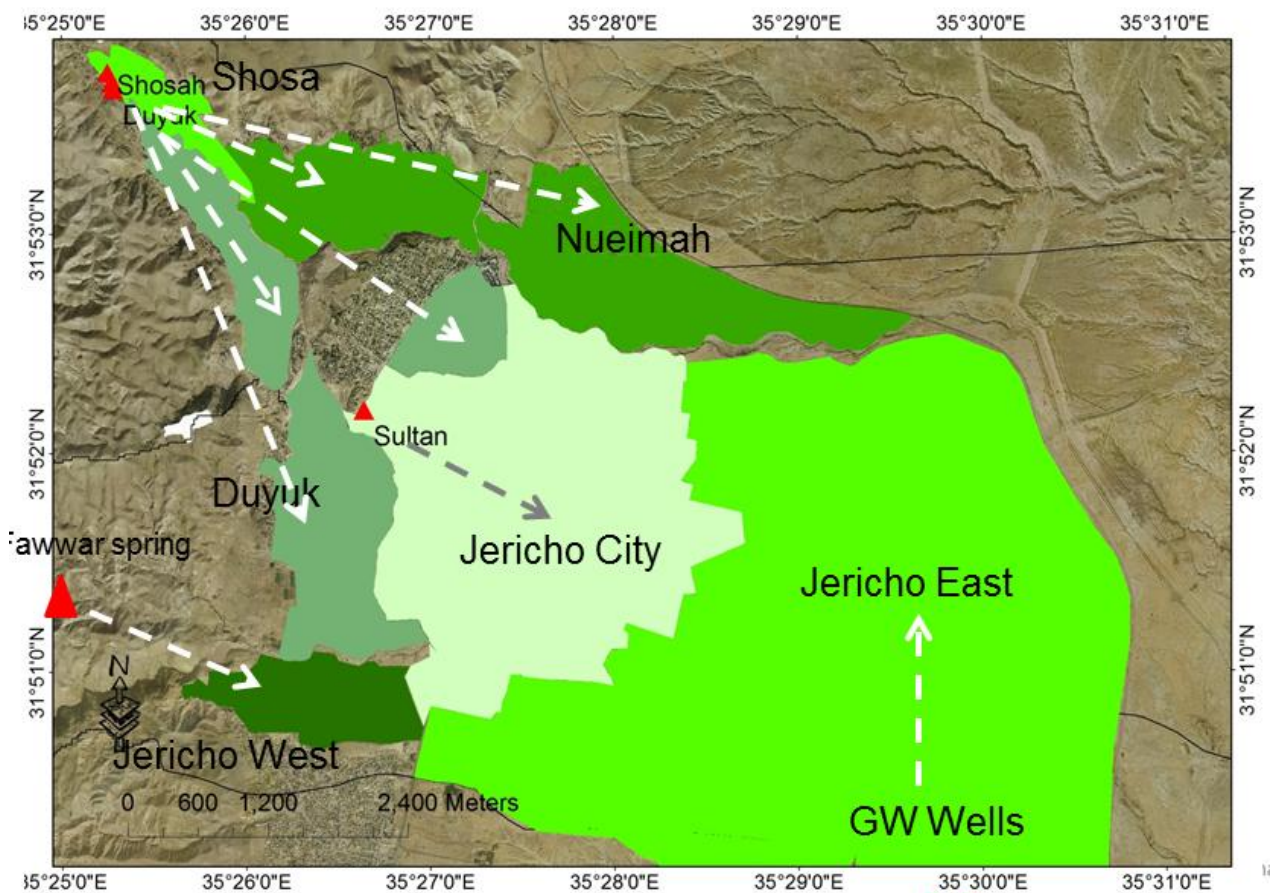


Figure 2: Three Jericho sub-areas

For the entire area of investigation a WEAP model was developed; its schematic view shows nodes and links, representing different water resources, infrastructures and demand sites, and the interconnections between them (Fig. 3). WEAP allows displaying, reproducing and processing information for various hydrological and socioeconomic conditions within specific time horizons. It allows to assess the impacts of water management options (for instance, improvements in meeting water demands for different users), and for special cases to evaluate their economic costs and benefits. Furthermore, WEAP can be run for various conditions (“scenarios”), such as changes in precipitation, population growth and others. The results can be displayed through graphs and tables.

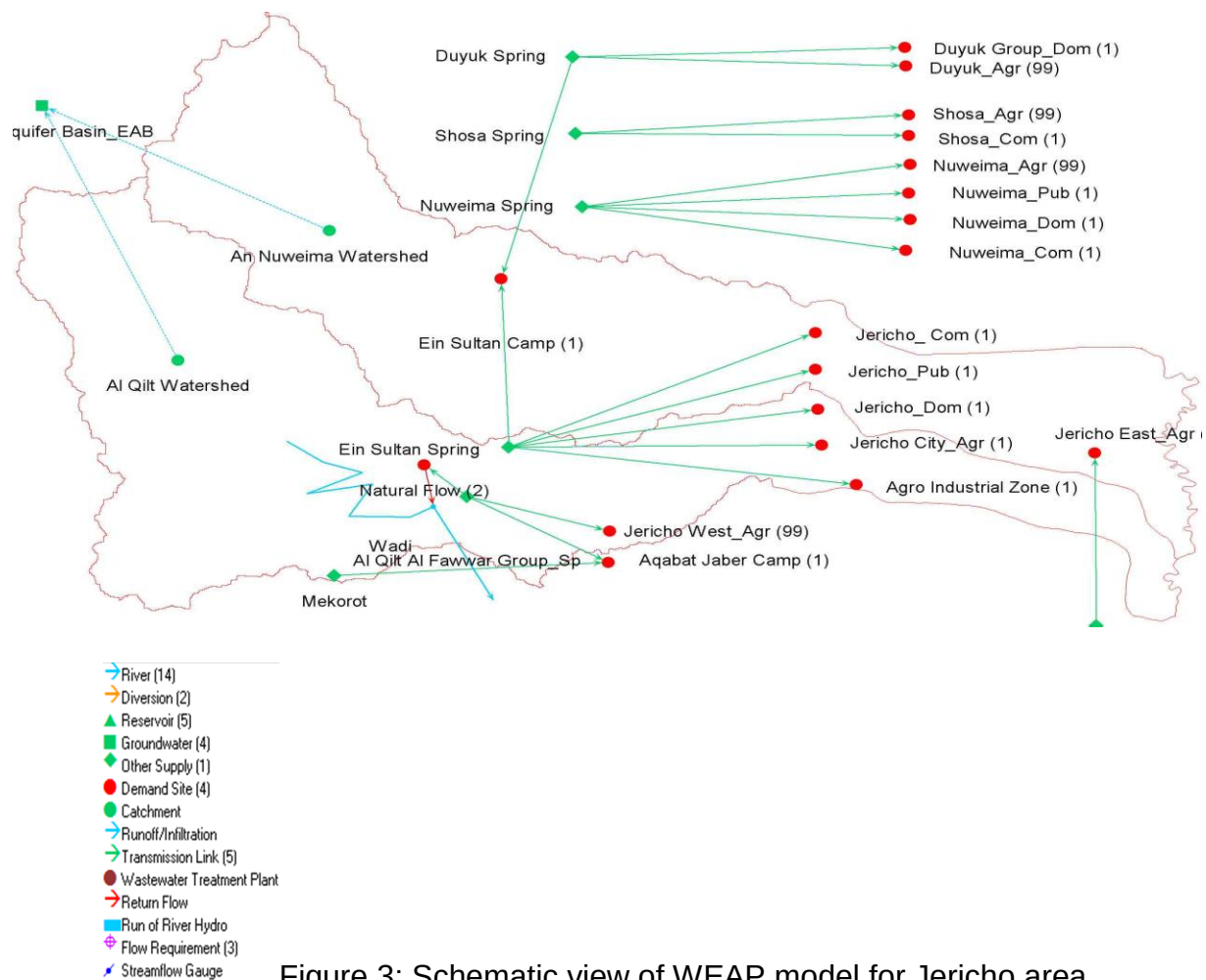


Figure 3: Schematic view of WEAP model for Jericho area

Chapter 1. The Jericho east sub-area

1. Water situation

Groundwater wells are concentrated in the eastern side of Jericho City where extensive agriculture exists (Fig. 4). Most of the wells are not working due to either the lack of maintenance and rehabilitation or the poor water quality and deep water levels. Salinity is the main problem and salinity increases with falling water levels that causes sea water intrusion from the Dead Sea. The groundwater quality is better in the western areas than in the eastern, because of the larger distance from the Dead Sea and the nearness to the Eastern Basin, where fresh water resources are available for natural recharge.

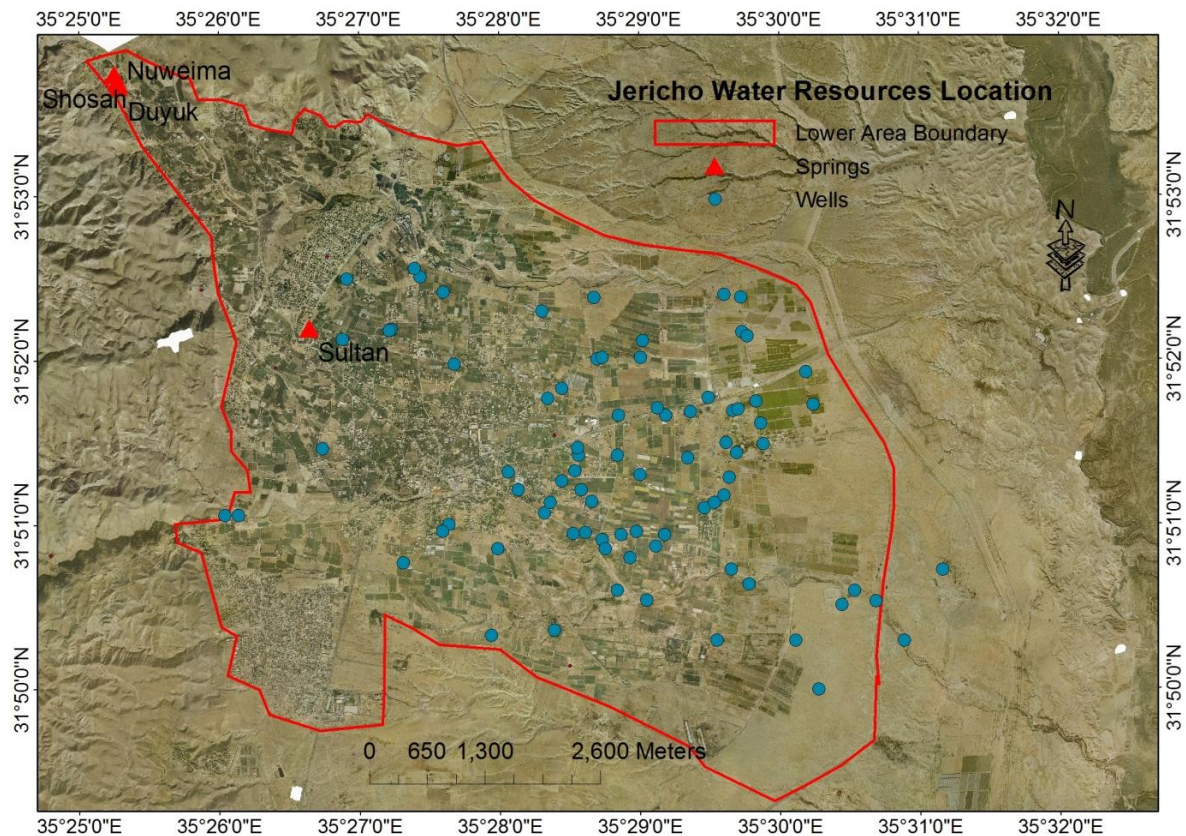


Figure 4: Location of groundwater wells in Jericho area (PHG 2011)

The Jericho East area includes 6,583 dunums in which 47% are arable lands and the rest is currently used for mostly vegetable crops. This area is currently supplied with about 2.8 Mm³/yr from groundwater wells (PHG, 2010). Only agricultural water users exist.

By using the WEAP model the demand of Jericho east sub-area can be projected if the total arable lands would be planted by a steady increase rate during the simulation period 2011 – 2031 (situation 1). The projected demand for water is about 5 Mm³/yr in 2031 (Fig.5).

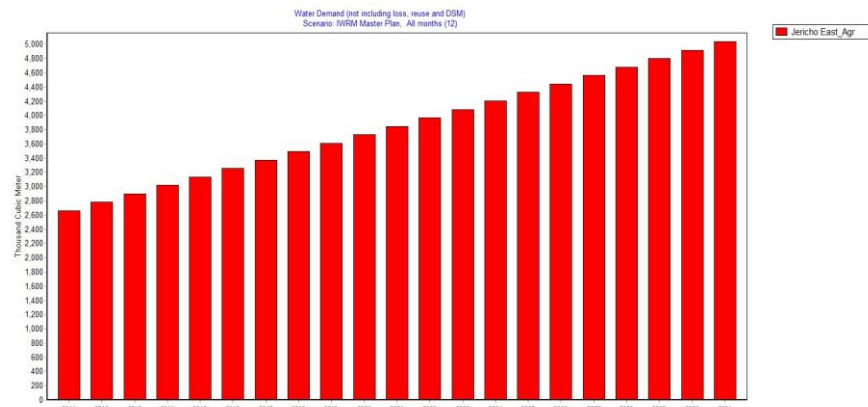


Figure 5: Jericho east water demand in 2011-2031

On the other hand, the availability of groundwater is expected to decrease in the coming years due to increasing salinity and declining precipitation. The decrease rate of 5.6 % is taken from the trend line of the wells abstraction (PHG, 2010). The projected values of the model state that available abstraction would be about 1 MCM in 2031 only (Fig. 6). Due to the increase in demand and decrease in supply, unmet demand will increase rapidly that alert for management options (Fig. 7).

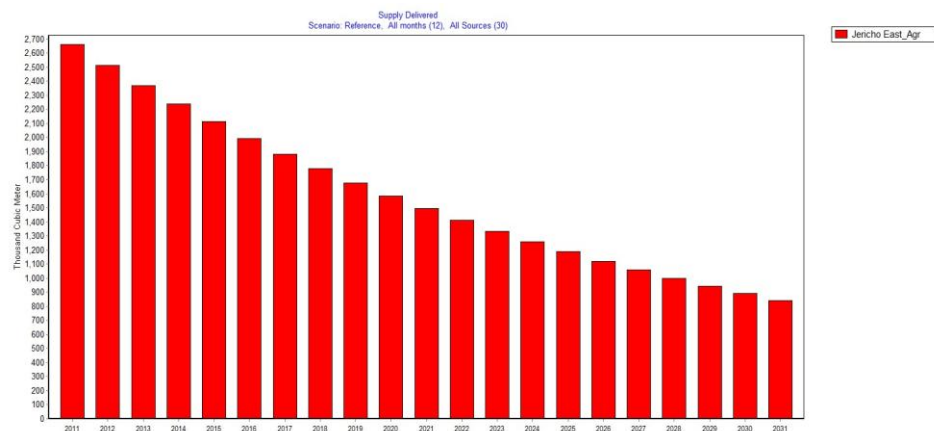


Figure 6: Jericho east water supply in 2011-2031

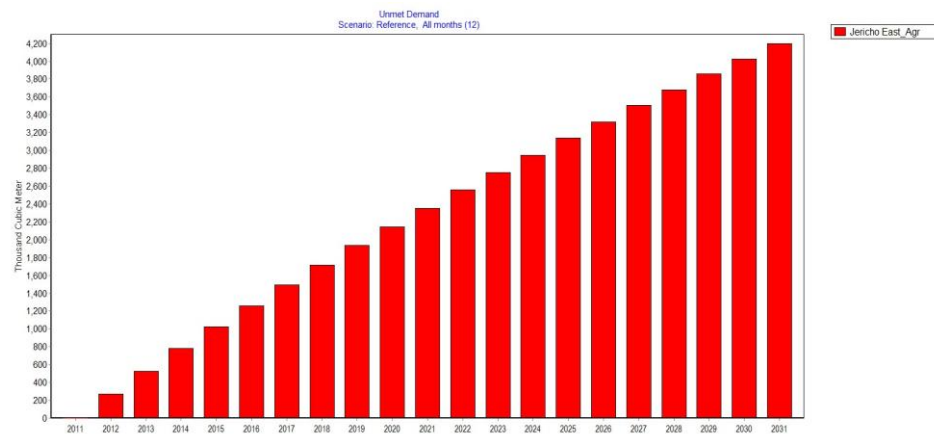


Figure 7: Jericho east water unmet demand in 2011-2031

Various assumptions regarding the expansion of agriculturally used land and declining water availability will render different prospected developments of water shortage. As in the section “Cost-benefit analysis” below pointed out, it can be assumed alternatively that the extension of farmland is dependent on the prospected increases in water supply (situation 2).

2. Water management options

The desalination of brackish water would improve the water situation mainly in the east agriculture area of Jericho. But further measures are to be considered, such as wastewater reuse and rainwater harvesting (Fig. 8). The following analyses will focus on these three options. Furthermore, a cost benefit analysis of the water protection area at the Ein Sultan spring will be carried out (not here, but in study 506).

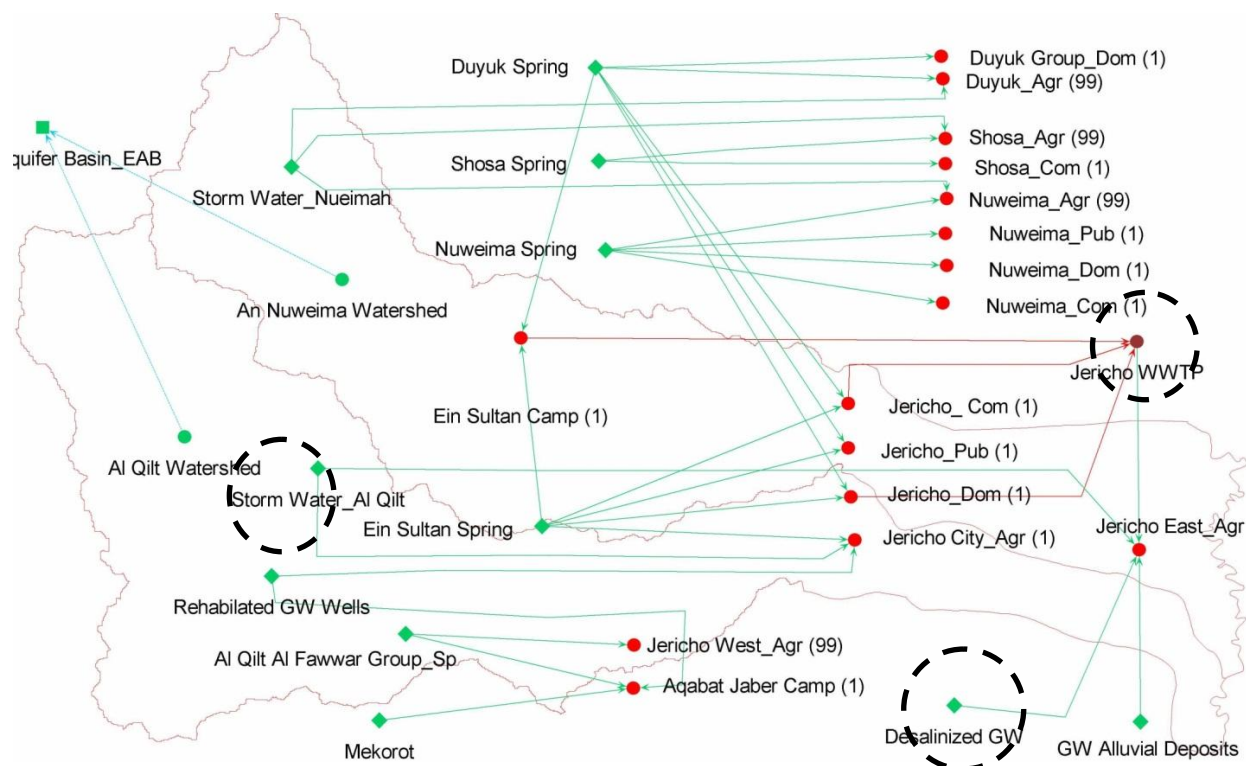


Figure 8: Schematic View of WEAP model different water management options for the Jericho east sub-area

3. Impact analysis

The current water availability for agricultural irrigation amounts to 2.8 Mm³/yr. As Table 1 shows, this volume can be augmented with 3.0 Mm³/yr by desalination of brackish groundwater, with 1.8 Mm³/yr by reuse of the effluents from the planned WWTP with 1.8 Mm³/yr and with 1.5 Mm³/yr by rainwater / storm water harvesting.

Supply name	Type	Supply (MCM/yr)
GW Alluvial Deposits	Current Account	2.8
Desalination of Brackish GW	IWRM	3.0
Waste Water Reuse	IWRM	1.8
Rainwater Harvesting from Al Qilt	IWRM	1.5

Table 1: Increases of water availability in the Jericho east sub-area

Figure 9a illustrates the development of unmet demand in agriculture, for instance, if the desalinated groundwater would be the only new resource. It is assumed that the farmers could expand their agriculturally used land by a steady growth rate if the water volumes required would be available (situation 1). Till 2022, the additional supply is sufficient, but then the unmet demand will emerge again, because the maximum capacity of the desalination plant is reached. Thus, further resources would be needed. The development of the unmet demand for each of the other two alternatives will be shown by the Figures 9b and 9c.

