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## **Conclusions and practical recommendations from water-related research in Palestine**

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**Meine Pieter van Dijk\***

Maastricht School of Management (MSM),  
P.O. Box 1203,  
6201BE Maastricht, The Netherlands  
Email: [dijkm@msm.nl](mailto:dijkm@msm.nl)  
\*Corresponding author

**Eldon R. Rene**

Department of Environmental Engineering and Water Technology,  
UNESCO-IHE Institute for Water Education,  
P.O. Box 3015, 2601 DA Delft, The Netherlands  
Email: [e.raj@unesco-ihe.org](mailto:e.raj@unesco-ihe.org)

**Hassan Sawalha**

Environmental Technology Engineering Department,  
Palestine Polytechnic University,  
Hebron, Palestine  
Email: [hsawalha@ppu.edu](mailto:hsawalha@ppu.edu)

**Sameer Shadeed**

Water and Environmental Studies Institute (WESI),  
An-Najah National University,  
Nablus, Palestine  
Email: [sshadeed@najah.edu](mailto:sshadeed@najah.edu)

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### **1 Introduction**

The Palestinian-Dutch Cooperation on Water (PADUCO) project is a platform for serving the Palestinian water sector through focusing on local problems with the urgent need to include partners and stakeholders from the Gaza Strip. Within this framework, national institutions were requested to show interest and support to scientific research by adopting proper policies, funding, and provision of accurate data (both reliable and up-to-date). Apart from several lab scale capacity building initiatives, issues pertaining to international water law, water rights, water governance and water management in the region were also demonstrated by various researchers. The conclusions and

recommendations were drawn by the editors of this special issue according to the following thematic research topics:

- 1 water resources in Palestine, particularly the West Bank
- 2 water issues in Gaza
- 3 drinking water issues
- 4 water governance assessments
- 5 pollution issues: water quality, sanitation and public health
- 6 water and agriculture.

## **2 Section 1: water resources in Palestine, particularly the West Bank**

Different methods can be used to assess the available water resources. In the following three papers, the methods used to determine the available stock of ground water range from using geographical information systems (GISs) to using models to estimate the quantity of water available and the possibility to add water to the currently available stock of ground water.

### *2.1 Evaluation and assessment of water budget in the Eastern Aquifer Basin of the West Bank, Palestine – Fadi Dweik, Mahmoud Rahil and Mhd. Suhyb Salama*

Dweik et al. studied the available groundwater in the Eastern Aquifer Basin, West Bank. Artificial recharge practice was considered as a feasible solution for the utilisation of the unused surplus runoff and spring water. The key findings of their study can be summarised as follows:

- a The authors developed a GIS-based water budget framework in conjunction with a hydrologic model to derive high resolution spatial temporal distribution of groundwater recharge for the Eastern Aquifer, which can be used for planning purposes.
- b The recharge of groundwater plays a complementing role in replenishing aquifers, which in turn affects the groundwater resources.
- c In addition to preparing a flowchart for water budget estimation, the authors also showed how to estimate water budget parameters for the geologic outcrops and the recharge area. They can help to secure sufficient water for the different sectors of the economy.

### *2.2 Evaluation of water harvesting and managed aquifer recharge potential in Upper Fara' basin in Palestine: comparing MYWAS and water productivity approaches – Bernardien Tiehatten et al.*

Multi-year water allocation system (MYWAS) and water productivity models were tested and found to be useful tools in stakeholder participation processes to decide on optimal

water harvesting and managed aquifer recharge (WH/MAR) measures at the basin level. MYWAS adaptation to evaluate sub-basin WH/MAR measures was successfully achieved in this research work. The key findings of this research can be summarised as follows:

- a It is not clear at forehand which users can benefit from stored water; hence, this is a politically disputed measure especially in the Israel-Palestine shared aquifer case.
- b Both models which were applied are useful tools in the stakeholder participation processes to decide on the optimal water harvesting or managed aquifer recharge (MAR) measures at the basin level.
- c MYWAS adaptation to evaluate sub-basin water harvesting or MAR measures has been successfully incorporated.
- d An analysis on WH/MAR measures for the total West Bank using both methodologies was recommended by the authors.
- e Upscaling can be done for both methods, provided that the input data is available on a detailed level appropriate for that scale.
- f Both check dams and land improvement are evaluated as economically feasible, but land improvement is the only intervention significantly increasing the water productivity in the area and subsequently high returns.

