PREFACE

The Regional Knowledge Network on Systemic Approaches to Sustainable Water Resources Management (R-KNOW) forms part of IUCN ROWA's Regional Programme on Water Resources and Climate Change and is implemented in close cooperation with a number of key partners in the MENA Water Sector, such as CEDARE in Egypt, PHG in Palestine, SPNL in Lebanon, AOW in Jordan, the Abdelmalek Essaâdi University of Tetouan in Morocco, and EMWIS in France. R-KNOW has been started as a project funded by the European Union (2013-2015) to assist in strengthening the application of systematic approaches to sustainable water resources management in five countries (Lebanon, Jordan, Palestine, Morocco and Egypt) and to share all relevant knowledge on these issues. The partners in R-KNOW have the firm commitment to pursue their collaboration and notably through activities that contribute to the RKNOW (http://www.rknow.net).

The core of this knowledge is the information collected on practical implementation of such systemic approaches in relevant pilot projects in different contexts. As lessons learned were not sufficiently shared among those intending to apply systemic approaches, it was deemed necessary to make an inventory of and synthesise the information about the experiences already made for others to refer and learn from[1].

As part of RKNOW's Knowledge Strategy for creating and sharing knowledge, knowledge products will be developed for its different Sustainable WRM Themes. This document is the first in a series of RKNOW knowledge products, bringing together work done in the domain of sustainable water resource management through integrated and participatory development approaches.

This document will share with a broad audience of practitioners and policy makers, notably in the West Asia and Mediterranean regions, **what integrated approaches are necessary to make water resource management and climate change resilience actions a success**. It will describe the underlying conceptual framework of these different approaches that underpin successful action in the four Thematic Areas distinguished within the RKNOW:

(i) Local Water Governance,
(ii) Climate Change and Water,
(iii) the Water, Food and Energy Nexus, and
(iv) **Innovative & Sustainable Water Technologies**.

This conceptual framework recognizes that in the region targeted by RKNOW, development and management of water resources is closely inter-linked with the development and management of drylands and rangelands through appropriate ecosystem approaches. The publication will illustrate the different integrated approaches proposed by sharing hands-on experience in their implementation, presented as specific case studies prepared by the RKNOW partners. From these case studies it will draw lessons and formulate recommendations that form part of the in-depth knowledge creation and sharing process engaged by the RKNOW partners and stakeholders in their respective five countries mentioned above.

[1] http://rknow.net/index.php/en/themes-en/project-database

CHAPTER 5. Innovative and Sustainable Water Technologies

Where empowerment and active involvement of local users and beneficiaries of water resources is a prerequisite to operate and sustain integrated water resource management (IWRM), there is also urgent need to explore how actually used water technologies can be innovated to make water resource management sustainable. This is all the more important in view of the imminent needs to adapt to processes of climate change and the erosion of ecosystems that provide the natural resource basis for use of water for agriculture. This Chapter will illustrate how such technological innovation could take place in one of the Palestinian watersheds as one outcome of a long process of social organization and participatory planning with stakeholders at both local and national levels. Hydrological flows from water run-off from the surrounding hills to recharge of aquifers from flood water form an important factor in preserving the agro-ecosystems in this very fertile but closed watershed. Good management of water resources and related ecosystems has indeed been enhanced by local water governance practice and social organization, also in view of a highly restrictive Israeli occupation measures that strongly affect access to water, compounded by possible climate change threats.