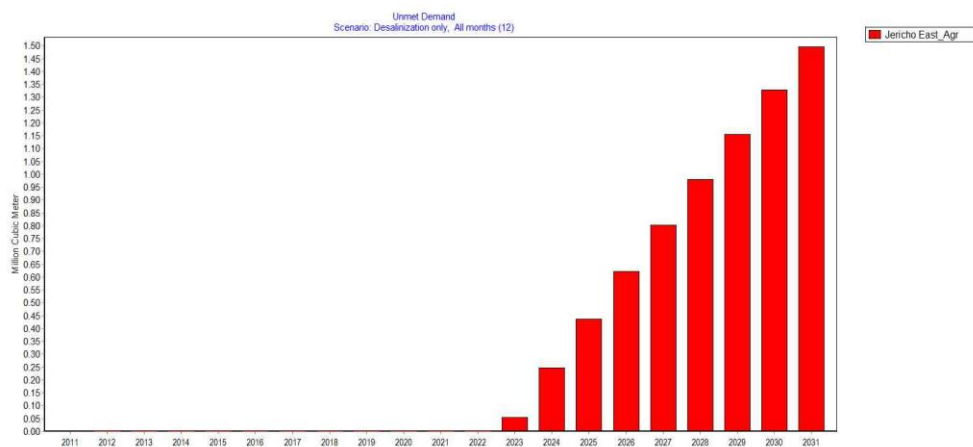


Figure 9a: Jericho east water unmet demand with desalination option only in 2011-2031

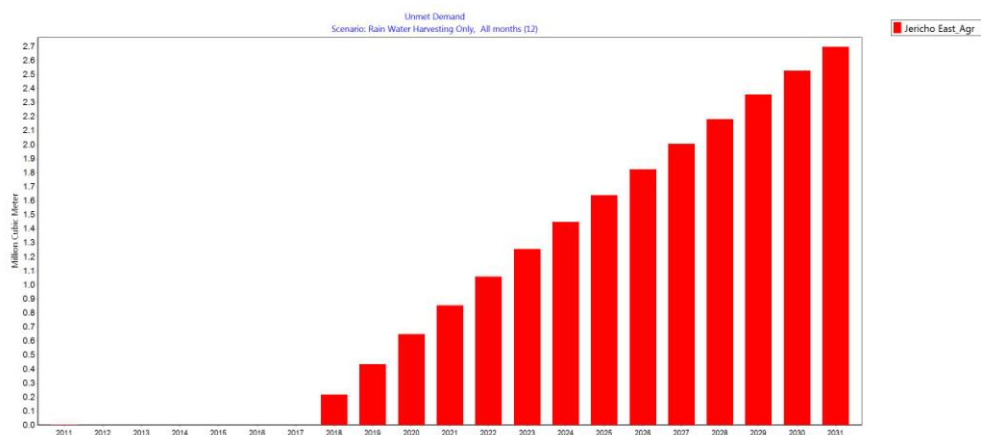


Figure 9b: Jericho east water unmet demand with rain water harvesting option only in 2011-2031

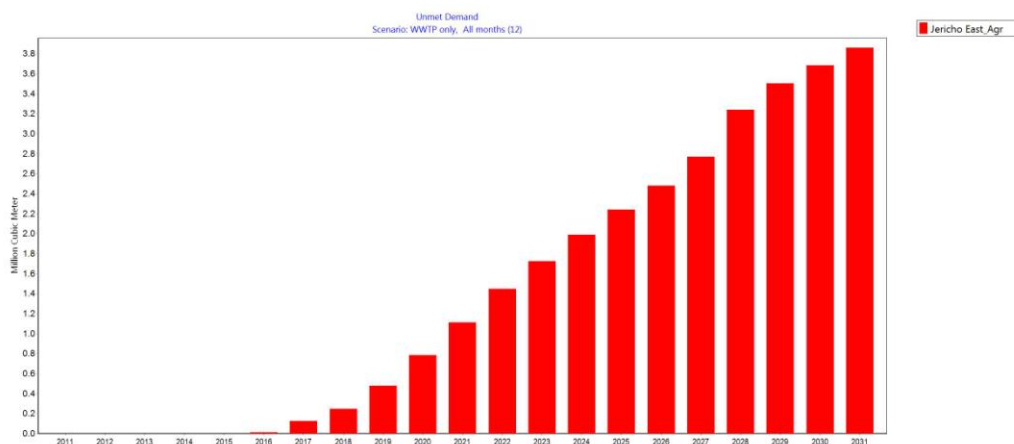


Figure 9c: Jericho east water unmet demand with wastewater reuse option only in 2011-2031

4. Cost-benefit analysis

In order to find out the most appropriate water management options and their combinations (IWRM strategies) together with their added values, cost-benefit analyses (CBA) were carried out. Even though the WEAP model provides a CBA module, we applied the Excel tool, because we were faced with some restrictions.

4.1. Cost of water management options

Desalination of brackish groundwater

Desalination is the process used to reduce the dissolved salts and other chemicals in a water source to meet the water quality standards for non-potable and potable uses. (Sieraclub 2012). Brackish water has more salinity than fresh water, but not as much as sea-water. Technically, brackish water contains between 0.5 and 30 grams of salt per litre — more often expressed as 0.5 to 30 parts per thousand (ppt or ‰).

Fresh Water	Brackish Water	Saline Water	Brine
<0.5	0.5-30	30-50	>50

Table 2: Water salinity based on dissolved salts in parts per thousand (USGS 2012)

The cost of brackish water desalination in Palestine can be assumed as the same like in Israel (ADAN Technical & Economic Services LTD 2011). Operational conveyance costs are not included as they are negligible due to gravitational flow. The construction cost is around 6 million USD; the annualised capital cost around 600,000 USD/yr (usable lifetime 20 years, 7.5% rate of interest) and the total variable cost about 0.78 USD/m³. This calculation includes the cost of groundwater abstraction, which is estimated to about 0.53 USD/m³ using diesel pumps.

Reuse of treated wastewater

Construction cost of a wastewater treatment plant generating 1.8 million m³ effluents per year and with a usable lifetime of 30 years is assumed to be 32 million USD, which include the capital cost of the collection network; the running cost amounts approximately to 1.5 NIS/m³, equivalent to 0.39 USD/m³. The costs of distributing the effluents to the farmlands, of storage and of special irrigation equipment are to be included (PHG, 2010) (Tab. 4).

Production (MCM/yr)	Annual capital cost *) (million USD/yr)	Variable cost (USD/m ³)
1.8	2,081	0.39

*) Rate of interest 5%

Table 3: Costs of wastewater treatment at Jericho east sub-area

Rain water harvesting

The cost of rain water harvesting has been estimated in literature to 15,000 € for each harvesting pool with a volume of 2,500 m³ (PHG master plan, 2010). Rain water flows to the Jericho east sub-area from Wadi Al-Qilt, which produces about 1.5 Mm³/yr (PHG master plan, 2010); this amount serves both Jericho city and Jericho east areas. Total projected cost of building the pools to collect harvested rain water is about 11 million USD and the annualised cost is around 939,000 USD/yr (usable lifetime 30 years and rate of interest 7.5%).

4.2. Economic benefits of water management options

In the Jericho east sub-area, only farmers demand water, which is used mainly for irrigation. Their economic benefits depend on the additional water supply that leads to an increase in their incomes (= profits) as the difference between their revenues and production cost (e.g. as seeds, fertilizers, pesticides, labour, etc.). The revenues are determined by the crop production per dunum, the market prices of agricultural products and the volume of water per dunum that is required for planting various products.

Table 4 shows for different types of plants the production per dunum, the market prices and the water requirements per dunum. Further, it shows the water profitability for each plant. The latter is calculated for each plant as follows:

$$\text{Profit/dunum} = (\text{production/dunum} \times \text{farm gate price}) - \text{production cost/dunum.}$$

$$\text{Water profitability} = \text{profit/dunum} / \text{water requirement/dunum.}$$

Plant	Production (kg/dunum)	Price (NIS/kg)	Water requirement (m ³ /dunum)	Water profitability (NIS/m ³)	Water profitability (USD/m ³ *)
cauliflower (autumn)	2500	1.5	500	4.78	
Cucumber (spring)	2500	1.6	400	5.09	
potato (autumn)	3000	1.5	450	5.76	
Cucumber (autumn)	2000	1.5	500	2.57	
potato (spring)	3000	1.5	350	6.19	
SQUASH (spring)	1400	1.5	500	0.98	
BEAN(spring)	900	3.0	400	2.83	
tomato (spring)	4000	1.0	600	2.74	
	Average water profitability of vegetables			3.87	1.01
banana	4000	3.2	2200	4.52	1.18
palms	1500	15.3	1800	11.3	2.96
Citrus	2375	2.3	1200	2.78	0.73

*) 1 USD=3.82 NIS

Table 4: Production, farm gate price, water requirement and water profitability of crops in the entire Jericho Area (Ministry of Agriculture; own calculations)

Table 5 shows the crop pattern we use for the calculation of the average water profitability in the Jericho east sub-area.

Type of crop	Percentages of crop (%)
Vegetables	37.70
Banana	0.00
Citrus	0.22
Palms	52.23
New palms *	9.85

*) New palms are not considered

Table 5: Crop patterns planted at Jericho east sub-area (Ministry of Agriculture)

For vegetables an average farm gate price is used as there are no crop-specific data available (The agricultural statistics provides data only for the crop categories vegetables, palms citrus, etc., but not for individual types of vegetables).

The weighted average of the **water profitability** in the Jericho east area can be estimated to 1.93 USD/m³. This number represents the unit economic benefit from each new water cubic meter supplied to the farmers.

With the term water profitability the additional farmers' gross income due to increases in water supply can be calculated. Note, that the following CBA does not include the charges associated with the additional water supply. For instance, the cost of extra fresh-water or treated wastewater delivered to the farmers is a cost component of these projects. Thus, adding it to the farmers' production cost would lead to double-counting. The question to which extent farmers should share such the costs of water projects is not a matter of economic efficiency but of financial feasibility, which will be discussed later in the chapter dealing with financial issues.

4.3. Cost benefit analysis of water management options

As in Figure 10 shown, the option with the **lowest cost per cubic meter** in comparison with the **economic benefits per cubic meter** is rain water harvesting, followed by the groundwater desalination and wastewater reuse (Fig.10). However, it must be taken into account:

1. The additional water supply of each of these new resources does not meet the demand within the planning period, if they would be employed as the only option;
2. The cost of water consists of variable and fixed components: the first one is related to the water volume produced, the second one are costs (e.g. buildings, equipments, etc.), which are not related to the water volume, and they incur even if there is no water production. Thus, the extent to which the new resource is being utilised determines the total unit cost of the option. **In the first years** of the planning period, when the increases in agricultural water demand are relative small - as mentioned above, a steady growth rate is assumed – the new resource (for instance, the plant providing desalinated brackish water) is not fully utilized, so that the total unit cost would be definitively higher than shown in Figure 10.

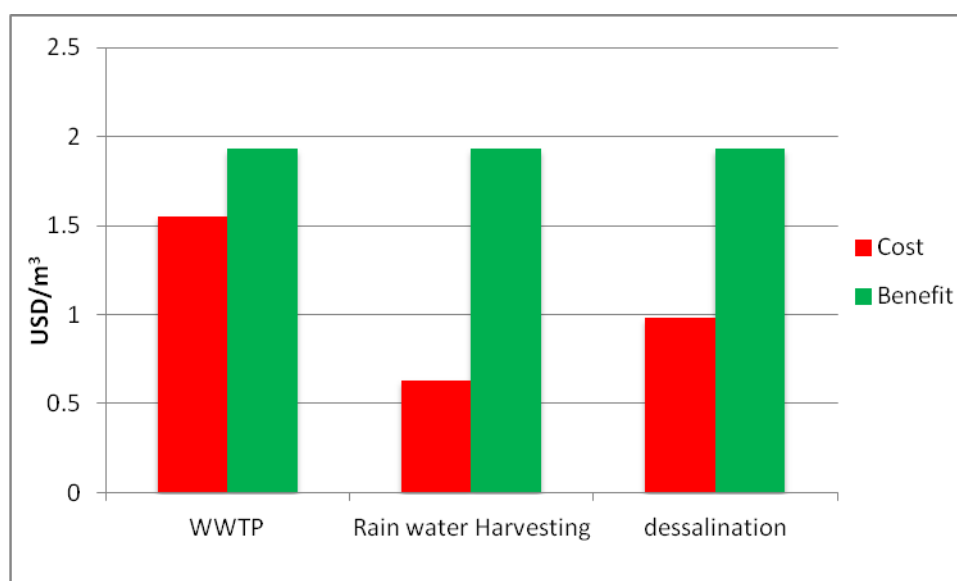


Figure 10: Unit costs and benefits of different water management options for the Jericho east sub-area

In order to highlight these important economic implications, in the following the results of the CBA will be displayed under timeline. As expected, in the first years of the planning period, the costs exceed the benefits at each of three water management options, whereas in the later years there will be significant positive net benefits. To be aware about these developments is crucial with respect to the **financial feasibility** of projects, which aim to improve the water situation: In the first years, there is no cost recovery, if the revenues from water delivery is the only basis to finance the projects; however, the excessive bene-

fits in the following years will allow to recover the costs over the entire planning period (situation 1).

In calculating the cost-benefit ratios there is an alternative approach possible: It is assumed that the farmers expand their agriculturally used land only if they get the water volumes needed (situation 2). Consequently, no unmet water demands emerge.

For example, the costs and benefits of wastewater reuse are displayed in the figures 11a and 11b. Indirect benefits show how much the service of wastewater collection and treatment would save costs of cesspits discharge. Each discharge costs approximately 180 NIS and each discharge amounts to 10 m³. It is assumed that usually 50 % of the wastewater produced is kept inside the cesspit and the rest is infiltrated to groundwater. The benefit of protecting groundwater from pollution should be taken into consideration, but it is extremely difficult to evaluate them in economic terms.

The economic impacts of water losses in the distribution network of 10% on the benefits are also shown. For both assumptions (situation 1 and situation 2), the development of the water demands for each of the three water management options have been obtained from the WEAP model.

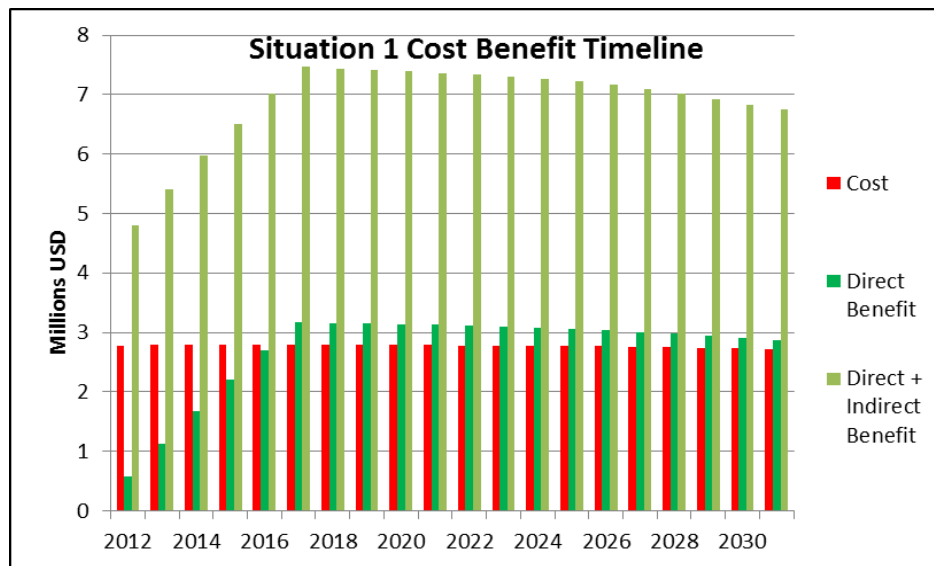


Figure 11a: Cost and benefit of reuse of treated wastewater with indirect benefits for the Jericho east sub-area at situation 1

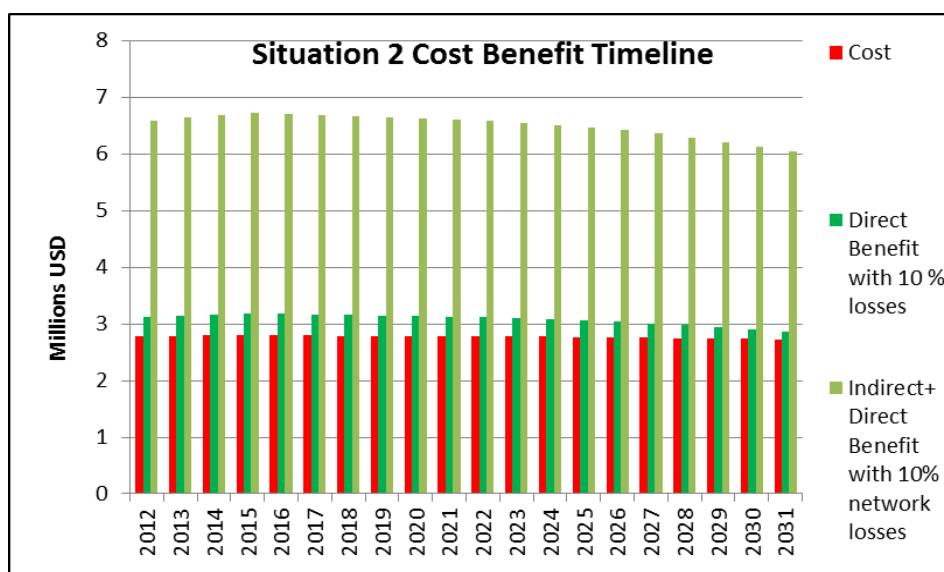


Figure 11b: Cost and benefit of reuse of treated wastewater with indirect benefits for the Jericho east sub-area

4.4 Results

Economic efficiency of water management options

The three options are ranked in table 6 in terms of unit values added. It shows that wastewater reuse is the best one, followed by rainwater harvesting and desalination of brackish water.

Water management options	Unit values added USD/m ³ *)
Desalination of brackish water	0.76
Rainwater harvesting from Al Qilt	1.11
Wastewater reuse **)	2.06 **)

*) Values at 100% use of capacity; water losses in the networks not considered

***) Cost savings in cesspits (indirect benefits) included

Table 6: The economic efficiency of water management options at the Jericho east sub-area

Priorities of water management options

The proposed water management options can provide a total supply volume of 6.3 Mm³/yr, while the projected water deficit for the Jericho east sub-area will increase from 1 Mm³/yr to

approximately 4.2 Mm³/yr only during the period from 2015 to 2031 (Table 7, Figure 7). This means, that not all the management options are to be implemented at the same time. Thus, priorities are to be allotted to each of the options. According to the CBA results, the **water reuse option** has the first priority (provided the indirect benefits are being considered), followed by the desalination of brackish groundwater and rainwater harvesting (Table 7).

Management Option	Supply (MCM/yr)	Served Area	Priority
Water reuse *)	1.8	Jericho East	1
Rainwater Harvesting from Al Qilt	1.5	Jericho East & Jericho City Agr.	2
Desalination of brackish GW	3.0	Jericho East	3

*) Including indirect benefits

Table 7: Priorities of water management options at Jericho east sub-area

Values added of IWRM strategies

To find out the most economically efficient combinations of the three options (IWRM strategy) within the planning period 2012 – 2031 needs a little bit more sophisticated methodology. However, at Jericho east sub-basin, where agriculture is the only water user, a simple approach can be employed.

Applying the priorities in table 7 during the planning period 2012 – 2031 would lead to time intervals with different combinations of the water management options A, B and C, if the water supply shall meet the continuously growing water demand in agriculture (situation 1 assumed). These combinations indicate IWRM strategies that can be supposed as most cost-beneficial (Table 8).

The lengths of the relevant time intervals are dependent on in which years a further option will be needed to prevent unmet demand (i.e. Fig. 9). The relative economic efficiency of each of the water management options in terms of annual value added determines the composition of each of the IWRM strategies at different years (Tab. 8). In order to implement the most cost-beneficial IWRM strategies, the option with the maximum values

added are to be selected first (here: water reuse), followed by the other options (here: rainwater harvesting and desalination of brackish water).

In developing the different IWRM strategies in the course of time the upper limits of the resource capacities (Tab. 7) are to be taken into consideration.

Year	Value added of options *) (Million USD/yr)			Value added of IWRM strategies ***) (Million USD/yr)	
	Reuse **)	Harvesting	Desalination		
2012	2.02			A	2.02
2013	2.61			A	2.61
...	...			A	...
2017	4.67			A	4.67
2018	4.65	- 0.79		B	3.86
2019	4.63	- 0.37		B	4.26
...	...	...		B	...
2025	4.45	1.97		B	6.42
2026	4.40	1.97	- 0.14	C	6.23
2027	4.34	1.97	0.08	C	6.39
...	...	...	...	C	
2031	4.02	1.97	0.96	C	6.95

*) Numbers are rounded. Minus values indicate costs exceeding the benefits due to low utilization of the infrastructure capacity.

**) The benefits of water reuse option include also the cost savings due to closing cesspits (indirect benefits). Water losses of 10% considered.

