Introduction: Water issues in Palestine, issues and possible solutions

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1 Introduction to the special issue[1]

Water scarcity is an increasingly challenging problem in Palestine due to increasing water use and climate change. The Palestinian-Dutch Academic Cooperation Program on Water (PADUCO)[2] studied this problem and builds on the collaborative efforts of various Dutch and Palestinian researchers.[3] The project paid special attention to four issues which had been identified as important and to give focus to the research[4]:

a non-conventional water resources

b water quality, sanitation and public health

c water and agricultural production

d water management and governance.

If water is scare one starts with identifying available quantities of water and its quality using geographical information system (GIS) as is shown in several contributions. There are also non-conventional water resources, such as using reused waste water, storing water in aquifers and more rigorous water demand management. The papers in this special issue are the result of the PADUCO project, deal with these issues and will be introduced and summarised under the following headings[5]:

1 water resource issues in the West Bank

2 water issues in Gaza

3 drinking water issues

4 water governance assessments

5 pollution issues

6 water and agriculture

7 practical conclusions and recommendations.

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

Dealing with water scarcity requires knowing how much water is available and how it will be used. 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 working with GIS to using models to estimate the quantity of water available and the possibility to add water to the currently available stock of rain and 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

This contribution looks at the available groundwater in the Eastern Aquifer Basin on the West Bank. Artificial recharge practice is considered as a feasible solution for the utilisation of the unused surplus runoff and spring water, which flows towards the Jordan Rift Valley from the West Bank. Treated wastewater in dry seasons as source for artificial recharge is tested for the possibility to be recharged into underground aquifers. The water balance in the Qilt catchment to define proper locations for managed aquifer recharge (MAR) options is calculated using different methods. The best suitable areas for artificial recharge were determined, using the soil moisture demand (SMD) model for semi-arid regions to calculate the water balance. Many parameters were used amongst others precipitation, temperature, relative humidity and solar radiation. The yearly recharge was 99 mm/year in the upper part of the catchment and 12 mm/year in its lower part.

Dweik et al. argue that the Eastern Basin Aquifer is a groundwater natural resource that constitutes the eastern portion of the mountain aquifer. The total area of this basin is estimated at 3,079.5 km^2. A large part of the Eastern basin is located within the eastern borders of the West Bank, Palestine. The majority of this aquifer area is located within the areas featured by low amount of rainfall in general. The resource is heavily exploited and abstraction is directly controlled and apportioned between Israel and the West Bank by Israel. The study assesses and evaluates the water budget in the Eastern basin at 1 km^2 resolution, through a comprehensive model of the Eastern aquifer by estimating the evapotranspiration (ET) (evaporation and transpiration), surface runoff, and groundwater recharge in the targeted aquifer for the period 1950–2000.

Water and its accompanying components is one of the most fundamental, challenging and critical problems facing the Palestinian society. The lack of adequate water resources has aggravated the usual competition between different end uses, i.e., the domestic/municipal, agricultural and industrial sectors. In recent years, the gap between the available water resources and the demand for water resources is exponentially increasing in the region. GIS-based tools have been used widely in the literature to curtail the spatial grids of various water budget components in any geographical location. Dweik et al. assessed and evaluated the water budget in the eastern aquifer, as a function of space and time, by developing a comprehensive model that estimates actual ET (evaporation and transpiration), surface runoff and groundwater recharge for 50 years (1950–2000). Fixed data were used for elevation, geology, geographic boundaries, groundwater boundaries, watershed basin boundary and the west bank aquifer boundaries (recharge areas). The results obtained from GIS modelling were compared with the

presently prevailing recharge values. The authors converted water budget grids into vector GIS contours and calculated the areas between the contours of the created contour maps using the ArcGIS Spatial Analyst software.

According to the authors, the reference ET of historic Palestine increased from west to east and from north to south, and its value varied between 1,600–2,400 mm/year. Concerning average annual surface runoff in the historic Palestine, its value varied between 0 and 660 mm/year. The average annual ground water recharge for the 50 years period in the study is ~200 million m^3/year. Besides, the authors also envisaged variations in the values from the eastern slopes till the central highlands in the West Bank and this variation was attributed to the variations in temperature and precipitation in the target areas.

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.