*2.3 Inventory of the potential artificial recharge practice in the Eastern Aquifer Basin: the case of Al-Qilt catchment, Palestine – Dalal Thaher, Marwan Ghanem and Ebel Smidt*

Thaler et al. also looked at the potential for MAR in the West Bank. Their key findings of their work include the following:

- a The catchment has favourable conditions to apply artificial recharge.
- b To quantify the recharge capacity, the amount of natural recharge in the area was estimated by using different methods. The results show that the yearly average recharge amounts to almost 100 mm/year in the upper part of the catchment and drops to about 10 mm/year in its lower part.
- c Based on these values and the good conditions for artificial recharge, it was concluded that most of the actual flood runoff which flows to the Jordan valley can be artificially recharged within Al-Qilt catchment.
- d However, according to the authors, follow-up research is needed concerning the technical and economic feasibility of artificial recharge schemes in the catchment.

### **3 Section 2: water issues in Gaza**

According to a recent UN report, the population in Gaza is likely to increase from 1.6 million to 2.1 million by 2020, and water issues has already been an important and complex subject to discuss due to natural, political and socio-economic situations in the

region. Although there are roughly 120 water desalination plants in Gaza, many of these plants are not licensed properly and/or they are operated illegally. Besides, there is lack of adequate infrastructure to manage the existing water resources in a sustainable manner. In view of these persisting problems, literature reports have suggested several measures:

- a The rehabilitation of water networks is recommended to reduce water losses.
- b The implementation of low-cost technologies to treat sewage water and re-use the treated water for agriculture can be promoted.
- c However, the strict implementation of desalination regulations is recommended and immediate actions should be undertaken to conserve aquifer water in the region.

### *3.1 Water supply management plan in Gaza Strip/Palestine – Ahmed Al-Yaqoubi*

As repeatedly highlighted in the literature and discussed in several water forums and conferences, the Gaza Strip does not have proper access to alternative water resources and it depends almost entirely on the coastal aquifer basin for its water supply. Nevertheless, in recent years, the existing aquifers are commoved and endangered by over-abstraction and pollution. This implies that, ~97% of Gaza's water is unfit for human consumption and that aquifers produce no more than 55 million m<sup>3</sup> of water/year. The prevailing political constraints currently make riparian cooperation over water resources in the coastal aquifer basin highly unlikely and this has currently triggered the emergence of non-formalised and illegally operated desalination facilities within the region.

Al-Yaqoubi has provided a wide range of conclusions, covering all the aspects of the undertaken study including water level, water quality, water supply, water balance and water demand management in the agriculture sector.

- a One of the foremost conclusions pertains to the existing situation in relation to water supply in Gaza, with strong rejection on the continuation of the 'status quo' as an acceptable option. There is an urgent need to secure sufficient drinking water of a better quality than the currently available water, which is often brackish.
- b By properly implementing the entire water demand management plan for Gaza, there will be significant positive implication on the groundwater deficit.
- c Without any water resources management plan, it is expected that the pumped water quality will not be suitable for irrigation due to salinity and sanitary issues.
- d If the recommendations made by the author in the paper are properly implemented, the water balance deficit will reach equilibrium status by the year 2021, with a surplus of about  $50 \times 10^6$  m<sup>3</sup>/year in the year 2035.
- e The conclusion is that less water will be available for agriculture in the Gaza Strip and integrated long-term solutions need to be considered for sustainable water resources management in the Gaza Strip.

