Evaluation of water harvesting and managed aquifer recharge potential in Upper Fara' basin in Palestine: comparing MYWAS and water productivity approaches

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Abstract: The Upper Wadi Fara’ basin, located at the West Bank, Palestine, has an average annual rainfall of 500 mm, which occurs only during winter. Agriculture uses stored soil water and complimentary irrigation from groundwater. Water harvesting (WH) and managed aquifer recharge (MAR) therefore is essential for sustainable water resources management in the basin. This study focuses on the comparison between two methods to determine best practices for WH/MAR. The first method uses the change in water productivity and can be considered a one parameter cost benefit analysis (CBA). The other method concerns the multi year water allocation system (MYWAS), which uses water demand curves to evaluate economic scenarios. It is concluded that the highest cost effectiveness of WH/MAR measures in upper Wadi Fara’ basin is reached when water is stored as soil water. However, this is a politically disputed measure in the Israel – Palestine shared aquifer. Both models are useful tools in decisive stakeholder participation processes.

Keywords: Palestine; water harvesting; managed aquifer recharge; MAR; water basin planning and management; multi year water allocation system; MYWAS.

Reference to this paper should be made as follows: Tiehatten, B., Assaf, K., Ghanem, M., Jayyousi, A., Marei, A., Mostert, E., Shadeed, S., Schoups, G., Smidt, E. and Zayed, O. (2017) ‘Evaluation of water harvesting and managed aquifer recharge potential in Upper Fara’ basin in Palestine: comparing MYWAS and water productivity approaches’, *Int. J. Global Environmental Issues*, Vol. 16, Nos. 1/2/3, pp.29–44.

Biographical notes: Bernardien Tiehatten has a Master degree in Water Management from the Technical University Delft, where she also did has Bachelor degree in Civil Engineering. Her master thesis on the subject presented in this paper, evaluation of water harvesting and managed aquifer recharge in the upper Fara' basin, Palstine using two models: MYWAS and water productivity. She graduated in 2015 and is now working as an Advisor for water and soil, mainly for governments.

Karen Assaf has a PhD in Environmental Science/Hydrology and a dissertation on artificial groundwater recharge. She started on appropriate footing when she entered the water deficient Middle East region. She has published many articles, books and reports on various aspects of water management and put forward the concept of the water 'usage' cycle, instead of the traditional water cycle. She is an avid advocate of the benefits that can be derived from MYWAS on both national and regional scales. Her knowledge and informal manner has made her a reference point for cooperation when dealing with water problems of the Middle East.

Marwan Ghanem is an Assistant Professor at Geography Department at Birzeit University in Palestine. He received his PhD in Hydrogeology and Hydrochemistry from the TU Bergekademie Freiberg in Germany (1999). He has more than 30 international publications and he is active in attending the international conferences. He has a membership of many water international organisations. His experience is in between the academic and research activities and he is active in society as an environmental specialist. He speaks the languages of English, German and Arabic.

Anan Jayyousi holds a PhD in Water Resources Planning and Management. He has more than 25 years of experience in the fields of planning, management and development of natural resources. He is a university Professor at An-Najah National University and has more than 50 journal articles in the area of water resources. During the last ten years, he led the Palestinian team of the GLOWA Jordan River Project dealing with the effect of climate change on water resources. Recently, he was appointed by the Palestinian President to be a member of the Board of Directors of the Water Sector Regulatory Council.

Amer Marei has a PhD in Hydrology and Hydrochemistry from the Applied Geology Westfaelische Wilhelms University Muenster, Germany (1992). He is the founder of the Earth & Environmental Sciences Department at Al-Quds University and established the Water & Environmental Research Lab at Al-Quds University where he is the Director. He is a member of DAAD – selection committee in Palestine, researches and teaches in geology, hydrology, hydrogeology and hydrochemistry.

Erik Mostert teaches water law and integrated water resources management at the Delft University of Technology and conducts research on the institutional aspects of water resources management. He had been involved in several research projects on participatory and adaptive water management and transboundary water issues. From 2011 to 2014 he was involved in the Groundwater in the Political Domain project, Palestinian case study, which was part of the CoCoon programme, funded by the Dutch Science foundation and the Dutch Ministry of Foreign Affairs.

Sameer Shadeed is an Assistant Professor of Water Resources at the Water and Environmental Studies Institute (WESI) at An-Najah National University, Nablus, Palestine. Since 2008, he is an active researcher and lecturer in the field of water resources modelling and management. He conducted several researches (e.g., hydrological modelling and agricultural best management practices). Moreover, he supervised the work of several graduate students in the field of water and environmental engineering. His teaching includes graduate and undergraduate aspects of water resources quantity and quality. Finally, he worked as individual freelance consultant for several national and international consultation companies and firms in the fields of water, environment and strategic planning.