Another research project looked at potential artificial recharge sites along Wadi Al Faria Basin. It aims to improve management aquifer recharge in Wadi Al Faria Basin through use of marginal water (flooding-, and treated waste water) in artificial recharge. Identifying potential sites along the Wadi drainage system is essential to meet the goal. A connection between the mountain aquifer system (Upper Cretaceous) and the Neogene aquifer system in the middle part of the Basin is found. The static groundwater table was measured in the majority of groundwater boreholes across the study area from Marj Sanoor in the west to Al Jeftlik area in the east, where groundwater table maps are built, so the groundwater movement systems among different aquifers are identified. The novel component of this research is to identify the aquifer natural recharge zones, and surface-groundwater connection, so 72 groundwater samples were collected from different aquifer systems (shallow, or deep). In addition, rainwater samples were collected from three Rainfall Samplers Stations during winter 2015. Historical hydro-chemical data was used to fill the gaps where groundwater sampling was not possible. The chemical analysis are conducted at AQU-Lab, and the environmental isotopes content of O18, Deuterium were analysed in the Ministry of Water and Irrigation in Jordan, and the rainwater samples are analysed in the IAE-lab-Vienna. Results for isotopes have been received in April 2016. By integrating the geological cross-section, lithological profiles, hydro-geological setting, hydro-chemical, and environmental isotopes results, three potential artificial recharge zones were identified. These are Marj Sanoor area for the Upper Faria zone, where flooding water could be used; Al Nasariah site in the middle where treated waste water could be applied, and Al Jeftlik site in the east where flooding water could be applied.

The Upper Wadi Fara' basin, located at the West Bank, has an average annual rainfall of 500 mm. Rain occurs only during winter time. Agricultural production takes place mostly in the dry spring and summer season using stored soil water and complimentary irrigation from groundwater. Water harvesting (WH) and MAR therefore is essential for sustainable water resources management in the basin. Three options of WH/MAR have been identified; land reclamation, small wadi retention structures and full wadi retention dams. A pilot retention dam has been finalised in 2014 in the basin and land reclamation is practiced intensively at the West Bank.

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 as only criterion for the evaluation and can be considered a one parameter cost benefit analysis (CBA). Water productivity is a relative simple criterion and has proven its value in water allocation management studies. The other method concerns the application of the multi year water allocation system (MYWAS), which is a more complex tool to evaluate different economic scenarios based on water demand curves. Pros and cons of both methods are analysed and results are compared. 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, while groundwater storage is in principle a no regret but less cost effective measure. Groundwater storage will always contribute to higher water availability and is therefore a no regret measure.

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

This PADUCO project looked at the potential for MAR in the West Bank. Identifying the potential of MAR sites for storing flood during winter season as well as treated wastewater is one of the major issues in Palestine to increase the water availability for both the private and public sector to cope with climate change and growing water needs. The catchments of the West Bank have to be analysed and classified from hydrological, hydrogeological, engineering and socio-economic perspectives in an integrated manner in order to select areas for MAR at a regional scale and additional specific artificial recharge test sites. The hydrological year cycle of the West Bank is changing from year to year and in an average frame of a seven years cycle, distinguished floods are happening. A huge amount of runoff is lost during such floods. Analysing changes in the rainfall patterns and finding suitable methods for storing water in winter times to be used in summer times is one of the top priorities at the Palestinian national policy making level.

This project combined existing knowledge and practical experience with new international insights and techniques and provided an overview of the areas that are suitable for different artificial recharge techniques in the West Bank based on a systematic approach and making use of GIS applications that facilitate the integration of new information. Hydrological, hydrogeological and water balance components were taken as the basis for MAR management.

As a result of high water demands in Al-Qilt catchment, the groundwater table is declining. To stop this process, artificial recharge of groundwater can be introduced to raise the water table again. In order to determine the best locations for artificial recharge the weighted overlay method (WOM) was used to determine the most proper locations for artificial recharge structures, using parameters as the slope, runoff, infiltration capacity, land use, density of wells and the depth of the ground water table. Results show that 91% of the total area is moderately suitable for artificial groundwater recharge by floodwater with a total area of 159 km^2. If treated wastewater is used as source for artificial recharge 66% of the total area is moderately suitable for artificial recharge with a total area of 115 km^2.

