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SMART – IWRM

Summarizing Report of D806 and D807

**Challenges of implementing IWRM in the Lower Jordan
Valley**

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The report addresses the main issues formulated within WP8, D806 and 807.

Challenges of implementing IWRM in the Lower Jordan Valley

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1 Introduction

The Lower Jordan Valley (LJV) (Figure 1) comprises parts of Israel, Jordan, and the Palestinian Territories and, in terms of per capita freshwater availability, is among the water scarcest regions worldwide. The current overexploitation of the natural surface and groundwater resources already shows severe impacts on environment and society. According to the observed trends of population growth and demand, the conditions are likely to be aggravated in the coming years.

On a regional scale, capacious seawater desalination and import schemes are presented as potential solutions. However, even if political and economic constraints and environmental concerns over such mega-projects can be overcome, the effective management and protection of the basins internal resources still remains a key requirement for the future water security in the LJV.



Figure 1: The Lower Jordan Valley (picture taken from the eastern escarpment in Jordan with view to the West Bank, photo J. Klinger)

In response to this situation, the responsible governments have already stated their commitment to foster IWRM (integrated water resources management) as well as the required major water sector reforms. However, each of the riparian states is vastly different in terms of institutional setting and capacity, awareness, economics, and water policy. Therefore, at present, there is no universally applicable basin-wide IWRM implementation concept for the LJV. In spite of this, there are common denominators that unite the different riparian states. Aside from the need for reliable and comprehensive information on the temporal and spatial availability of the regions' conventional water resources, the understanding of treated wastewater, brackish groundwater, and storm runoff as genuine parts of the water management cycle highlights the importance for IWRM in such water

stressed regions. The critical challenges in this regard are the establishment of measures that are technically adapted to local physical conditions as well as conceptually adapted to the respective socio-economic realities.

The multilateral research and development project SMART (Sustainable Management of Available Resources with Innovative Technologies) was a research initiative with partners from Germany, Israel, Jordan and the Palestinian Territories. Through a series of local pilot studies and demonstration sites in sub-catchments in the LJV within this project, these topics have been investigated.

2 The Lower Jordan Valley

2.1 Geographical, hydro-geological settings and climate

The LJV in the Middle East is part of an extensive geological transform fault system and is shared by Israel, Jordan, and the Palestinian Territories. It extends over 100 km from Lake Tiberias in the north to the mouth of River Jordan at the Dead Sea in the south. As part of the LJV, the SMART project region comprises an area of approximately 5,000 km² including the valley floor with a width of 8 to 15 km as well as numerous tributary sub-basins (called ‘wadis’) east and west of the River Jordan (Flexer et al. 2009). The project area is bordered by mountain ridges on the eastern side along the cities of Irbid, Amman, and Madaba, and on the western side along the cities of Nablus, Ramallah, Jerusalem, and Hebron (Figure 2).

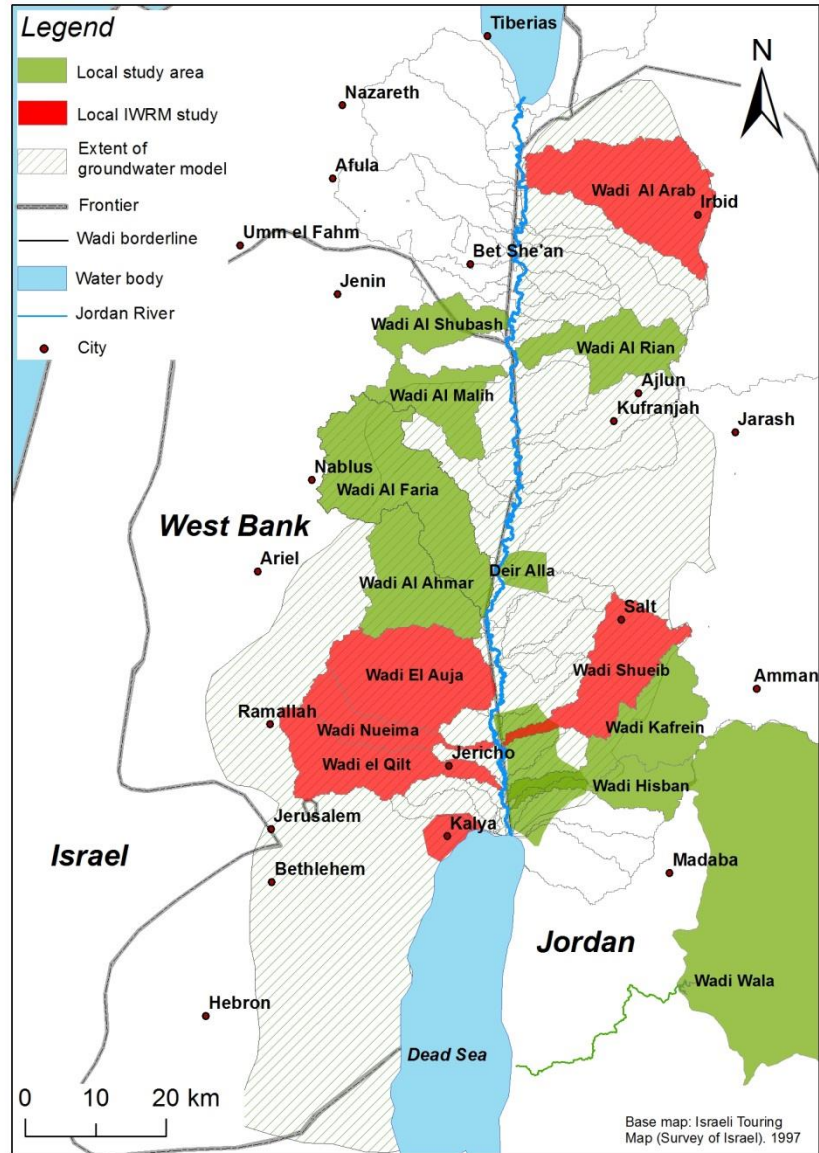


Figure 2: Overview of the SMART project area in the LJV. The green and red coloured areas display the study areas and the trans-boundary groundwater model is shown by the hatched area.

The Dead Sea is the lowest area topographically and lies currently at about 420 m below sea level, while the surrounding mountain ridges reach altitudes of 1,200 m above sea level.

The climate in the project region is arid to Mediterranean. Arid conditions prevail down in the Jordan Valley with precipitations below 150 mm/y, whereas the potential evaporation can exceed 2,600 mm/y. Along the mountain ridges, Mediterranean climate dominates with precipitation of 600 to 800 mm/y and a potential evaporation of 1,600 to 1,900 mm/y (Flexer et al. 2009).

2.2 Water resources in the Lower Jordan Valley

The LJV lies within a region where water demands frequently exceed the availability of resources. As such, water shortage is a problem for daily life, especially in dry periods. As the average water available per person is below 150 m³/y, this region is facing absolute water scarcity according to the FAO (see FAO 2012). This situation is aggravated by declining natural groundwater recharge and the constant population growth. Based on this indicator, Jordan and the Palestinian Territories can be described as regions suffering extreme water shortage. The deficit of water demand and water availability is already significant and will face an aggravated increase in the next ten to fifteen years. Table 1 provides a water budget for both present and future conditions in the riparian states of the LJV.