*3.2 Visualising the spatial distribution of diarrheal disease using the geographical information system: a WASH perspective – Reem Abu Shomar, Mahmood Abdelatif and Yaser Kishawi*

Shomar et al. tried to visualise the spatial distribution of diarrheal disease using GIS in Gaza Strip. A geo-database was developed using disease attributes and spatial data based on the available statistics and the spatial distribution of the health facilities where the diarrheal cases were reported. Based on this modelling work, the following key conclusions were drawn by the authors:

- a GIS was found to be a practically reliable tool to get a good mapping of the seriousness of the issue.
- b The study could be a helpful tool to design evidence-based water, sanitation and hygiene (WASH) interventions that contribute in minimising the public health risks.
- c Recommendations for improved WASH services for risk mitigation were also identified.

**4 Section 3: drinking water issues**

Drinking water scarcity is not as such an immediate problem at the West Bank, as evidenced in Gaza. However, increasing population, more urbanisation and consumption of water implies that there is a need for rigorous planning and management of the current stocks.

*4.1 Drinking water loss management in Palestine: a case study of the Hebron city water distribution network – Samah Jawad Jabari*

Jabari studied the performance of water distribution systems in terms of non-revenue water (NRW) in Palestine by considering the water distribution network of Hebron city as a case study. The author reviewed several preventive methods to avoid water loss and suggested best management practices that can be adopted to suit the prevailing local conditions. The basic data used for this research was collected from the Palestinian Water Authority (PWA) and Hebron Municipality (HM) archive. A questionnaire was specifically prepared in order to collect the necessary data for water auditing and assessing the views of stakeholder in PWA and HM and envisage the current status of water losses and NRW in the Hebron water distribution system. Methodologically, the analysis of water losses was carried out using the water loss and auditing software developed by the American Water Works Association (AWWA). The following reasons were cited as the factors that governed these losses and should be dealt with:

- a Unauthorised consumption.
- b The current billing system and the delay in issuing water consumption bills.
- c A number of registration issues with the water meters.
- d Improper organisation and processing of the available data.

- e Fluctuating water pressure within the water network.

From a water balance perspective, in Hebron city, more than 40% of the water supplied prior to the year 2011 was without revenue and therefore considered as a loss. According to the field survey, analysis of results, and comments and opinion of interviewed staff, the strategy for reducing water losses should consider the following aspects:

- a A proper organisation and analysis of the data by appointing special supervisors.
- b Providing adequate training to the staff members involved.
- c Updating existing monitoring and metering devices.
- d Follow good leak detection practices and quickly responding to leak scenarios.
- e Implementing strict quality control through the enactment of stricter regulations and policies in the region.

A policy for water losses reduction exists in Palestine. However, the number of qualified staffs available to carry out the activities related to leak detection is low, and there is a lack of appropriate technologies for water loss reduction, and maintenance system.

#### *4.2 The political economy of water, water pricing in Palestine and how to create incentives for cost recovery – Meine Pieter van Dijk*

It is a well-known fact that, most of the Middle East countries experience water issues and noticeably these issues are severely felt by the Palestinian Authority. In recent years, the problem has worsened due to the decrease in useable water reserves, population growth and the rising demand for water. Besides, in the framework of the 1994 Cairo Agreement, control over the water supply system in the Gaza Strip was given to the Palestinians. Their responsibilities include the following: management, development and maintenance of the water supply and sewerage systems. Highlighting water pricing in Palestine, Van Dijk reviewed the prevailing practices and scenarios in the region and provided new directions on how to operationalise water pricing and create better incentives for cost recovery. The following aspects were highlighted by the author:

- 1 the progress with Annex 10 of the Oslo agreement
- 2 present drinking water situation
- 3 water pricing
- 4 wastewater situation in Palestine
- 5 cost recovery for water supply and wastewater projects
- 6 an example of public private partnerships (PPP) in wastewater treatment by the Delfland water board.