5.1 Marj Sanour Watershed Management

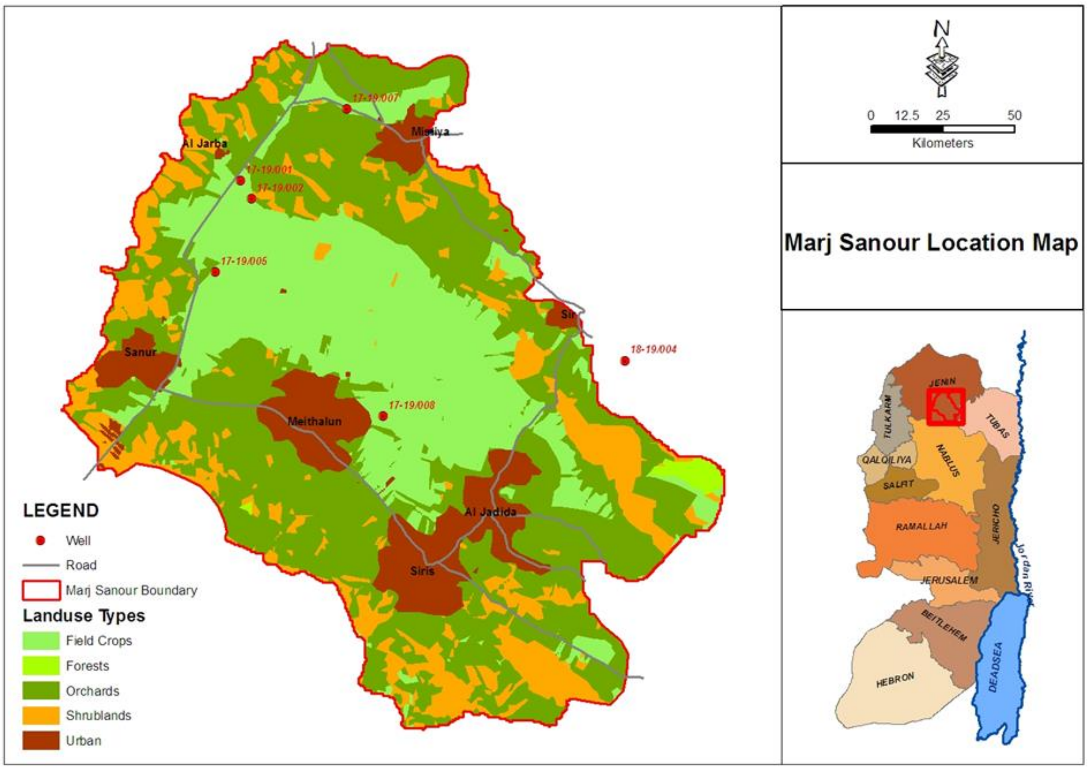
Mountain ecosystems in Palestine

Description of the watershed

Marj Sanour is a small watershed of a valley in Jenin Governorate in the northern part of the West Bank in historic Palestine. The watershed covers about 59 km^2, with a valley floor of 16 km^2 (16,000 dunum) and is situated within the area of the North-Eastern Aquifer Basin (Jenin-Nablus Basin) and has a Mediterranean Climate (SEARCH, Weshahi et al, 2013). Much of the surrounding hills are planted with fruit orchards (26,241 dunum), dominantly olives, the most important cash crop in the country used for producing olive oil and other tree crops such as olives, grapes, figs, almonds and nuts In addition rainfed crops are grown including grain and vegetables as wells as vegetables based on irrigated agriculture (16,640 dunum), while bee keeping and livestock are common in the watershed region (Weshahi, 2013).

Marj Sanour (Sayel Weshahi)

Seven villages are situated in the watershed with a total population of 27,500. Landownership averages 13 dunum but can reach 250 dunum. Around 60 % of farmers own less than 10 dunum and around 15% more than 20 dunum (Weshahi et al, 2013). Most farmers, apart from their own land also rent land from others. Due to geological conditions, the valley has no surface water outlet, and as a result the valley is flooded almost every year, forming a lake of in places more than 4 meter deep. This water comes from surface run-off from the hills due to poor land management and water conservation. Rainfall (sometimes snow) can vary between 400 and 1200 mm with an average of 634 mm/year (Weshahi et al , 2013). In years of heavy rainfall the total amount of water standing in the valley can reach up to 10 million m³, while in very dry years flood volume is still about 1 million m³ (in the winter of 1991/1992 it reached an exceptional high volume of over 20 million m³) (Weshahi et al, 2013).