The table reflects that all riparian states include prospective increasing water demand in their water strategies. The reuse of treated wastewater, the inland brackish water desalination, and seawater desalination is planned to be reinforced so that the water demand deficit can be mitigated. For instance, in case of Israel, reuse of treated wastewater is being practiced at a large scale e. g. at Shafdan (Cikurel et al. 2012), and the government is currently implementing a large seawater desalination program along the Mediterranean coastline (Dreizin 2006).

Table 1: Current and projected water availability and demand in adjacent countries in the LJV according to the respective water strategies

	Israel		Jordan		Palestinian Territories (West Bank)	
Year	2010	2020	2010	2025	2010	2022
Freshwater resources (MCM/year)	1,170 ⁽³⁾	1,170 ⁽³⁾	780 ⁽⁷⁾	483 ⁽⁸⁾	127 ⁽⁴⁾	> 127 ⁽⁶⁾
Inland brackish water desalination (MCM/year)	25	75 ⁽¹⁾	57	82	0.5	22
Seawater desalination (MCM/year)	270	650 ⁽²⁾	--	370	--	--
TWW reuse in agriculture (MCM/year)	400	570 ⁽¹⁾	100	247	--	30.6
Population (million)	7.7	9.1	6.1	8.5	2.65 ⁽⁵⁾	5.7
Total water demand (MCM/year)	1,994	2,596	1,315	1,652	125 ⁽⁵⁾	712 ⁽⁹⁾
Deficit of water (demand – resources) (MCM/year)	129	131	361	470	2	>>2

Abbreviations: TWW=Treated Wastewater; MCM=Million Cubic Meters

Superscript numbers: ⁽¹⁾ 2015 value, ⁽²⁾ 2017 value, ⁽³⁾ Pumped water, ⁽⁴⁾ Domestic and agricultural water supply, including purchases from Mekorot utility, ⁽⁵⁾ 2012 value, ⁽⁶⁾ Depends on the access to water resources, ⁽⁷⁾ Estimated natural groundwater and surface water resources, ⁽⁸⁾ Renewable and non-renewable groundwater only, ⁽⁹⁾ Long-term water strategy as of 2022.

Sources: Guttman, J. (2011), Rosenthal, G. and Katz, D. (2010), Palestinian Water Authority (2012), RCW & MWI (2009)

In Jordan, water reuse, especially for irrigation purposes in agriculture, is being practiced as well. Major infrastructural projects like the Disi water conveyance pipeline or the Red Sea – Dead Sea water conveyance project represent two of the main future options. In the northern part of Jordan, the water situation is getting particularly worse due to the crises in Syria. The UNHCR (October 2014) indicate almost 3.2 million Syrian refugees in the Middle East, 620,000 refugees are officially registered in Jordan. Jordan's Ministry of Water and Irrigation announced estimates up to 1.3 million Syrian refugees in Jordan by the end of 2014. As such, the country has experienced a defacto population growth of more than 20 % within the last two years, compared to the total population of 6.3 million (in 2012).

The situation in the Palestinian Territories, especially at the West Bank, is characterized by the limited access to natural resources and on-going conflict with Israel. The availability of water per capita ranges from 29 to 150 l/d, but is mostly below 80 l/d, with widespread seasonal water cut-offs, mainly during dry summers. 30% of the communities or 700,000 people are currently not served by any water network. In these areas, purchasing water from trucks and hauling water from standpipes are typical practices. Due to the lack of water, many people use untreated wastewater to irrigate their farms and gardens without taking into consideration health and environmental risks especially to children and pregnant women. The gap between supply and demand will increase dramatically in the coming years.

In all three regions, by adjusting the allocation of water among the three riparian countries together with additional measures, such as water reuse, brackish water desalination and storm water harvesting, the insufficient water supply could be radically improved. The development and application of an approach addressing IWRM principles could provide a way towards an efficient, equitable and sustainable development and management of the scarce water resource in the LJV.

3 The SMART project: objectives and major outcomes

The SMART project represents a multilateral and interdisciplinary research initiative with 23 partners from universities, research centres, water authorities, decision relevant institutions, external experts as well as partners from the industry from Germany, Israel, the Palestinian Territories and Jordan. The project was funded by the German Federal Ministry of Education and Research (BMBF) from 2006 to 2014. The overall goal was to develop a concept for integrated water resource management for the LJV to ensure an optimized and sustainable use of all water resources in the region. It was the aim that the developed, applied and validated concepts throughout the project should be transferable to other regions suffering from natural and/or anthropogenic water scarcity (DoW 2010).

Under the umbrella of an integrated water resource management scheme, the study addressed relevant ecologic, economic, and social issues and built upon the assessment of conventional water resources as well as unconventional water resources. This was based on the investigation and evaluation of water resources that were not taken into account for use due to qualitative or storage deficits. Therefore, suitable techniques had been developed, demonstrated and in parts implemented. Figure 3 illustrates the project structure and reflects the interlinkage of work packages (WP). The following text summarizes the outcomes of each work package.

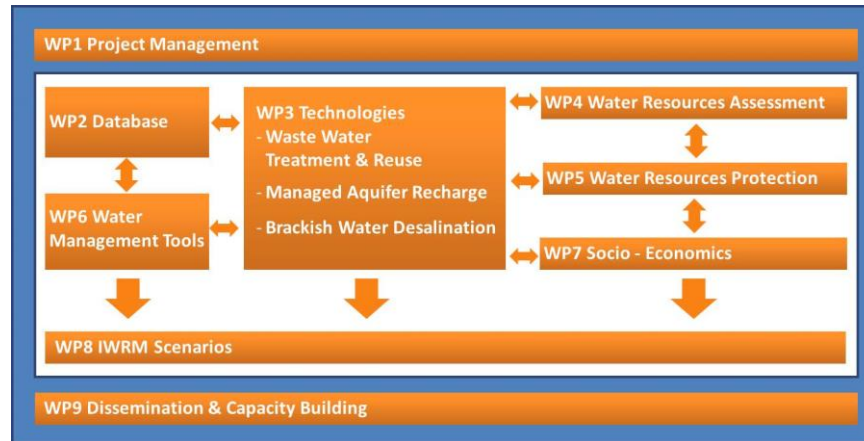


Figure 3: Project structure of the SMART project

For decision-making in natural resources management, a detailed database of all available variables and measurements is essential. As seen in Figure 3, WP 2 included the development of a comprehensive database management system called DAISY (Data and Information SYstem) (Geyer 2014). Partners of the riparian states of the LJV contributed data to the database, which continues to operate. Currently, approximately 2 million data records exist within the database, which underlines the success of the trans-boundary approach of the project. The database's interface, which can be used to display and download data, can be found at: https://www.ufz.de/daisy_harvester/

In the field of waste water treatment (WP 3-1), five different technologies towards the reuse of wastewater had been developed and adapted, complying with the Jordanian Standard (JS 893-2006). In total, seven decentralised waste water treatment (DWWT) systems for individual households and multi-family houses had been implemented in Jordan (Mueller and Abbassi 2014, Van Afferden et al. 2010, Boog et al. 2014). With regard to Managed Aquifer Recharge (MAR, WP 3-2) an evaluation of relevant biogeochemical processes during the vertical infiltration, as well as socio-economic considerations concerning the feasibility of MAR implementation was performed and six test sites were studied (Tiehm et al 2011, Zemmann et al. 2014, Xanke et al. 2015). Suitable sites for the desalination of brackish groundwater (WP 3-3) were identified by geophysical and analytical methods along the Jordan Valley (JV) (Salameh & Frimmel 2010, Saravia et al. 2013). An innovative water treatment plant, which uses low pressure reverse osmosis membranes to treat the challenging groundwater, was built in Karameh, Jordan. This facility has the potential to generate 10 m³/h of treated water (Frimmel and Flexer 2014).