***) In appendix 1 all the IWRM values can be found.

Table 8: Scheme for calculating the values added of different IWRM strategies at Jericho east sub-area

In Table 8, the added values resulting from different water management options and IWRM strategies in each year of the planning period 2012 – 2031 are displayed on the basis of a specific growth rate of crop production. The IWRM strategies A, B and C consist of following components (Table 9):

IWRM strategy	Combination of water management options
A	Water reuse
B	Water reuse + rainwater harvesting
C	Water reuse + rainwater harvesting + desalination of brackish water

Table 9: IWRM strategies at the Jericho east sub-area

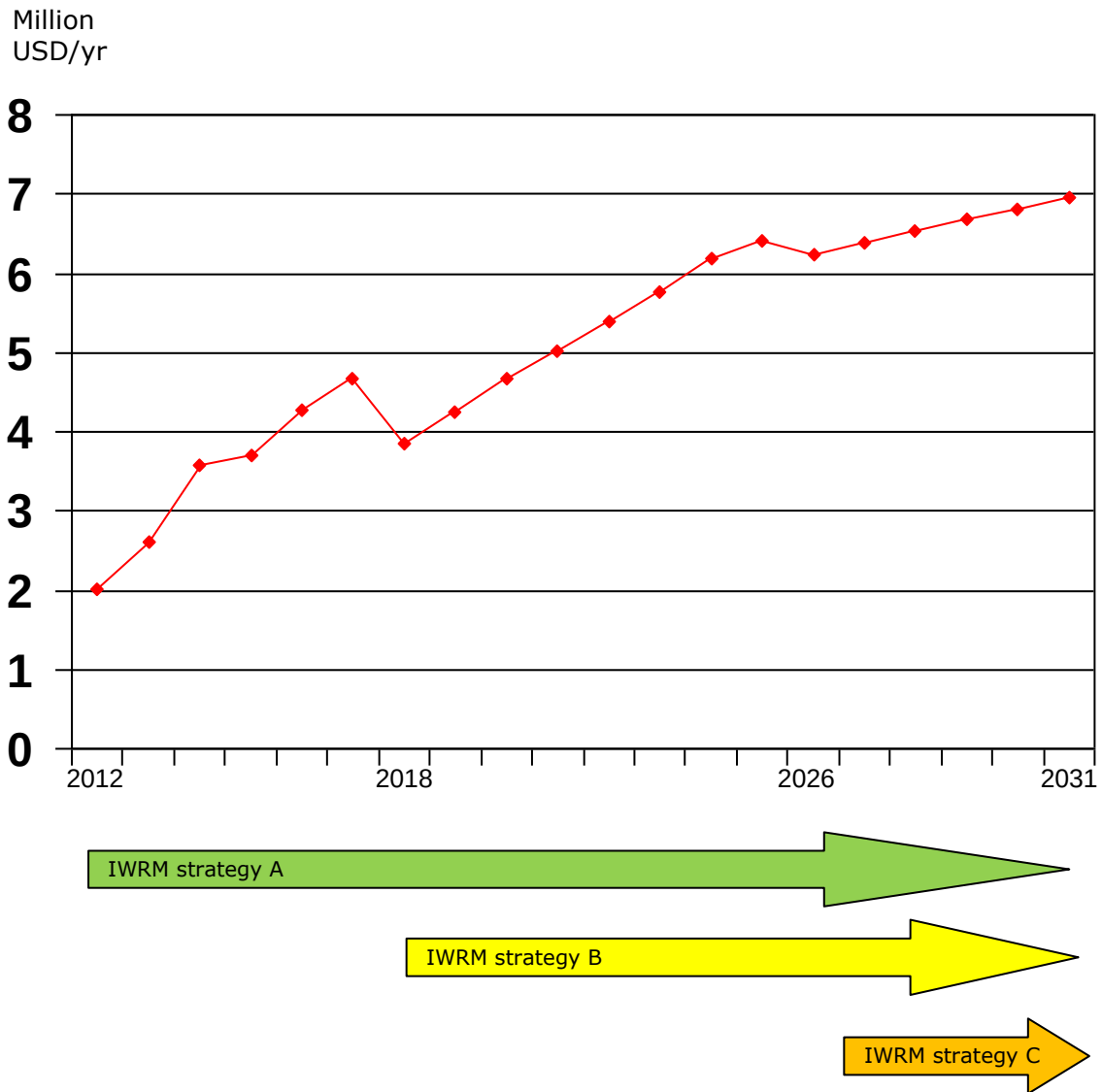


Fig. 12: Values added of IWRM strategies within 2012 and 2031 at the Jericho east sub-area

From table 8 and figure 12, it can be seen how the increases in values added of the IWRM strategies A, B and C are composed within the planning period.

The values in table 8 and the shape of the curve in figure 12 are dependent on several influencing factors, such as the costs, water profitability and the growth rate of crop production. For example, if the later rate is increasing, the curve will be shifted upwards. This means that each of the water management options and IWRM strategies A, B and C is to be implemented earlier.

Such a time-referenced CBA can provide a guideline for water managers, who want to decide when water projects (e.g. wastewater treatment & reuse, storm water harvesting, desalination of brackish, etc.) should be constructed and which capacity they should have to maximise the total added value.

They have to take into consideration, first of all, the following influencing factors:

- Growth rate of water demands,
- Variations in water availability (affected by increasing or declining precipitation and others),
- Cost of water projects and water values for different users.

As mentioned, the time intervals between the implementation of the IWRM strategies A, B and C depend on the upper capacity limits of each of the three new resources. Note, there are also upper limits for agriculturally used areas, which will be reached earlier, if the growth rate of crop production and consequently the water demand are higher.

More results

- Each of the three water management options yields values added. However, in cases of rainwater harvesting and of brackish water desalination the costs will exceed the benefits in the first years after their installation, because the capacities are not utilized fully. Then, the yearly values added will increase continuously. Once the upper limits of the capacities are reached, the added values remains constant at a high level. In the planning process, the water manager gets important information, whether the extension of one of these capacities or the transition to the other option will be worthwhile. By that, figure 12 may become steeper. Of course, this applies to the wastewater reuse option as well.
- The construction of wastewater treatment plants (WWTP) aims primarily to reducing the pollution caused by untreated wastewater, which is generated by different water users (e.g. citizens). Usually municipalities are committed by law to treat wastewater and to comply with quality requirements for discharging the effluents into the aquatic environment (e.g. rivers). If these quality requirements are not sufficient for applying the effluents in irrigated agriculture, additional treatment equipments are needed (such as

tertiary treatment). Only the cost of these extra equipments and additional conveyance systems (such as channels and storages) should be considered as the cost of the wastewater reuse option. This refers either to existing WWTPs, which will be upgraded, or to WWTPs, which are to be built due to mandatory regulations. Thus, the CBA of the reuse option should address only the cost and the benefits associated with this option. Nevertheless, the positive environmental impacts resulting from wastewater reuse should be pointed out, such as less pollution of rivers or reduced overexploitation of groundwater. But there may be also adverse impacts, if soils and aquifers will be contaminated by water reuse.

- The net benefits (i.e. values added) of the reuse option indicated in figures 11a and 11b will probably be higher if we take into account the costs associated with water reuse only (such as the additional cost of upgrading the treatment technology together with the costs of storages and conveyance systems required). Note, that subject of the CBA is not the WWTP, but the water reuse option. In the first case, all costs and all benefits of a WWTP would have to be considered, i.e. in addition to the economic benefits also the positive environmental impacts, such as the reduced pollution of water bodies. Since these impacts does not represent economic benefits, sometimes surrogates are applied to evaluate them in monetary units. For instance, the cost of a new WWTP (including capital and operation costs) may indicate the lower limit of the citizens' readiness to pay for less water pollution (otherwise it would not have been constructed). In terms of CBA this means, that the treatment cost will be compensated by the environmental benefits, which are valued at least by the willingness to pay for protecting the environment.
- It should be mentioned, that the values added resulting from water reuse will probably be influenced by the population growth as more people create more wastewater, so that the availability of the treated effluents is increasing each year. On the other hand, if municipal users take water saving measures the generation of wastewater will decrease. The latter impact can be seen in the figures 11a and 11b showing declines in the values added from 2018 to 2031 (see also Table 10).
- From the viewpoint of financial feasibility, the decision to construct a new WWTP depends generally on the total cost of the plant and on the availability of financial resources. The more farmers and other donors are ready to contribute to the total cost, the more the construction of new WWTPs can be realised. This applies particularly to developing countries, where often the investments in wastewater treatment and reuse are not affordable for municipalities.

- The economic impacts of changes in the crop pattern at Jericho east sub-area should be explored as they will affect the water profitability in irrigated agriculture. Of special importance is that the Palestinian Ministry of Agriculture is promoting such changes, in particular new lands with palms and grapes, which are more profitable and can better resist soil deterioration by increasing salinity.

Chapter 2. Jericho central sub-area

1. Water situation

The Jericho central sub-area is located in the centre of the study area (Fig. 2). In this area with the city of Jericho, there are domestic, agricultural, commercial and public water users. Currently, this area is supplied with water from the Ein Sultan Spring that produces about 5.5 Mm³/yr (PWA, 2011). Water for domestic use is distributed through a pipe network, while water for agriculture use is supplied through an open channel network. Population is expected to grow rapidly in the next decades, so that the water demand will increase. The arable land is currently not fully used and the expansion of agriculture would only be possible if additional water resources will be available. Figure 16 shows the WEAP schematic view for this sub-area.

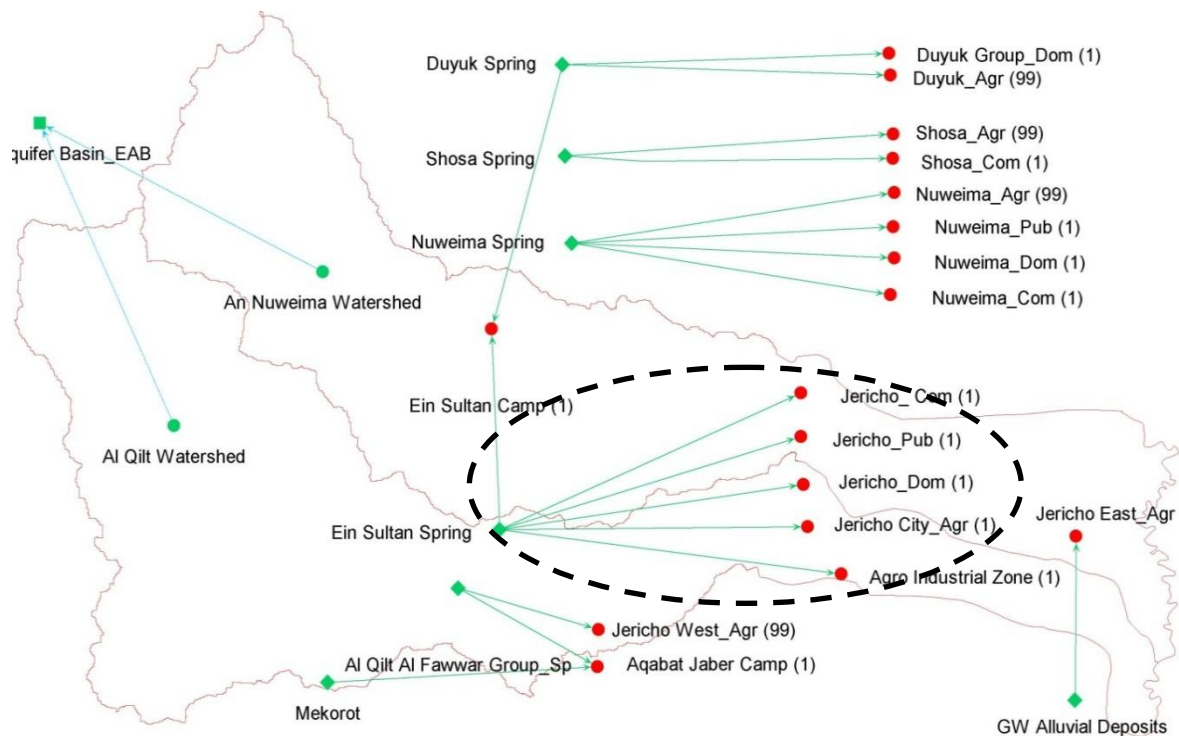


Figure 13: WEAP schematic view of the Jericho central sub-area at the current situation

As input data for WEAP the following assumptions have been made:

- City of Jericho: Population growth rate of 2.9%; the water demands of domestic, commercial and public users will increase at the same rate.
- Agriculture: Provided the water required is available, agricultural activities would increase, and all arable lands would be fully used by end of the modelling period. For the increase rate of land use an assumption must be made: the same rate as the other water users; it is a steadily linear growth rate. The urban areas are supposed to increase as well due to the growing population.

The development of the total projected water demand is shown in Figure 14. In 2031, it will amount to approximately 6.5 Mm³.

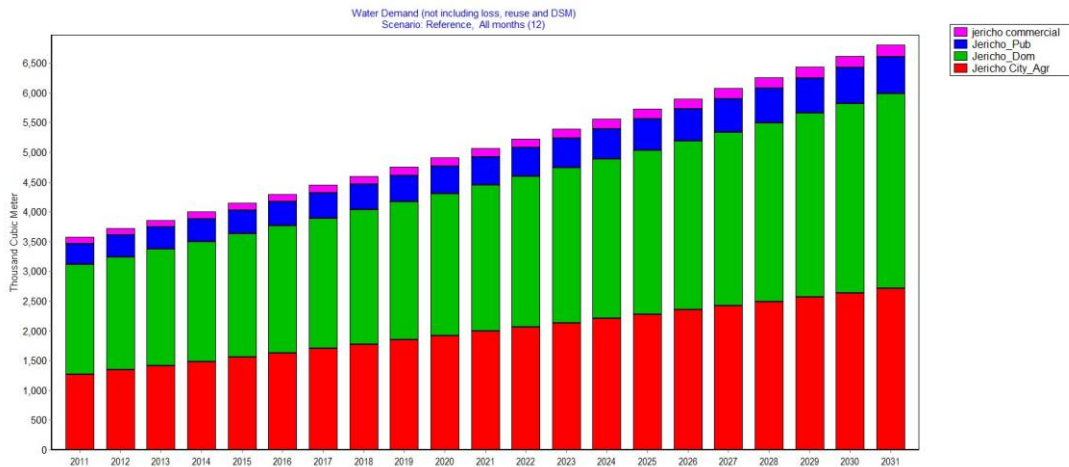


Figure 14: Jericho City water demand in 2011-2031

On the other hand, the available spring water from the Ein Sultan is expected to decrease in the coming years. The assumed decrease rate of 1% per year is taken from the trend line of the spring water availability (PHG 2010). The assumed projected water volumes delivered to the different users are displayed in Figure 15. In 2031, the total possible water supply will be approximately 2.8 Mm³. Consequently, the rapid increases of unmet demands call for a better water management (Figure 16).

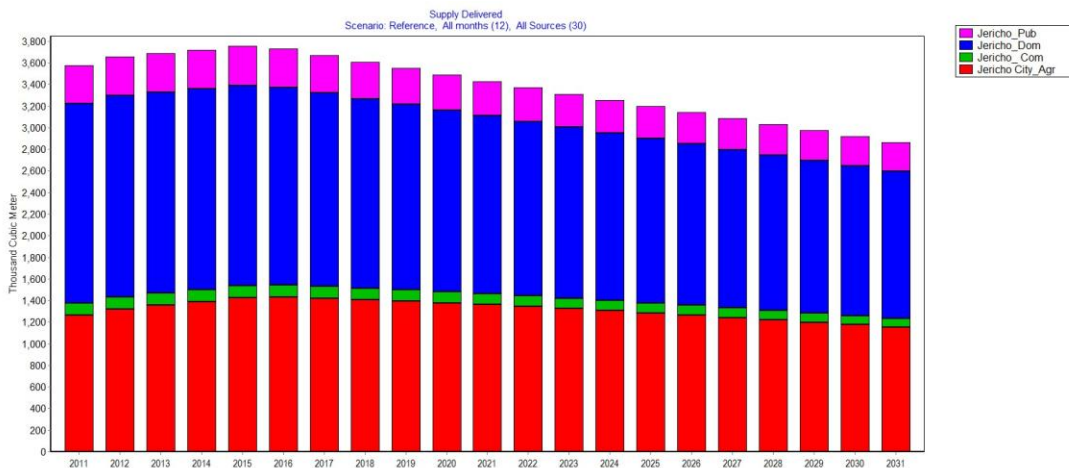


Figure 15: Potential water supply for the Jericho central sub-area in 2011-2031

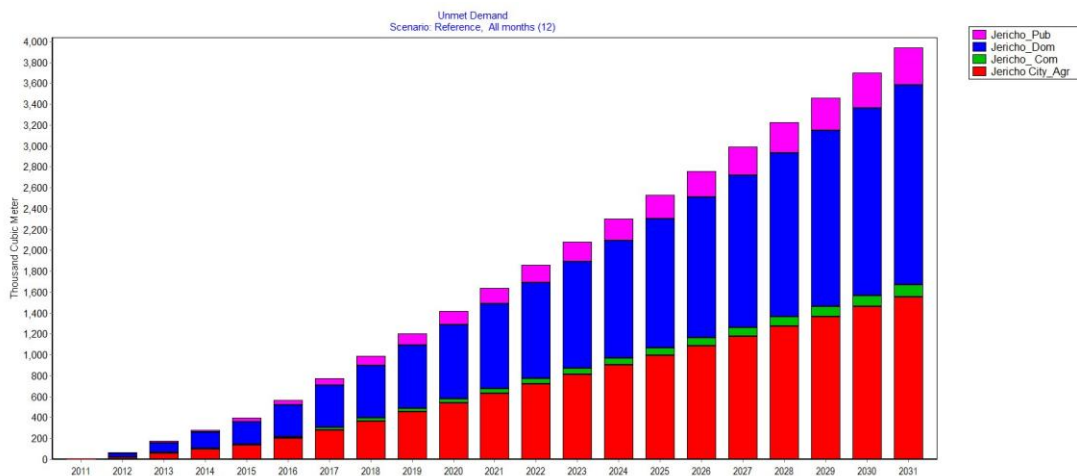


Figure 16: Unmet water demand at the Jericho central sub-area in 2011-2031

2. Water management options

The following options will be evaluated in terms of costs, economic benefits and added values:

- Rehabilitation of groundwater wells
- Intersectoral water transfer: The municipality takes over farmers' water rights from Duyuk spring
- Rain water harvesting from Al Qilt watershed
- Demand Management
- Rehabilitation of water distribution networks
- Water protection zones (will be analysed separately in study 506).

3. Impact analysis

Table 10 shows the different proposed options with their projected effects. In Figure 17, the WEAP schematic view is displayed, which indicates the location most of the options.

The water supply exceeds the total water demand, if all the management options would be implemented ("IWRM master plan").

Supply name	Type	Supply (MCM/Yr)
Ein Sultan Spring	Current Account	5.5
Rehabilitation of GW wells	IWRM	1.58
Intersectoral water transfer from Duyuk spring	IWRM	0.34
Rain water harvesting from Al Qilt	IWRM	1.5
Demand management	IWRM	0.038 - 1.31*
Rehabilitation of water networks	IWRM	0.043 - 0.79**

* Stepwise reduce of water consumption from 250 l/c/d to 150 l/c/d

** Keep losses in all networks at 24 % by stepwise rehabilitation

Table 10: Proposed management options for the Jericho central sub-area

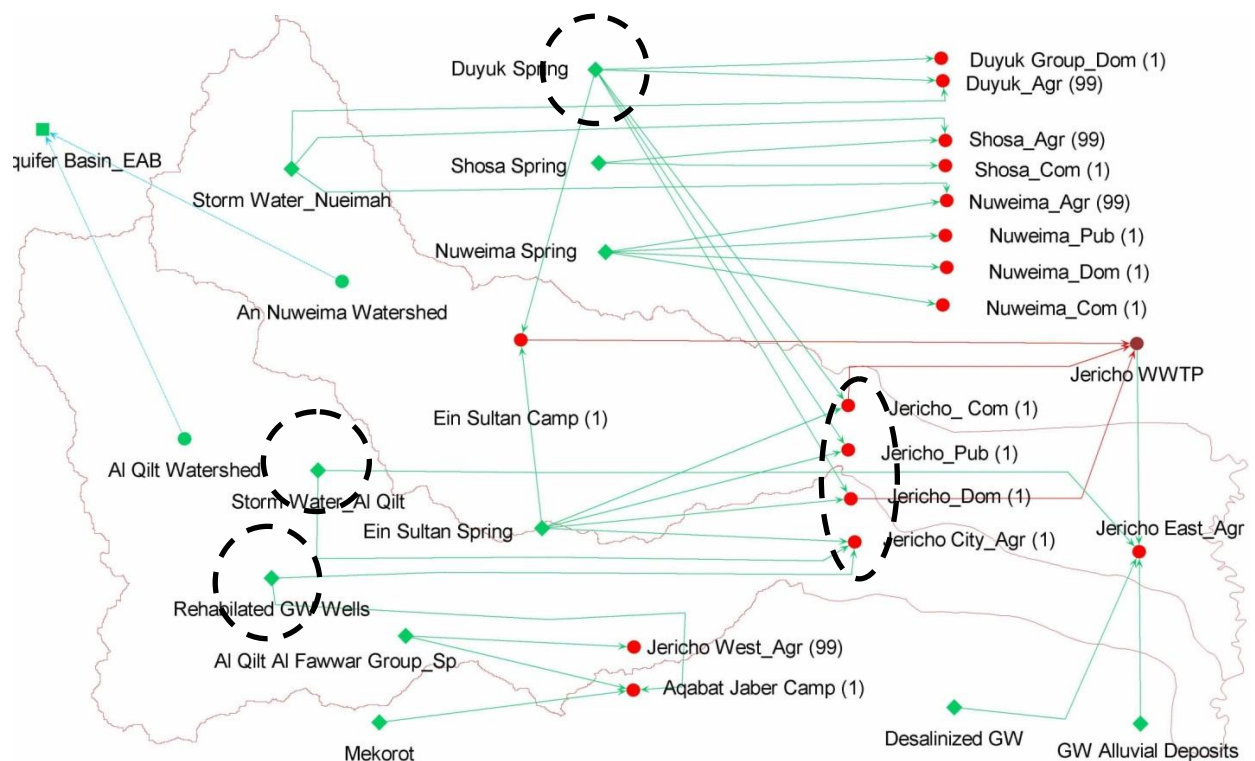


Figure 17: Schematic view of WEAP model for the Jericho central sub-area with water management options (IWRM master plan)

4. Cost-benefit analysis

As in the Jericho eastern sub-area, the question arises which water management options and which combinations (IWRM strategies) are preferable in terms of economic efficiency. Again, the Excel tool was applied to calculate the costs and economic benefits projected within the planning period.