Map of Marj Sanour watershed

Because the rainwater cannot penetrate the heavy nutrient-rich clay soils eroded from the hills in recent ancient times, it is not possible to be recharged entirely to the shallow Jenin aquifer (of Eocene formation with a water level depth of 100 to 140 m from ground surface) and most is lost to evaporation and cannot be used in the following dry season for irrigation when there is water scarcity. The flooded area is around 5,000 dunum (average between 1990 and 2007) with a peak of 9,000 dunum in 1991/1992 (Weshahi et al, 2013). Thus, farming is limited both by flooding and the lack of water (drought) in the dry season. To compensate for this lack of surface water, further pressure is placed on the shallow groundwater reservoir.

Indeed, in spite of the important but unreliable flood water, groundwater remains the main water source in the Marj Sanour Watershed. While domestic water is mainly abstracted from deeper aquifers (notably from the Turonian-Upper Cenomanian Aquifer at more than 700 m depth), the shallow aquifer is mainly used for agricultural purposes. Abstraction of water from this shallow aquifer is mainly from around 50 irregular agricultural wells drilled in the area and estimated at 2.27 million m³ /year (Weshahi et al, 2013). Due to this over-pumping the water table of the shallow aquifer has dropped in the last 15 years by 80 meter or more than 5 meter/year. With still 20 meter depth of ground water left, it means that if no measures are taken there will be no water left in the aquifer in 4 to 5 years from now. Where this drop in ground water levels has caused serious reductions in pumping from agricultural wells, farmers have been forced to seek alternatives to increase water availability to sustain agriculture in the area.

It is important to note also that the Marj Sanour (marj means valley) is quite high positioned in the landscape and serves in fact as a "water tower" for the surrounding lower valleys, the aquifers underlying the marj feeding the wells in Qabatia to the north and springs and wells in Faria'a to the east.

Box 1. Real-time monitoring technology for water resources in Palestine

Groundwater is the main source of water in Palestine, but is under high stress of exploitation and contamination, for an important part due to severe access restrictions by Israeli Occupation Authorities. Widely observed effects are a decline of water tables as well as deterioration of groundwater quality. In many coastal areas, seawater intrusion or land subsidence is experienced.
Monitoring of an aquifer is of fundamental importance as a basis for groundwater resources management. Monitoring, data collection and analysis provide the information that enables rational management decisions on all kinds of groundwater resources and with regard to sustainability issues. At the same time, manual monitoring of groundwater levels using cable data loggers is a time and resource consuming activity. It often requires two or more people, it can damage the equipment, and does not even guarantee data series that are continuous. "Diver" water level data loggers are the world's most widely used instruments for automatic measurement and registration of groundwater level, conductivity, temperature, and other parameters.

Water level loggers can be read and programmed onsite or linked to a telemetry system for complete offsite management. For these reasons, the Palestinian Water Authority has installed an automated retrieval of diver data. The new technology with automated reels for divers is significantly time and efforts saving. This provides online flow monitoring for 48 potable water wells through transmission of the flow data to a central control room in Ramallah.

In the future, wireless data measurement will be added to the well monitoring network so that no manual involvement for retrieval will be needed, with no chance for diver damage, and only one person will be required to do the readings, bringing the time needed for collection of data to much less than at present.

Programme development background (2003 – 2015)[2]

As described above, it was urgent for all concerned to understand the options for dealing with both drought and flooding, two main problems that were blocking development and to find watershed management solutions that held benefits for all stakeholders. A watershed development plan was developed between 2008 and 2010 with close involvement of the seven communities in the watershed and with support from PHG and UAWC in a project that formed part of IUCNs Regional Water Resources and Dryland (REWARD) Programme in the Middle East. The watershed plan should enhance sustainable use of surface water and improved agricultural development, while diminishing the pressure on the groundwater reserves. The development of the watershed management plan built on earlier participatory stakeholder-led water sector planning efforts in Maithaloun, the main community in the watershed, by the EU funded EMPOWERS project with CARE International, PHG and UAWC.

[2] Adapted from case study in SPRING on ground water management (Laban, P., 2016; Social organization in ground water management; IN: SPRING, WANI, IUCN.