In the long-term planning of an integrated water management scheme, the assessment of surface water and groundwater resources (WP 4) are the most important components. Within the project, direct measurements of discharge compo-

nents (surface, groundwater and waste water) components, water budgeting and forward modelling with hydrological models have been performed on catchment scale along the JV. The measurements provided improved estimates these water resources in the region (Schmidt et al 2013).

With regard to groundwater protection (WP 5), detailed evaluation of water quality and trace contaminants in the LJV and adjacent Wadis was performed, with a focus on wastewater impacts on groundwater resources (Zemann et al. 2015, Tiehm et al. 2013). The development and initial implementation of continuous monitoring techniques at a karst spring in Jordan could be connected to the regional drinking water network. A sustainable outcome of SMART is the advancement of groundwater protection zoning concepts, with initial implementation in the Palestine Territories (Goldscheider and Guttman 2014).

The focus in WP 6 (IWRM tools) was on the development, deployment, and application of state of the art tools for IWRM, including a web-based set of visual tools for water resources management, a platform for risk assessment (see <http://www.ewre.com/smartdss/publish.htm>) as well as a web-based visual platform for knowledge management (DROPEDIA, see <http://www.dropedia.iwr-smart2.org> (Riepl, 2013, Kaempgen et al. 2014, Bensabat et al. 2014)).

The works in WP 7 (socio – economics) focussed on tools for cost benefit analysis (CBA), cost-effectiveness analysis (CEA), multi-criteria analysis (MCA), financial feasibility analysis, social acceptance analysis, and hydro-economic models that aimed to increase the economic efficiency of water management projects at basin level (Heinz et al. 2014).

The WP IWRM scenarios (WP 8) focussed on the provision of planning criteria on the sub-basin level and the integration of results from other work packages into combined IWRM approaches (Wolff et al 2012).

The WP 9 encompassed all work packages and addressed the dissemination and capacity development of each individual work package. The direct outcome of this work was the knowledge transfer and training to schools, including teachers and technicians. The teaching materials and booklets were published in English and Arabic language (<http://www.waterfunforlife.de/projects-partners-promoters.html>).

Furthermore, academic capacities were built within doctorate program, within which 26 doctoral students from Israel, Jordan, the Palestinian Territories and Germany participated. Scientific advanced training for researchers from the region ensured the preservation of a sustainable development and supported the trans-boundary cooperation. The publication and dissemination of the results are documented in more than 35 papers in international journals (v. Afferden and Ali 2014).

The studies in SMART are multifaceted and were performed on almost all spatial, technical and institutional levels reaching from field investigations and technology demonstration, to stakeholder consultations. However, the focus is on local IWRM studies as they incorporate the experiences within the course of the project.

4 IWRM in the Lower Jordan Valley

4.1 Basic requirements for IWRM implementation

IWRM is a framework which promotes a coordinated development and management of water (GWP 2004). However, IWRM can only be effectively implemented if the affected regions adapt their water policies continuously to the changing boundary conditions (Wolff et al. 2012, Biswas 2004, Riepl 2013). The riparian states of the LJV have declared to incorporate IWRM principles in their water strategies and numerous studies to support the decision making process have been published. As an example, innovative water management options like sea water desalination, water trading, brackish water desalination in the Middle East (Fischer and Lee 2011, Mohsen and Jaber 2001) have been described within publications in terms of economic assessments of such alternative options. Other studies focused on economically efficient measures in the agricultural sector (Ramirez et al. 2009), as most of the water is consumed by irrigated agriculture to ensure food security (in Jordan approximately 75 %). Proposals for the integrated management of the shared trans-boundary water resources of the Jordan River Basin were discussed previously in the 1990s by Shuval (1994). These studies are valuable as they describe the process of the implementation of important IWRM elements.

In the following sections, the authors illustrate how SMART accomplished water management assessments of the riparian countries taking basic IWRM principles into consideration. First, the local IWRM studies within the project are introduced and the stepwise approach is presented (Section 4.2). Based on a profound analysis of the different national water strategies in the LJV (Section 4.3) and the dynamics of the water sectors' changes, e.g. due to population growth, detailed scenarios have been compiled to take the specific boundary conditions into account (Section 4.4).

The relevant components of the water strategies, including the applied water management options and developed scenarios had been incorporated into a framework (Section 4.6) for the assessment of the respective water strategy by the use of defined performance indicators. The indicators are introduced and discussed in Section 4.5.

4.2 Introduction and overview about local IWRM studies in the LJV on sub-basin scale

The principles of the Global Water Partnership postulate that integrated water resource management is built upon a clear understanding of the river basin processes (GWP 2009, FAO 2012). In accordance to these principles, adapted water management strategies are the prerequisite to reach the long term goals. The processes of defining how these goals can be reached are described in individual strategies covering periods of 10 – 20 years. Within the SMART project, comprehensive studies on the development of adapted IWRM concepts have been conducted on the sub-basin scale for the identification of water related problems to provide technically feasible solutions. The involvement of local stakeholders, through scientific steering project meetings and workshops, as well as representatives of international cooperation, ensured realistic assumptions and input in developing water management options and scenarios. This involvement is a prerequisite for the sustainability of IWRM concepts.

Local IWRM studies have been developed and applied in four different areas on the sub-basin and settlement scale: Wadi Cluster Auja, Nuema and Quilt (see Rusteberg et al. 2014) as well as the local study Kalya (Guttman & Bensabat 2013) on the western side of the Jordan River and Wadi Al-Arab (Rödiger 2013) and Wadi Shueib (Riepl 2013) in Jordan. The main characteristics reflecting this integrated approach are displayed in Table 2.

1 **Table 2: Overview of the local IWRM studies and their main characteristics**

Properties	Wadi Cluster Auja / Nuema / Quilt	Kalya	Wadi Al-Arab	Wadi Shueib
Location of sub-basin / study area	West Bank	West Bank	Jordan	Jordan
Area	577 km ²	< 10 km ²	300 km ²	190 km ²
Time line: current status	2010	2010	1980 – 2008	1994-2009
Time line scenario	2050	No scenarios defined	No scenarios defined	2010-2025
IWRM measures rely on	Participative approach, interaction of water experts and stakeholders	Participative approach, interaction of water experts and stakeholders	Hydrological assessment – artificial re-charge as key technology	Jordan's Water strategy water for Life
Ranking of measures, setting of priorities and definition of scenarios	AHP, Multi-criteria analysis; Local IWRM strategies as combined water management measures	AHP, Definition of alternative water management options using multi-criteria decision procedure	Multi-response calibration, Scenario: re-charge of TWW and storm water	Based on Jordan's Water strategy water for Life and Action Plan
Scenario modelling / optimise strategy	Multi-Objective Optimization / Pareto-Frontier	-	J2000g; FEFLOW	WEAP21
Involved stakeholder, decision maker	PWA, PHG, MoA, MEKOROT	MEKOROT	MWI, WAJ, JVA	MWI, WAJ, JVA

2 Abbreviations used: AHP: Analytical Hierarchy Process, J2000g: proper name; FEFLOW:
3 Finite Element Flow, WEAP21: Water Evaluation and Planning System, PWA: Palestinian
4 Water Authority, PHG: Palestinian Hydrology Group, MoA: Palestinian Ministry of Agriculture,
5 MEKOROT Israel National Water Company, MWI: Ministry of Water and Irrigation (including
6 Water Authority of Jordan (WAJ) and Jordan Valley Authority (JVA)).