Gerrit Schoups has been an Assistant Professor in the Water Resources Management group at the TU Delft since August 2007. Most of his time is devoted to research – this includes pursuing his own research interests and advising students. He is also involved in teaching activities in the Civil Engineering Bachelor's program at the TU Delft. Previously, he studied at Gent University in Belgium, where he obtained a degree in Agricultural Engineering. Subsequently, he moved to California and completed his PhD research in hydrology at UC Davis in the Department of Land Air and Water Resources. This was followed by two post-doctoral research positions at Stanford University in the Department of Geological and Environmental Sciences, and the Flemish Institute for Technological Research (VITO).

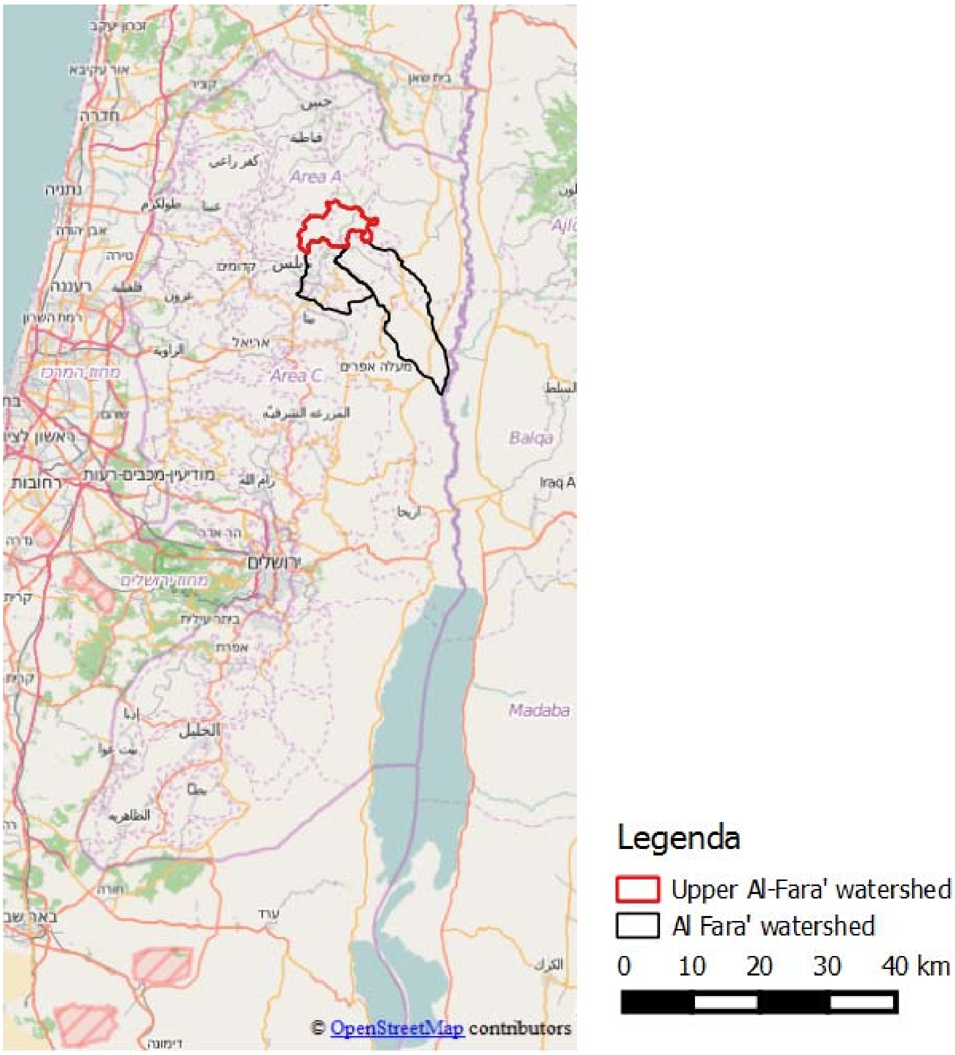
Ebel Smidt is a registered mediator and water resources management expert. He has 35 years long term experiences in practical water management, knowledge transfer and institutional strengthening of organisations in Egypt, Mozambique, Netherlands, Romania and Rwanda. He gained short term experiences in Abu Dhabi, Israel, Hungary, Namibia and Tunisia. He is a graduate in Physics (BSc) and Hydrogeology (MSc) at the Amsterdam Free University with complementary studies in Engineering Geology at Delft University of Technology and courses in Anthropology and Project Management at the Open University. He is principal and senior consultant and mediator at SG Consultancy and Mediation.