Application of the EMPOWERS Planning Cycle in Marj Sanour began in 2003 with an in-depth stakeholder analysis involving most relevant ministries – Palestine Water Authority (PWA), Ministry of Agriculture (MoA) and Ministry of Local Government (MLG) and Environmental Quality Authority (EQA) – at both governorate and national levels, water and land use groups and other community based organizations (CBOs), village and municipality councils, non-governmental organizations (NGOs) working in the area, and a Jenin-based university. The analysis looked at how these groups relate to the watershed in terms of their tasks, roles, interests and mandates. It also looked at information flows among them and their decision and coordination patterns.

Two platforms ensured participation of different local interest groups as well as the buy-in of the government institutions. An informal local stakeholder platform was set up for village council and civil society groups in the seven villages, NGOs working in the area, and officials at the governorate level. A national steering committee was also created involving community representatives, NGOs and national government agencies. Through the local platform, a participatory planning and decision-making process was used to work towards a vision for a long-term management plan for the Marj Sanour watershed. At the same time, and with the support of the national steering committee, a shared information-base of scientific and engineering data was developed as well as a decision support system for planning and testing different scenarios and strategies under which the vision for the watershed could be achieved. What is also important in the case of Marj Sanour that in this valley there is a special problem, the flooding, that cannot be solved at the individual or community level; this shared problem was an important reason for people and organizations to work together.

Following intensive discussions, seven villages decided to develop the Marj Sanour Watershed Association to coordinate and implement activities for all water and agriculture related activities, from drinking water supply and irrigation practices to soil and water conservation in the hilly parts of the watershed. The Watershed Association, formally registered with the government, now represents the villages in wider fora, where it can present proposals to the government agencies and the donor community, based on the conducted studies and results of the decision support system and the watershed development plan.

Further study has been done between 2011 and 2013 on climate change vulnerability and resilience in the water shed (Weshahi, 2013). Following IPCC (2007) parameters (Exposure, Sensitivity and Adaptive Capacity) the Marj Sanour watershed is categorized as highly vulnerable to drought and flood. An in-depth stakeholder consultation has developed a shared vision to respond to such vulnerability. This vision is formulated as follows:

> *Rural livelihoods in Marj Sanour watershed area are rescued through demonstrating effective ecosystem/watershed management tool and improving conjunctive use of both ground and surface water in order to improve agricultural practices.*

To strengthen community and watershed resilience in terms of diversity, sustainable infrastructure and technology, self-organization and learning, a set of priority actions were developed, with the most important infrastructure/technology actions being in the domains of water harvesting, reclamation and rehabilitation of land and ground water recharge.

Resulting main technical interventions that were proposed

<u>The watershed development plan</u>

The watershed development plan is the outcome of the above described multi-stakeholder participatory planning process and is endorsed by the MoA and PWA and the Marj Sanour Watershed Association that is registered with the the Ministry of Interior. It has received interest from development and funding organizations, triggering around 1 million USD of S&W conservation and water infrastructure investments until now and another 3 million USD for new similar investments, mainly for recharge wells and water reservoirs in the valley floor, and soil and water conservation through land rehabilitation and land reclamation on the hill slopes.

<u>Soil and water conservation in the hills surrounding the valley.</u>
To solve the flooding problem and carry over water to the dry season, the stakeholder group – using the mutual planning and multi-criteria analysis - recommended several projects centring on stopping floodwaters before they reach the valley by improving the terracing and water retention of soils in the hills and by building cisterns in the hills to collect and store water for supplementary irrigation of trees and crops on terraces as well as – thanks to restored terraces - to improve water retention and infiltration to the shallow aquifer. . They also recommended building more cisterns in the valley to carry over water to the dry season. Thus through land management (rehabilitation and reclamation and water harvesting), the water can be more evenly distributed over time to benefit both the hill and valley dwellers as well as the ecosystems in the watershed, while releasing pressure on groundwater reserves. Land rehabilitation in the form of stone retaining walls for terraces and cisterns is costing in average around 700 USD/dunum, including a 25% contribution from benefitting farmers (150 USD/dunum for about 30 meter retaining walls; and a cistern of 40 m^3 serving 3 dunums at a cost of 2,000 USD). Heavier works of land reclamation is costing around 1500 USD/dunum, the latter however resulting in more productive land (better soils/less stones, and more olive/almond trees that can be planted per dunum).