According to van Dijk, the Joint Water Committee (JWC) was originally created in the Oslo agreement with a vision to carry out activities such as the rightful re-division and monitoring of the current use of water in the region. However, Van Dijk argues that the JWC does not function this way, and it has caused an important hurdle in the peace process. Besides, the author stressed that water pricing should be based on an economic

analysis of present water uses and a baseline scenario should sketch the economic development trends based on the following key aspects:

- 1 assessment of cost recovery and water services pricing
- 2 cost effectiveness of measures
- 3 identifying knowledge gaps
- 4 continuously monitoring, identifying and documenting significant water issues.

From a practical viewpoint, the author recommended a number of strategies to achieve cost recovery, that were based on previous world wide practical experience:

- 1 improved metering practices
- 2 technical and administrative unbundling of service delivery
- 3 incentive-based performance contracts for private operators
- 4 salary bonuses for meeting for performance targets.

From a wastewater perspective, the author recommends that there should be close monitoring of the quality of treated sewer water and creates a mutual 'win-win' situation for farmers and wastewater treatment plants (WWTPs) in the region. He recommends:

- a The water sector in Palestine is subject to water scarcity and geopolitical, social and economic constraints, but allows for private sector initiatives.
- b There are strong arguments to implement the water annex (number 10) of the Geneva initiative more rigorously. The Water Annex of the Geneva agreement speaks about: Equitable sharing of the total amount of good quality water in Israel and Palestine
- c It stresses the need to protect, preserve and conserve the existing water sources, which is not happening and suggests that projects must be implemented on a rational economic basis with adequate pricing, which is not happening.
- d The progress should be monitored more closely; for example, taking stock of the quantity and quality of the ground water and how much is used by each side. Certainly, the Palestinians do not get a fair share of the water resources, which limits Palestine's agricultural production severely.
- e On the positive side, there are now better studies available and the international community has become more aware of the situation prevailing in Palestine.
- f The costs of water are known, the principles to be applied to determine realistic tariffs have been tried out and the structure is in place to arrive at more realistic water pricing in the face of the occupation and the consequences of it.
- g It may be politically difficult to increase the current water tariffs in different sectors, but it would certainly lead to more rational use of water and to better guided investments in water conservation, treatment, distribution and desalination efforts.
- h Strategies have been tried elsewhere to achieve cost recovery and would be relevant for Palestine as well:
  - improved metering practices (for example, in Bangalore in India)

- technical and administrative unbundling of water services delivery tasks
- incentive-based performance contracts for operators
- bonuses for meeting performance targets.
- i It is important to describe the tasks and responsibilities of the different institutions: PWA, MoA, EQA, local governments, etc.
- j Water service providers should be supported to achieve timely water bill payment and rescheduling of overdue bills. Incentives for debt re-payments could be introduced.
- k Introduce more systematic water demand management for drinking, industrial and agricultural water.
- l Promote PPP in water and sanitation to increase the efficiency of the system.
- m It is better for the Palestinians to treat the wastewater instead of discharging it into the Wadis to be treated in Israel as it will also have the benefit from the wastewater reuse in the agriculture sector.
- n Treating and reusing of the wastewater from the targeted streams will increase the volume of agricultural water by 12%.
- o PWA should make detailed CBAs and feasibility studies for each Wadi to study more alternatives and inspect the best specific solution for each Wadi in terms of WWTP location, treatment technology, reuse area and irrigated crops.

## 5 Section 4: water governance assessments

Water governance is a complex system that involves a wide range of administrative, political, economic, and social elements that work together for the delivery and management of water resources. Mainly, water governance aims at guiding decision-making with regards to water resource development and management. Under this theme, the researchers used a suitable tool to assess water governance in two locations, concerning two different activities and using two different methods.

