Surface water storage reservoir at Auja, Palestinian Territories (© Muath Abu Sadah)

Managed aquifer recharge (MAR) planning for the Jericho-Auja area

Florian Walter[1/4], Bernd Rusteberg[1], Muath Abu Sadah[2], Abdelrahman Tamimi[3], Torsten Lange[4], Martin Sauter[4]

KEY FINDINGS

The alluvial aquifer system around Jericho-Auja is overexploited.

MAR implementation at the study area is an obligatory measure but requires the installation of additional deep wells and hydro-infrastructure for the collection, treatment and reuse of waste water in irrigated agriculture in the context of the integrated management of the local conventional and non-conventional water resources (IWRM).

Spring discharge from numerous springs present a great water potential and is, therefore, the most important source of water in the area. Corresponding surpluses should be used together with surface runoff directly for Managed Aquifer Recharge, while additional local water resources should be used for irrigation purposes.

Three infiltration sites are suggested to allow for the controlled recharge of the shallow alluvial groundwater system (one site at Auja, two sites at Jericho).

The site in Auja is proposed to be implemented as pilot facility.

MAR infiltration ponds should be implemented together with passive infiltration wells in order to maximize the recharge efficiency.

Water transfer from neighboring basins and even from more distant areas will be required in order to ensure sustainable agricultural development and to avoid the depletion of the alluvial shallow aquifer system.

Introduction and Objectives

MAR studies at Jericho and Auja conducted during the SMART-MOVE project were based on the results of the prior SMART II project and earlier studies (e.g. Rusteberg et al., 2014, 2014a, 2014b; Rahman, 2011; Rahman et al., 2012). The prior research already stated the overexploitation of the shallow alluvial aquifer system. The aquifer was identified as suitable for MAR purposes. Preliminary studies were conducted in order to select appropriate infiltration sites for controlled aquifer recharge. The present research studies performance and impact of different MAR implementation strategies in the context of an integrated management of all available water resources, especially with regards to the alluvial groundwater system, taking different climatic and socio-economic development scenarios into consideration. The research finally aims at the development of recommendations for MAR implementation in the study area and, specifically, on the installation and operation of a MAR pilot plant at Auja village.

Methodology

Based on the results of the European project Gabardine (Rusteberg et al., 2012), a new integrated MAR planning approach has been developed and applied to the case study of Jericho-Auja (Figure 1). It consists of ten steps that are aligned in an iterative manner and designed to be applicable for any given case study that aims at the assessment of MAR feasibility and recommendations for MAR implementation. The central element is the development and comparison of alternative MAR strategies as key measure in the context of IWRM implementation. The

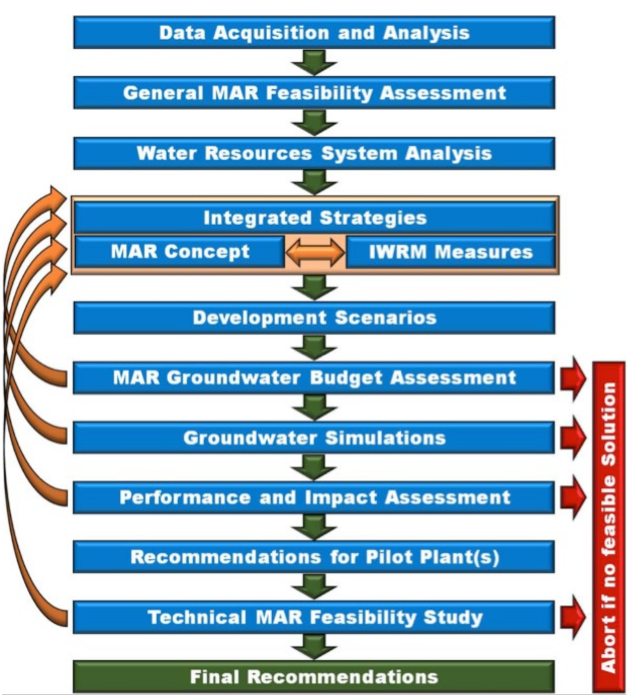

Figure 1: Illustrated overview of suggested integrated MAR planning approach (Walter, 2018).

impact and performance of each strategy as a combination of measure, is analyzed by water budget assessments and groundwater-simulations for different climatic and socio-economic development scenarios.