<u>Artificial recharge of shallow aquifers from flood water</u>.
To get rid of the water over-flooding the valley, strongly impeding agriculture on otherwise very rich soils, proposals have been developed to drill as a pilot two artificial water recharge wells that, after filtering the water from sediments and pollutants, bring excess water to the underlying shallow aquifer, now at around 140 meters deep.

The pilot demonstrates that artificial recharge is a very promising alternative that can contribute to enhancing ground water supplies. Groundwater recharge wells are suggested to be one of the most suitable techniques for the Marj Sanour area due to the following reasons:

a) availability of floodwater in the area on an almost annual basis, as large parts of the Marj are submerged during a period of a few months;
b) good storage potential within shallower aquifers, especially in view of receding ground water tables.

Filtration System - Gabions, around an artificial recharge well

The two pilot recharge wells were designed by the Palestinian Hydrology Group (PHG) and drilled under their technical supervision as an activity of the Land and Water Resources Management Project, implemented by UAWC and funded by the Netherlands. The main aim, as described above, is to assist in recovering the accelerated decline of groundwater levels, minimize the submerged agricultural area and in the long-term avoid that there will be no water anymore for agriculture on the very rich soils of this valley. The two wells were drilled in the areas that would flood the most, and the recharging water now passes through a filtration system that was built for the purpose of cleaning it up from sediment as the main contaminant of concern. It is estimated that the shallow aquifer will be recharged with about 9,000 m^3/day by the two wells; this means around 300,000 m^3 on an annual basis for an average flooding period in different parts of the valley of about one month. The groundwater level is planned to be monitored through the agricultural wells in the surrounding area.

As part of the participatory planning and decision process described above, a workshop was conducted in the Marj Sanour municipality in 2014, in the presence of the Palestinian Water Authority, Ministry of Agriculture of Palestine, PHG, the Union of Agricultural Work Committees (UAWC), farmers, Marj Sanour Watershed Association and well owners, to discuss the location of the two pilot artificial recharge wells. As stakeholders agreed, the Watershed Association supplied the land and is now managing the project with the support of all stakeholders. The locations of the boreholes were chosen in the area of the Marj that is most exposed to flooding but that is away from the mainstreams to avoid strong runoff loaded with huge quantity of suspended materials.

Further studies have been made on risks of chemical and biological pollution to make sure that this water will not pollute the aquifer. Chemical pollution is assessed as being minimal and not more than in other areas. Although studies on biological contamination are still underway, it is safe to say that, with the information available today, such contamination effects will be very little. Two recharge wells have been installed as a pilot at a cost of 60,000 USD each. As mentioned they are able to drain together 300,000 m^3 from the flooded valley that in years of heavy rain can contain around 10 million m^3. When 8 other recharge wells are installed, the resulting recharge of the aquifer could compensate the over abstraction for irrigation by the many irregular wells in the valley, now estimated at 2.27 million m^3/year. This would avoid a catastrophic situation that in 5 years time irrigated agriculture would not anymore be possible in this extremely fertile valley that can produce two to three crops a year. Moreover the recharged water will also benefit the springs and wells in nearby areas, such as in Faria'a and Qabatia. The installation of recharge wells is quite an innovation, unique in Palestine and even in the region. Staff of PHG is now requested to provide technical advice on similar interventions in Jordan, Iraq and Tunisia. Apart from the two pilot recharge wells also earth water ponds are constructed in the valley floor with a capacity of 25,000 m^3, for storage of flood water.

References:

Laban, P. (2016): *Social Organization in Ground Water Management.* In: SPRING, Publication Series of the Water and Nature Initiative (WANI) of the IUCN Global Water Programme (in final preparation).

Weshahi, Sayel, Majed Naser, Sireen Abu Jamous and Ayman Rabi, (2013). *Vulnerability & Resilience Assessment: Marj Sanour Watershed*. Social, Ecological and Agricultural Resilience in the Face of Climate Change (SEARCH); IUCN, PHG and UAWC, Amman/Ramallah.