3 Section 2: Water issues in Gaza

Although not a part of the first stage of PADUCO different invited papers discussed the serious nature of the water problems in Gaza. Hence, a special section of this issue will be used for more technical papers related to water issues in Gaza.

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

The invited special speaker for the PADUCO final conference from the Palestinian Water Authority (PWA) in Gaza, Mr. Ahmed Al-Yaqoubi, described the situation in Gaza as: 'groundwater, the only source of water in Gaza, is now massively over-pumped and the aquifer is showing clear signs of imminent failure or collapse, with rapidly advancing degradation of the water resources in terms of quality and quantity. Al-Yaqoubi addressed the PWA's views for effective water supply management in the Gaza, with a primary focus on issues at the strategic level pertaining to water supply as well as its implication on water deficit recovery. The study was carried out based on the first component of the Gaza Emergency Technical Assistance Programme (GETAP) which is known as the comparative study of options (CSO) for an additional supply of water for the Gaza. According to the author, this study also reflects the ongoing and planned water supply options in conjunction with treated wastewater infiltration and wastewater reuse for agriculture.

The over extraction from the aquifer has resulted in drawdown of the groundwater with resulting intrusion of seawater and upcoming the underlying saline water. The major water quality problems are high salinity and high nitrate concentrations in the aquifer. At present, an about 96% of the domestic water pumped from the aquifer is far from the World Health Organization (WHO) standard in terms of chloride (250 mg/l) and nitrate (NO_3) concentration. It is expected that in case of continuing to depend on groundwater as the only drinking water resource the aquifer system will collapse and fail Gaza completely. In his paper, the demand for irrigation water is calculated and the quality of the groundwater is discussed. Two regional desalination plants have been proposed to be installed with a total capacity of ~119×10^6 m^3/year by the year 2035.

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

Abu Shomar et al. tried to visualise the spatial distribution of diarrheal disease using GIS. The Gaza is facing a serious challenge in terms of quantity and quality of water, posing significant health threats to the Gaza population. According to the statistics, water-borne disease, including diarrhoea among children reached alerting thresholds several times. Utilising GIS for insightful and well-informed decision-making is expected to help in minimising public health risks related to water pollution including the diarrheal diseases. The aim of the study is to visualise the spatial distribution of one of the main recognised water born disease, which is diarrhoea, based on an established geo-statistical database. Moreover, discussion on the impacts attributed to the existing poor quality of water and

sanitation in the Gaza Strip was incorporated. A geo-database was created and the results were visualised using ArcMap 10.2 software.

The distribution of diarrheal disease per the five Gaza districts was presented and visualised for the year 2013 showing that the northern district has the highest number of registered cases followed by the KhanYounis district. The areas where diarrheal disease is more prevalent at the municipal level were also highlighted using coloured symbology indicating the most vulnerable areas such as Beit Lahia, Beit Hanoun, and Al Nuserat municipalities. The study served as a pilot for an integrated GIS-based water quality and public health monitoring program and showed that GIS can be a very helpful tool to visualise the prevalence of one of the serious water-borne diseases and to identify the vulnerable populations for better decision making and proper WASH intervention.

4 Section 3: Drinking water issues

Drinking water systems are exposed to both natural and manmade risks. Among the manmade risks is the water loss, which remains a major concern in Palestine, ass loss levels are estimated at approximately 40% to 50%, which is high according to international standards.

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

Scarce water means Palestine has to economise on the use of water. An easy start is drinking water loss management, where the losses in the current distribution system are minimised. In the PADUCO program, one study focussed on the city water distribution network of Hebron and the possibility to minimise losses. The author carried out an analysis of the results and estimated the apparent losses, real losses and total water losses in the study area.

Water supply utilities should fulfil water requirements in quantitative and qualitative terms. This research studies the performance of water distribution systems in Palestine taking Hebron city water distribution network as a case study. The main objective is to audit the water losses in the water distribution network and obtain more information on current water loss prevention and management practices.

The results of this study revealed that the estimated water losses in the Hebron city are high and reach more than 30%. The main factors that contribute to water losses are:

x the inaccuracies in billing volumes

y unauthorised consumption

z the method of estimating consumptions through faulty metres.