Omar Zayed is working at the Palestinian Water Authority, the regulating body of the water sector in State of Palestine since 20 years. He is working as a Director of Studies & Hydrological Monitoring Department within the Water Resources Directorate. He graduated in 1986 at the Yarmouk University, Jordan and took his MSc at the same University in1990. His interest focuses on water resources management, water monitoring and assessment, in addition of other water related issues. He was one of the main focal points in the Conflict & Cooperation over Natural Water Resources (Cocoon), which was implemented between countries of the North and the South (Ethiobia, Yemen and Palestine) which have common interest in several water and politics issues.

1 Introduction

This research focuses on the upper Al-Fara', a sub-catchment of the Al-Fara' catchment, see Figure 1. This area is part of the 'food basket' and the main economic activity is agriculture, which also translates in the land use; approximately 71% of the land is covered with open field agriculture, greenhouses and olives. Water shortages negatively affect the agricultural yield, and a decreased yield causes decreased economic value of the agriculture (Scheierling et al., 2014). Since the area greatly depends on the agricultural benefits, prevention of water shortage is of importance.

Figure 1 Location upper Al-Fara' catchment (see online version for colours)



Rainwater harvesting (RWH) and managed aquifer recharge (MAR) are two options to decrease the water shortages. RWH is a method implemented to decrease rainfall generated runoff and retain precipitation water for domestic or agricultural purposes (Gould and Nissen-Petersen, 1999). RWH knows many different techniques and applications and can be implemented on small and large scale. Depending on the purpose and possibilities of the area RWH interventions can be divided in roof catchment systems, rock- or ground catchment systems and check- or earth dams (Gould and Nissen-Petersen, 1999). Another technique is the improvement of land from uncultivated to cultivated land, mainly done by de-rocking of land (IFAD). This method does not use construction to store the rainwater, but directly uses the water for agricultural purposes. RWH has been widely implemented in semi-arid and Mediterranean areas to decrease water losses and increase water productivity (Biazin et al., 2012; Gould and

Nissen-Petersen, 1999; Helmreich and Horn, 2009; LRC, 2010; MOPIC, 1998; Shadeed, 2011; Shadeed and Lange, 2010).

MAR is used to increase water availability by increasing infiltration to the aquifer and use the aquifer for storage. The use of groundwater as a storage is very valuable since the water stored is not subject to evaporation and due to filtration capacity of the soil contaminations are limited as well. There are several techniques for MAR, retention dams, flooding field or infiltration wells, the first two techniques require a geography suitable for infiltration (Dillon et al., 2009; EPA, 1999; Maliva and Missimer, 2012). MAR has increasingly been implemented in areas where groundwater depletion and water scarcity are issues at stake (Dillon et al., 2009; EPA, 1999; Hughes et al., 2008; Maliva and Missimer, 2012; Rahman et al., 2013).

RWH interventions can be combined with MAR interventions since the water can be used for infiltration to the groundwater and/or direct use for other purposes such as irrigation.

2 Models to evaluate RWH/MAR interventions: MYWAS/WEAP and water productivity

To evaluate RWH/MAR interventions in the area, the technical feasibility is of importance to assess which interventions can be implemented and what impact they have on the water balance. However, interventions to retain and store water should not only be assessed on their technical feasibility. The construction of interventions need investments, and investors need to see if the interventions are also economic feasible before the plans are executed. When assessing the economic benefits of interventions in a certain location this can be compared to benefits created in other locations. Also, it can be evaluated which intervention in one catchment, will produce the highest returns. Even though technical feasibility might be no issue, economically there can be an optimal choice. Two methods to evaluate the economic feasibility are applied in this case study, multi year water allocation system (MYWAS)/WEAP and water productivity. The two methods that are essentially very different, MYWAS/WEAP is a rather complex economic tool and computes the shadow values for water and can be considered a tool to evaluate societal economic values. Water productivity is a more practical tool to measure the benefits of investments or production means, for example extensively used by the World Bank to produce country statistics.[1] It is therefore more straight forward and transparent than MYWAS/WEAP and computes the agricultural value per cubic meter of water.