8 Due to the significant differences in water strategies and the economic and so-
9 cial development within each state, an up-scaled concept on IWRM for Lower
10 Jordan River basin could not be formulated in that stage. Hence, a set of three dif-
11 ferent approaches have been applied and partly developed, assessing the socio-
12 economic as well as the environmental impact on sub-basin scale. Each of the ap-

proaches were based on a detailed water balance that allowed the evaluation of the current situation, the water management in the respective sub-basin, and the water management options in the context of population growth and climate change. The basic steps for the set-up of the local IWRM studies are summarised in Figure 4. The process scheme serves as a guide for the construction of a framework for water resources planning towards implementation.



Figure 4: Scheme for the setup of an IWRM approach developed for the Wadi Shueib.

4.3 Water strategies in the region and integration of IWRM into the respective policies

Water management plans for the use of regional water resources in the Jordan River Basin have been developed since 1900 when Abraham Burkart first developed proposals for water distribution. Within the Frangia Plan (1913), recommendations were made to transfer Yarmouk River flows to Tiberias for storage and for generating electricity. Since then, numerous plans targeting the water distribution in the Middle East had been developed e. g. Ionides Plan (1939), Hays (1947), United Nations Partition Plan (1947) (Attili et al. 2014, Bassat and Ginio 2011).

After the declaration of the State of Israel in 1948, the governments in the region began to pursue national plans for water resources exploitation of the Jordan River Basin (Haddadin 2002). However, these unilateral activities soon led to water-related disputes and conflicts between the riparian countries. In 1953, and as a response to the USA initiatives, Lebanon, Syria, Jordan, and Israel commenced the “Johnston Plan”, with the goal of a multilateral agreement on water use rights for the Jordan River (Smith 1966). Although the plan was technically accepted, it was never ratified by the Arab League due to politically motivated reasons related to the Arab-Israeli tensions (Wishart 1990). Infrastructural activities on both sides of the Jordan River, such as the construction of National Water Carrier in Israel or the East Ghor Kanal in Jordan resulted in smaller military conflicts (Al-Kloub & Abu-Taleb 1998).

Despite the persistent potential for conflict, the countries of the Jordan River Basin have also realized their urgent need for cooperation during the last decades. During the 1990s the riparian states began serious negotiations, foremost with bilateral legal agreements on the distribution of the water resources (surface water and groundwater) in the Jordan River Basin (Haddadin 2002; Jägerskog 2003). The two central agreements in this respect are the Israel–Jordan Treaty of Peace signed in 1994 and the Israeli-Palestinian Interim Agreement (also: Oslo II) from 1995 (Interim Agreement 1995; Treaty of Peace 1994).

Until the 1990s, the developed water plans negotiated mainly water management matters, e. g. water rights and water distribution among the riparian countries and did not take social-, economic, and ecological effects on the long run into account (Riepl 2013). A significant paradigm shift evolved after the International Conference on Water and the Environment in Dublin in 1992, where the principles of IWRM were clearly formulated.

The Jordanian Ministry of Water and Irrigation (MWI) started to adapt integrated management principles within its national water policies during the 1990s (Riepl 2013). The latest long term strategy was published in 2009 (MWI 2009). However, this strategy is still subject to discussion within the national administration. The authorities in Israel and Palestine are in the final stage of developing and approving comprehensive strategy papers after years of intermediary targets and temporary declarations of intent. The objectives of this strategy can be grouped into three categories:

- Continuous supply of water for a growing population for the purpose of securing and improving current living standards, which includes water for domestic purposes as well as for economic activities in industry, trade, and agriculture;
- Improving the sustainability of available water and water resources in terms of quality and quantity, and;
- Independence from water imports under the politically sensitive regional settings.

All three states support IWRM, in particular with respect to the second objective, but their current water policies clearly assign the highest priority to the mobilization of all potential water resources through advanced technologies (Bein Committee 2010, MWI 2009, MOPAD 2010). Expectations in Israel and Jordan focus predominately on the scheduled development of capacities in seawater desalination, while the Palestinian national plan for the West Bank relies primarily on water recycling and larger shares from local water resources.

The adoption of IWRM into the national strategies originates from the riparian states' acknowledgement of the need to adapt current water cycles into conceivable changes in their water balances. These changes include anticipated impacts from climate change, as well as the effects of increased water supply. Prognoses on effects from climate change in the LJR predict a decrease of 10 to 20 % in annual precipitation, a seasonal shift and shortening of the rainy season, higher temperatures, and an increasing occurrence of extreme weather events, such as droughts and flash floods. Estimations of the timing of the onset of significant changes vary between the expectation of first effects towards the end of the ongoing decade and the established change of overall climatic conditions until the end of the 21st century (UNDP 2009; Samuels et al. 2011). The task of IWRM in the existing strategies is therefore threefold:

- Bridge the gap in water availability between the current situation of growing water scarcity and anticipated future conditions by the mobilization and better management of local water resources;
- Guide and design the transformation process in a way that minimizes potential hazards while incorporating the expected changes in water balances; and
- Adjust the currently applied approaches to water resources management to the requirements of achieving the strategic objectives in the long run.

To date, however, the existing concepts and planning still rely on more general ideas of IWRM and define practical solutions only for selected elements. One reason for the lack of comprehensive designs of IWRM set-ups are deficiencies in applying technical knowledge regarding integrated solutions to specific problems. Another major reason is the strong dependency of water sector strategies with strategies from other sectors, such as urbanization, industry, rural development, agriculture, and environment as well as the financial sector.

The consideration of these dependencies, which are defined under the term 'water coherence' in the international discussion (OECD 2012), require that decision

makers and researchers first align their contributions to the existing national strategies, even if those topics may not always constitute the highest priorities from the viewpoint of IWRM. Introducing IWRM priorities, which are not already part of the national strategies, is a mid- to long-term task, as this task demands thorough appreciation of values from all sectors of the national economy and goes far beyond the scope of exclusive decision making by water scientists.

4.4 Scenarios – valuable tools for quantitative impact assessments of IWRM measures in Jordan, the Palestinian Territories and Israel

The objective of the scenario development was to provide a baseline for quantitative impact assessments of IWRM measures and strategies in local IWRM studies. This included the quantification of anticipated developments in the water sector under "most likely" assumptions relating to the future conditions and potential variation within those conditions. Direct downscaling from the available regional scenarios by multiple organizations and projects proved to be unsatisfactory due to the strong heterogeneity of the sub-regions. Therefore, the scenarios needed to be completed or even replaced by data and information from the respective national and local water administrations as well as from local scenario exercises. The local approaches for both sides of the river Jordan had been coached by SMART partners during the period of the project (Wolff et al. 2013; AFD/PHG 2011) and its results are summarized below.