### 5.1 *Assessment of water governance in the West Bank, Palestine – Tariq Judeh, Marwan Haddad and Gül Özerol*

Judeh et al. focused on water management in the rural areas, using quantitative (survey) techniques and pre-determined governance dimensions. The following recommendations were made by the authors:

- a To improve the effectiveness of the Palestinian water governance system in terms of coping better with water scarcity.
- b It is also recommended that the strengths and weaknesses of the water governance system, which are respectively indicated by the supportive and restrictive dimensions in the research, are comprehensively addressed by water sector actors and this assessment is reviewed and improved in a timely manner.



- c The following dimensions were indicated by the governance assessment tool (GAT) as requiring improvement (in this order): political status, social status, problem perspectives and goal ambitions, infrastructure and institutions.

**5.2** *Governing the reuse of treated wastewater in irrigation: the case study of Jericho, Palestine – Nasser Al-Khatib, Jawad A.H. Shoqeir, Gül Özerol and Linda Majaj*

Al-Khatib et al. performed a more qualitative study of the reuse of treated wastewater in Jericho district. The authors have bridged the knowledge gap and outlined the governance factors that facilitate or hinder the reuse of treated wastewater for irrigation in Palestine. An assessment tool was used to investigate the various dimensions and qualities of water governance in Palestine. Jericho was selected as the case study site, given its significant role for agricultural production in Palestine. The following key conclusions were made from their work:

- a Wastewater reuse in irrigation is one of the innovative methods to provide additional water supply for agriculture and to save freshwater resources for human consumption.
- b The main factors affecting the use of treated wastewater for irrigation purposes are: weak collaboration among the various actors in the water and wastewater sectors, a lack of coherence between the legal and economic instruments to achieve the use of treated wastewater.
- c Finally, no appropriate infrastructure is in place and there is no general social acceptance of the use of treated wastewater.

**6 Section 5: pollution issues: water quality, sanitation and public health**

Wastewater resulting from local Palestinian industries is highly contaminated with different types of pollutants including heavy metals, toxic chemicals, organic and biological substances. The wastewater is currently released to sewer network and local environment without proper treatment causing severe damage to the municipal WWTPs. The papers presented under this thematic section focused on the treatment of wastewater generated from olive mills and dairy processing.

**6.1** *Adsorption of organic pollutants from dairy wastewater on soil: pollution problem and control – Maher Al-Jabari, Nadia Iqefan, Nareman Zahdeh and Hiba Dweik*

In this paper, the organic pollutants present in wastewater from dairy industry were removed through adsorption onto soil particles with relatively fast adsorption kinetics. The equilibrium adsorption capacity and removal percentage of the organic pollutants increased with increasing stirring rate and soil particles to wastewater ratios. Besides, the adsorption process favoured acidic conditions; the adsorption capacity at high pH values approached zero. The authors concluded that:

- a The adsorption process used in the present study is rather cheap and might be successfully applied for the treatment of wastewater generated from other industries.
- b It is recommended to investigate the same adsorption process in packed bed, as it resembles natural water percolation through soil.
- c Besides, a packed bed reactor consisting of soil particles can be used as a post-treatment option to treat dairy industry wastewater, before releasing the treated water into sewer systems.

**6.2 Anaerobic biodegradation of olive mill wastewater: batch and UASB reactor performance – Wala 'a Alshiekh Abdallah, Omar Zimmo, Eldon R. Rene and Peter van der Steen**

This paper reports the use of lab-scale up flow anaerobic sludge blanket (UASB) reactor for the treatment of olive mills wastewater (OMW). The anaerobic treatment of OMW effectively reduced the chemical oxygen demand (COD) of the wastewater and showed high methane yield of 0.4 to 0.8 L (methane)/g (COD removed). The cumulative methane production varied between ~1,200 and 2,250 ml, over a period of 55 days, depending on the volume of OMW added (0, 10 or 20 ml, respectively). Besides, a gradual improvement on biogas production rate was observed when higher organic loading rates (OLRs) were applied to the reactor. The following conclusions were derived from this research:

- a The treatment techniques presented in this paper is just one way of reducing the water pollution.
- b However, a national strategy is required that involves the implementation of the existing regulations and issuing of new regulations to enforce the industry to properly treat their wastewater before being released to the sewer network or local environment.
- c Wastewater treatment could be carried out either in situ or in centralised industrial WWTPs.