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

This paper takes an economic angle to look at (drinking) water. Van Dijk argues that the Water Annex of the Geneva initiative[6] speaks about equitable sharing of the total amount of good quality water in Israel and Palestine. The initiative stresses the need to protect,

preserve and conserve existing water sources. Projects must be implemented on a rational economic basis with adequate pricing. The Annex continues to limit the scope, to provide definitions and to suggest a just and rightful re-division. In his contribution, van Dijk checks the progress with Annex 10 of the Geneva agreement and discusses the water and sanitation situation in Palestine, before dealing with pricing issues, incentives for cost recovery and possibilities for applying the polluter pays principle (PPP). The real challenge is to implement the ideas of Annex 10, which would lead to economically feasible drinking water and wastewater treatment (WWT) plants and would make Palestine less dependent on Israel for WWT. He also explores the possibility of involving the private sector through Public Private Partnerships (PPP) in financing and managing drinking water and WWT plants.

5 Section 4: Water governance assessments

The water governance project had the title 'Re-thinking water governance systems to cope with water scarcity'. Governance systems that provide the enabling political, institutional and legal conditions are crucial for implementing measures to alleviate water scarcity. Hence, it is necessary to improve the effectiveness of the Palestinian water governance system in terms of coping with water scarcity. For this purpose, the project applied a governance assessment tool (GAT), which consists of a matrix of five dimensions and four criteria, and has been previously tested in other countries.

Three assessments were conducted within the scope of the project. The first assessment covered the West Bank and data were collected through a quantitative interview design, based on a modification of the GAT according to the political and institutional context of Palestine. A focus group meeting was also organised to discuss the results of the interviews and the Palestinian water sector governance in general. The second and third assessment adopted a qualitative approach to assess the governance of the reuse of treated wastewater in Jericho (paper 10) and the governance of climate change adaptation in the political context of the Israeli-Palestinian conflict.

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

Tariq Judeh et al. assessed water governance in the West Bank through 30 interviews and a focus group meeting, conducted with the participation of representatives from the major stakeholders of the sector. It was found that the five most satisfactory dimensions or the least in need of change and upgrading were in this order: water quality, responsibilities and resources, technology systems, rules enforcement, and strategies and instruments and the most critical five dimensions in need of change and improvement were in this order: political status, social status, problem perspectives and goal ambitions, infrastructure and institutions.

It is concluded that the application of the governance matrix, which was tailored to the Palestinian social, political and economic context combined with focus group meeting and discussions, constitute an appropriate methodology for water governance assessment in Palestine.

Focus group meeting participants expressed unsatisfactory views of the current Palestinian water sector governance, as the participants see it mostly as steering and directing daily water issues in Palestine. The overall assessment of the governance system shows that political status and social status constitute the two most restrictive dimensions (the most in need of improvement), whereas water quality and responsibilities and resources are the most two supportive dimensions (the least in need of improvement) of the water governance system.

It is recommended that the strengths and weaknesses of the water governance system, which are respectively indicated by the supportive and restrictive dimensions, are comprehensively addressed by water sector actors and this assessment is reviewed and improved in a timely manner.[7]

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

Nasser Al-Khatib et al. studied the governing of the reuse of treated wastewater in irrigation. They carried out a case study of Jericho. In resource-scarce settings such as Palestine, the governance of water resources represents a complex interplay of economic, political, legal, financial, social and environmental factors that guide and facilitate interactions among various stakeholders.

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. Although wastewater reuse represents a significant potential to account for the scarcity of water and the complexity of the Palestinian context, the governance of the reuse of treated wastewater in Palestine is understudied. The paper aims at bridging this knowledge gap and outlining 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. Based on stakeholder interviews and document reviews, our assessment of the governance of treated wastewater reuse reveals three main factors that are affecting the reuse of treated wastewater for irrigation purposes.

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

The research concerning water quality, sanitation and public health consisted of different projects. One project focussed on heavy metals impacts on membrane bioreactors (MBRs) and activated sludge systems: removal efficacy and biofouling potential. The use of MBRs for WWT has expanded and led to a significant knowledge expansion and experience related to their design and operation. Recently, two of three large scale MBRs are in operation and comply with local and regional stringent regulations for reclaimed water use in agricultural irrigation. However, lack of local experience in operations and management (O&M) exacerbated by illicit industrial discharges from food and agriculture sector and bio fouling continue to hamper an increased implementation of MBR at a large scale. Although the validation of operational process pertinent to stress conditions due to inorganic (heavy metals) and high organic (for example, olive mill

wastewater) on the performance of MBR facilities warrants further investigation, there were some interesting results.