4.1. Cost of water management options

Rehabilitation of groundwater wells

Three old wells are to be rehabilitated, which are expected to produce 180 m³/h. This water resource is designed mainly for agricultural irrigation in Jericho City area, but possibly also for the Aqabat Jabir camp located outside the Jericho City area. Table 10 shows the capital and running cost of this option.

Production (MCM/yr)	Capital cost (USD)	Running cost (USD/m ³)	Annual capital cost * (USD/yr)
1.58	227,955	0.39	19,301

* Life period: 30 years; interest rate: 7.5%

Table 11: Cost of Rehabilitation of groundwater wells designed for the city of Jericho

Intersectoral water transfer

This option represents an **intersectoral water transfer from agricultural to municipal users**. Every farmer in Duyuk area (village near Jericho City) has a share in the Duyuk spring and the share of water is distributed during a time period of irrigation. The Jericho municipality sought to increase water supply to its area for domestic, commercial and public use and one of the solutions was to buy water rights in Duyuk Spring from the farmers. The water volume to be transferred is 27,900 m³/month, which is equivalent to about 0.33 Mm³/yr. The estimated total cost is 338,852 USD, including storage tank and a 3,200 m pipe line (PHG master plan 2010) corresponding to annualised cost of around 28,700 USD/yr (usable lifetime 30 years; rate of interest 7.5%). Operation cost is not considered.

Rain water harvesting

Rain water flows to the Jericho east sub-area from Wadi Al-Qilt, which produces about 1.5 Mm³/yr (PHG master plan, 2010); this amount serves both Jericho city and Jericho east areas. Total projected cost of building the pools to collect harvested rain water is about 11 million USD and the annualised cost around 938, 000 USD/yr (usable lifetime 30 years, rate of interest).

Demand Management

This option is proposed to decrease the current water consumption in the city of Jericho. It is planned to reduce the water use from 250 l/c/d to be 150 l/c/d in the next 20 years. We assume total cost of 100,000 €, equivalent to 123,219 USD and around 10,400 USD/yr.

Rehabilitation of water networks

Network losses are estimated to be 24%, but this number is expected to increase due to the continuous deterioration of the network and the poor maintenance - a phenomenon widespread in Palestine. To keep the losses at 24 %, the total cost of maintenance and rehabilitation is estimated to 1,232,000 USD, equivalent to 104,331 USD/yr (PHG, 2010) (no operation cost needed due to gravity; labour cost assumed to be included in annual capital cost).

4.2. Economic benefits of water management options

In order to estimate the economic benefits for the domestic and commercial users information are required, such as on water prices (Tables 12 and 13) and increases in water supply to meet the unmet demands (Fig. 16).

Regarding the agriculture data on crop pattern, crop prices and water profitability are needed (Table 14). The economic benefit for the farmers due to more water is determined by the crop-specific production per dunum (water productivity), farm gate prices and water requirements (cf. the calculation in the above section 4.2 for the Jericho east sub-area). Crop pattern in Jericho City area have been provided by the research project “Innovative Approach for Efficient Management of Ein Sultan Spring in Jericho” (Abdul-Hamid Musa Barghouthi 2009).

Domestic water tariffs

Customer Categories According to Consumption (2009)				
Block no.	Consumption range (m ³)	Price (NIS/m ³)	Number of Customers Per Block	Percentage of Customers Per Block (%)
1	0 -100 m ³	1 NIS/m ³	3207	78%
2	101 -150 m ³	2 NIS/m ³	497	12%
3	151-250 m ³	4 NIS/m ³	296	7%
4	> 250 m ³	5 NIS/m ³	133	3%
TOTAL			4133	100%
Average Price of water: 1.45 NIS/m³ equivalent to 0.38 USD/m³				

Table 12: Domestic water tariff of Jericho City (Water Master Plan for Jericho City – Proposed Draft Water Tariff Report, PHG 2010)

Commercial water tariffs

Commercial water tariffs				
Category	Consumption Quantity	Fee	Number of Customers (2009)	Tax (Maintenance + Meter Reading)
Min.	30 NIS/cycle			
1	0 -20 m ³	1 NIS/m ³	275 Customers	10 NIS
2	21 -50 m ³	2 NIS/m ³	69 Customers	10 NIS
3	51-100 m ³	4 NIS/m ³	37 Customers	10 NIS
4	> 101 m ³	5 NIS/m ³	36 Customers	10 NIS
Total # of Commercial Customers			417 Customers	
Average price of water sold: 1.77 NIS/m ³ equivalent to 0.46 USD/m ³				

Table 13: Commercial water tariffs of Jericho City (Water Master Plan for Jericho City – Proposed Draft Water Tariff Report, PHG 2010)

Note that the average water profitability of 1.93 USD/m³ for all the crops in the Jericho east sub-area differs significantly from that at the Jericho City area with 0.79 USD/m³ (Tab. 13).

The next step is to estimate the economic benefits for each of the water users if the different options would be implemented to augment their water supplies. For the domestic and commercial water users the additional water volumes delivered will be multiplied with the respective water prices rendering the economic benefits per year (Tables 12 and 13).

For the agricultural water users, the additional water is to be multiplied with weighted average water profitability of 0.79 USD/m³ (Tab. 14).

Water profitability in irrigated agriculture

Type of crop	Percentage (%)	Water profitability (USD/m ³) *
Banana	3.85	1.18
Citrus	19.23	0.73
Squash	16.65	0.26
Tomato	16.65	0.72
G beans	0.90	0.74
Pepper**	2.25	1.01
Cabbage	3.60	1.01
Cauliflower	3.60	1.25
J. Mallows	22.49	1.01
Sweet Corn	0.90	1.01
Egg plant	7.65	1.01
Cucumber***	1.80	1.00
Average		0.79

Exchange rate = 1 USD=3.82 NIS. Average water profitability for all vegetables and for spring and autumn cucumber were used due to lack of data

Table 14: Water profitability of various crops planted in Jericho City Area (Barghouthi 2009; Ministry of Agriculture)

4.3. Cost benefit analysis of water management options

Once the costs and economic benefits of each of the water management options are known, the CBA can be performed. Similar to the Jericho east sub-area, in the following the results of examples will be displayed over the planning period 2011 – 2031.

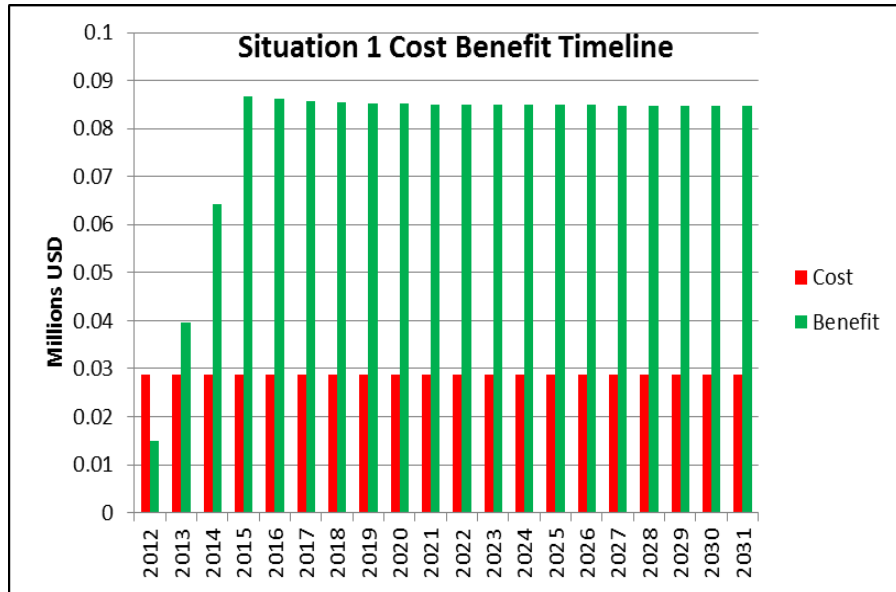


Fig. 18: Costs and benefits of intersectoral water transfer at the Jericho central sub-area

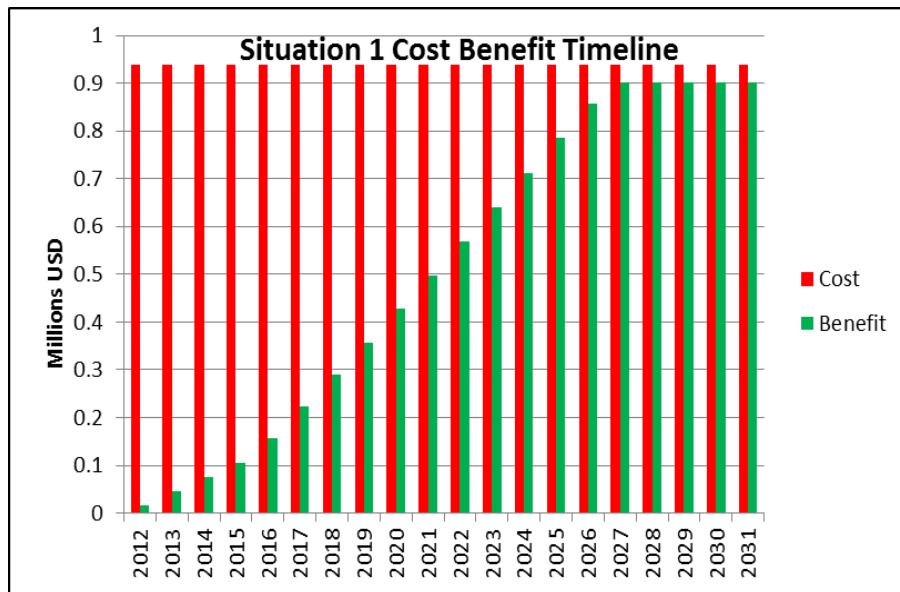


Fig. 19: Costs and benefits of rainwater harvesting at the Jericho central sub-area

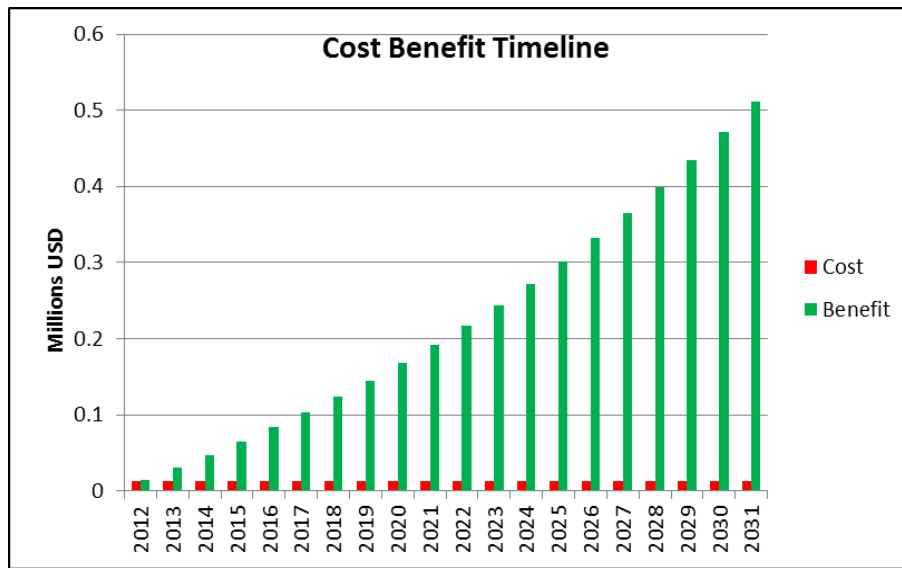


Fig. 20: Costs and benefits of demand management at the Jericho central sub-area

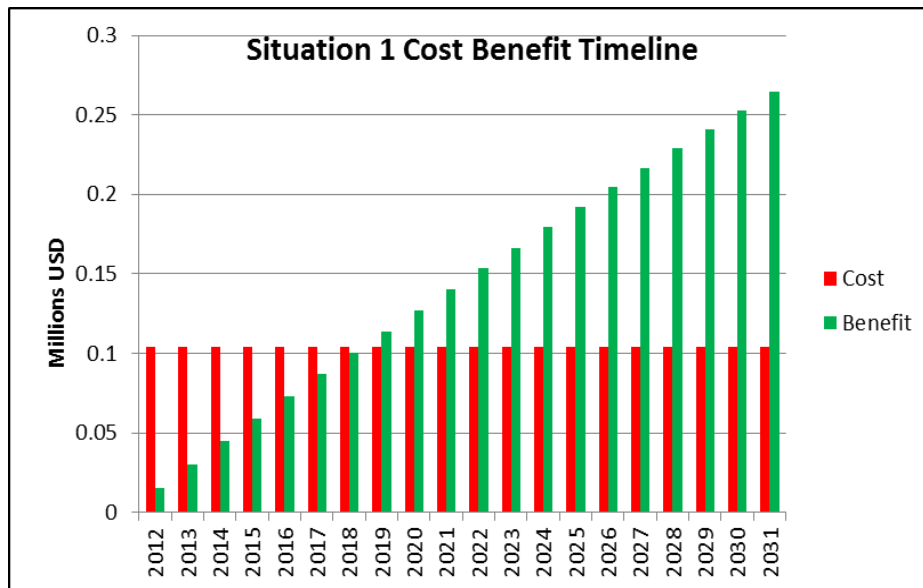


Fig. 21: Costs and benefits of rehabilitation of water networks at the Jericho central sub-area at situation 1

4.4 Results

Economic efficiency of water management options

Table 14 shows the economic efficiency of different water management options in terms of unit values added. The options demand management, rehabilitation of water networks and

intersectoral water transfer refer to domestic, public and commercial water users. The first option has the highest value.

The options rainwater harvesting and rehabilitation of groundwater wells refer to the agricultural users. Due to the water losses in the distribution systems, the values are very low. Measures to prevent water losses should be undertaken first. Thus, the following analysis will focus on the municipal water users only.

	Unit values added USD/m ³	
	Municipality	Agriculture
Rainwater harvesting *)		-0.033
Rehabilitation of groundwater wells *), **)		0.05
Intersectoral water transfer *)	0.23	
Rehabilitation of water networks ***)	- 0.57 - 0.42	
Demand management ****)	0.07 – 0.37	

*) Value at a capacity utilisation of 100% and water losses of 24% is considered.

**) 27.8% of the additional water availability is not delivered to the agricultural users, but to the Aqabat Jabir camp for free. However, the value added should be taken into account by using the average domestic water tariff.

***) Lower value in 2013 and upper value in 2031 (Fig. 21).

****) Lower value at 5% water saving of 100 l/c/d and population of 20,840 in 2012; upper value at 100% water saving of 100 l/c/d and population of 35,875 in 2031 (Fig. 20).

Table 15: The economic efficiency of water management options at the Jericho central sub-area

Values added of IWRM strategies

Applying the priorities in table 15 for non-agricultural users renders time intervals with different combinations of options, to ensure that the additional water supplies will meet the growing water demand. These combinations indicate the most cost-beneficial IWRM strategies. Similar to the Jericho east sub-basin, the lengths of each of the time intervals are dependent on in which years further options will be needed to close the water deficits (Fig. 16).

The relative economic efficiency of each of the water management options in terms of value added determines the composition of each of the IWRM strategies at different years. In developing the different IWRM strategies in the course of time the upper limits of

the resource capacities are to be taken into account. Again, the most appropriate capacities can be subject of IWRM strategies as well.

For the group of domestic, public and commercial water users ("municipality"), two IWRM strategies A and B will be assessed in terms of total values (Tables 16 and 17):

IWRM strategy	Combination of water management options
A	Demand management + rehabilitation of networks
B	Demand management + rehabilitation of networks + intersectoral water transfer.

Table 16: IWRM strategies at the Jericho central sub-area

Each of the IWRM strategies aims to cover the growing unmet demand in the course of time: From 2012 to 2017 the IWRM strategy A will be sufficient; from 2018 to 2031 the IWRM strategy B should to be implemented.

Table 16 shows the added values of each of the different options and IWRM strategies for the group of the municipal users. In Figure 22 the aggregated added values are displayed that will be generated by the both IWRM strategies A and B. The calculations are based on the following assumptions:

1. Each of the options is selected according to their relative economic efficiency in order to maximise the total added values in each year.
2. The water volumes needed for covering the unmet demand are multiplied with the average domestic water tariff of 0.38 USD/m³ as a lower boundary for the economic benefits of the different options. As mentioned, within the period from 2012 to 2017, the water volumes released by demand management and rehabilitation of networks are to be used (IWRM strategy A). Then, from 2018 to 2031, additional water from the Duyuk spring transferred from the agricultural users to the city of Jericho will be required (IWRM strategy B).
3. In some years, the costs exceed the benefits because the capacity of the new infrastructure is not fully used. In 2012 and 2013, for example, only a small part of the saved water due to the rehabilitated network is needed, so that the value added is negative. Another example is the storage tank together with the pipe line to transfer water from the Duyuk Spring in the period from 2018 to 2020. In the following years however, the capacity will be fully utilized and the benefits will exceed the costs.

Year	Value added of options *) (1000 USD/yr)			Value added of IWRM strategies *) (1000 USD/yr)	
	Demand management	Rehabilitation of networks	Intersectoral water transfer		
2012	2.3	- 18.9		A	- 16.6
2013	17.6	- 6.8		A	10.8
...	...	...		A	...
2017	87.9	46.0		A	133.9
2018	108.0	74.5	- 25.2	B	157.3
2019	129.0	102.3	- 11.5	B	219.5
...	...	...	...	B	...
2025	281.3	207.2	44.3	B	532.8
2026	311.4	228.5	51.4	B	591.3
2027	342.9	249.4	58.3	B	650.6
...	...	...	...	B	...
2031	485.5	303.8	78.8	B	868.1

*) Numbers are rounded. Minus values indicate costs exceeding the benefits due to low utilization of the infrastructure capacity. The sum of the added values generated by different options renders the added value of the respective IWRM strategy in each year. In appendix 2 all the IWRM values can be found.

Table 17: Scheme for calculating the values added of different IWRM strategies at Jericho central sub-area – domestic, public and commercial water users

Period	Cost (USD/yr)
2012 - 2015	20,866
2016 - 2019	41,732
2020 - 2023	62,598
2024 - 2027	83,464
2028 - 2031	104,331

Table 18: Stepwise cost development in rehabilitating the networks at central sub-area

- In contrast to the other two options, it is assumed that the investment cost for rehabilitating the networks of 104,331 USD will be distributed over the planning period from 2012

to 2031 in 5 stages. The yearly cost will be raised each after 4 years due to increasing capital and labour cost per year caused by the stepwise rehabilitation of the networks (Table 18). If the total investment cost of around 1.2 million USD would be spent already at the beginning of the planning period, the yearly costs are excessively high in the first years.

5. It is assumed that the costs and benefits are underlying the same inflation rate, so that both are proxies of the real values.

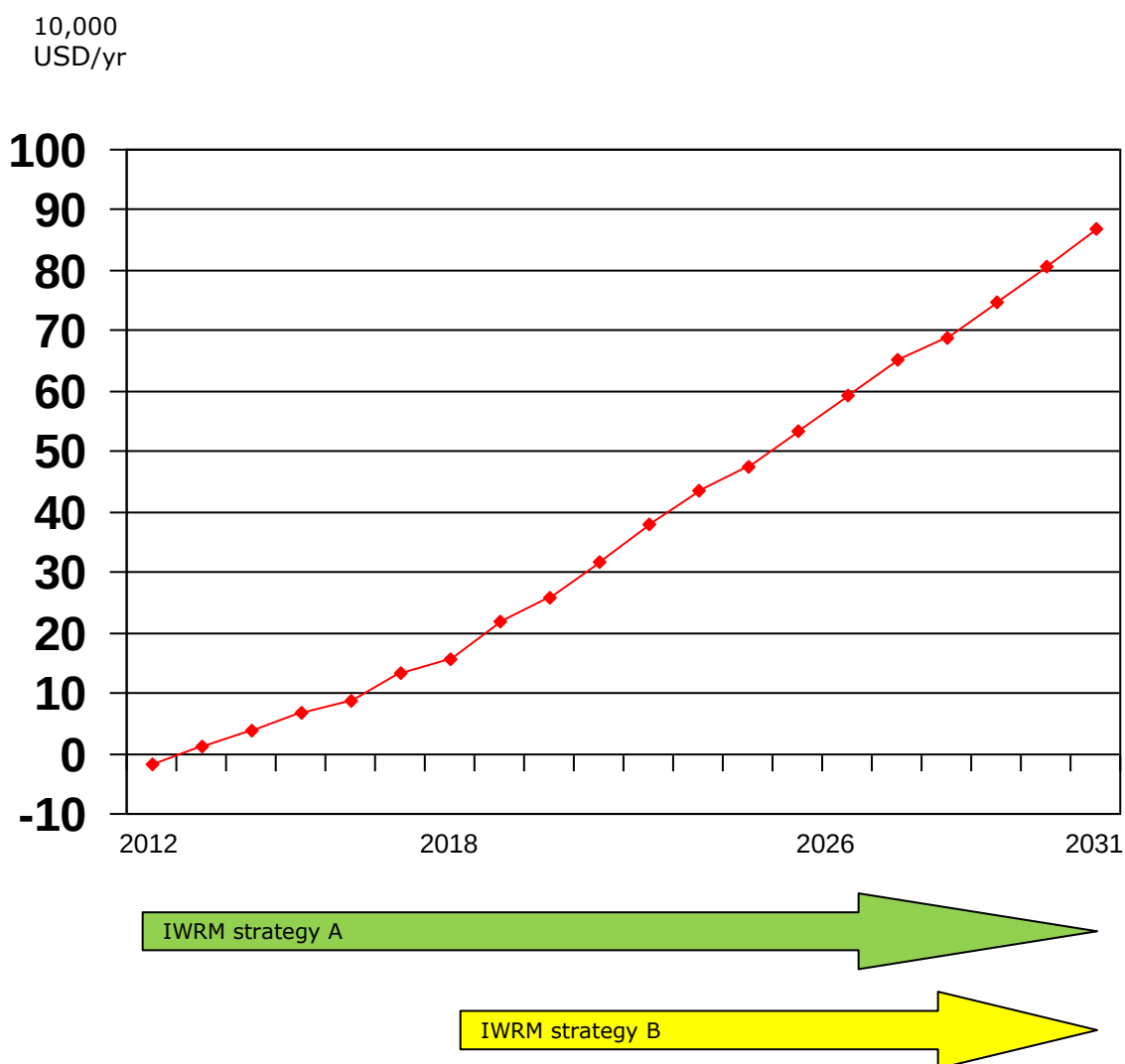


Fig. 22: Values added of IWRM strategies within 2012 and 2031 at the Jericho central sub-area

The slight flats at the curve after each four years (such in 2016, 2020, 2024 and 2028) are caused by the stepwise increase of the cost in rehabilitating the networks as explained above (Table 18). Further, the reason for the flat in 2018 is the need of using the water from the Duyuk spring and the investment cost of the storage tank and pipe line to transfer water to the city of Jericho: in the first years, the capacity of this infrastructure will not be fully utilized, so that the total added value will be slightly diminished.