Results

Three suitable locations were identified: one at Auja village and further two at the City of Jericho (Figure 2). For each location the implementation of new hydro-infrastructure is required. It is suggested to use spring discharge and surface runoff as a source of MAR. Since the existing water transport and distribution network implies high losses of water, maintenance and modernization measures are required. Existing canals and pipelines require rehabilitation and their extension to minimize water losses during transport and to enable the efficient water transfer from the springs to the individual MAR location. These measures refer to all springs in the area: Auja, Nueimah Spring Group, Sultan Spring and the Qilt Spring Group.

The suggested locations are downstream of the Wadis where storm flood events occur on a highly irregular basis. The construction of additional earth dams at Wadi Nueimah and Wadi Qilt is required for the retention of surface water runoff. Further additional pipelines are needed to transfer the captured surface water to the MAR infiltration sites. Pre-treatment, for example by settling pits, is required to reduce sediment load. Detailed information on the dimensioning and cost of all hydro-infrastructure required for MAR implementation is provided by Rusteberg et al. (2018).

Table 1: MAR-Strategies that were analyzed at the Jericho-Auja case study.

IWRM STRATEGY	SPRING DISCHARGE	RETENTION OF SURFACE RUNOFF	TREATED EFFLUENT REUSE	DEEP WELLS
A	X	-	-	-
B	X	-	X	X
C	X	-	X	-
D	X	-	-	X
E	X	X	-	-
F	X	X	X	X
G	X	X	X	-
H	X	X	-	X

Table 1 presents different strategies for MAR planning and management. Strategy performance and impacts were studied by water budget assessments and groundwater flow simulations for different development scenarios. The results show clearly that MAR cannot be implemented as single, isolated water resources management measure but should be part of an overall IWRM implementation strategy. Due to the water potential of the deep carbonate aquifer system, the construction of deep wells in both municipalities is highly recommended. Further, the reuse of treated waste water contributes significantly to the resilience of the water resources system against high hydrological variability.

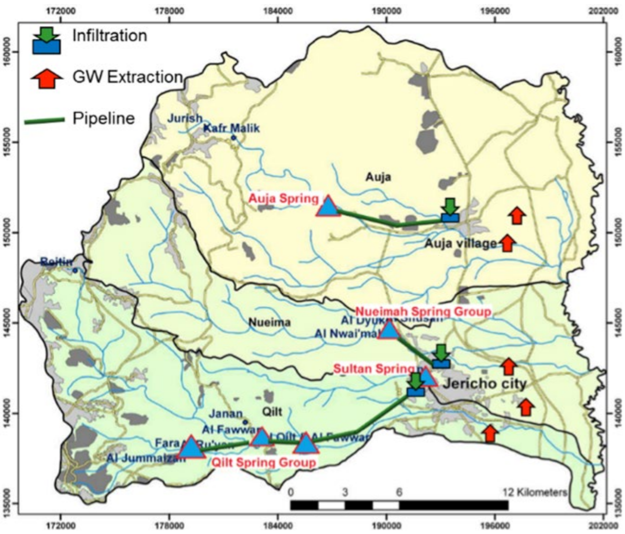

Figure 2: Schematic of suggested MAR locations in the Jericho-Auja Wadi Cluster.

Figure 3 shows that, after covering the total water requirements just by means of spring discharge, according to strategy A, little water surplus would be available for controlled groundwater recharge (blue columns), resulting in large water deficits. The accumulated water deficit after balancing for 20 years is 193.5 MCM (black line). This deficit, averaging about 8 MCM per year, can only be partially covered by controlled groundwater recharge.