"MYWAS is a tool that the user can employ to explore the consequences of various decisions and alternate circumstances" (Fisher et al., 2005). MYWAS estimates the value of water in different locations, taking account the special values associated with water. It also estimates the benefits to be obtained from optimal use of water resources (Fisher et al., 2005). Water is regarded as an economic good, implying that it has costs and benefits. Only the most beneficial activities will be realised, finding the economical optimum (Jayyousi, 2001).

To calculate the economical optimum allocation of water MYWAS develops demand curves, these are unique per demand point. A demand curve represents the relationship between water price and the quantity an entity is willing and able to buy. The demand curves developed by MYWAS are constant price elasticity demand curves. It implies that the price elasticity is constant over the different price ranges of the demand curve, it is always a fraction of the demand. The other inputs needed to develop a demand curve are price and quantity points. The quantity point indicates the water demand at a certain price, which is the price point. An important note for water demand is that this is not the actual water use, but the amount that a person would use when water use is not limited (Fisher et al., 2005).

Shadow values are the output of MYWAS and given per demand point. The shadow value is the sum of the marginal costs and the scarcity rent. Marginal costs are the costs of producing the water, also referred to as conveyance and extraction costs. The scarcity rent is the value of the water itself. A new project is economically feasible if the shadow values of the water are higher than the marginal costs of the water produced by this project. An important note is that the shadow values are not necessarily equal to the charged price.

Agricultural water productivity is applied to assess the productivity of the water used for agricultural purposes. It assesses if water can be differently allocated to create a more efficient and productive use (Scheierling et al., 2014; Zoebl, 2006). Water productivity in its general form is defined as the 'output per unit of water use' (Molden, 1997), the output being agricultural profits. Because of its simplicity, the method is transparent, but the simplistic approach can also eliminate the more complex reality.

For the hydro-economic evaluation done in this research, the economic water productivity is relevant. Data such as yield values, production costs and water costs are used to determine the net benefits of yields (Zoebl, 2006). Costs of irrigation water will be taken into account, where precipitation water is free. For the water, a combination of precipitation and irrigation water is used since agricultural production depends on both water resources.

In this research, the Surface Energy Balance Algorithm for Land (SEBAL) is used to determine water productivity. SEBAL solves the surface energy balance and calculates the evapotranspiration and biomass production; biomass water productivity (Zwart and Bastiaanssen, 2008). It is an image-processing model that calculates actual and potential evaporation rates (WaterWatch, http://www.waterwatch.nl/tools0/sebal/sebal-a-scientific-description.html). "SEBAL computes a complete radiation and energy balance along with the resistances for momentum, heat and water vapour transport for every individual pixel. The resistances are a function of state conditions such as soil water potential (and thus soil moisture), wind speed and air temperature and change from day-to-day" (WaterWatch, http://www.waterwatch.nl/tools0/sebal/sebal-a-scientific-description.html). The method is developed by WaterWatch and validated by several European and US universities (Zwart and Bastiaanssen, 2008) by applying and comparing the results in the field.

Current sub-optimal management of water and land leads to significant losses of water in the form of unproductive evapotranspiration and runoff in the system. Water shortage is not only caused by the annual water quantity, but also by the uneven distribution in time and space. Because the majority of agricultural activity of the West Bank is located in the Al-Fara' watershed, it is of importance to develop methods to prevent agricultural water shortages. In order to gain more insight in the hydro-economic feasibility of RWH/MAR interventions, MYWAS and water productivity are applied.

3 Methodology

The methodology of the research is based on four main steps. First, a preliminary baseline analysis of the area is done and the water balance is computed.

As a second step, the areal investigation and characteristics are used to draft RWH and MAR interventions feasible in the area. These are analysed and the costs and benefits per option are defined.

The third step is the hydro-economic evaluation using MYWAS and water productivity, of which the results conclude in a policy advice.

The fourth step compares the outcome of the two methods and by focusing on the ranking of the scenarios the differences in approach are analysed. To decide on the most appropriate model for the case study, the characteristics of the area are combined with the model approach, resulting in a recommendation for model choice. The possibilities and weaknesses of the methods, in relation with RWH and MAR, are assessed, concluding with lessons learned for future use and upscaling possibilities.

4 Results

The baseline analysis resulted in the water balance:

$$dS = P + Ir - ET - D - Q\_r,$$

where dS is the change in soil storage, P is the precipitation, Ir the irrigation quantity, ET the actual evapotranspiration, D the deep percolation and Q_r the runoff. Assuming the change in soil storage (dS) is zero over a year, the evapotranspiration is the only unknown and can be computed by solving the water balance. Table 1 shows that the total yearly evapotranspiration is 21.52 MCM.