Study areas in Jordan: The development of scenarios for Jordan was based on a series of workshops with experts and stakeholders from MWI, WAJ and JVA in 2010 and 2011 and took place under the umbrella of Jordan's planning mission on water demand management (MWI/AFD 2011). Results focused on a time projection until 2025 and considered demographic development and economic development as major drivers in Jordan's water sector.

In Jordan, the potential of wastewater recycling would satisfy the current agricultural water demand in Wadi Shueib as well as in Wadi Arab, while freshwater for domestic purposes will always rely on water imports under the current settlement structure. However, it is likely that the increased availability of water would result in an extension of irrigation areas.

The amount of treated wastewater, which may be alternatively allocated to aquifer recharge, depends at least as much on the aforementioned capacities of farming systems as on its quality. The increasing amount of wastewater is the result of increasing water imports in both areas. Potential from wastewater treatment will therefore depend on the overall development of Jordan's freshwater conveyor infrastructure and water production in other regions. Any sustainable planning of local wastewater treatment coverage will crucially rely on the inclusion of these supra-regional interdependencies in the planning process. Figure 5 displays the

situation in Wadi Shueib as an example for the situation in the Jordanian areas of interest.

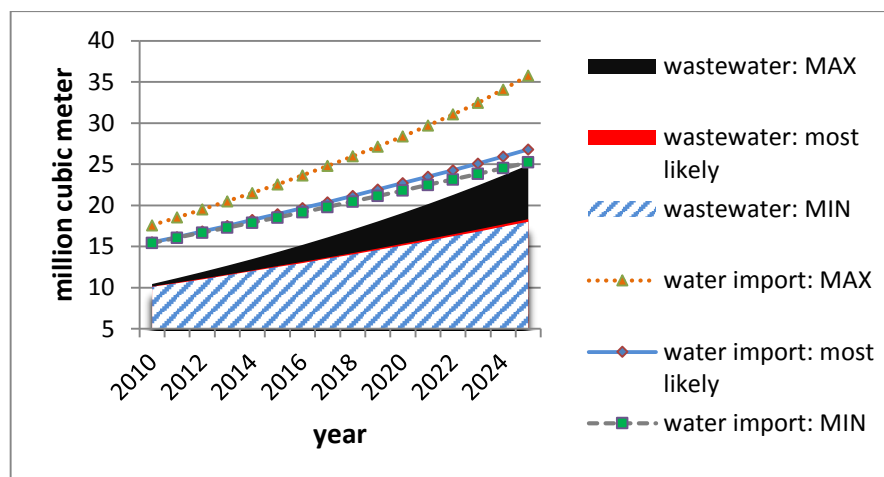


Figure 5: Water supply scenarios and relationship to wastewater availability, Wadi Shueib

Study areas in the West Bank:

Scenarios for the Palestinian research areas relied on workshops for the development of the Water Master Plan for Jericho City and focused on the same time horizon, i.e. until 2025. The stakeholders in Jericho identified "management and coordination among stakeholders" and "resource availability under climate change" as the two most significant drivers for future developments in the water sector (AFD/PHG 2011). The governorate of Jericho is not driven by natural water scarcity, but water availability. Water consumption in urban areas is significantly higher than in comparable communities on the East Bank, but also significantly lower than in Israeli settlements. Water availability restricts the potential of agricultural production and forces Palestinian farmers to leave large areas of cultivated land as fallow land. The start of operations of the large-scale wastewater treatment plant in Jericho East will provide sufficient capacity for the full sanitation of the Jericho governorate beyond the scenario period until 2025.

The current estimations of the stakeholders in Jericho indicate that desalinization of brackish groundwater from wells in Jericho East will become a potential contributor to local water supply after 2025. The potential, alternative development of these factors lead to the specification of the two scenarios "optimal development", which assumes the successful implementation of managerial and technical improvements, and "business as usual", which assumes no changes in resource availability and the current water governance (Figure 6).

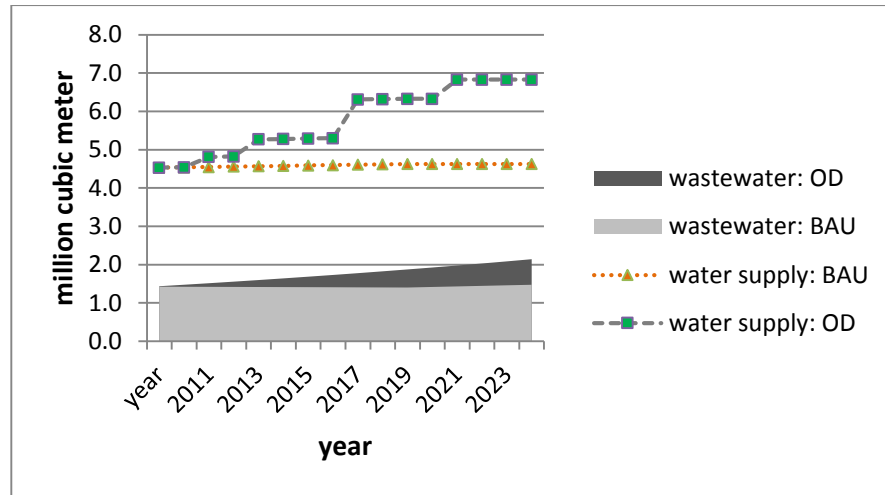


Figure 6: Water supply scenarios, research region Jericho (acronyms: BAU = Business As Usual, OD = Optimal Development)

This estimation relies on the current technological state of the art of desalinization plants and may change if technical innovation leads to economically sound solutions before that date. Scenarios for the Israeli settlement of Kalya relied on information from local SMART partners, by since recent official scenario exercises were not available.

4.5 Indicators for IWRM assessment

In general, suitable indicators for the performance of IWRM depend on its contributions to the strategic objectives of the national water sector strategies. A further recommendation is the compliance with the DAC evaluation criteria, stipulated by the Development Assistance Committee of the Organization for Economic Co-operation and Development (DAC, see OECD 1991), which focus on the five basic fields: relevance, effectiveness, efficiency, impact, and sustainability. The importance of the DAC criteria lies not only in the provision of a professional framework for evaluations, but also has relevance in regard to requests for support and funding from European donors and others. The third constraint that determines the suitability of indicators is the required costs for collecting information about the indicators, which may force monitoring and evaluation (M&E) to find a compromise between ideal and feasible analyses.

Comparatively straightforward performance indicators (e.g. the provision of water quantities of a given quality at a certain point in time with minimal costs) are typical project and operational process measurements. Such indicators help in assessing the merit of technical and managerial components, but only constitute one component in the evaluation of comprehensive IWRM strategies (Wolff *et al.*

2012). It is due to the third constraint, the costs of information gathering and measurements, that an equally comprehensive set of suitable indicators is rarely practicable for continuous M&E systems.