The remaining water deficits would have to be covered by shallow wells and other local water resources to ensure irrigation development. Figure 4 clearly shows the effects of the 5-year dry period after 10 years. During this period, no spring discharge can be provided for controlled groundwater recharge and the water deficits exceed 12 (MCM)/ a. As expected, additional

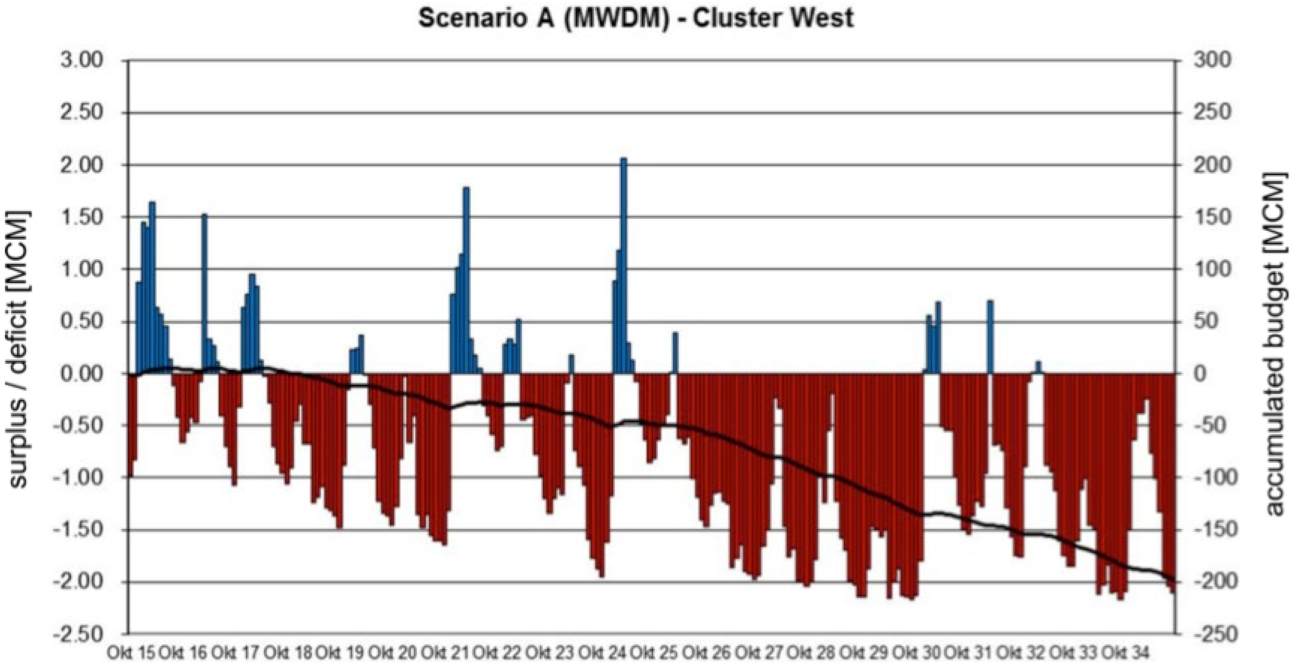

Figure 3: Water budget assessment for MAR strategy A for the upcoming 20 years under the assumption of moderate climate conditions.

local water resources should be activated to cover or minimize water deficits. The results show the need for an integrated water management approach.

Figure 4 shows the results of the water budget calculations against the background of the dry climate scenario (MDDM) for strategy F. The influence of the extended dry period of 10 years is clearly visible. Groundwater recharge can only be carried out within a few months, with almost significant water deficits during the extended dry period. During this period, monthly water deficits average nearly 1 MCM. The accumulated budget line assumes negative values after 7 years, resulting in an accumulated water deficit of 94 MCM at the end of the 20 years planning horizon.

The assessment was supported by groundwater flow modelling (Abu Sadah, 2017). By analyzing the impact of the designed measures for different climate and socio-economic development scenarios, the MAR locations (Figure 2) could be optimized.

Figure 5 compares the impact of different MAR strategies on the future evolution of the mean groundwater level in the study area, taking into account the dry climate scenario and full agricultural development. In the case of the so-called „Do