Capacity building, networking and knowledge sharing are crucial considering capable wastewater professionals and needed knowledge to successfully design, monitor and operate MBRs. Knowledge must be enhanced by basic understanding of pollutants removal, validation of process performance, and biofouling to successfully implement and ensure their sustainability.

Establishing a research and development (R&D) group nucleus at Birzeit University (BZU) on MBR technology is crucial to obtain basic scientific and practical knowledge on the process performance of MBR system. Today, the use of membrane based technologies, more especially MBRs, either as a main step in municipal WWT chain or as single post-treatment step has shown an innovative way of achieving high quality reclaimed water suitable for multi-beneficial applications.

The aim of this research study was to explore the performance of both large- and pilot-scale MBR systems serving Altireh suburb-Ramallah, BZU campus, under variable operational conditions. Anza and Beit Dajan activated sludge systems are used as a reference. The results envisaged from this study will enhance capacity building through R&D efforts, and facilitate improvements for the risk assessment and management of large scale MBR facilities used for reclaimed water use in agricultural irrigation.

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

Eqefan et al. deal with industrial pollution by studying adsorption of organic pollutants from dairy wastewater on the soil. This paper responds to the need of controlling the industrial pollution resulting from the dairy industry. It investigates the adsorption of organic pollutants in dairy wastewater onto soil particles, from two angles: soil pollution and WWT.

An experimental research methodology is used, by performing batch adsorption experiments. The obtained kinetic curves of chemical oxygen demand (COD), BOD and pollutant surface concentration enable analysing the performance of the adsorption process. An experimental parametric study is performed. It includes the effect of pH, dosage, stirring rate and organics initial concentration. The results indicate that acidic soils will be polluted with dairy wastewater more than alkaline soil. Experimental kinetic curves are modelled with pseudo first order and second order rate equations. The kinetics is found to be best fitted by pseudo second order model. A number of conclusions are drawn from the research.

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

Another project studied the treatment of olive mill wastewater in the rural areas of the West Bank. Olive mill wastes (OMW), both liquid and solid fractions, are considered a major environmental problem in the West Bank. An increase in olive oil production, the generation of exceedingly large amounts of wastewater and poor waste management

practices have all contributed to social and environmental burden in the region. The idea was to test a two-stage process consisting of a first-stage sand filter for removing solid fractions, followed by an aerobic process (activated sludge) and to investigate a novel approach of integrating an UASB reactor, as a biogas recovery step, to the aerobic process. It was envisioned that both lab-and pilot-scale demonstration of these (bio) processes would be realised, as well as a techno-socio-economic analysis. For knowledge dissemination, collaboration would be sought from privately operated olive mills in the region and from European (research) partners. The paper presents the results.

Abdallah et al. look at anaerobic biodegradation of olive mill wastewater: batch and UASB reactor performance. The keywords are COD removal, methane yield, olive mill wastewater (OMW water), organic loading rate (OLR) and upflow anaerobic sludge blanket (UASB) reactor. Uncontrolled disposal of olive mill wastewater (OMW water) contributes to one of the emerging environmental problems in the West Bank. In this study, batch biodegradability tests were carried out to determine the suitability of OMW water for anaerobic digestion, COD removal and potential methane (CH_4) yield. The batch bottles were prepared with anaerobic sludge and different volumes of olive mill wastewater. The cumulative CH_4 production varied between ~1,200 and 2,250 ml, while the CH_4 yield (l/g COD removed) in the bottles were 0.54, 0.58, 0.40 and 0.81, respectively. The reason for these values being higher than the theoretical value is unknown. The biodegradability of the mixture of OMW water and sludge was calculated based on the gas production rate and found to be 43, 58, 53, and 59%, respectively. Furthermore, the biodegradability based on the COD removal was found to be 28, 35, 47, and 26, respectively. Besides, in this study, anaerobic treatment of OMW water was investigated in an UASB reactor at OLRs varying between 1.6 and 8 kg COD/m^3 d^{-1} at a hydraulic retention time (HRT) of 15 h. The results from this study showed stable COD removal efficiencies (~85%) for OLRs up to 7.6 kg/m^3 d^{-1}. A gradual improvement in the biogas production rate was observed when higher OLRs were applied. The highest observed CH_4 yield was about 0.37 L CH_4/g of COD removed.