Concerning RWH and MAR, several studies have been done in the upper al-Fara', resulting in three RWH/MAR options that are most suitable for the area: land improvement, the construction of a retention dam downstream and the construction of smaller retention dams in the course of the wadi.

The land improvement will change the land use from nature to agricultural land. The productive evapotranspiration will increase and the unproductive evapotranspiration will decrease. The influence on the runoff is negligible (Shadeed, 2011). Approximately 30% (5.9 km^2) of the unproductive land of the upper Al-Fara' catchment has been indicated as suitable for land improvement (LRC, 2010). The costs for improving the land are approximately 1 USD/m^2 (3.9 ILS/m^2) (PHG, 2015a, 2015b), a total of USD 5,935,222.00 for 5.9 km^2. These costs do not include the investments of the first cultivation, such as seeds or seedlings greenhouses or enrichment of the ground. These extra costs are dependent on the choice of cultivation and are assumed to be equal to one year of costs of a certain land use. The maintenance costs of land improvement are assumed to be included in the standard farmers activities.

Table 1 The water balance (average over a year)

dS = P + G – ET – D – Qr				
		MCM in	*MCM out*	*mm/year*
dS	Soil storage	0.00		0
P	Precipitation	28.00		500
G	Groundwater used for Irrigation	5.15		92
D	Deep percolation		9.73	174
Qr	Runoff		0.03	1
ET	Actual evapotranspiration		23.39	436
	Total	33.15	33.15	

In 2013, a retention dam was built in the upper Al-Fara' watershed. The dam was built to retain the runoff, favouring infiltration to recharge the groundwater (EQA et al., 2004; Gonzales et al., 2012; Moshe, 2008). The dam mainly influences runoff in the winter water balance. The dam has a capacity of 34,000 m^3, and collects the runoff generated in the upper Al-Fara'. It is assumed that the dam has enough capacity to retain all generated runoff. The retained water is estimated to be 0.03 MCM, which is infiltrating to the groundwater. The costs are USD 373,767.98 (ILS 1,440,500.00) for the construction of the dam (Nonner, 2015). The maintenance costs of the retention dam are estimated to be USD 2,594.71 (Nonner, 2015).

Check dams are smaller dams that are constructed in the wadi to prevent large runoff quantities to occur, the water trapped at the dams is infiltrated in the aquifer or is used as irrigation for the local farmers. Check dams are effective in small channels with a contributing drainage area of 2–10 acres (EPA, 2014; Knoop et al., 2012; VDCR, 1995). With a drainage area of 25,000 m^2 (6 acres), a total of 22 dams can be constructed in the wadi, resulting in 1,680 m^3 of water per year. The costs of a single stone check dam is approximately 645 NIS (Knoop et al., 2012; US EPA, 1992), making a total of NIS 14,448.00. The maintenance costs are estimated to be USD 259.47.

The investment costs for both the retention – as the check dams are merely the costs of developing the structures. It does not take into account the investments made to distribute water or change/implement crops.

The shadow value of the upper Al-Fara' is calculated to be 1.2 USD/m^3 (4.2 NIS/m^3) for the current situation. The marginal costs for land improvement, retention dam and check dams are respectively 0.35 USD/m^3, 1.32 USD/m^3, and 0.37 USD/m^3. All the marginal costs are lower than the shadow value and therefore scenarios 1–3 are economically feasible.

In order to analyse the economic impact of the different RWH and MAR interventions, scenarios are developed. To assess the interventions properly, the first three scenarios will consist of one of the three interventions. The other scenarios are development by combinations, developed by assessing compatibility of the interventions and the available water quantity. The retention dam is included in all the scenarios where multiple interventions are taken into account, because the dam is already in place.

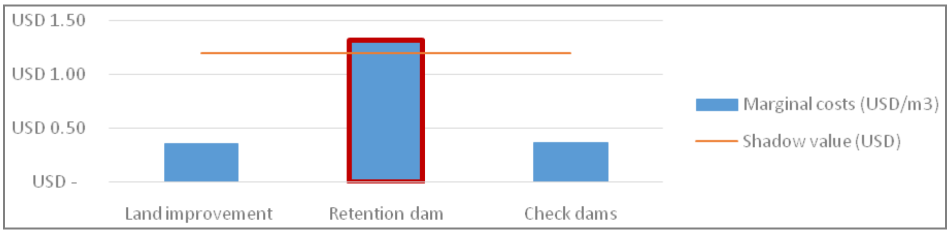
4.1 MYWAS model

The MYWAS model is restricted to demand points that are linked to the north-eastern groundwater aquifer; Tubas, Jenin and the upper Al-Fara'.