5.2. Renewable Energy & Water Pumping: technology innovation in the Bahareya Oasis

Oasis ecosystems in Egypt

This case study highlights the role of renewable energy in improving water governance, tackling climate change, and facilitating sustainable agricultural development for food production in Egypt and the MENA region at large. In the Bahareya Oasis of Egypt, a young Cairo-based private company 'Karmsolar', a Solar Technology Provider, worked with local farmers at a technological innovation of solar water pumping for agricultural production.

In off-grid desert locations, ground water extraction is the primary stage of the agricultural process. To comprehensively tackle the water-energy-food nexus and climate change debate, energy needs must also be addressed in off-grid locations such as oasis where agriculture is an important basis for livelihoods. Food and other crop production begin here with the extraction of water from underground aquifer systems, for which high energy is needed.

KarmSolar's is developing, testing and now operating in Bahareya Oasis High-Capacity Off-Grid Battery-Free Solar Water Pumping ("SWP") systems that power high capacity submersible electric pumps with energy generated by a photovoltaic solar installation. The SWP system can be applied on the majority of pumps commonly used in the agricultural sector and, while upgrading the pumping system, will also allow the partial replacement of diesel generators. The SWP system allows stable pump operation at variable speeds, matching the changing available solar energy, therefore maximizing system efficiency due to low energy waste and maximum pump output. This is done through custom-design to adapt to the power needs of submersible pumps that can be easily scaled to meet changing energy demands, which in turn allow the drawing of water at increasing depths[3]. However, a Transfer Switch can be installed to utilize both solar and diesel energy sources, if a diesel generator is needed to extend pump operation hours at non solar peak times.

It is obvious that such technological innovations have direct social and economic effects on oasis farmers and other stakeholders within the agricultural sector, but also on the environment and its natural resources. The case study also demonstrates that renewable energy projects are not only possible with provision of grants and subsidies. This is especially important where subsidies have become unsustainable as these come at a steadily increasing cost and cannot easily be up-scaled beyond a pilot area.

Having taking the initiative on a private sector basis, it places innovative companies as KarmSolar as an important actor in 1) reducing the cost of water supply (which is directly affected by energy costs incurred by running pumping systems), 2) limiting groundwater withdrawal rates, and 3) better administering aquifer and climate data (through the use of a Solar Management Interface – "SMI"). Private investors however, require policies that provide space for or even catalyse approaches that can maximise commercial benefits. The case study also demonstrates that despite the initially perceived limited economic interest, the private sector is looking for new opportunities and in many emerging markets[4]. It can indeed be assumed that the private sector is more likely to understand an integrated supply chain than public silos, and could hence be more effective at analysing and subsequently resolving the challenges of developing approaches to

[3] http://karmsolar.com/pumping-irrigation/

[4] ICA-IUCN-IWA (2015) Nexus trade-offs and strategies for addressing the water, agriculture and energy security nexus in Africa. Geneva – December 2015. http://www.iwa-network.org/downloads/1450107971-Nexus%20Trade-off%20and%20Strategies_%20ICA%20Report_%20Dec%202015_2.pdf

integration of water, food and energy demands as has been described in the former Chapter on nexus approaches[5].

5.3 Desalination of brackish water for agriculture – Marj Na'ajah

Oasis ecosystems in the Jordan valley, Palestine

The Jericho district in the Palestinian Jordan Valley suffers from the upsurge of salt water in the aquifers. The Jordan Valley is situated between 150 and 350 meter below sea level and has an arid climate. The Eastern Aquifer Basin, which is the main source of water supply for irrigation in the district, comprises a layer of saltwater covered with lenses of freshwater. The cropping pattern in the study region is mainly vegetables (93% of the total cultivated area of 111.3 hectares in the village). Wealthy Palestinian farmers and Israeli settlers, however, are shifting from growing vegetables to other high salinity resistant crops such as date palm. In order to cope with the shortage of suitable irrigation water and poor quality in terms of increasing salinity, the Ministry of Agriculture of Palestine has installed a desalination unit for low water quality agriculture at the well in Marj Na'ajah, about 40 km north to Jericho in the Northern part of the Jordan Valley. The total number of direct beneficiaries is around 40 farmers though the intervention could benefit around 200 more people indirectly. The desalinated water is mixed with brackish water from the aquifer wells and with this mixture a total area of around 300 dunum can be irrigated.