7 Section 6: Water and agriculture

Two PADUCO research projects dealt explicitly with water and agriculture. The project entitled ‘development of agricultural best management practices to preserve groundwater quality’ focused on the groundwater system in the Faria catchment which is the sole utilisable water resource for both domestic and agricultural purposes as for the entire West Bank. This source is currently under increasing water quantity and quality stress due to many factors, such as increasing demand, economic development, population growth, and pollution from discharging of untreated wastewater in the Wadis and from the uncontrolled agricultural activities. This project comes to assist in supporting the control and management of the agricultural practices that cause the pollution of the limited, vulnerable, and stressed groundwater resources due to the lack of cost-effective decision making tools in the study area. The main goal of this project is to develop an efficient management tool for decision makers and stakeholders to delineate the areas of high suitability for cost-effective agricultural practices such that groundwater pollution is minimised while socio-economic conditions are enhanced. The specific objectives were:

1 to develop a baseline conditions for the study area with emphasis on assessment of the current uncontrolled agricultural activities, groundwater contamination monitoring and vulnerability assessment

2 to develop an agricultural land use suitability map based on multi-criteria, sub-criteria, and measurement indicators

3 to identify the linkage between areas of contamination/vulnerability with land use practices

4 to identify the scenarios of BMPs that are practical and readily implementable in a cost effective manner

5 to assess the possible impacts of the developed scenarios (due to the introduced BMPs) with emphasis on groundwater quality

6 to provide the results and proposed BMPs in a consistent decision framework to the regulators.

One output of this research is the following paper.

Secondly a project focussed on increasing crop yields and productivity of rainfed agriculture.

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

In PADUCO the project entitled 'improving crop yield and production from rainfed agriculture in Jenin' focussed on increasing crop yields and productivity of rainfed agriculture. The main goal of this project is to improve the contribution of rainfed agriculture to food security in the Jenin Governorate. The specific objectives were:

1 to study the response of rainfed crops' yield and production to different scenarios of variation in climatic conditions (e.g., rainfall and temperature)

2 to generate new and relevant technical knowledge that can be applied by research institutions and private companies

3 to improve the policies and strategies concerning rainfed agriculture and adaptation to climate change

4 to study the perceptions of farmers and policy makers towards climate change and adaptation

5 to improve capacity and raise awareness for farmers, extended farmers, and other relevant stakeholders.

One output of this research is the above-mentioned paper.

The land cover has been under pressure by human activities throughout the history. Human needs are the major driving forces behind land-cover transformation and change. At the global level, population growth and socio-economic development have a significant impact on land resources. Recently, scholars added climate change as one of the major factors that affects land-cover change and transformation. In the West Bank,

the situation is more complicated, where geopolitical constraints due to the Israeli occupation and lack of control over land resources are added to the mentioned factors above. In the West Bank fertile land is 16% of the total land; 87% of the cultivated land is rainfed, 11% is pastureland and 2% is irrigated land. This paper focuses on agricultural land degradation and shrinkage by time and tries to reveal the major factors behind this change. The geographic focus of the paper is Jenin, a major agricultural area in the West Bank, Palestine. Statistical data and aerial photos were analysed, shape files were developed using GIS software, and related attribute data were linked to the spatial data for analysis. The study showed that urban growth is one of the major factors threatening agricultural lands in the study area, where both irrigated and rainfed agriculture are impacted by this growth.

Thawaba et al. look at the effect of land-use/land-cover change on the future of rainfed agriculture in the Jenin Governorate. The land cover has been under pressure by human activities throughout the history. Human needs are the major driving forces behind land-cover transformation and change. At the global level, population growth and socio-economic development have a significant impact on land resources. Recently, scholars added climate change as one of the major factors that affects land-cover change and transformation. In the West Bank, the situation is more complicated, where geopolitical constraints due to the Israeli occupation and lack of control over land resources are added to the mentioned factors above. In the West Bank fertile land is 16% of the total land; 87% of the cultivated land is rainfed, 11% is pastureland and 2% is irrigated land. This paper focuses on agricultural land degradation and shrinkage by time and tries to reveal the major factors behind this change. The geographic focus of the paper is Jenin, a major agricultural area in the West Bank, Palestine. Statistical data and aerial photos were analysed, shape files were developed using GIS software, and related attribute data were linked to the spatial data for analysis. The study showed that urban growth is one of the major factors threatening agricultural lands in the study area, where both irrigated and rainfed agriculture are impacted by this growth.