The shadow value of Al-Fara' is 1.2 USD/m^3 (4.2 NIS/m^3), this is an effect of the high willingness to pay combined with the significant difference between demand and supply requirement (1.3 MCM). When changing the available water for the Al-Fara' by introducing a retention dam, it is shown that the quantity of water is too low to change the shadow value.

The shadow values calculated by the MYWAS model are compared to the shadow values of the interventions. It can be seen that the marginal costs of the land improvement are lower than the shadow values. This indicates that the social value of water is higher than the costs of water created by land improvement, and economically the investment would be feasible. The same holds for check dams. However, it does not hold for the retention dam. A quick overview of the marginal costs of additional water from the interventions and the shadow value is shown in Figure 2.

Figure 2 Shadow value (USD) compared to marginal costs of interventions (USD/m^3) (see online version for colours)



Source: Tiehatten (2015)

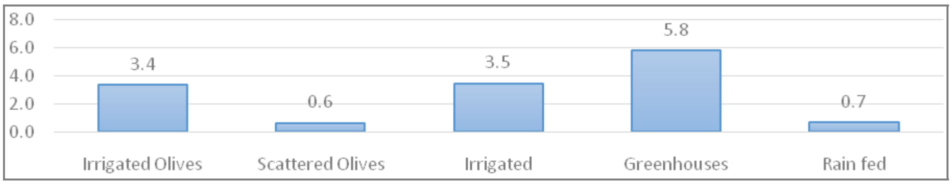
4.2 Water productivity calculations

Water productivity calculations present the overall crop water productivity (CWP) and the CWP per land use for the current situation. For the calculations of scenario 0, the overall CWP is presented (see Figure 4), also the CWP per land use (see Figure 3). Both calculations are done with the use of SEBAL.

The difference between scattered olives (rain fed) and rain fed agriculture is limited, see Figure 3. Therefore, when implementing rain fed agriculture the preference of the farmer can be decisive.

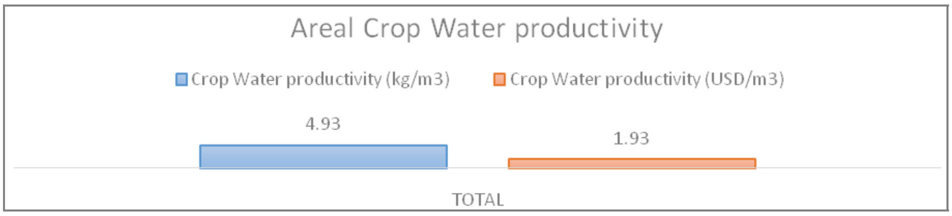
For greenhouses estimated crop water requirements are used (based on a field survey done in Jenin and Sanur by the Ministry of Agriculture in 2015 and 2010), because SEBAL cannot be used in areas which are covered. The values are high compared to the irrigated open field crops, this can explained by the amount of harvest per year. Greenhouse tomatoes are harvested throughout the year, and cucumbers are harvested twice a year. The values are yearly, and if CWP is compared to the other land uses it can be seen that it is not unrealistic high.

Figure 3 Crop water productivity (USD/m^3) (see online version for colours)



Source: Tiehatten (2015)

Figure 4 CWP – scenario 0 (see online version for colours)



Source: Tiehatten (2015)

4.3 Scenarios 1–6

The returns per scenario (Table 2), economic CWP (Figure 5) and the payback period (Figure 6) illustrate the results from the six scenarios.

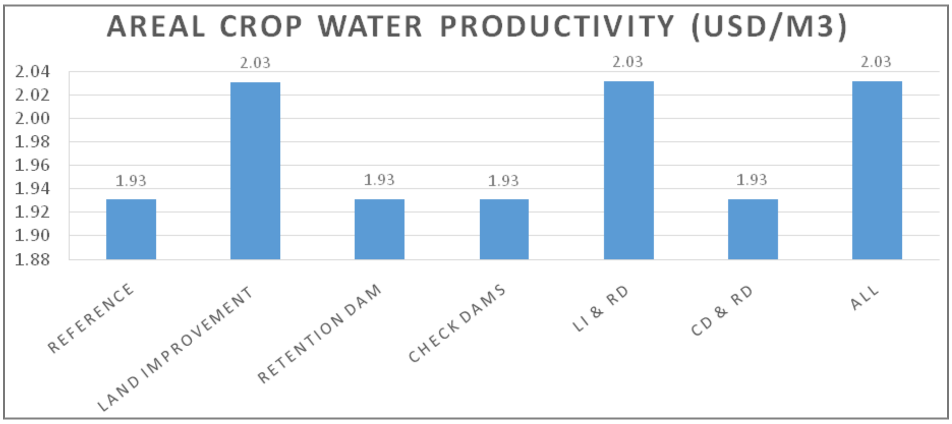
Table 2 Returns per year per scenario

	Land improvement	*Retention dam*	*Check dams*	*LI and RD*	*CD & RD*	*All*
Returns (USD)	1,141,389.00	29,001.00	1,595.00	1,170,390.00	30,596.00	1,171,985.00