More results

- As the Figures 18, 20 and 21 show, most of the water management options would yield values added. An exception is the option rainwater harvesting from Al Qilt (Fig. 19). In this case, water losses of 24% are one of the reasons. Without such losses, the economic benefits would be higher resulting in values added in the years from 2025 to 2031, because in these years the capacity of the new resource will be sufficiently utilised (80% and more). A further reason of the negative net benefits is the low average water profitability 0.79 USD/CM (in comparison with Jericho east sub-area). The planting of crops with higher profitability would enhance the economic efficiency of rainwater harvesting.
- The costs of intersectoral water transfer between agricultural and municipal users must be raised with the income losses in agriculture caused by the release of water. These losses can be approximated by the amount of money the municipality pays for the water rights.
- Unmet demand particularly for municipal water users might emerge, if the relevant options, such as demand management and rehabilitation of networks, will not be implemented in time. In such a situation, temporary reallocation of freshwater from agriculture to these users may be advisable. This means that the extra water supply can lead to additional values added, provided the agricultural users will not be faced with economic losses: the increase in water availability due to the rehabilitated groundwater wells and storm water harvesting will exceed the agricultural demand in the critical years. Such a water management that considers simultaneously different sources and users can lead to a further increase of the total values by optimising the water allocation.
- With regard to the municipal water users the values added can be raised by higher water tariffs. As mentioned earlier, often the current tariffs do not reflect the real cost of water services and understate the willingness to pay of water users.

Chapter 3. Jericho Shosa / Duyuk and Nueimah sub-area

1. Water situation

In the Jericho northern sub-area there are villages that depend on agriculture as the main source of income. The water sources are the three adjacent Shosa, Nueimah and Duyuk springs (Figure 23).

The major water use is the irrigation for agricultural purposes, only a few commercial and public activities exist. The domestic water users are mainly farmers living in the villages. The discharge of the springs varies from one year to another due to different climate conditions. According to the official numbers issued by the Palestinian Water Authority (PWA) the average yearly discharges of the Duyuk, Nueimah and Shosa springs amount 4.34 MCM, 2.65 MCM and 0.63 MCM, respectively (PWA, 2011).

The domestic water demand is not a concern at this area as it is considered as minor compared with the agricultural demand. Nevertheless, the water allocation system gives priority to domestic use. The remaining quantity of water is distributed upon a local water quota. Each farmer has a water right to irrigate his land within a given period of time from open channels carrying water from the springs.

To project the water demand by using the WEAP model, the following assumptions are made:

1. Population is increasing in the modelling period (2011-2031) under the current growth rate of 2.9 %.
2. Commercial and public activities increase with the same growth rate of population.
3. Agricultural activities would increase, and all arable lands would be fully used by end of the modelling period, the increase rate of land use is steadily linear growth rate. There is no expansion of urban areas due to the low population in the Shosa / Duyuk and Nueimah areas.

The projected increase in water demands per year for the Shosa / Duyuk area and the Nueimah area in 2031 are estimated to from 2.25 MCM to about 7.5 MCM and from 1.41 to about 4.3 MCM, respectively.

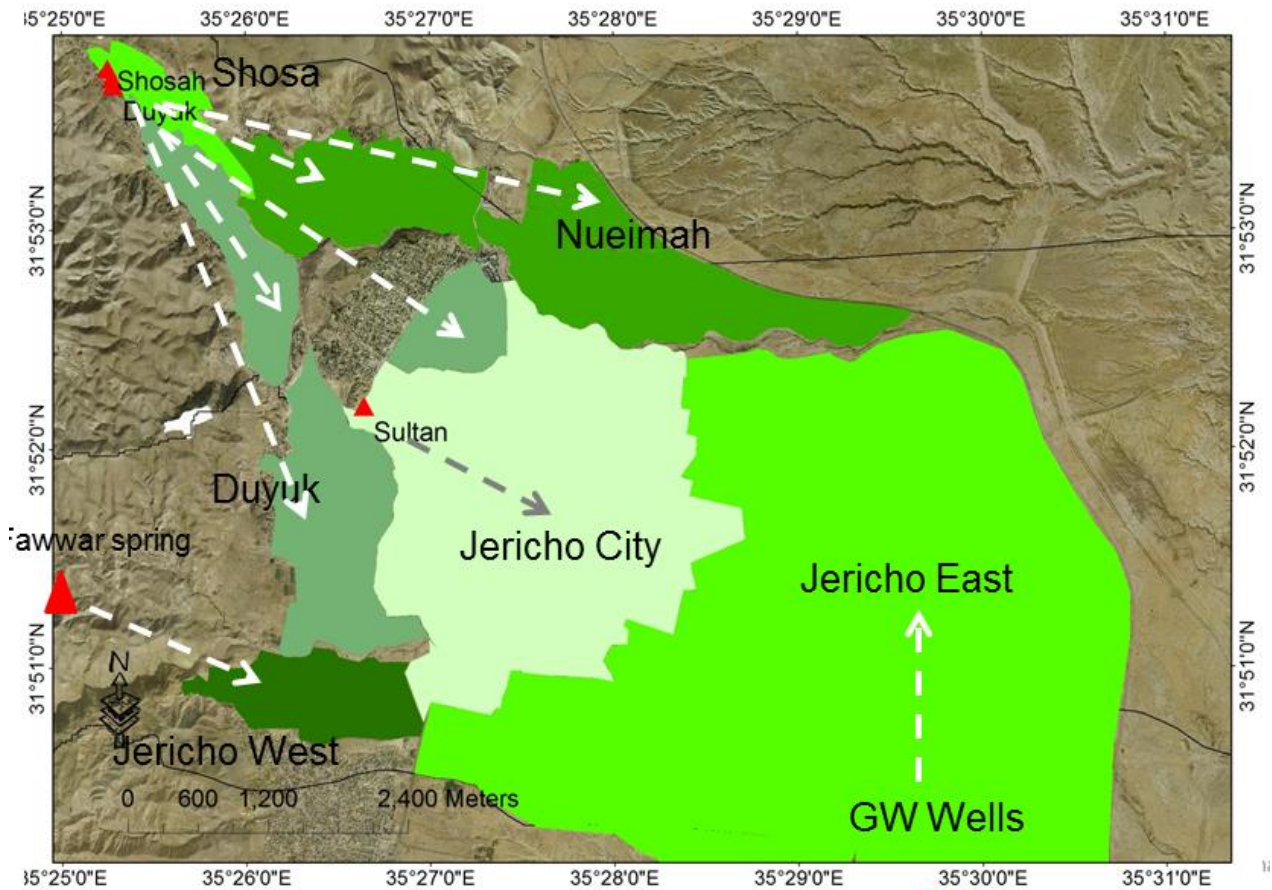


Fig. 23: Sub areas in the Jericho area

On the other hand, the water supply from the Shosa, Duyuk and Nueimah springs is expected to decrease in the coming years. The decrease rate is taken from the trend line of the spring discharges. According to the model calculations, the projected values of water quantity, which can be delivered in 2031 to the Shosa / Duyuk area and the Nueimah area, will be approximately 1.82 MCM and 1.18 MCM, respectively only, compared with 2.3 MCM and 1.3 MCM in 2012.

Since the total water demand will increase and the water availability will decrease, the unmet water demand is expected to grow rapidly, which calls for management options. The unmet demand in 2031 for the Shosa / Duyuk area is expected to reach around 5.59 MCM (Fig. 24) and for the Nueimah area 3.12 MCM (Fig. 25).



Fig. 24: Duyuk and Shosa water unmet demand in 2011-2031

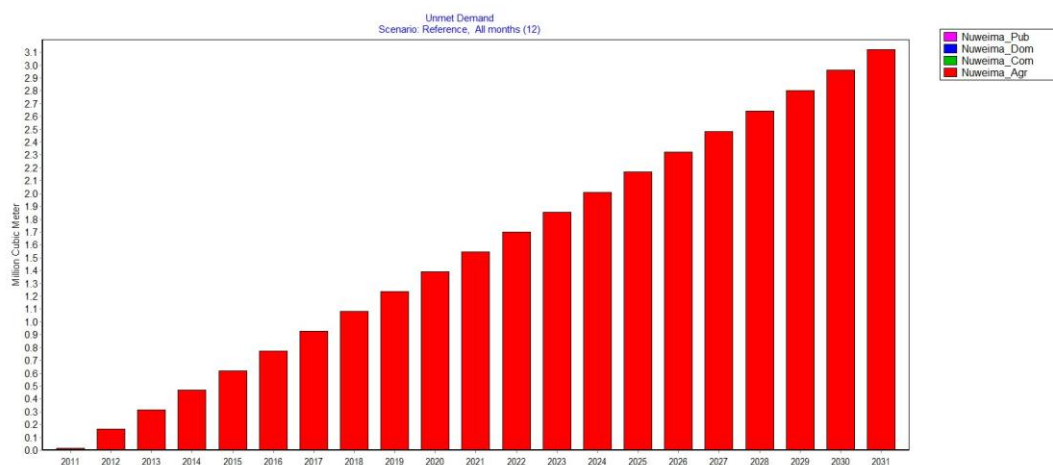


Fig. 25: Nueimah water unmet demand in 2011-2031

2. Water management options

Different options are proposed to decrease water shortage for Shosa / Duyuk and Nueimah areas (Tab 19):

1. Rainwater harvesting from Nueimah watershed.
2. Decrease of network losses by replacement of open channel with closed pipe distribution networks.

Figure 24 shows the schematic view of WEAP with the water management options.

Water management option	Type	Supply (MCM/yr)
Rainwater Harvesting from Nueimah	IWRM	1.0
Replacement of open channel with closed pipe distribution networks	IWRM	Reduce losses to 24 % 1.7 – 1.0

Table 19: Proposed water management options for the Shosa / Duyuk and Nueimah sub-areas

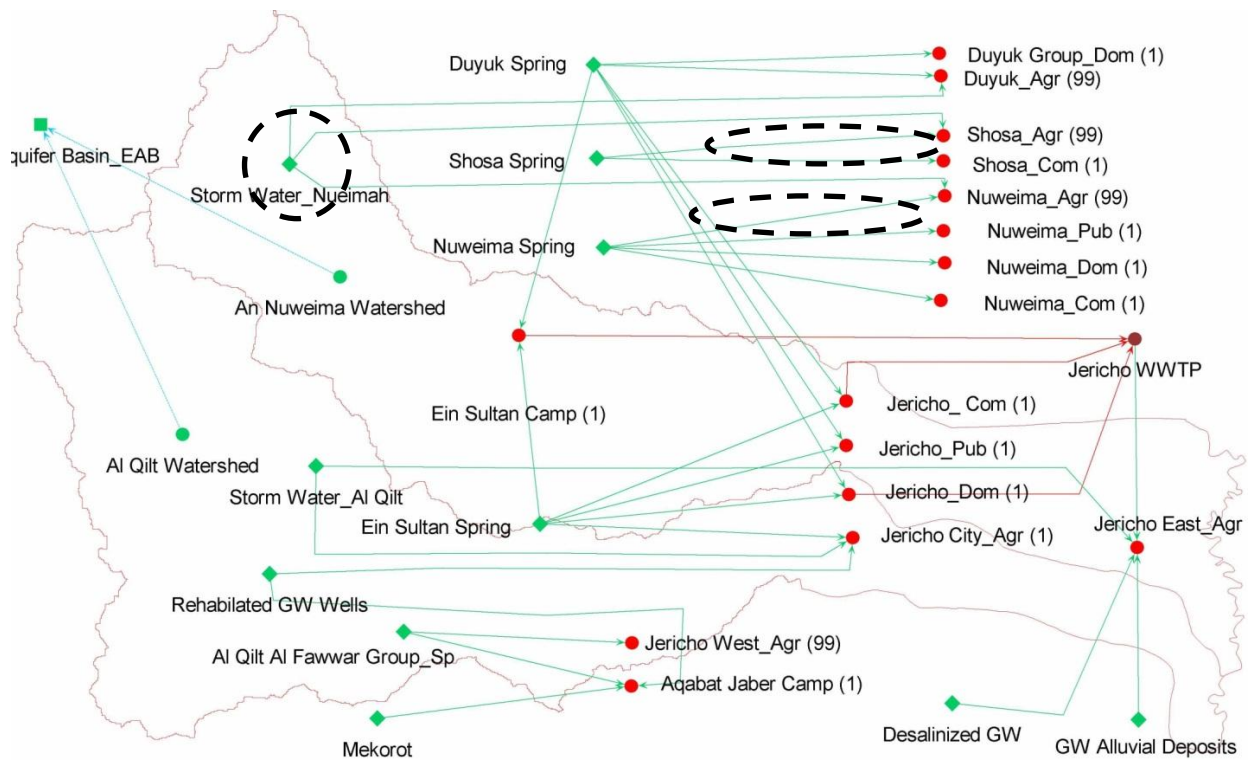


Fig.26: Schematic view of WEAP model with the water management options for the Shosa / Duyuk and Nueimah sub-areas

3. Impact analysis

As the following figures show, applying even all the proposed management options would not resolve the problem of unmet demand in the near future, but would decrease the water shortage only (Fig. 27 and Fig. 28). This means that no ranking of the options are needed.

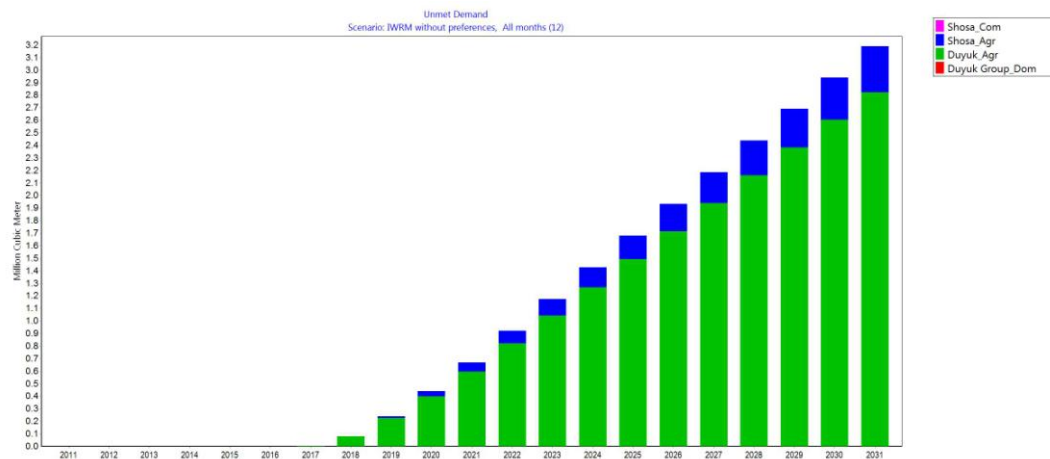


Fig.27: Shosa / Duyuk water unmet demand if all management options would be implemented in 2011-2031

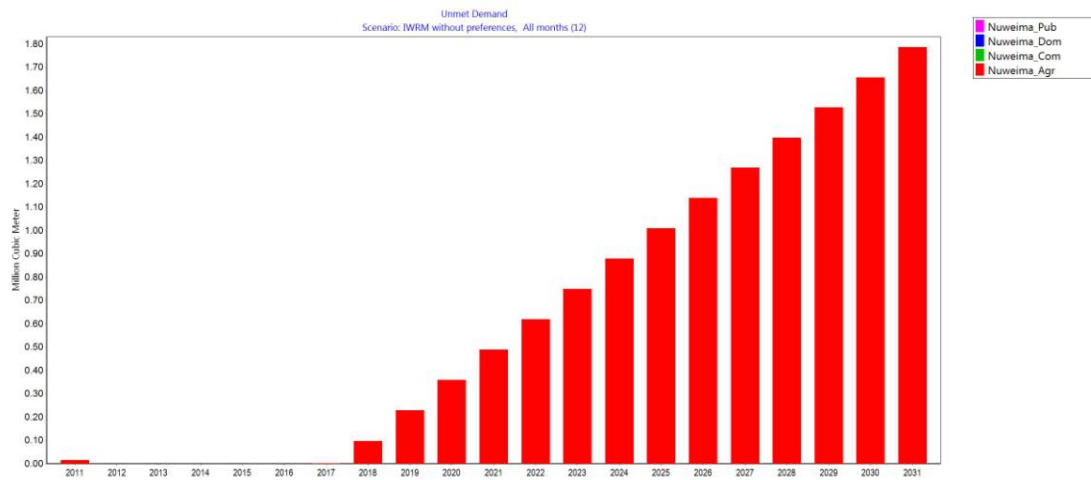


Fig. 28: Nueimah water unmet demand if all management options would be implemented in 2011-2031

The question is which values added can be expected for the different areas Shosa / Duyuk and Nueimah, where the farmers are the main water users.

4. Cost-benefit analysis

4.1 Cost of water management options

Rain Water harvesting from Wadi Nueimah

Through rain water harvesting from Wadi Nueimah located near Duyuk Nueimah sub-basin 1.0 MCM/yr could be collected (PHG master plan, 2010). This amount of water serves agriculture lands in Duyuk, Nueimah and Shosa villages. To construct small pools with a vol-

ume of 2500 m³ per each pool; cost has been estimated 15,000 USD for each pool (PHG master plan, 2010). The total investment cost of the pools to collect harvested rain water amounts to 7.39 million USD corresponding to 625,986 USD/yr (usable lifetime 30 years, rate of interest 7.5%) and 0.63 USD/MCM. No operation cost is needed due to gravity flow.

Reduction of losses by replacement of open channel by closed pipe network

The current network losses are estimated to 50 % due to the open channel system that causes high leakages and evaporation. A solution is to replace the open channel by a closed pipe network to reduce losses and to increase the water volumes delivered. A previous project was implemented already in the Jericho city area. The cost of the project was 3 million USD for a 35 km pipe system with different sizes (4" - 16" pipes). In order to get a reliable estimation a bench marking was used. The estimated length of the open channel network was obtained through GIS as the basis to calculate the expected location and distribution of the new proposed network. The length of the proposed network can be estimated to 32.3 km (Fig. 12).