The research under SMART led to the definition of three IWRM-specific areas of indicators (Wolff *et al.* 2012, p. 1412), which have analogous indicators in the national water strategies of all three riparian states and in the DAC criteria. Discussions among the participating scientists and stakeholders within the frame of separate sessions allowed a second step for the identification of the most meaningful, although not comprehensive, individual indicator from each of these three sets. The development of these indicators was rated as central first step in assessing the success of IWRM approaches and the selection between alternative IWRM strategies.

- Indicator 1: Closure of gaps in municipal water demand. IWRM-specific area: potential additional water supply, DAC-criteria: relevance, effectiveness and impact
- Indicator 2: Recuperation of total costs for water services (supply and sanitation). IWRM-specific area: costs of additional water through improved technologies, DAC-criterion: efficiency and sustainability
- Indicator 3: Environmental Water Stress (EWS). IWRM-specific area: controlled mass flows, pollutants in water and land, DAC-criterion: relevance, effectiveness and sustainability

The local IWRM studies presented below show that the outcomes of alternative IWRM strategies can be assessed by using most of the above mentioned performance indicators.

4.6 Local IWRM studies in the Lower Jordan Valley

4.6.1 Introduction

The IWRM approach which was developed on the western side of the Jordan River, i. e. the local IWRM study on the Wadi cluster Auja, Nuema and Qilt in the Palestinian Territories (see Figure 2) is briefly summarised in section 4.6.2. Parts of the framework had been promoted for many years and, in the meantime, are partially implemented within the Ministry of Water and Irrigation, Amman. The local IWRM study on Wadi Shueib in Jordan is therefore described in more detail (see section 4.6.3).

4.6.2 IWRM study Wadi Cluster Auja, Nuema, Qilt

In the western sub-catchment cluster of the LJV, comprising the Wadis Auja, Nueimah and Qilt, a methodological approach (concept) has been developed which leads to an integrated water resources development plan. The approach is characterized as a water resources planning and is strictly participative, involving the relevant stakeholders. The final water resources development plan indicates

clearly how priority interventions in terms of structural measures (e.g. pipelines, surface water retention structures, shallow or deep wells) and management measures (e.g. subsurface water storage and recovery by Managed Aquifer Recharge, demand management or water mixing) should be combined. The final water development plan, specified as a IWRM strategy, presents the best balanced solution between the most relevant social, environmental and economic water development objectives and stakeholder preferences. Software tools, including e. g. a Multi-Criteria-Optimisation algorithm, have been developed to support the decision making process (see Wolf et al. 2010, Kaempgen et al. 2014), e.g. with regards to the identification satisfactory compromise solutions between conflicting development objectives and ranking of alternative IWRM strategies (software may be downloaded and installed: <http://www.ewre.com/smartdss/publish.htm>).

The approach schematically displayed in Figure 7 has been applied for the typical rural sub-basin of Wadi Auja in cooperation with stakeholders, such as the Palestinian Water Authority (PWA), the Palestinian Ministry of Agriculture (MoA), the Israeli Water Supply Company (MEKOROT) and the Palestinian Hydrology Group (PHG) (further details see Rusteberg et al. 2014).

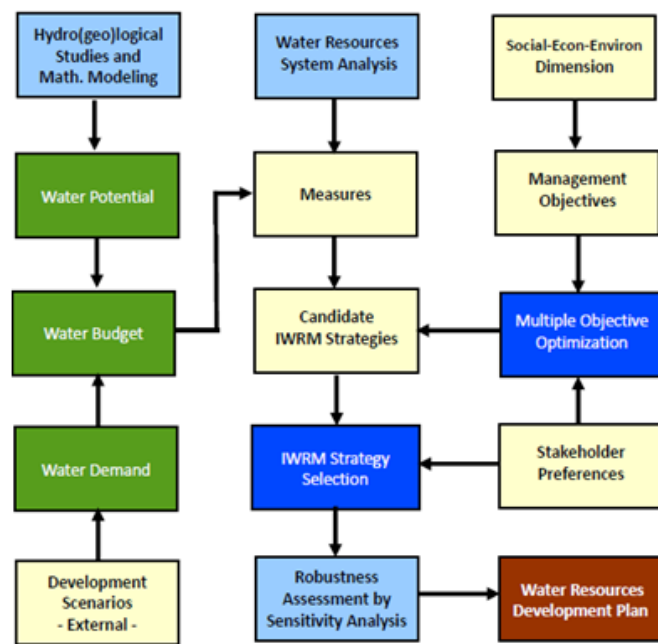


Figure 7: Scheme for the local IWRM study applied at the Wadi Cluster Auja, Nuema, Quilt in the LJV (Rusteberg et al. 2014)

4.6.3 IWRM study Wadi Shueib, Jordan

Study area and water resources

The Wadi Shueib is a Jordanian side valley incised into the eastern rift shoulder of the Lower Jordan River Basin (see Figure 2) with a catchment area of 198 km² upstream of the 1.4 MCM (million cubic meters) Shueib Reservoir. The karstified Upper Cretaceous Aquifer Complex is the primary source of fresh water and feeds several springs with a combined average discharge of about 10 MCM/y. However, the aquifer also receives unintentional recharge and is particularly vulnerable to pollution from abundant domestic sewage leakages (Abu-Jaber et al. 1997, BGR & MWI 2010, Werz 2006). Thus, growing demand is combined with pollution-induced yield reduction and high physical losses (28 %) in the supply infrastructure (MWI 2004). As a consequence, water imports have increased considerably during the last years, although the quantity of local freshwater could be still sufficient to cover the officially anticipated supply of 100 l/c/d for the approximately 120,000 domestic users.

Future projections based on official demographic scenarios (HPC 2009) would result in almost 50% imported water for the drinking water supply until 2025, if less mitigation actions are taken. However, increased imports would compete with neighbouring demand sites, particularly the nearby Jordanian capital Amman. Downstream farms in the Jordan Valley receive irrigation water from the Shueib Reservoir and any alteration of the allocation system must also consider the impact on these communities.

Objectives of the local IWRM study for Wadi Shueib

With the involvement of local stakeholders, a specific concept was taken as the basis for the management strategy of the Wadi Shueib catchment. The concept is outlined by the following steps:

- 1) Identification of the basic IWRM components for the specific sub-basin;
- 2) Reporting the gaps between existing water technologies and modern technologies that could be introduced;
- 3) Definition of the needs and challenges of the specific water management plan;
- 4) Determination if alternative water management options can be integrated into the IWRM plan;
- 5) Development of a transparent framework for the quantitative downscaling of regional scenarios to sub-basin scale.

The primary objective of the modelling approach was to develop a local IWRM study to test the IWRM planning possibilities provided to the local decision makers (Riepl 2013). The data were received directly from water sector institutions (WAJ, laboratories, etc.) in Jordan and their respective monitoring programs. For

the model construction, the WEAP21 Water Evaluation and Planning (WEAP) tool was used. The location and schematic processes are shown in Figure 8.