The results show that the areal economic CWP (USD/m^3) is only influenced by the introduction of land improvement. When implementing a dam, the water that can be used for irrigation increases and causes a change in the acreage per land use. The additional water makes more land available for more productive land use from rain fed agriculture, 0.7 USD/m^3, to irrigated agriculture, 3.5 USD/m^3. This increases the areal CWP, however, the acreage change only increases the areal CWP with 0.0006 USD/m^3, and therefore it does not show in Figure 5. For the land improvement, the rainwater that was unproductively used by nature is now productively used by cultivated land, this is a larger change and therefore it can be observed in Figure 5. Furthermore, it causes an increase in net benefits because nature does not create yield benefits, increasing the CWP.

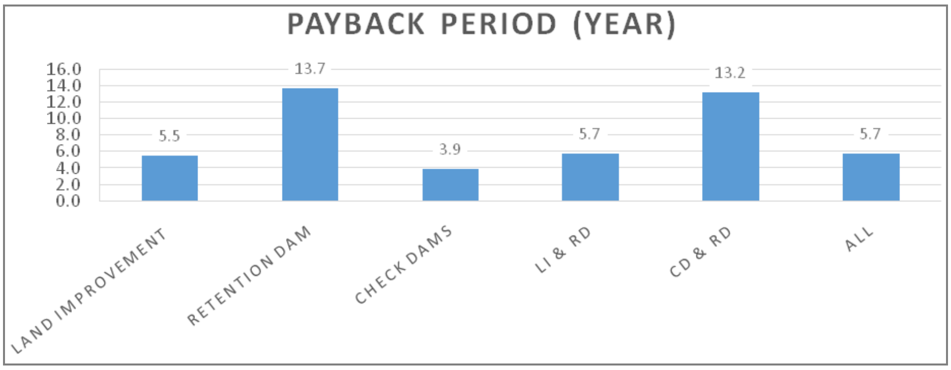
To calculate the payback period for the scenarios, the total investments are compared to the returns per year. The returns of the check dams are low but because of the low investments the payback period of the check dams is lowest of all interventions, 2.6 years. The payback period of the retention dam is significantly higher because of the low investment-return ratio. Land improvement returns are high, making the payback period relatively low.

Figure 5 Crop water productivity (USD/m^3) per scenario (see online version for colours)



Source: Tiehatten (2015)

Figure 6 Payback period per scenario (see online version for colours)



Source: Tiehatten (2015)

Table 3 CWP – ranking scenarios (see online version for colours)

Ranking	*Land improvement*	*Retention dam*	*Check dams*	*LI and RD*	*CD and RD*	*All*
Economic WP	1	2	2	1	2	1
Payback	2	5	1	3	4	3
Returns	3	5	6	2	4	1
Overall	6	12	9	6	10	5

In Table 3, the six scenarios are ranked from 1–6, 1 for the most beneficial and six for the lowest. For equal scenarios the same ranking is given. The lowest sum of the ranks is regarded as the optimal solution, this shows that combining the three interventions is the optimal scenario. Combining the three interventions give a high areal CWP, relatively low payback period and highest returns. Where the check dams have no effect on the areal CWP and almost no returns, but they are relatively cheap and could be regarded as a 'no regret' intervention.

5 Discussion

5.1 Sensitivity of input data

To make an evaluation of the sensitivity of input data, a sensitivity matrix for both MYWAS/WEAP and water productivity is computed (Tiehatten, 2015).

For MYWAS/WEAP, the irrigation crop water requirement (ICWR) and the willingness to pay show the highest uncertainty and therefore most effect on the results. The shadow values, as computed by MYWAS/WEAP, are an underestimation regarding the willingness to pay, but an overestimation regarding ICWR. Because ICWR has more effect on the outcome the shadow values, the results are regarded as overestimations (Tiehatten, 2015).[2]

For water productivity, the data with the highest uncertainty and the most effect on the results are the economic benefits per crop and the yield (kg). The results from water productivity are regarded as an overestimation because of the overestimation of the benefits of the computed yield (Tiehatten, 2015).