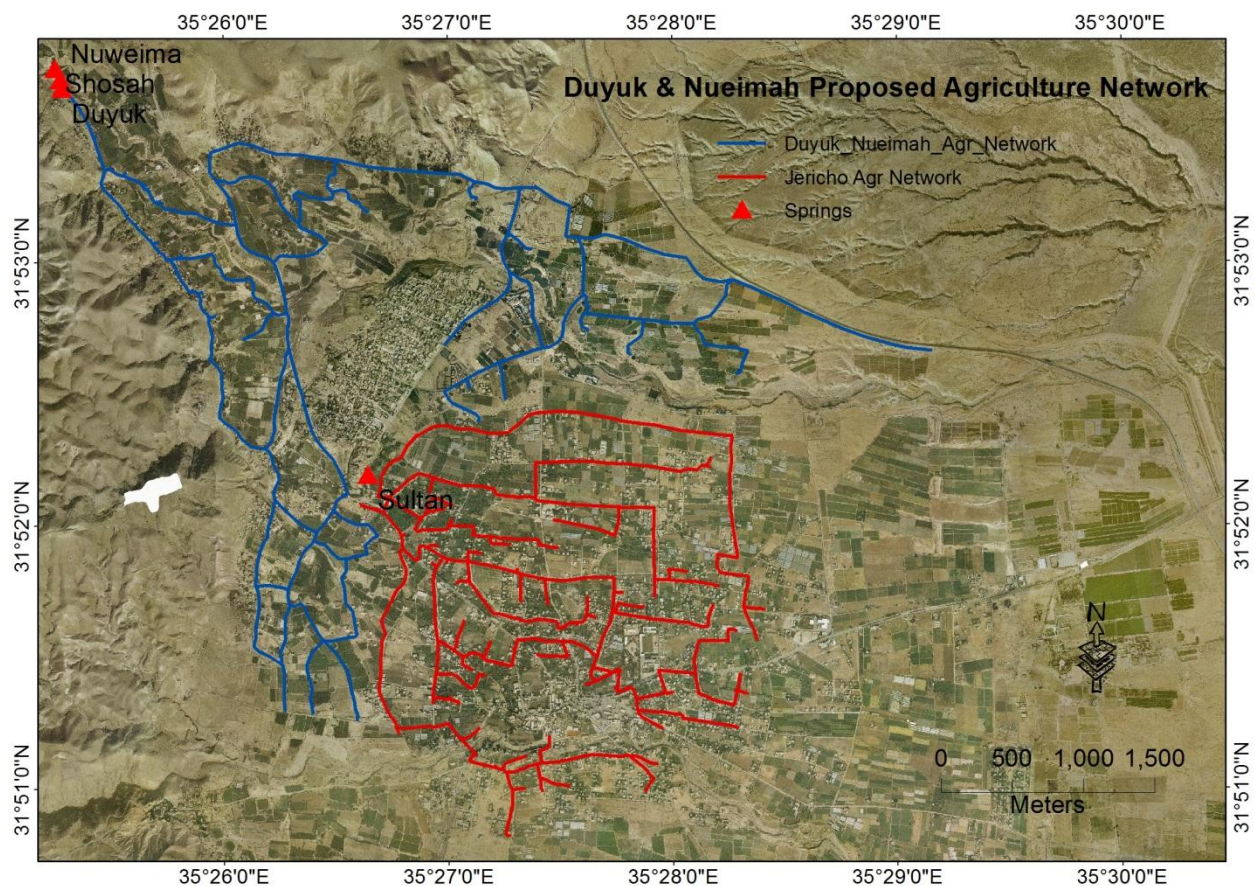


Fig. 29: Open channel agricultural network in Duyuk and Nueimah sub-basins (flow by gravity) to be replaced

By benchmarking with the project that was implemented in Jericho city, the total cost of the new network leading to a reduction of water losses in networks to 24% is estimated to 2.77 Million USD, corresponding to 234,539 USD/yr (usable lifetime 30 years, rate of interest 7.5%).

4.2 Benefit of water management options

Especially the farmers, the main users in the Shosa / Duyuk and Nueimah areas, will benefit from the additional water supply. The weighted average water profitability in irrigated agriculture will be used to calculate the extra incomes of farmers (Tables 20 and 21). The relevant influencing factors are the crop production per dunum, the crop prices and the water volumes needed per dunum for planting different crops. These factors render the extra revenue in agriculture, from which the costs of labour, pesticides, fertilizers, machinery and irrigation energy must be abstracted.

Item	Percentage (%)	Water profitability (USD/m ³)
Banana	44.58	1.18
Vegetables**	37.60	1.01
New palms	0.00	0.00
Palms	7.22	2.96
Citrus	8.64	0.73
Plastic houses	1.95	0.73
Average		1.20

Exchange rate 1 USD=3.82 NIS

** Average marginal benefit of all vegetables is assumed due to lack of data

Table 20: Water profitability of different crops planted in Duyuk sub-area
(Ministry of Agriculture)

The weighted average of the water profitability amounts to 1.38 USD/m³ at the Shosa / Nueimah area and to 1.2 USD/m³ at the Duyuk area.

Item	Percentage (%)	Water profitability (USD/m ³)
Banana	11.54	1.18
Vegetables**	41.03	1.01
New palms	4.34	0.00
Palms	22.88	2.96
Citrus	9.47	0.73
Plastic houses	10.75	0.73
Average		1.38

Exchange rate 1 USD=3.82 NIS

** Average water profitability of all vegetables is assumed due to lack of data

Table 21: Water profitability of different crops in Nueimah sub-area
(Ministry of Agriculture)

4.3 Cost – benefit analysis of water management options

The following figures 30a and 30b show the time series of costs and benefits for situation 1 (agriculture expansion under steady growth rate):

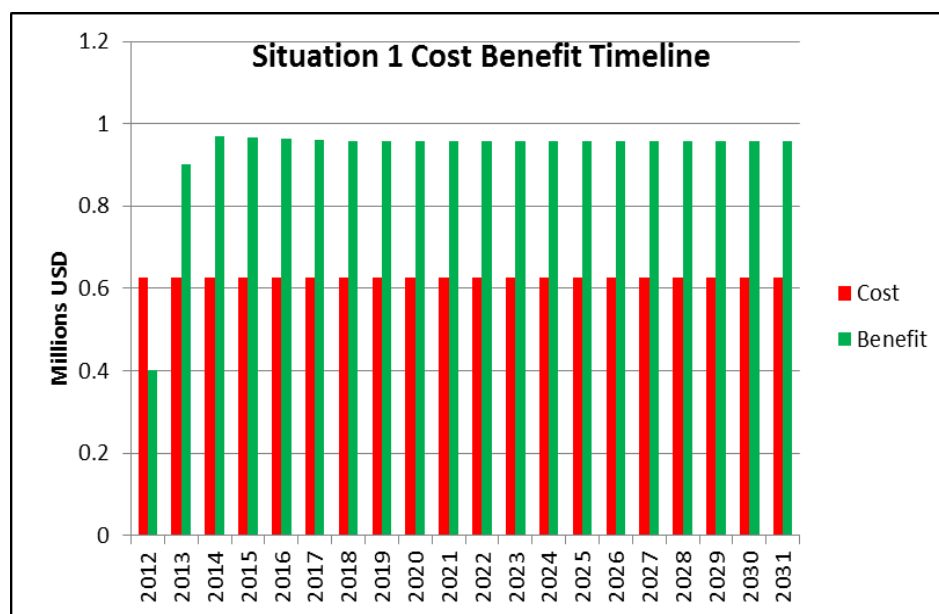


Fig. 30a: Rain water harvesting from Wadi Nueimah at situation 1

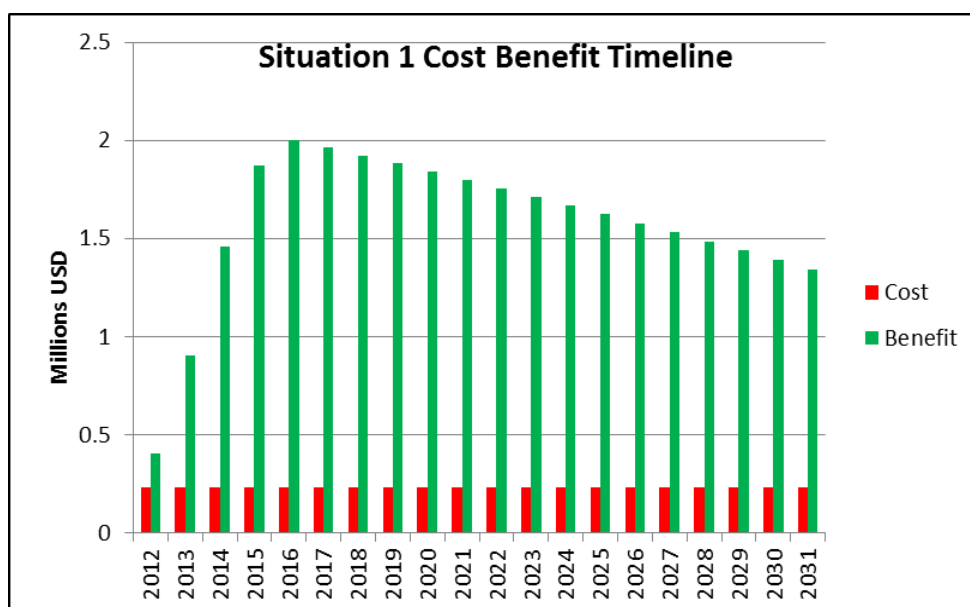


Fig. 30b: Costs and benefits of replacement of open channel with pipe network

Economic efficiency of water management options

The economic efficiency of the option replacement of open channels with a pipe network is higher than that of the option rainwater harvesting (Tab. 22).

Water management option	Unit values added (USD/m ³)
Rainwater harvesting (each year)	0.66
Replacement of open channels with a pipeline network (2012 – 2031)	1.11 – 1.01

Table 22: The economic efficiency of water management options at the Shosa / Duyuk and Nueimah sub-areas

Added values of IWRM strategies

As mentioned already, even though both options would be implemented, the water needs at the Shosa / Duyuk and Nueimah areas will exceed the water supply in the near future (Fig. 27 and Fig. 28). Both measures are to be implemented soon without any ranking. Thus, no priorities among the individual options will be determined to minimise the costs and maximise the added values (in contrast to the Jericho east and central sub-areas).

More results

- At situation 1, where the irrigation water needs are assumed to grow by a steady rate, the value added of the two options would rise from 2013 to 2014, if the option rainwater harvesting will be implemented only because the capacity of the new water resource is limited to 1 MCM/yr. In the following years, the value added would be the same (Fig. 30a). In 2012, there is no value added, because the low crop production renders an economic benefit that is lower than the cost of the water management option.
- If the option replacing open channels with pipelines would be implemented only, water losses can be avoided by 26% of the total delivery from the springs leading to an increase of the water availability for agricultural irrigation. At situation 1, from 2012 to 2016 the values added will increase due to the growing water needs and then will decrease from the year 2017 upwards, because of the continuous reduction of the water volumes, which will be discharged from the springs, so that less water losses can be avoided (Fig 30b).
- At the Shosa / Duyuk and Nueimah areas, more water for the irrigated agriculture could lead to additional values added, if further water management options would be implemented, such as regional water transfer or artificial groundwater recharge

PART II. JORDAN RIVER VALLEY

This chapter gives an overview of the current status of the investigation at the Jordan River Valley. The water situation, the unmet demands, the impacts of water management options and examples of CBA results will be shown.

1. Water situation

Jordan valley is one of the most water scarce areas in the Middle East. This situation is caused by the high water demand for irrigation and the limited water availability resulting in rivalries between agricultural, domestic and commercial water users. Further influencing factors are the unfavourable climatic conditions, such as high temperatures and changes in precipitations, and restrictive political arrangements regarding the access to trans-boundary water resources.

With respect to the importance of Jordan Valley as a 'food basket' for Jordan and as a major source for the drinking water supply of the city of Amman and other municipalities, IWRM concepts are urgently needed for reallocation and more efficient use of the water resources. The WEAP model allows simulating current water balances, future trends and alternative IWRM strategies. Since a few years, WEAP is being used by the Jordan Ministry of Water and Irrigation (MWI) to test different water management options at each of the Jordan water basins. MWI will present the outcomes in the Jordan National Water Master Plan.

The Jordan Valley is part of the Great Rift Valley, which extends from Turkey into East Africa. The area under our investigation starts from the Tiberius Lake and ends at the Dead Sea (Fig. 1). It is a narrow strip catchment area with a length of about 120 km and a width varying from 5 to 10 km. It covers an area of about 1,105 km²; the altitude varies from 210 m below to 410 m below the sea level (NWMP 2008).

The climate in the Jordan Valley is semitropical with hot summers and warm winters. The average daily mean temperature is about 31 °C in summer and 15 °C in winter. The mean annual rainfall for the northern part reaches 300-400 mm but it drops to 100-250 mm in the southern part (NWMP 2008). Table 23 shows the mean annual rainfall and areas for the two climatic zones in the Jordan valley.

Agro-Climatic Zone Name	Area (km²)	Mean Annual Rainfall (MCM)	Mean Annual Rainfall (mm)
Northern Jordan Valley	642	220	345
Southern Jordan Valley	463	100	220

Table 23: Mean annual rainfall at northern and southern Jordan Valley

Three groundwater basins included in the study area are: The Yarmouk basin, the Jordan valley basin and the relevant side wadis basins. These groundwater basins consist of different hydro-geological units. In the study area, about 45 Mm³/yr are pumped from three main well fields: The Mukheibeh well field (25 Mm³/yr), the Wadi Arab well field (12 Mm³/yr), and the Kafranjeh well field (Mm³/yr) (Ayadi 2006).

The Jordan River basin derives its water from the Jordan River of Jordan, the Yarmouk River and the Zarqa rivers that drain in the Dead Sea. The natural system flow of the Jordan River basin is disturbed by diversion weirs and water development projects in Israel. Consequently, the Jordan River flow at the lower reaches is almost negligible.

Land use in the Jordan Valley is mainly irrigated agriculture, but there are also urban water users. Natural vegetation and rain fed agriculture can also be found, especially at the valley's eastern sides.

The study area intersects five main water sub-basins: The Yarmouk sub-basin, the Northern and Southern Jordan valley sub-basins and the Northern and Southern Rift side wadis; they drain towards the Jordan Rift Valley and discharge into the Dead Sea. These main basins generate more than 90% of the actual available surface water resources in Jordan (NWMP 2004) (Figure 31). The Yarmouk River in the north of the study area is diverted at Adasiya into the King Abdullah Canal (KAC). During the last 40 years, the flow of the Yarmouk River at Adasiya has dropped from 6.3 (1963) to 1.8 cubic meters per second (2004) (MWI 2004).

Al-Wihda dam was held in the Yarmouk basin on the borders between Jordan and Syria; it was supposed to provide Jordan with about 100 million cubic meters per year, but now it does not store more than 30 Million cubic meters.

The Zarqa River originates in Western Amman and flows from eastwards to the town of Zarqa and then northwards to join the wadi Dhuleil - that is considered as its main tributary - and flows finally westwards towards the Jordan Valley. The flow of the Zarqa River is

controlled by the King Talal Dam. The mean annual surface runoff of the Zarqa River basin is around 100 Mm³/yr (NWMP 2004).

The most important surface waters on the eastern escarpment are the wadis El Arab, Ziglab, Jurum, Yabis, Kufrinja, Rajib, Shu'eib, Kafrein and Hisban. The total runoff from these side wadis is estimated at 90 million cubic meters per year. The water resources at the Zarqa river catchment area are being used in the Jordan Valley catchments and high lands for irrigated agriculture.

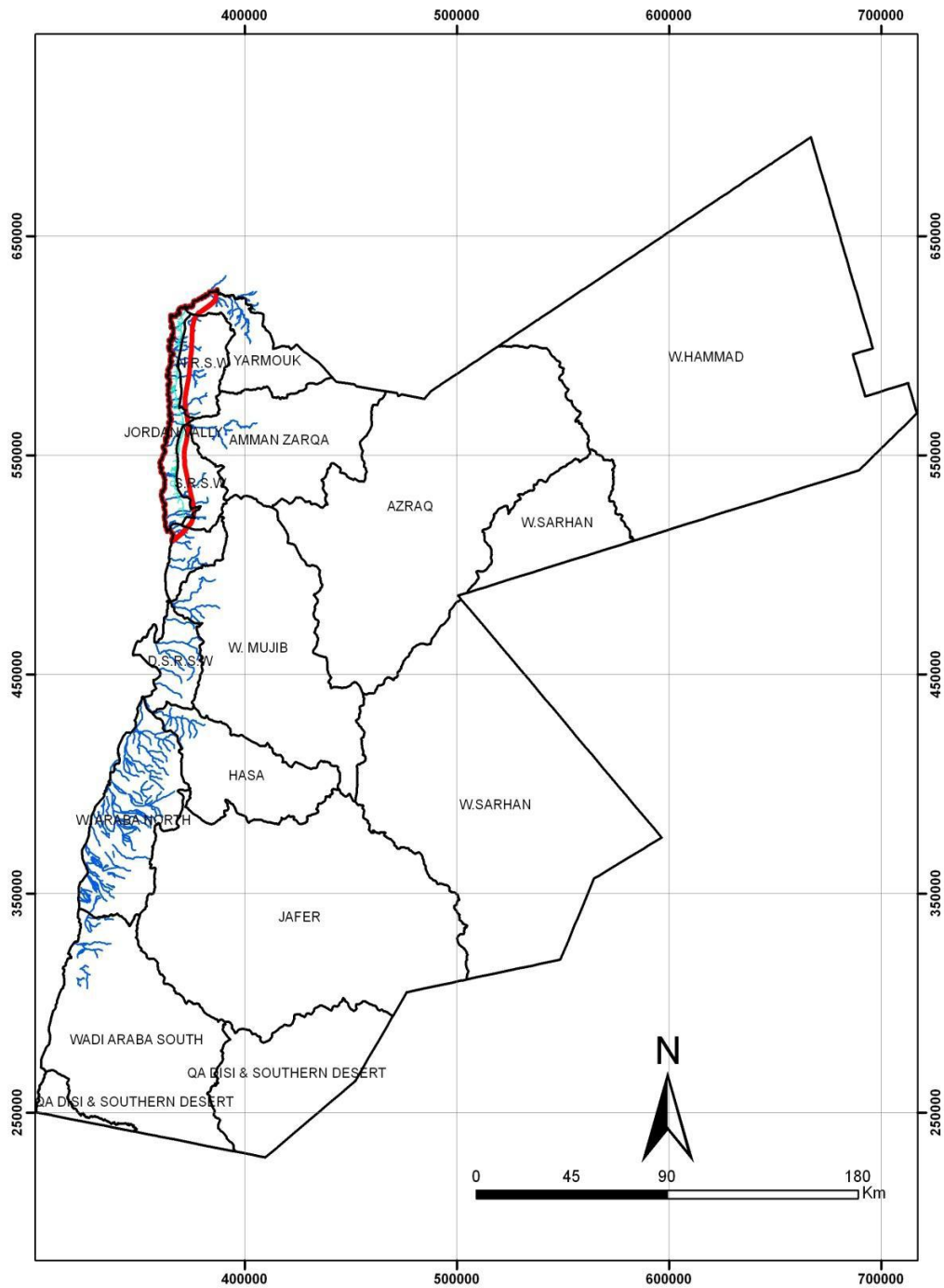


Figure 31: Surface water basins in Jordan

The water situation at the study area in terms of demand, supply and unmet demand can be described by using a simplified WEAP model. In Figure 32 the WEAP schematic view for the area under investigation is displayed.

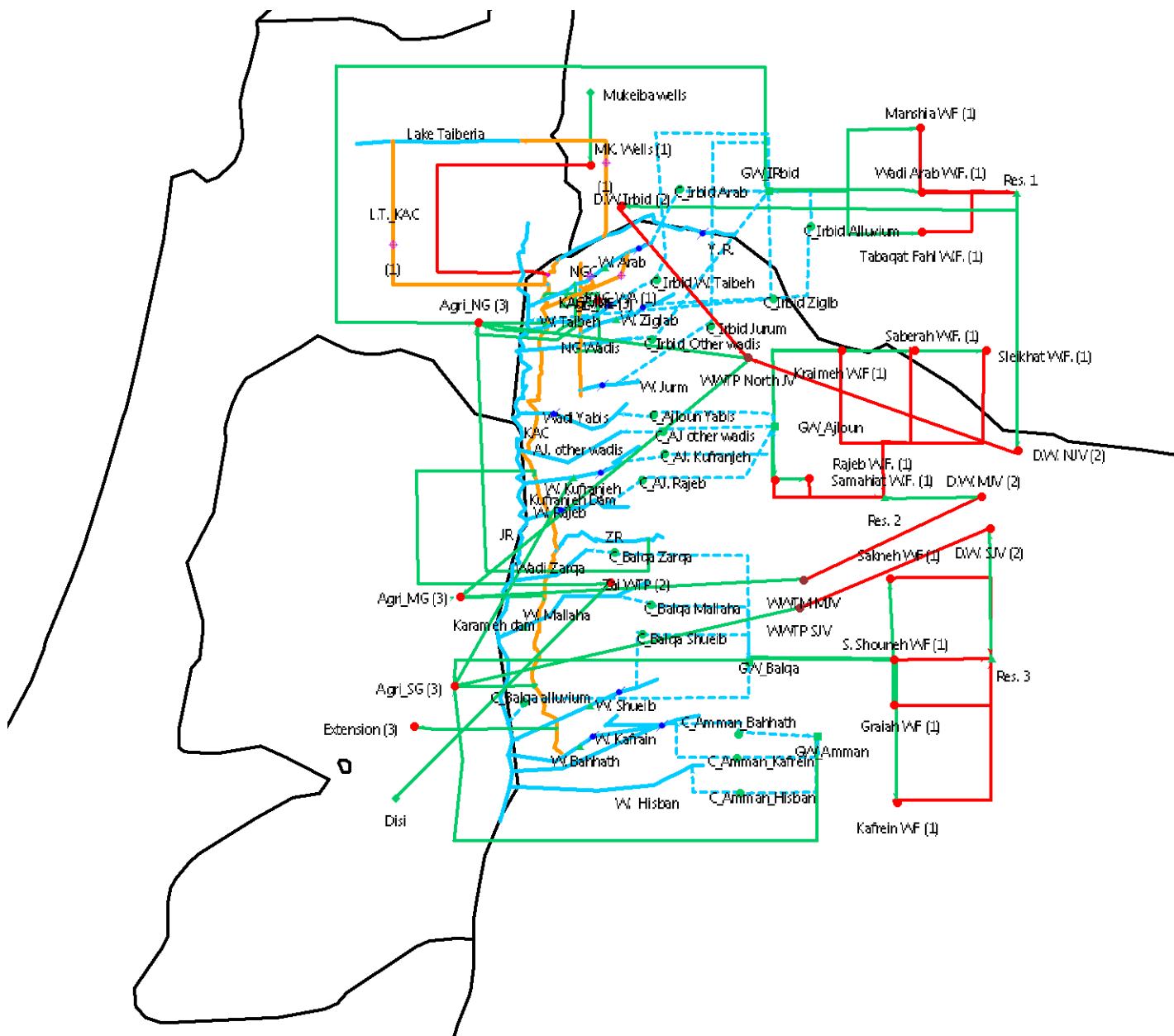


Figure 32: WEAP schematic view of the Jordan Valley case study

Figure 33 shows the total unmet demand under the reference scenario in the period 2011 - 2030.