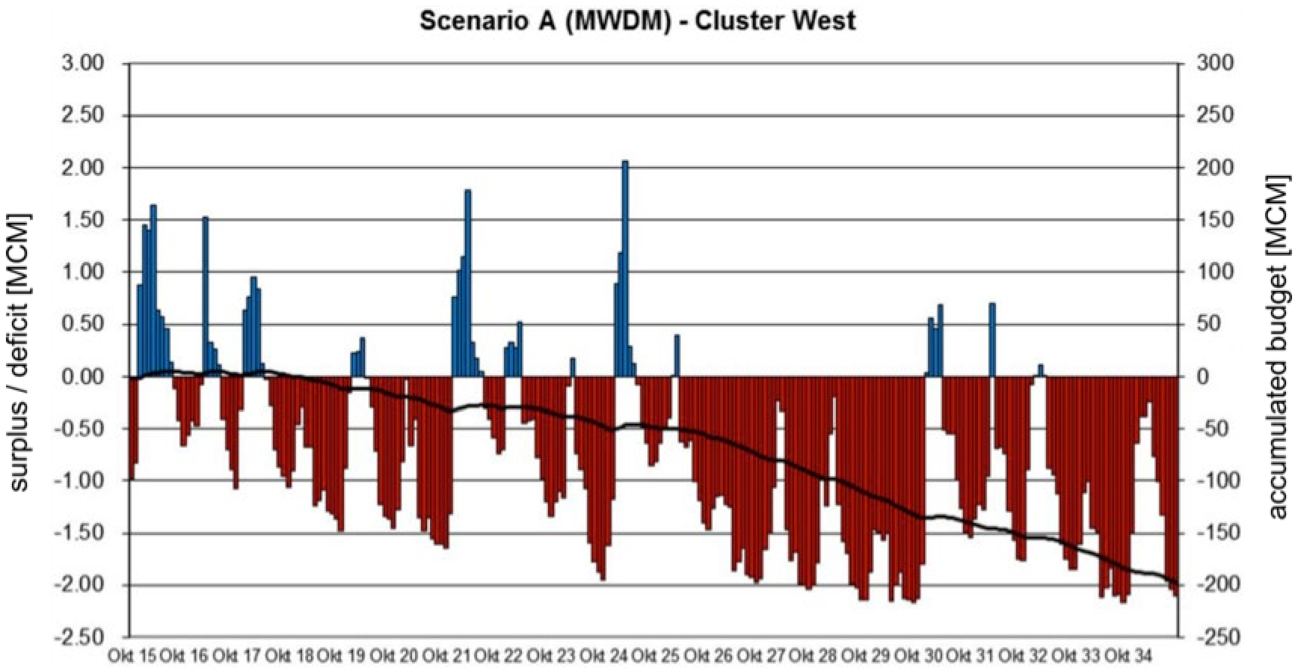

Figure 4: Water budget assessment for MAR strategy F for the upcoming 20 years under the assumption of dry climate conditions.

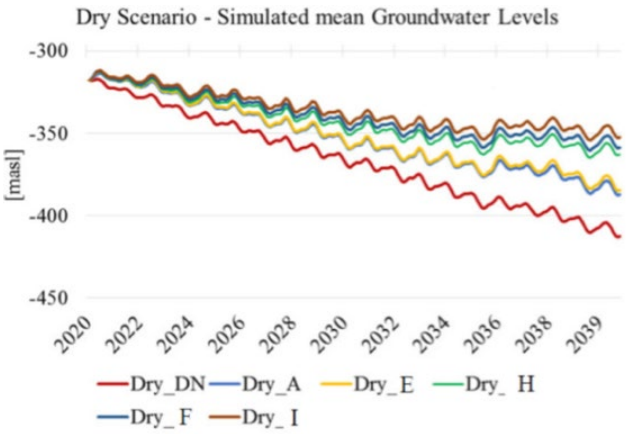

Figure 5: Simulation of mean groundwater levels for all three MAR sites under extreme climatic scenario with agricultural extension for all developed strategies (Walter, 2018).

Nothing Approach“ (DN: Without MAR implementation: lower red line), the groundwater level decreases drastically during the simulation period of 20 years. By MAR implementation as part of the integrated strategy F the groundwater level draw-down can be reduced by more than half of the total.

Strategy I (dark red top line), not previously considered, refers to the import of treated wastewater from El-Bireh, near the city of Ramallah to be applied for irrigated agriculture. The import of sewage gives a slight improvement compared to strategy F, but groundwater level decrease is still significant. The necessary extension of the irrigated area, despite integrated water management and MAR implementation, can only be realized at the expense of an accelerated lowering of the groundwater table of the shallow alluvial aquifer.