5.2 Limitations and opportunities

The result of MYWAS is one value, which can be of good use when communicating to policy makers who are familiar with economic models and the meaning of shadow values. However, discussing the result with people in the field is difficult, because their lack of economic knowledge. Also, to develop a demand curve, MYWAS/WEAP uses only one parameter to express the complex system of water requirements in an agricultural area and implementing variations in the agricultural system is not possible (Vaughan, 2011).

For the complexity of agricultural practices, predictions are difficult to make. The model can include a growth factor, but this is a complicated parameter to estimate (Fisher and Huber-Lee, 2005). One of the complication results from sub-optimal irrigation choice of farmers.

MYWAS/WEAP cannot be used to support specific agricultural policies, such as most productive crop, it is a model indicating the economic values of water (Fakhri and Mayyaleh, 2014).

Water productivity is used to create an overview of the efficiency water. The method is transparent and the results are applicable to the field situation. Therefore, discussing and debating the results with non-experts or in the field is an option and can be beneficial for both the results as for the communication to the involved parties. A limitation of using CWP is that it is not possible to advice on a more beneficial crop, since not all crops have the same value per kg. The non-water costs of production can be determined per crop and are not very sensitive to differences in farm techniques. However, when determining the benefits per crop, fluctuation in the market price is not taken into account, this is a limitation to the accuracy of the economic CWP.

Interventions adjusting the status quo of the groundwater table also affect other catchments, but are not part of this research. Also, the research is limited to the agricultural demand and use of water and merely evaluates the impact of interventions in the area. It does not advise on changes in agricultural techniques, crop choice or crop calendars.

6 Conclusions

Three interventions are technically feasible in the upper Al-Fara': land improvement, a retention dam and check dams. In total six scenarios are developed combining these interventions to analyse the economic feasibility of the interventions. The retention dam is already implemented and therefore always included in assessing multiple interventions scenarios.

The results of MYWAS/WEAP show that the shadow value of the water in the upper Al-Fara' is lower than the marginal costs of the additional water of the retention dam, indicating that the retention dam is not the optimal intervention. Check dams and land improvement are evaluated as economically feasible.

The results of water productivity show three main criteria to evaluate the scenarios: economic water productivity, returns and payback period. Land improvement is the only intervention significantly increasing the water productivity in the area, also the returns are highest. Even though the investments of land improvement are high, the investment return ratio results in an average payback period of 5.5 years, compared to 13.7 years for the retention dam, and 3.9 years for the check dams.

A policy advice can best be given using the results from both methods. MYWAS/WEAP results show that the retention dam is not the optimal solution in the area. This is explained by the low runoff rate and therefore the low additional recharge. Water productivity results do not indicate a negative economic value for the retention dam, however it does not increase water productivity and has a low investment-return ratio (payback period is more than twice as long as for land improvement). The optimal economic choice would be to combine the land improvement with the check dams.

The use of both methods is proven to provide supplementary insight and data. Therefore, an advice based on supplementary use of the results of both methods is broader supported; it is based on both water economics (MYWAS/WEAP) as agricultural analyses (economic CWP).

SEBAL can be used to prepare input data for both methods, not only for water productivity. Especially to compute the ICWR data in MYWAS/WEAP, now based plant specific general data. ICWR has a high effect on the results and has a high uncertainty. By using SEBAL, this data can be determined using actual field data, making it more accurate.

Upscaling can be done for both methods, provided that the input data is available on a detailed level appropriate for that scale. SEBAL is a useful tool for both methods: for water productivity evapotranspiration and biomass production can be determined and for MYWAS/WEAP the ICWR on larger scale can be determined. However, the availability of good land use map of sufficient detail is a starting point. Without this, limited conclusions can be derived from SEBAL images. Also, special attention is required for the input data with the highest impact on the results and the highest uncertainty: ICWR and willingness to pay for MYWAS/WEAP, benefits per crop and yield for water productivity.

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Notes

1 See http://data.worldbank.org/indicator/ER.GDP.FWTL.M3.KD. Palestine (found as West Bank and Gaza in the table had an overall water productivity in 2014 of \$25 per m^3 total withdrawn water, comparable with Jordan (\$31 per m^3). Both countries are well ranked in the top of the middle class water productivity countries.

2 With a price point of 4 NIS (decrease of 20%) and ICWR of 410 mm (decrease of 20%) the shadow value is reduced to 3.4 NIS.