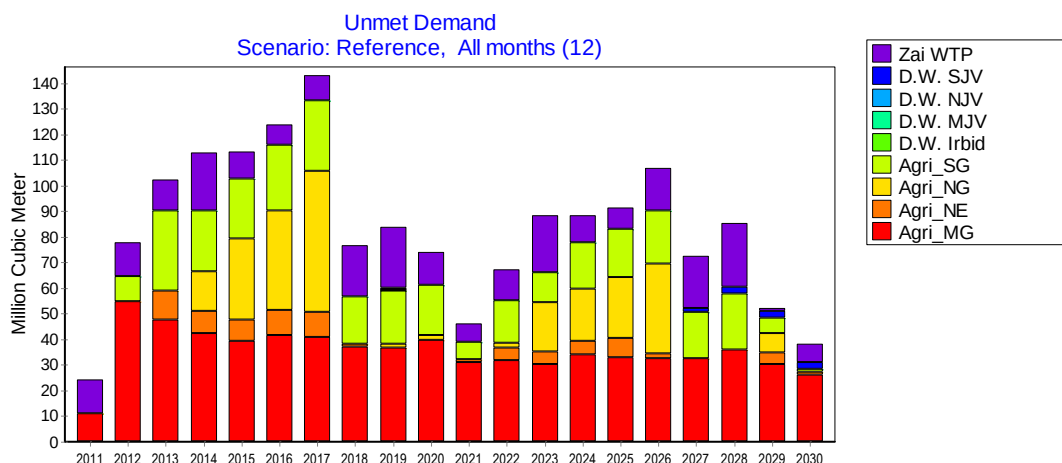


Figure 33: Total unmet demand at Jordan Valley under the reference scenario

The variations of unmet demands over the years reflect the prospected changes in water availability.

2. Water management options

The following analysis addresses several water management options; some of them are already in construction, such as the Disi conveyor and Kufranjeh dam:

The Disi conveyor project

The purpose of the Disi conveyor project is to pump water from Disi fossil aquifer to Amman and other governorates over a distance of about 300 km. The aquifer lies beneath the desert in southern Jordan and north-western Saudi-Arabia. The project is under construction and it will be finished presumably by the end of 2013. The additional water supply will amount to around 100 Mm³/yr (MWI, National Water Strategy, 2008). It will mitigate the water shortage for Amman and surroundings but not completely resolve the water deficit. Further, it may play a role for water reallocating at basin level and can mitigate the overexploitation of groundwater resources by slowing down the dramatic decline of their water levels.

The Kufranjeh dam

Minimizing the gap between water demand and the available water resources enforces the Jordan government to construct further dams at the major wadis to utilize the runoffs flow-

ing into the Jordan Valley and Dead Sea. Despite the financial limitations, MWI is planning augment the water availability. An example is the Kufranjeh dam at the wadi Kufranjeh (south of the wadi Shueib) with a usable storage capacity of 5 Mm³. The water will be available mainly for agricultural irrigation in the southern Jordan Valley from 2015.

Water reuse option

In Jordan, treated wastewater became one of the most important non-conventional water resources especially for irrigation use. The volume of effluents will grow further in the near future. One of the reasons of that are the increases in using freshwater resources, which are continuously being developed, resulting in larger volumes of wastewater. Another reason is the increasing connectivity to WWTPs, i.e. more customers are connected to existing WWTPs or to new one. Currently, the households in the Jordan Valley, as it is the case for most of the rural areas in Jordan, are not connected to the public sanitary networks. The people use septic tanks instead to get rid of the wastewater causing pollution of aquifers and wadis. Under the water reuse option, it is suggested to construct three decentralized WWTPs; one of them is located in the northern area and will serve around 87 thousand persons. The second one is located in the middle of the Jordan Valley and will serve around 48 thousand persons and the third one is in the southern area for around 39 thousand persons.

More efficient water use in irrigated agriculture

Improving irrigation water use efficiency is one of the top priorities of MWI, because at the Jordan Valley the agriculture uses mainly groundwater resources. The MWI declared recently a set of policies to achieve this task, such as by encouraging and supporting farmers to use modern irrigation systems (drip irrigation), by revising the irrigation water tariff and by promoting high value crop cultivation to raise the water profitability for the farmers. The majority of farmers (approximately 80%) apply already efficient irrigation techniques. We will evaluate the impacts of further improving the irrigation water efficiency by additional 10 % on the water availability for irrigation purposes.

3. Impact analysis

The key question is to which extent the unmet demands of agricultural and domestic water users can be reduced compared with the reference scenario presented in Figure 33. By

employing WEAP, the impacts of each of the water management options on the water deficits within the planning period will be estimated - Figures 34, 35, 36 and 37.

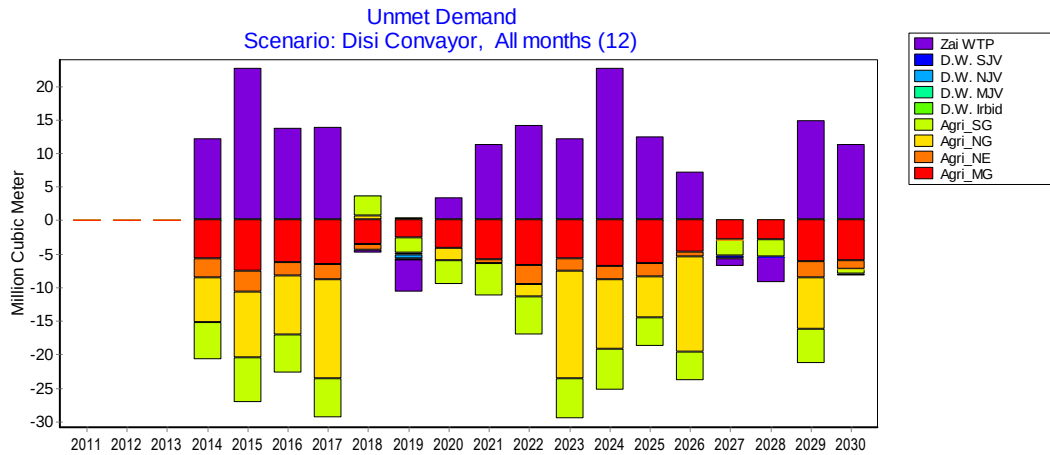


Figure 34: Total unmet demand under the Disi conveyor option relative to the reference scenario

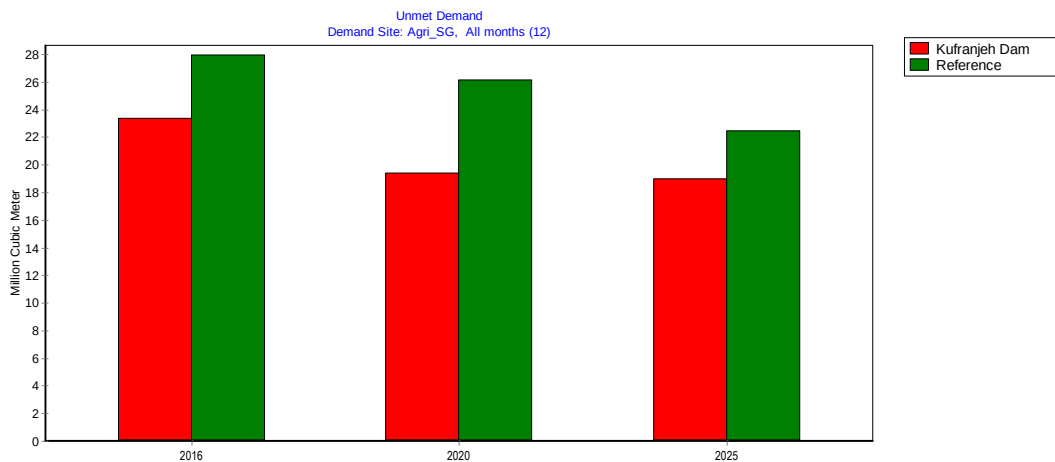


Figure 35: Total unmet agricultural water demand in the southern Jordan valley under the Kufranjeh dam option compared with the reference scenario

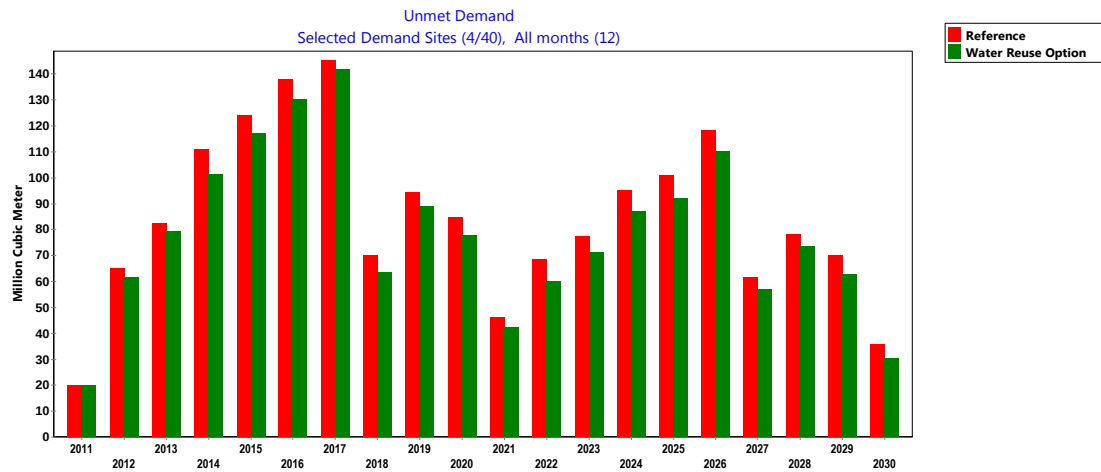


Figure 36: Total water unmet demand in agriculture under the water reuse option relative to the reference scenario

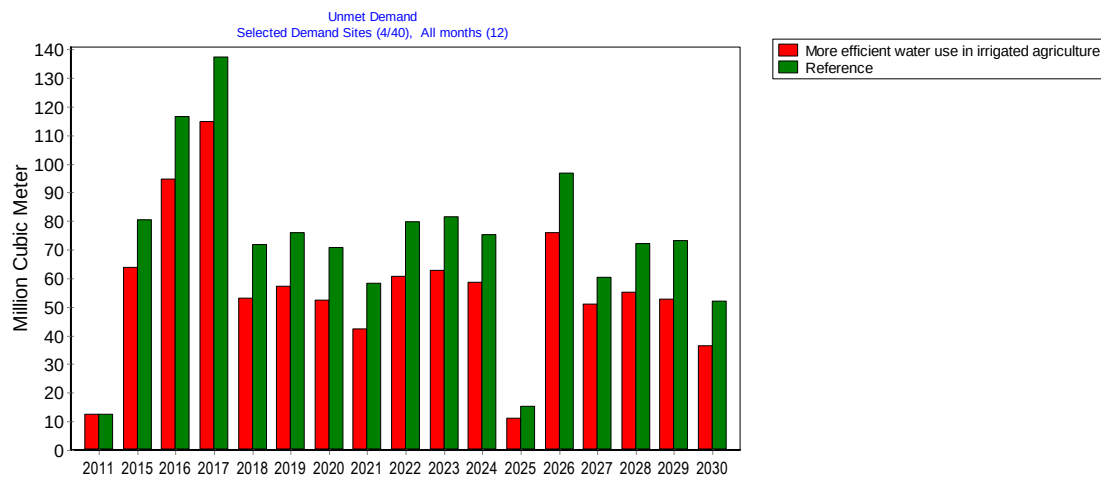


Figure 37: Total unmet demand in agriculture at Jordan Valley under the efficient irrigation option compared with the reference scenario

4. Cost-benefit analysis

Reallocation of Disi water

No CBA was carried out due to missing data.

Kufrankeh Dam

Initial capital cost of 3 million US\$ for this dam was entered to the WEAP model. The annualized capital costs are 0.19 million US\$/yr, assuming a useable lifetime of 50 years and using a discount rate of 6%. Dams are typically long-durable assets. Note that the annualized capital cost will increase only slightly, if lifetimes longer than 50 years would be taken into account. Furthermore, a dam can be replaced prematurely, if it has to give way to another infrastructure. Thus, a usable lifetime of 50 years is a reasonable estimate.

The water volume of the Kufrankeh dam is assumed to be 5 MCM/yr on average. The variable operation costs and the fixed operation cost are estimated to be 0.3 US\$/m³ and around 5,000 US\$/yr, respectively. The water from Kufrankeh dam water will be used presumably for agricultural irrigation. An average water profitability of 1.25 USD/m³ is assumed.

	Cost (Million US\$/yr)	Benefit (Million US\$/yr)
Annualized capital cost *)	0.190	
Variable operating cost **)	1.5	
Fixed operating cost	0.005	
Total	1.695	6.25 ***)

*) 3 million US\$ initial investment; 50 years usable lifetime; 6% discount rate.

**) 5 MCM/yr multiplied with 0.3 US\$/m³

***) 5 MCM/yr multiplied with 1.25 US\$/m³.

Table 24: Costs and benefits of the Kufrankeh dam

As Table 24 shows, the value added of the dam can be approximated to 4.5 million US\$ as an annual average. Note, that the financing scheme can influence the annual costs. For instance, at the Built Operate Transfer (BOT) approach applied increasingly for public infrastructures, the concession right is granted to private contractors to invest and to operate the water project within a certain period. As BOT will be applied in case of the Kufrankeh dam, the annual capital cost will be significantly higher compared with the above estimated value. The pay back period (amortisation) is 20 years and shorter than the supposed usable lifetime (depreciation). For the CBA, however, the annualized capital cost based on the useful lifetime should be taken into account (Table 23). Otherwise, the benefits emerging in the years beyond 20 years will be compared with annual capital cost of zero in the following 30 years (as in these years no loans must be paid back). It should be mentioned, that the BOT approach is more attractive for the future generation rather than for the present as the

latter has to pay the cost with higher charges. But the future generation may be charged as well in order to build up a fund, from which the replacement cost can be financed by using own resources instead of loans.

More efficient water use in irrigated agriculture

Water use efficiency in irrigation means using water in an efficient way by using suitable irrigation methods. It is assumed that the drip irrigation technique will be used in order to improve the water use efficiency by 10%. Drip irrigation, also known as trickle irrigation or micro-irrigation or localized irrigation, is an irrigation method that saves water and fertilizers by allowing water to drip slowly to the roots of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters. It is done through narrow tubes that deliver water directly to the base of the plant.

The initial capital cost for installing this technique is estimated to around 45 US\$ per dunum, which is equal to 5.5 million US\$ for the entire agricultural area in Jordan Valley. The variable and fixed operating costs are assumed to be 0.3 US\$ per cubic meter and around 10,000 US\$ per year, respectively. The economic benefits of approximately 0.5 US\$ per cubic meter saved in irrigation are taken into account as lower bound. If water is released, then other users can use this water. The resulting benefits depend on the water value for the other users or uses. The released water can be used to expand farmlands or to replace more costly water (e.g. deep wells, desalinated brackish water, etc.). Or, domestic users may enjoy improvements in water supply; the benefits can be calculated by using the domestic water tariff. The potential of released water volume due to applying more drip irrigation techniques amounts to approximately 20 MCM/yr (Fig. 37).

	Cost (Million US\$/yr)	Benefit (Million US\$/yr)
Annualized capital cost *)	0.747	
Variable operating cost **)	6.000	
Fixed operating cost	0.010	
Total	6.757	10 ***)

*) 5.5 million US\$ initial investment; 10 years usable lifetime; 6% rate of interest.

**) 20 MCM/yr multiplied with 0.3 US\$/m³

***) 20 MCM/yr multiplied with 0.5 US\$/m³.

Table 25: Cost and benefits of more efficient irrigation techniques

As table 25 shows, the value added can be approximated to about 3.2 million US\$/yr as lower bound. This estimate is based on the assumption that the released water will be actually used mainly for irrigation purposes in agriculture to meet the demand in years with low precipitation. Figure 38 below displays the results of cost benefit analysis over the years.

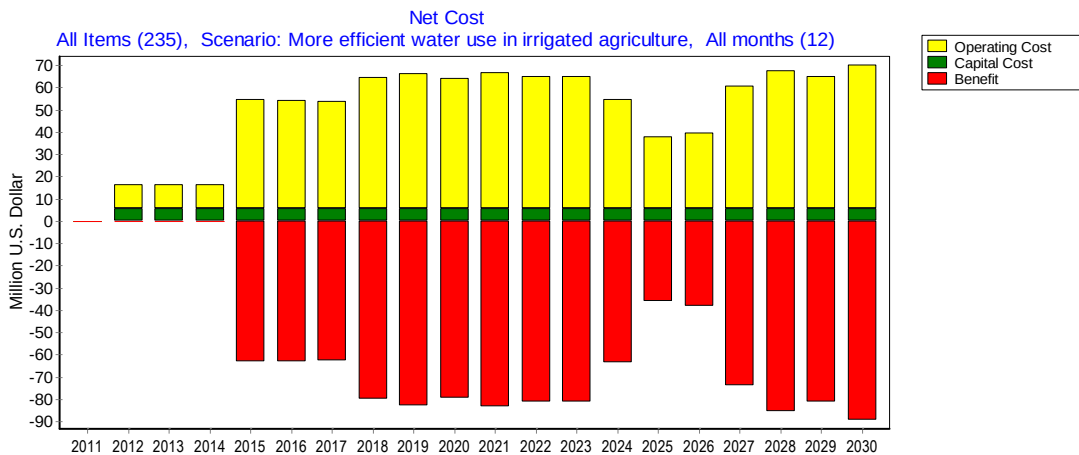


Figure 38: Costs and benefits of the efficient irrigation option at Jordan Valley

Water reuse

As figure 36 indicates, the effluents generated by the three WWTPs range from 6 to 9 MCM/yr over the years. Assuming that this water volumes will be used in irrigated agriculture with an average water profitability of 1.25 US\$/m³, additional benefits of about 9 million US\$/yr on the average can be expected. The sum of the total annualized capital cost, variable and fixed cost of the WWTPs can be estimated to about 1.3 million US\$/yr, respectively (Table 26). The benefit and the value added can be approximated to around 9.4 million US\$/yr and about 8 US\$/yr, respectively. As this result indicates, considerable values can be expected.

However, the question arises as to which costs accrue really to the water reuse option. Under the assumption that the main purpose of the WWTPs is to prevent water pollution, only the extra costs required to reach the prescribed quality of effluents and convey them to the agricultural areas should be considered.

	Cost (Million US\$/yr)	Benefit (Million US\$/yr)
Annualized capital cost *)	0.033	
Variable operating cost	1.125	
Fixed operating cost	0.150	
Total	1.308	7.5 – 11.25 **)

*) 600.000 US\$ initial investment; 50 years usable lifetime; 5% rate of interest.

**) The amounts of effluents ranges from 6 to 9 MCM/yr, multiplied with water profitability of 1.25 US\$/m³.

Table 26: Costs and benefits of wastewater treatment plants

Supposing that these extra costs are in the range from 10 to 30% of the total treatment cost (or on average 0.26 million US\$/yr) and the average benefit amounts to 9.38 million US\$/yr, the reuse option will lead to an approximated value added of around 9.12 million US\$/yr, calculated as follows:

Value added of the water reuse option = economic benefit minus 20% of total cost of WWTPs = 9.38 million US\$/yr minus 0.26 million US\$/yr = 9.12 US\$/yr.

This approximation is based on the assumption that the effluents will be applied fully for irrigation purposes in agriculture.

Results of CBA

The main water user in the Jordan valley is the irrigated agriculture. Table 28 shows the predicted increases in water availability for this sector on yearly average due each of the water management options (Tab. 27).

	Increase in water availability on average (MCM/yr)
Kufranjeh dam *)	5.5
More irrigation efficiency	20
Water reuse	7.5

*) Southern Jordan valley only

Table 27: Increases in water availability for irrigated agriculture at lower Jordan valley

The numbers provide an idea how much the water management options could contribute to reduce the unmet demand in agriculture of about 100 MCM/yr as an annual average,

namely less than 50%. This situation calls for further measures to alleviate the water deficit in the Jordan valley.

In Table 28, the approximated values added of the three options are compared. The water reuse projects have the highest values added, followed by the Kufranjeh dam and improvement in irrigation efficiency.

	Cost (Million US\$/yr)	Benefit (Million US\$/yr)	Value added (Million US\$/yr)	Value added (US\$/m ³)
Kufranjeh dam *)	1.7	6.3	4.6	0.84
More irrigation efficiency	6.8	10.0	3.2	0.16
Water reuse **)	1.3	9.4	8.1 / 9.1	1.07 / 1.2

*) Southern Jordan valley only

**) The higher numbers show the added value under the assumption that only 20% of the WWTP cost represent the cost of water reuse

Table 28: Cost, benefits and values added of water management options at Lower Jordan valley

This indicates that especially water reuse projects should be promoted in improving the water situation at Jordan valley.

Nevertheless, as long as the big gap between water supply and demand continues, each of the three options and further measures (such as artificial groundwater recharge, more reservoirs and conveyance systems) are to be realised.

PART III. Financial implications of IWRM

Introduction

The investigation in the previous chapters focussed on the economic efficiency of water projects. The goal was to find out those management options and IWRM strategies that lead to benefits higher than the costs and to values added. But who should contribute to the costs and how the values added should be distributed among them? These questions are crucial with respect to the financial feasibility of water projects. The implementation of even economically efficient management options can fail, if there are no sufficient financial resources. Usually, projects are to be financed by charging the water users, such as farmers, citizens and entrepreneurs. In special cases, however, they cannot fully afford the costs. Other funds are required, such as governmental, private or international donors (e.g. World Bank, USAID and KfW). In the following, the financial implications of IWRM at the sub-basins investigated will be highlighted. Table 29 provides an overview of the financial issues discussed in the case studies:

Full cost principle

All the costs of water projects should be taken into account. Otherwise, the water users would not get the right information about the financial requirements.