The water budget assessment and groundwater simulation studies revealed that additional water imports to the area from neighboring basins and even from more distant areas will be required in order to ensure sustainable agricultural development and to avoid the depletion of the alluvial shallow aquifer system.

Further Research Needs

It is highly recommended to install at least one MAR pilot plant in the area, preferably at Auja. It should be fed by spring discharge and retained surface runoff from the Auja dam. The plant should be designed as passive infiltration ponds with additional dug wells to increase infiltration rates. At least two ponds should be installed in parallel to switch operation regularly to maintain the ponds, especially against clogging. The experiment should be combined with tracer tests and monitoring of the groundwater level and quality around and downstream the test facility. Furthermore, it is highly recommended to combine the pilot plant with a new deep well. The well should supply the local municipality and farms directly and not be used for MAR. It should compensate for withdrawing water from the spring to use for the experiment.

AUTHORS / FURTHER CONTRIBUTING PARTNERS

RWC[1], HEC[2], PHG[3], UGOE[4]

CONTACT

Prof. Dr. Martin Sauter

Georg August University Göttingen, Germany, Applied Geology
Goldschmidtstrasse 3
37077 Göttingen

martin.sauter@geo.uni-goettingen.de

References and Further Reading

ABU SADAH (2017): Development of a Modflow groundwater model Jericho-Auja. Unpublished report, SMART-MOVE Project. HEC Ramallah, Palestine.

RAHMAN, M. A., (2011): Decision Support for Managed Aquifer Recharge (MAR) Project Planning to Mitigate Water Scarcity based on Non-conventional Water Resources. PhD Thesis. Georg-August-University-Göttingen.

RAHMAN, M. A., RUSTEBERG, B., GOGU, R. C., LOBO FERREIRA, J. P., SAUTER, M. (2012): A new spatial multi-criteria decision support tool for site selection for implementation of managed aquifer recharge. Journal of Envrionmental Management 99, pp. 61 -75

RUSTEBERG, B., WALTER, F., SADAH, M.A., TAMIMI, A., NOFAL, I., T. LANGE, M.SAUTER; 2018: : Planning of MAR-facilities in the case study area Jericho-Auja, taking spring discharges and storm water utilization into account, BMBF-Research Project SMART-MOVE (FKZ 02WM1355H), Project Deliverable D2.1.1.

RUSTEBERG, B., RAHMAN, M.A., J. BEAR, J. BENSABAT, R.C. GOGU, S. BROUYERE, P. WOJDA, M.A. SADAH, J.P. LOBO-FERREIRA, SAUTER, M. (2012): Decision support for MAR planning in the context of integrated water resources management, Chapter 23 in: Advances in Water Reclamation Technologies for Safe Managed Aquifer Recharge - Christian Kazner, Thomas Wintgens, Peter Dillon, 2012 - ISBN – 9781843393443.

RUSTEBERG, B., BENSABAT, J., WALTER, F., RIEPL, D., GUTTMAN, Y., TAMIMI, A. R., SAUTER, M. (2014): IWRM Strategies at local sub-basin level, sensitivity analysis and performance assessment. Unpublished report, Deliverable D803-804-805, SMART II project. Georg-August-Unviersity Göttingen.

RUSTEBERG, B., WALTER, F., ALKHOURY, W., TAMIMI, A. R., GUTTMAN, Y., SAUTER, M. (2014a): Quantification and spatial delineation of currently untapped water resources. Unpublished report, Project Deliverable D402, SMART II project. Georg-August-Unviersity Göttingen.

RUSTEBERG, B., WALTER, F., XANKE, J., KLINGER, J., SADAH, M. A., MAREI, A., SALAMEH, E., GUTTMAN, Y. AND TAMIMI, A. R. (2014b): Development, Evaluation and Ranking of Managed Aquifer Recharge (MAR) Planning Options in Case Study Areas of the Lower Jordan Valley. Unpublished report, Project Deliverable D318-320, SMART II project. Georg-August-University Göttingen.

WALTER, F. (2018): Conceptual Planning of Managed Aquifer Recharge in the Context of Integrated Water Resources Management for a semi-arid and a tropical Case Study in Palestine and Brazil: A new Integrated MAR Planning Approach. - PhD Thesis. Georg-August-Universität Göttingen.