## **7 Section 6: water and agriculture**

Limited availability of land and the geo-political situation in the West Bank are impacting land-use/land cover at the regional level. Different climatic zones also affect agricultural practices in different areas, where in semi-arid areas (eastern parts) lands are pasture and sandy. Additionally, in the coastal area (western parts), both the land and water resources are under Israeli control, so the rest is mountain ridge where most of the Palestinian built-up areas are located.

*7.1 Effect of land-use/land-cover change on the future of rainfed agriculture in the Jenin Governorate, Palestine – Salem Thawaba, Maher Abu-Madi and Gül Özerol*

Jenin Governorate is not a unique case in land-use change in Palestine, since such changes are taking place in all governorates. It is clear that the main challenge facing both rain-fed and irrigated agriculture in Jenin is urban growth and the expanding of built-up areas. In the study site, built up area was monitored for ten years, from 2004 until 2014. The study showed that urban growth is one of the major threats on agricultural land. Built up area expansion in Jenin city is taking place on the fertile irrigated agricultural lands, while it is encroaching into the rain-fed agricultural lands in the other localities in the governorate. The authors conclude:

- a If urban growth would continue in the same rate of 6 km<sup>2</sup>/year, the governorate will face a significant problem regarding agricultural production and food security.
- b Attention should be focused on the mechanisms for the protection of agricultural land.
- c Finally, there is an urgent need to prepare a master plan to show how and where to absorb urban growth with minimal impact on natural resources.

*7.2 Developing a GIS-based agro-land suitability map for the Faria agricultural catchment, Palestine – Sameer M. Shadeed, Atta M.E. Abboushi and Mohammad N. Almasri*

This study dealt with constraint analysis of land suitability for agriculture in the Faria catchment using GIS based on the available data. The major advantage of employing GIS in developing agro-land suitability map is that a high degree of customisability can be attained. It enables the user to add, remove layers and change the relative importance weights of the layers. It should be noted that determining the weights is subjective. In this context, it is advisable to perform a sensitivity analysis by varying the weights in order to provide insights into the generated agro-land suitability map. Although the resolution of the available datasets is coarse, this research provides an overall picture about the degree of agricultural suitability in the catchment. This in turn indicates that even under conditions of improper data yet much can be performed to assist the decision makers (for instance the Ministry of agriculture and the PWA). The authors made the following key conclusions in their research:

- a The developed agro-land suitability map delineates areas for sustainable agricultural expansion in the Faria catchment.
- b Other factors such as socio-economic, marketing and pricing may have potential impacts on agro-land suitability mapping.
- c The developed agro-land suitability map for the Faria catchment shed light on how the weighted overlay summation process (WOSP) can guide sustainable strategy development so that, the socio-economic conditions are maximised, and simultaneously, the groundwater quality deterioration is minimised.

## 8 Conclusions

It is important to formulate policies based on an in-depth analysis of the existing problems in a society. They need to be followed with the help of a systematic implementation and vigorous monitoring system at the national level. To facilitate this, more research on water issues in Palestine is required. Hopefully, this will be possible in the framework of a second phase of the PADUCO program. It will be necessary to work as researchers in close collaboration with other stakeholders. The so-called 'learning alliances' (Sutherland et al., 2012) would bring together users, non-governmental organisations, local governments and other stakeholders and assure the study of relevant issues and the implementation of workable solutions with other stakeholders. They tend to come up with more practical conclusions and recommendations, which will also help to improve the water scarcity problem in Palestine.

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