Regarding the costs of water reuse at the Jericho central sub-area, there are two different views: a) The total cost of wastewater treatment plants (WWTP) or b) only the extra cost of higher quality standards for using the effluents (together with the costs of storage and conveyance) should be taken into account. The value added from water reuse in case a) is lower than in case b) as the total treatment cost is considered. Note that the CBA of water reuse projects should not address the total cost of WWTP, but of water reclamation only, unless the main reason for constructing the plant is to provide farmers with treated wastewater.

Moreover, it is important to emphasize that including the charges levied on farmers into the cost of the water reuse (the price farmers have to pay for reclaimed water) would be wrong, as this leads to double counting.

A further financial aspect concerns the impacts on farmers' income if they would have to pay the full costs of wastewater reuse.

Water pricing

Both the 'water user pays principle' and 'polluter pays principle' should be applied. According to these principles the costs of both water supply and sanitation have to be paid fully by the user.

As the calculations at the Jericho east sub-area above show, the farmers' income would rise by approximately 300 USD/dunum per year due to for the water reuse option. This increase in incomes may represent a sufficient economic incentive for farmers to join the project and to contribute to the costs. As mentioned above, usually the cost of wastewater treatment due to stricter quality standards should be taken into account. The total cost of WWTP should not be charged on farmers; other financial sources are required, such as the revenues from municipal water tariffs.

On the other hand, the financing of water projects could be facilitated if farmers with high income gains would contribute to the cost as far as possible. Negotiations appear to be the best way to find an agreement about the cost sharing. In case, the municipality cannot afford the cost, the Palestinian government or / and international donors should support the project. This is always justified, if considerable values added can be expected, which include not only the gains in agriculture but also other economic benefits, such as the cost savings due to closed cesspits (Figures 11a and 11b). Even if the economic values added are moderate, the financing of water reuse projects can be worthwhile due to their potential environmental benefits (for instance, restoration of groundwater levels).

Cost recovery

Other financial problems may emerge if the water demand for irrigation purposes is relatively small after the construction of a water project. In the first years, the costs can exceed the economic benefits. As the calculations for the Jericho east sub-area shows, in the first years there is no cost recovery, if the revenues from charging farmers are the only basis for financing the project. But the increased benefits in the following years will allow recovering the costs over the entire planning period (Figure 11a, Table 8).

However, it may be that the latter assumption cannot be upheld, if the farmers pay the cost of water reclamation only. Therefore, the municipality has to ensure the cost recovery of the project by charging also the citizens. If this is not affordable, further funds become needed. In special situations, the gains in the farmers' incomes can be negligible, if they would be charged with the full costs of water reuse. In such cases, farmers should

get the water by discount prices or for free. The financial problem concerning the first years after the construction of the infrastructure, as mentioned above, applies also to other projects, such as desalination of brackish water, storm water harvesting and rehabilitation of wells at the Jericho sub-areas

As outlined in the Jordan Valley case study, the financing scheme can influence the annual costs. For instance, at the Built Operate Transfer (BOT) approach applied increasingly for public infrastructures, the concession right is granted to private contractors to invest and to operate the water project within a certain period. As BOT will be applied in case of the Kufranjeh dam, the annual capital cost will be significantly higher compared with the above estimated value. The payback period (amortisation) is 20 years and shorter than the supposed usable lifetime (depreciation).

For the CBA, however, the annualized capital cost based on the useful lifetime should be taken into account (Table 23). Otherwise, the benefits emerging in the years beyond 20 years will be compared with annual capital cost of zero in the following 30 years (as in these years no loans must be paid back). It should be mentioned, that the BOT approach is more attractive for the future generation rather than for the present as the latter has to pay the cost with higher charges. But the future generation may be charged as well in order to build up a fund, from which the replacement cost can be financed by using own resources instead of loans.

As described at the Jericho central sub-area, trading schemes between farmers and the municipality allow financing water projects, such interregional transfers of resources.

Optimisation

In case of various combinations of options (IWRM strategies), the cost benefit analysis can identify the most economically efficient sequence of different options in the course of time, demonstrated at the Jericho east and central sub areas (Table 8, Table 9, Figure 12, Table 15, Table 16, and Figure 22)). Such an optimal sequence of constructing water projects allows maximising the total values added over the years. This leads to less financial requirements with respect to charging water users and raising funds from other sources.

Reallocation of water resources

From the financial perspective it is essential to specify the gains and losses resulting from IWRM strategies. In the best case, all parties involved will gain and there will be a fair distribution of the values added. At the Jericho central sub-area, several different water users

such as farmers, citizens and entrepreneurs are supplied from the new resources, which can be allocated separately to different users: The new resources from rehabilitated groundwater wells and storm water harvesting are mainly designed for agricultural irrigation; the water transported from the Duyuk spring and saved by rehabilitation of networks are dedicated for municipal users.

However, by water reallocation municipal users may benefit, whereas the agricultural users will not be faced with economic losses. At the Jericho central sub-basin, for example, the extra supply devoted for agricultural irrigation amounts to around 3 MCM/yr, but the demand is supposed to grow from currently 0.01 MCM/yr to 1.4 MCM/yr in 2031 only. On the other hand, for municipal water users there will be a water shortage in the near future, if the new resources cannot become available in time. At such a case, the financing of new projects can be facilitated by reallocation of water resources.

Financial issues	Description
Full cost principle	The true costs of water projects are to be taken into account
Water pricing	Water users have to pay the full cost of water projects by considering all the beneficiaries
Cost recovery	The financing of water projects should be ensured by adequate charging of users, trading schemes, grants and build operate transfers
Optimization	By maximizing the values added of water projects the financial requirements can be reduced
Reallocation of resources	Resources should be allocated to users as cost-beneficially as possible to ensure the financing of new water projects
Water trading	The financial feasibility of projects can be facilitated by buying water rights
Distribution of costs and benefits	Water exchange between agriculture and cities can be financed by adequate distribution of costs and benefits

Table 29: Overview of financial implications of IWRM strategies

Water trading

At the Jericho central sub-area an intersectoral water transfer from agricultural to municipal users will be practiced (0.33 MCM/yr). Every farmer in Duyuk area (village near Jericho

City) has a share in the Duyuk spring and the share of water is distributed during a time period of irrigation. The Jericho municipality sought to increase water supply to its area for domestic, commercial and public use and one of the solutions was to buy water rights in Duyuk Spring from the farmers. The estimated total infrastructure cost includes the capital cost for a storage tank and pipe line.

There are additional costs reflecting the income losses due to less water for irrigation purposes. This water trading results in value added depending on the payments needed to compensate the farmers per cubic meter (= price of water right). The unit cost amounts to 0.087 USD/m³ and the average domestic water price is 0.38 USD/m³. Thus, as long as the price for water right is lower than around 0.29 USD/m³ the water trade will pay. This calculation is to be slightly modified, if the higher water prices for commercial users would be taken into account.

The CBA at the Jericho central sub-area supposes that the municipality would have to pay no compensation payments to the farmers. However, it depends on the price of the water right, whether the water trade will result in values added. If the water average profitability in agriculture at the Jericho sub-basin (0.79 USD/m³) would be used as the basis for determining the price, the cost would exceed clearly the benefit. Therefore, to find an agreement between the farmers and the municipality negotiations are needed, by which the actual income losses are to be explored.

Distribution of the costs and benefits

As demonstrated by using the example of wastewater reuse projects, the economic efficiency of IWRM strategies depends on the difference between the net benefits in irrigated agriculture and the costs. However, there may be further benefits, so that the extent to which the costs will be levied to farmers can be different.

There is a common view that the beneficiaries should bear the costs of water services. But in special situations, the increase in farmers' incomes may be relatively moderate, and there are other stakeholders, who benefit from the same project. At such a case, the implementation of a water reuse option may fail, if only farmers will be charged, who will refuse to join the project.

On the other hand, if farmers would use the treated wastewater, freshwater could be released for improving the water supply of citizens resulting in considerable benefits. To ensure the financial feasibility of the project, the water price for the citizens should be

raised. In special cases, it may be advisable to waive charging the farmers and even to grant compensation payments.

Such an intersectoral water exchange may be established at the Jericho east and central sub-areas: A part of the effluents from the projected WWTP may be used for irrigation in agriculture; less water from freshwater resources, such as the En Sultan Spring and rehabilitated wells, would be required. The released water can be used for municipal users. Such agreements may be possible also for the option storm water harvesting, where the increase in farmers' incomes is relatively small and municipal users could benefit considerably.

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APPENDIX 1. Value added of IWRM strategies at Jericho east sub-area

Value added (million USD/yr)	2.02	2.61	3.57	3.71	4.27	4.67	3.86
Year	2012	2013	2014	2015	2016	2017	2018

Value added (million USD/yr)	4.26	4.66	5.03	5.39	5.77	6.19	6.42
Year	2019	2020	2021	2022	2023	2024	2025

Value added (million USD/yr)	6.23	6.39	6.54	6.68	6.81	6.95
Year	2026	2027	2028	2029	2030	2031

APPENDIX 2. Value added of IWRM strategies at Jericho central sub-area

Value added (1000 USD/yr)	-16.6	10.8	38.0	66.1	85.7	133.9	157.3
Year	2012	2013	2014	2015	2016	2017	2018

Value added (1000 USD/yr)	219.5	257.6	317.6	376.1	435.8	473.0	532.8
Year	2019	2020	2021	2022	2023	2024	2025

Value added (1000 USD/yr)	591.3	650.6	689.2	748.2	807.2	686.1
Year	2026	2027	2028	2029	2030	2031

APPENDIX 3. Components of WEAP applied in the Jordan Valley case study

Provided by Ali Hayajneh

The complex water system in the Jordan Valley is represented by a simplified version of WEAP. The main irrigation water requirements are symbolized by different demand centres. Water transferred to Amman is represented as a transition line to a demand node; river by river lines, etc. The current conditions, such as precipitation, river flows, crop patterns, agriculturally used areas, irrigation efficiencies and so on, were entered into WEAP.

The WEAP model needs to be calibrated. The results from running the basis scenario are to be compared with the actual data. Once the model has been verified, it can be used to predict future water balances. Future scenarios have been constructed on the basis of national water management strategies, population growth rates, domestic water demands, water projects, climate change, etc.

The description of WEAP aims to provide a general idea on the utilization of this model for water balancing at the Lower Jordan Valley.

The WEAP schematic of the lower Jordan Valley consists of the following components:

1. Demand nodes,
2. Sources,
3. Catchment nodes,
4. Dams,
5. Local reservoirs,
6. Well fields,
7. Transmission lines,
8. Diversions,
9. Zai water treatment plant, and
10. Other supply

1. Water demands

Agricultural demand

Demand nodes:

- North Ghor demand which represents agricultural demand in the Northern Jordan Valley within Irbid governorate.
- North east Ghor demand, which represents agricultural demand east of KAC in the northern Jordan Valley.
- The NE demand is supplied by Wadi Al Arab and Wadi Ziglab,
- Middle Ghore agricultural demand which represents agricultural demand in the middle Ghore within Balqa governorate.
- MG is supplied by KAC by blended water that is: KAC water mixed with As Samra effluent that comes from KTD.
- South Ghore demand which is supplied by blended water from KAC.
- Hisban Kafrein Agriculture which is located east of KAC.
- H.K. agriculture is supplied from Kafrein and Hisban dams.
- Agricultural demand south of KAC is supplied by groundwater.
- Other local demands around side wadis which are supplied from the side wadis.

Domestic demand

Demand nodes:

- Drinking water demand for the northern Jordan valley.
- Drinking water demand for the middle Jordan Valley.
- Drinking water demand for the Southern Jordan Valley.
- Drinking water demand node for Irbid city which receives water from Wadi Al Arab.
- Zai water treatment plant is expressed as a domestic demand node.

All domestic demands are supplied from groundwater resources.

2. Water sources

- Zarka River, water from Zarqa River flows to KAC,
- Yarmouk River (within YR basin) which discharges at the head of KAC,
- Mukeiba wells which discharges some short distance from KAC head,
- Taiberia lake which discharges short distance from KAC head,
- A groundwater node per governorate is included. Groundwater nodes are:
 - GW_Irbid,
 - GW_Ajloun,
 - GW_Balqa,

- GW_Amman.

- Side wadis nodes are:

- Wadi Al Arab,
- Wadi Ziglab,
- Wadi Abu Ziad,
- Wadi Jurum,
- Wadi Shueib,
- Wadi Kafrein,
- Wadi Hisban,
- Wadi Taibah,
- Wadi Yabis,
- Wadi Kufranjeh,
- Wadi Rajeb,
- Wadi Zarqa,
- Wadi Mallaha, and
- Wadi Bahhath.

3. Water catchments

A catchment's node is included per side wadi. The JV schematic includes the following catchment's nodes:

C_Irbid Ziglab, C_Irbid Arab, C_Irbid Alluvium, C_Irbid Jurum, C_Irbid W.Taibeh,
C_Irbid, other wadies C_Ajloun yabis, C_Ajloun other wadis, C Aj Kufrabjeh,
C_Aj Rajeb, C_Balqa Zarqa, C_Balqa Mallaha, C_Balqa Shueib, C_Balqa Alluvium,
C_Balqa Bahhath, C_Kafrein, C_Hisban.

4. Dams

- Wadi Al Arab dam on Wadi Al Arab,
- Shurahbil dam on Wadi Ziglab,
- Shueib dam on Wadi Shueib,
- Kafrein dam on Wadi Bahhath, and

- Karameh dam on Wadi Mallaha.

5. Stream flow gauges

WEAP schematic includes stream flow gauges at the flowing locations:

- Yarmouk River at Adasiya,
- Wadi Al Arab,
- Wadi Taibeh,
- Wadi Zigalb,
- Wadi Abu Ziad,
- Wadi Jurum,
- Wadi Yabis,
- Wadi Kufranjeh,
- Wadi Rajeb,
- Wadi Shueib,
- Wadi Bahhath.

6. Well fields

Well fields supply the different regions of the JV with drinking water. The following well fields are included:

- Well fields that supply the northern Jordan Valley with drinking water:
 - Manshia WF
 - Wadi Arab WF
 - Tabaqat Fahl WF
 - Kraimeh WF
 - Saberah WF
 - Sleikhat WF
- Well fields that supply the middle Jordan Valley with drinking water
 - Rajeb WF
 - Samahiat WF
- Well fields that supply southern JV with drinking water.
 - Sakneh WF
 - South Shouneh WF

- Graiah WF
- Kafrein WF

7. Transfer System

The transfer system for the irrigation demand sites consists of:

- King Abdulla Canal is the main transfer system in the Jordan Valley.
- North East Courier which is the transfer system in the east northern part of KAC.

8. Diversions

- A diversion from Yarmouk River to Taiberia Lake,
- A diversion from Taiberia Lake to KAC,
- A diversion represents KAC,
- A diversion represents the North Ghore Courier (NGC),
- A diversion from KAC to Wadi Al Arab,
- A diversion from Wadi Al Arab to NGC,
- A diversion which represents the tunnel connects YR to KAC.

9. Lake Taiberia System

Lake Taiberia is represented by a river. A head flow of 10 m³/s is assumed.

Lake Taiberia is connected to the Jordan river by a diversion the maximum capacity of which equals historical flow from YR to L.T. for the years 2000-2008.

Lake Taiberia is connected to KAC by a diversion. The maximum capacity of which is the historical flow from L.T. to KAC for the years 2000-2010.

10. Mukheiba Wells System

Mukheiba wells are represented by another source node and a demand node. Water flows from Mukheiba wells to the demand node and then water flows from the demand node to KAC via a return flow line. Consumption at the Mukheiba wells demand node is set to zero all the times, so that all water that flows from the other source node to the demand node return to KAC.

Input data

The Current Account Year for the JV WEAP is 2000. The calibration period is from 2000 till 2008.

1. Domestic demand sites

1.1. Water use data

Annual activity level is represented by the size of population. Population data for the current year as well as for the years 2001-2004 were taken from the MWI Water Information System. For the years 2005 till 2010, growth rate of 2.6% was used. Per capita annual water use for the years 2000 to 2010 was taken from the MWI record where annual water use was based on actual pumping records. Water demand or use input to WEAP was calculated as follows:

Water demand = $(1 - \text{administrative loss}/100) * (1 - \text{physical loss}/100) * \text{Water pumped}$.

Monthly variation in water use was calculated based on the actual water pumped for the years 2000-2010.

1.2. Loss and reuse

Loss rate at domestic demand sites which is the administrative loss was taken from MWI records. Non Revenue Water is calculated based on actual pumping and billed water. The difference between pumped and billed is the NRW. No reuse was assumed at the JV within domestic demand sites.

2. Agricultural Demand sites

For the main agricultural demand sites in the JV, five types of crops are planted which are:

- Field crops,
- Vegetables,
- Fruit trees,
- Banana, and
- Citrus

2.1. Annual Activity Level

For agricultural demand sites the annual activity level is the area. The area planted by each of the above crops is input at all agricultural demand sites in the JV.

2.2. Annual water use

Annual water use for irrigation demand sites is represented by the crop-specific water requirements per dunum.

Reference scenario data

1. Domestic demand sites

1.1. Water use data

1.1.1. Annual Activity level

Growth rates used for population estimation are taken from Department of Statistics. Growth rate for the year 2030 was estimated at 1.9%. Population growth rates used are given in Table 1.

Year	2008	2010	2015	2020	2030	
Growth rate, %	2.6	2.2	2.2	2.0	1.9	1.5

Table1: Population growth rates

The same monthly pumping rates at the water fields (WF) between 2000 and 2010 were assumed between 2011 and 2030.

1.1.2. Annual water use

The following per capita use in Table 2 which are published in Jordan's water strategy were used.

Year	2010	2015	2020	2030
Net water demand in lit./c/d	80	100	110	120

Table 2: Per capita annual water use rate

1.1.3. Monthly variation

No considerable variation in the monthly variation was noticed from year to year for the calibration years 2000 – 2010. The monthly variation for the year 2008 was used for the years from 2011 till 2030.

1.2. Loss and reuse

1.2.1 Loss rate

The following loss rates published in Jordan's water strategy are used. 50% is assumed as administrative and the other 50% is assumed as physical. Loss rate input to WEAP is given in Table 4.

Year	2010	2015	2020	2030
Loss rate	45	37	28	25

Table 4: Non Revenue Water for the planning period

2. Agricultural demand sites

Irrigated areas and annual water use for agricultural demand sites are assumed to remain steady between 2010 and 2030.

Losses in the irrigation system are taken from the published numbers in the NWMP (2004). The conveyance losses as well as the application losses, published in the NWMP, are given in the Tables 5 and 6 below.

Year	1998	2005	2010	2015	2020
Irri JV North	68	68	72	75	80
Irri JV South	77	77	79	81	83
Irri Southern					
Chera	82	82	82	82	84
Irri Wadi Araba	78	78	80	80	81
Aqaba_JRV	79	79	80	80.4	81
Total JRV	72.6	72.7	76	78.1	81.3

Table 5: Irrigation water application efficiency (NWMP, 2004)

JRV Region	Conveyance efficiency
Irbid N. Valley	95
Balqa N. Valley	95
Balqa S. Valley: excl. 14 km Ext.	92

Balqa S. Valley: 14 km Ext. excl. Wells	92
Total JRV	89.51

Table 6: Irrigation water conveyance efficiency for the years 1998 till 2020 (NWMP, 2004)

ANNEX SYNOPSIS OF THE WP7 SOCIOECONOMIC STUDIES

This synopsis will provide an overview of the outcomes from the socioeconomic studies of WP7 prepared for SMART II by pointing out their key messages. The purpose is to demonstrate the significance of socioeconomic issues in implementing the IWRM approach at the Lower Rift Jordan Valley. The 11 studies address a broad range and great variety of water-related domains, including:

- Population growth; production of foods and other goods
- Employment of manpower; employment of manpower; usage of land
- Availability of water resources; water demands of agricultural, domestic and industrial users
- Water scarcity; water quality and ecological services
- Construction of water infrastructures; costs and benefits of water services
- Water pricing and governmental water policies
- Institutional and political situation; participation frameworks.

All these factors have to be considered in assessing and implementing IWRM strategies as they influence the utilization of water resources and vice versa. The following list shows the titles of the 11 WP7 studies; the numbers of the deliverables are set in brackets.

1. Cost Benefit Analysis of decentralised wastewater treatment and reuse in Jordan: An application in Maghareeb and Ma'addi (701 & 704).
2. Environmental and socioeconomic benefits of decentralised wastewater treatment (DWWT) in Palestine (702).
3. Assessing the impacts of different water qualities and quantities on farmer income and their economic situation in Palestine (703)
4. Assessing the impacts of different water qualities and quantities on farmer income and their economic situation in the Jordan Valley (703).
5. Cost effectiveness of individual technologies, such as decentralised wastewater treatment (DWWT) and water reuse, managed aquifer recharge (MAR) and brackish water treatment (BRA) (705).
6. Costs and benefits and the financial feasibility of alternative IWRM strategies at selected areas in the Lower Jordan Valley and Palestine (706 & 707).
7. Costs of different IWRM technologies in the West Bank (708).
8. Social acceptability of different IWRM technologies in the West Bank (709).

9. Institutional feasibility of alternative IWRM technologies in the West Bank (710).
10. Assessment of multiple water qualities in Israeli municipalities (711).
11. Participating framework for the decentralized wastewater treatment and water reuse for Jordan (712).

The summaries of each of the WP7 studies are presented in a separated document.