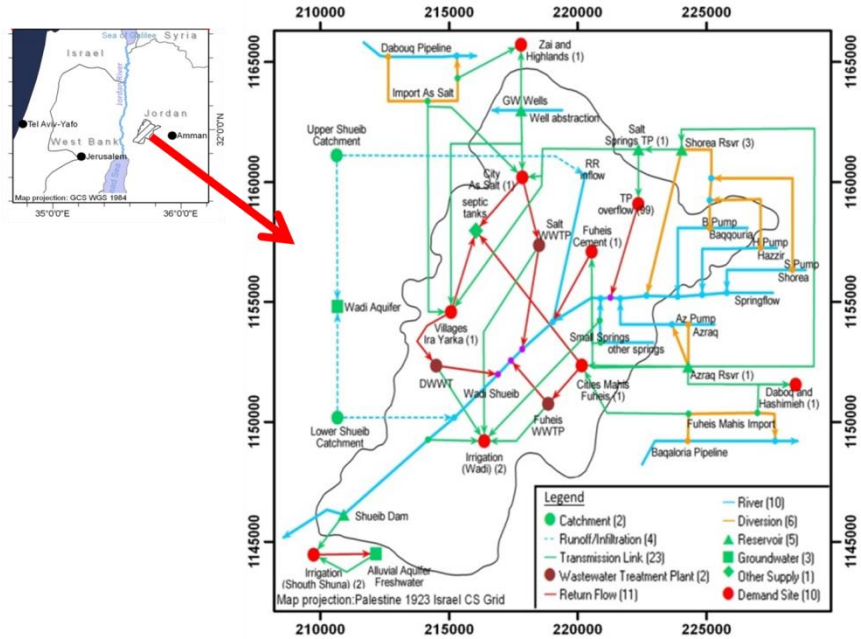


Figure 8: Location and schematic WEAP21 presentation of the Wadi Shueib catchment (Riepl 2013)

After the model was satisfactorily conceptualized, calibrated and validated (Riepl 2013), it was used to simulate various scenarios. Planning alternatives were derived from the Jordanian National Water Strategy (MWI 2009) as a subset of appropriate goals and measures for the local water sector challenges (Table 3).

Table 3: Strategic objectives of the Jordanian Water Strategy, implementation in the Wadi Shueib area, and selected indicators for performance evaluation.

National IWRM Objective	Implementation in the Wadi Shueib model	Performance Indicator
Increase volume of captured and treated wastewater	Increase the sewer connection ratio in As Salt, Fuheis and Mahis (i. e. major cities in Wadi Shueib)	I.1b: Municipal wastewater re-charge ratio [%] (WWrecharge)
	Leakage reduction from municipal wastewater	
	Install decentralized wastewater treatment units for rural communities	
	Decrease the losses from septic tanks	
Maximize Resources Availability	Increase amount of treated wastewater directly allocated to agriculture	I.2a: Available groundwater for internal use [m ³ /c/y] (AWR _{internal} /gw)
	Cement factory builds rainwater harvesting pool	
Secure constant drinking water supply	Increase capacity and efficiency of pumping stations and Salt Springs microfiltration plant to meet needs	I.3a: Municipal water supply shortage index [-] (WSS _{municipal})
	Reduction of physical supply losses	I.4a: Municipal water supply requirement [m ³ /time step] (WSR _{municipal})
Demand management	Per capita domestic consumption does not rise above 120 l/c/d	I.5: Full water service cost [JD/m ³] (FSC _{uc/municipal})
Improve cost efficiency of water services	Increases of revenue per supplied m ³ from the water treatment plants and the water imports	I.6: Environmental water stress [-] (WSI _{rf})
Protect water resources and environment	Spring protection zones	
	Monitor minimum flow requirement for wadi stream.	

For the scenarios, the identified alternatives were combined in two action plans for the Wadi Shueib area: a *Business as Usual* (BAU) strategy assuming the currently active projects are continued and finished until 2025 (projects marked as bold in the second column of Table 3); and a *Full Implementation* (FI) development scenario assuming the full range of stated implementation approaches is realized until 2025 (the complete second column of Table 3). Both planning alternatives were

set in a 15-year horizon considering two alternative sets of external driving forces. Driving forces were chosen to agree with the official projections for climatic conditions (MWI 2009), demographic growth (HPC 2009) and water demand development (RCW & MWI 2009) as recognized by the Jordanian water sector institutions. The driving forces grouped in a set of four planning scenarios are depicted Figure 9.

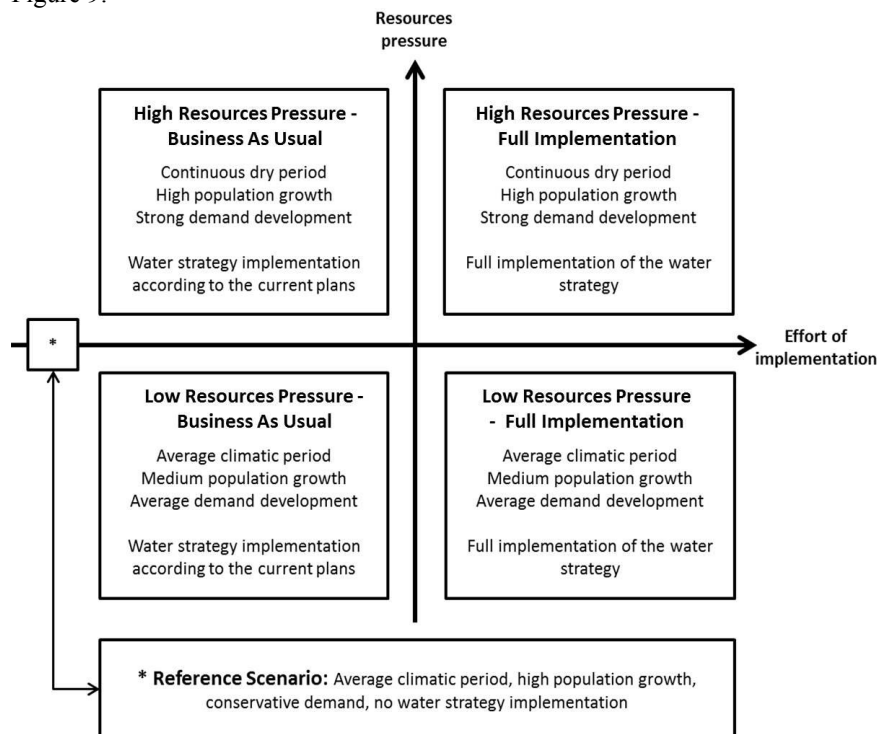


Figure 9: Alternative development scenarios until 2025. The scenarios are characterised by the development of the drivers towards a future of high or low resources pressure (HRP or LRP) and towards a business as usual or a full implementation of the water strategy objectives (BAU or FI) (Riepl 2013).

The scenario simulations conclude that only an increased effort (Full implementation scenarios) will enable a progress towards the goals of the national water strategy and a successful IWRM process in the Wadi Shueib area. The current projects in the area, even when extended into the near future (BAU scenarios), appear to be incapable of relieving water supply problems. Furthermore, meeting future requirements is strongly dependent on the uncertainty of near to mid-future climatic, population growth and water demand development.

The modelled and standardized performance scores for the most significant indicators for the planning scenarios are plotted for comparison (Figure 10). The major downside of the FI alternative is that considerable investment costs are in-

involved. Due to the reduction of expensive water import volumes, the unit cost of water services does not rise linear with the anticipated investments. Yet, it was still simulated to significantly increase from the current 0.595 to 0.958 Jordanian Dinar/m³ in the LRP-FI scenario in 2025 (Note: 1 JD corresponds to approximately 1.4 US Dollar). However, in the light of the current water sector expenditures (including MWI, WAJ, JVA, Aqaba Water Company, and Miyahuna) that were estimated at approximately 500 million Jordanian Dinar (JD) in 2010 (Sommaripa 2011), the anticipated investment costs for the FI scenarios (~94 million JD over 15 years in a region with 2-3 % of the country's population) are not overambitious. This is particularly the case with aspiring mega-projects like the Red-Sea-Dead-Sea canal with currently estimated costs of approximately 4 – 8 billion JD (World Bank 2009).