Desalination is a water saving alternative to brackish water irrigation but its diffusion as a viable method of water treatment has been limited by high costs and concern about the lack of plant nutrients in desalinated water. Technological advances have made desalination an economically feasible solution for high-return

5 Allan et-al 2015: "The Water-Food-Energy Nexus: an Introduction to Nexus Concepts and some Conceptual and Operational Problems", International Journal of WRD

agriculture, especially in arid regions where water cost may be excessive due to distance from, or depth to, the water supply. The desalination unit in Marj Na'ajah that works with reverse osmosis technology has an inlet capacity of 75 m^3/hr and an outlet capacity of 55 m^3/hr. Salinity at the inlet is 4500 - 5000 ppm and at the outlet only 200 ppm. Installation cost was 160,000 USD, including the desalination unit 100,000 $ and the storage tanks, pumping units and brine line (60,000$).

By the end of the first agricultural season, an increase in crop productivity and crop quality was experienced by the farmers. As a result, the cropping pattern in the area has changed and new crops such as peas, beans, okra, and other salt-sensitive crops are now being cultivated successfully.

The Ministry of Agriculture was however concerned about the impact of using desalinated water on soil and plant productivity, especially in the absence of enough studies of these effects on the soil type of the area, i.e. clay loam saline soil. Two field studies were therefore commissioned to research the effects of irrigating heavy saline soil with pure desalinated water (TDS 200ppm) compared with recommended blended desalinated water (TDS 750ppm). The studies would particularly focus on Soil Sodium Adsorption Ratio (SAR) at different depths, soil structure, and water movement in the saline soil profile; and investigate the effect of irrigating heavy saline soil with desalinated water and blended water on plant productivity and fruit quality. Tomato was selected for the field research for its long growing season (October to March) to give a better indication about the effect of irrigation on the plant productivity and soil prosperities. The Box below presents the main results of the two studies.

Box 1. Results of field studies

Effects on soil properties of irrigating heavy saline soils with desalinated water

- A clear increase of the Sodium Adsorption Ratio (SAR) especially in the upper 15 cm soil layer.
- A negative impact on soil structure in the surface layer (15 cm)
- An increase of horizontal water movement and a decrease if vertical water movement as compared with brackish water.

Effects of irrigating heavy saline soils with desalinated water on plant productivity and quality

- A decrease in macronutrient content (N, P, K, and Ca) of heavy saline soil with decreasing water salinity (the decrease ranges from 45-77% and was highest for Ca.
- Desalinated water, and raw saline water, gave the lowest level of tomato crop production with only 12 kg, and 13 kg respectively; w
- When tomato is grown in heavy saline soils this effect can be alleviated by blending desalinized irrigation water with brackish water.
- Irrigating heavy saline soil with raw saline water and blended water with TDS 750 ppm gave the best fruit quality results, while desalinated water gave the lowest fruit quality

On the basis of the field study results it is recommended that Calcium and Magnesium should be added to the soil while blending desalinated with brackish water can be considered as a low cost strategy to increase Calcium and Magnesium content in the soil. Improving soil management practises to increase leaching of sodium salinity out of the root zone should nonetheless be encouraged as well as further studies of the amount of fertilizers needed under the different water salinity levels and of the long-term effects of desalinated water on the fertility of heavy saline soil and plant growth (by measurements over consecutive years of planting these soils with crops. Such studies should be done under direct supervision by the soil and irrigation experts to follow the farmers who are using desalinated water for irrigating their farms.

Social acceptance was also an important factor in the uptake of this practice. What helped with that was the short film produced in 2014 by the Ministry of Agriculture to show the reactions and feedback of the farmers about the effects of the desalination unit on their income.