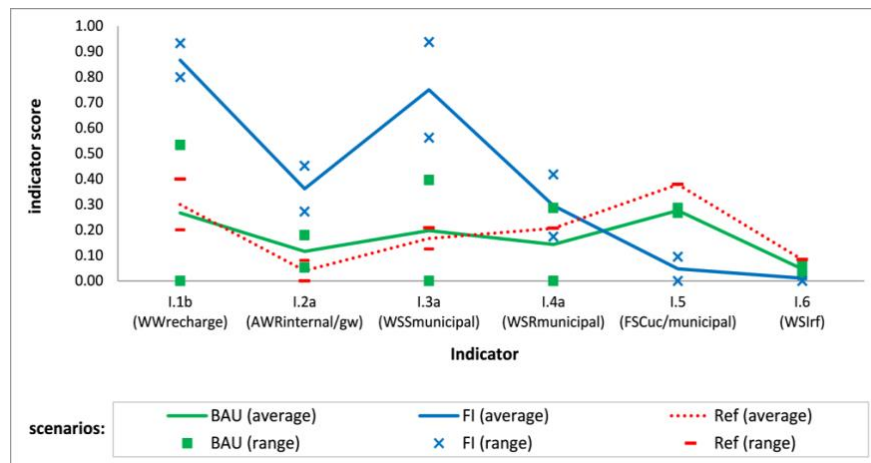


Figure 10: Summary of the standardized scenario simulation results for the BAU and FI planning alternatives. Higher score indicates a better performance. A broad range in scores expresses sensitivity to the external scenario driving forces (LRP/HRP).

Acronyms: BAU = Business As Usual, FI = Full Implementation, Ref = Reference scenario; I.1b, I.2-4a, I.5 and I.6 = Performance Indicators, detailed description see Table 3.

Regardless of this major infrastructural projects, it is expected that further water tariff reforms will be necessary to progress towards the objective of cost recovery in the water sector; considering that currently, the revenues of the WAJ and the public companies do not cover their annual expenditures (Segura/IP3 Partners LLC 2009).

The simulation results in the Wadi Shueib study also reflect the general Jordanian situation. During the last decade, the water sector has mostly focused on the

maximization and development of resources, as well as the extension of sanitation services. Until recently, the reduction of the tremendous water losses and the realization of efficient demand management and water awareness campaigns have played secondary roles.

Limitations and Uncertainties

The presented study provides valuable quantification for items such as water costs, but does not give any insight about the difficulties experienced during approach setup. Obstacles arise throughout the data acquisition, quality control, and data processing. These are extensive, time consuming tasks due to the widespread distribution of data over several competent authorities. Moreover, a significant discrepancy in data format throughout collection needed to be managed. While some data were available in digital form and therefore relatively easy to process and incorporated, there was also other data still stored in rudimentary formats, i.e. handwritten notes, which required transcription and standardization into digital formats.

The quality of the input data was identified as a limiting factor as the accuracy of the results is always highly dependent on quality input. Some of the provided parameters are only available as aggregated values (i.e. daily to monthly averages), which requires interpolation of data to maintain temporal consistency. This interpolation increases the uncertainty of the calculated results, e. g. groundwater recharge.

Further limitations are inherent within the WEAP code itself, which represents the groundwater component in the catchment as a relatively simple bucket model. To obtain a more holistic and comprehensive assessment in the future, the coupling of WEAP with numerical groundwater models is necessary.

A basic requirement for the implementation of planning tools and technologies is the economic assessment of the results. The presented IWRM study Wadi Shueib included a cost calculation and provided a first estimate of the economic effects and costs of the water management options. Nevertheless, decision makers and donors need to be provided with a solid economic assessment. Cost Benefit Analyses, Multi-Criteria-Analyses (Bensabat et al. 2014, Heinz et al. 2014) or the calculation with MYWAS (Multi Year Water Allocation), which is based on the WEAP model, employ a wide range of highly sophisticated economic methodologies and aim to deriving appropriate water prices and economically efficient IWRM strategies to tackle particularly water scarcity problems (Fisher and Huber-Lee 2012, Fisher et al. 2005).

For a sustainable transfer of knowledge from research to implementation, an interface between the project and the competent authorities is a fundamental prerequisite. In SMART, a national implementation committee (NICE) could be established directly at the MWI in Amman, Jordan. The focus of NICE is directed on the implementation of decentralized wastewater treatment plants in Jordan. The mission of a national implementation committee needs to be adapted to the project outcomes.

Above all, IWRM and its implementation is not just a task at the end of the research and development project but should be viewed as vigorous and long term process that requires competent consultation and highly motivated staff.

In SMART it was experienced that successful implementation should be started with the beginning of the project. Meaning the dialog with development banks and stakeholders needs to be initiated from the beginning of the project.

5 Summary and recommendations

SMART is an IWRM project in the water scarce region of the LJV with the objective to support the stakeholders with the development and implementation of adapted water strategies. The project is taking into account both conventional and non-conventional water resources and was conducted at numerous demonstration sites for decentralised wastewater treatment and reuse, managed aquifer recharge and brackish water desalination.

Local studies integrating basic elements of IWRM have been developed and applied on sub-basin scale on the eastern and western side of the Jordan River. Each of the studies includes the evaluation of existing water management systems as well as an assessment of future development scenarios including the aforementioned technology implementation. The basic steps were derived and incorporated into a process scheme for the set-up of a framework for water resources planning and implementation (see Figure 4). This scheme may serve as a guideline for other regions facing water scarcity.

The approach for the Wadi Shueib, which was already in parts implemented and in use by the stakeholders in Jordan, consisted of a combined modelling and scenario planning framework describing a potential path towards an operational realization of the ambitious IWRM concept on the sub-basin scale. The modular framework is based on the analysis of the water strategy, planned water management options and scenario definition. As such, the framework appears to be viable for expansion and continuous development. The detailed analysis of the standard objectives with regard to implementation options and suitable performance measures (indicators) is an important contribution to the local IWRM planning endeavours. In this regard, the study offers a proof of concept and a methodological framework for the application in other sub-basin scale sites.

The established scenarios are only a subset of options that provide a basic framework. For the further application in planning and strategy decisions, the development of other scenarios is recommended, for example, isolating selected aspects of the full implementation of options or other combinations of conditions. The model presented in this study is flexible enough to implement such changes in relatively short time.

The modelling framework for Wadi Shueib presented here successfully illustrates the objective to provide decision makers with interdisciplinary and integrated planning support that is equally based on national IWRM policies as well as on

sound science. It is therefore a viable instrument to progress towards operational IWRM and may be transferred to other regions suffering water scarcity.

While the framework provided by SMART has been proven on catchment scale, it would be necessary in a next step to upscale it to cluster scales relevant to water management to derive a generalized IWRM concept.

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