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

The development of agricultural sector is important for achieving food security at national level. An important aspect in such development considers the land use and utilisation. This study develops an agro-land suitability map to achieve the optimum utilisation of the available land resources for sustainable agricultural production in the Faria agricultural catchment, Palestine. Faria catchment (320 km^2), located in the north-eastern part of the West Bank, Palestine, is considered the food basket that provides the West Bank with different vegetables and crops given its climate, soil fertility and water availability. In this study, the agro-land suitability map was developed based on a combination of spatial weighted factors for different criteria including topography, soil, land use, accessibility, climate, water availability, and groundwater vulnerability. The GIS is used to develop the agro-land suitability map for the Faria catchment by adopting the analytic hierarchy process (AHP) approach. The AHP is one of the multi-criteria decision-making approaches that are commonly used in agricultural land use suitability

analysis. The developed agro-land suitability map is intrinsic and indicates different levels of land suitability to agricultural production. The evaluation of spatial variability was carried out in terms of suitability ratings from highly suitable to unsuitable. Results indicate that about 49% and 6% of the total area of Faria catchment are moderately and highly suitable for agricultural practices, respectively. Whereas marginally and unsuitable areas represent about 41% and 4%, respectively. Agricultural investment in such areas is not feasible and will negatively affect the sustainable agricultural practices in the catchment. The implementation of the obtained results is envisaged to support any governmental policy shifts towards wide spread adoption of sustainable agriculture in Palestine.

The 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, yet the work 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). In general, the developed agro-land suitability map delineates areas for sustainable agricultural expansion in the Faria catchment. In particular, other factors such as socio-economic, marketing and pricing may have potential impacts on agro-land suitability mapping. Finally, the developed agro-land suitability map for the Faria catchment shed light on how the WOSP can guide sustainable strategy development so that, the socio-economic conditions are maximised, and simultaneously, the groundwater quality deterioration is minimised.

8 Section 7: Practical conclusions

8.1 Conclusions and practical recommendations from water-related research in Palestine – Meine Pieter van Dijk, Eldon R. Rene, Hassan Sawalha and Sameer Shadeed Nablus

The practical conclusions and recommendations will be presented at the end of this special issue, after presenting first the papers on which they are based.

References

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List of abbreviations

AHP	Analytic hierarchy process
ANU	An-Najah National University
AQU	Al-Quds University
ARIJ	Applied Research Institute-Jerusalem
BZU	Birzeit University
CBA	Cost benefit analysis
CH_4	Methane
COD	Chemical oxygen demand
CSO	Comparative study of options
CWP	Crop water productivity
DBFO	Design, construct, finance and operate
DBP	Disinfection by-products
EPA	Environmental Protection Agency
EQA	Environmental Quality Authority
ET	Evapotranspiration
EU	European Union
FGD	Focus group discussion
GAT	Governance assessment tool
GETAP	Gaza Emergency Technical Assistance Programme
GIS	Geographical information system
H	Per hour
HRT	Hydraulic retention time
ICWR	Irrigation crop water requirement
Km	Kilometre
L	Litre
LRC	Land Research Centre
MAR	Managed aquifer recharge
MBR	Membrane bioreactors
MCM	Millions of cubic metres
Mg	Milligram
MoA	Ministry of Agriculture
MoH	Ministry of Health
MoHE	Ministry of Higher Education
MSM	Maastricht School of Management
MYWAS	Multi year water allocation system
NO3	Nitrate
OMW	Olive mill wastewater
O&M	Operations and maintenance
OLR	Organic loading rates

List of abbreviations (continued)

OMW	Olive mill waste
OPT	Occupied Palestinian Territories
PADUCO	Palestinian-Dutch Academic Cooperation Program on Water
PHG	Palestinian Hydrology Group
Ph	A scale used to specify the acidity or basicity of an aqueous solution
PPP	Polluter pays principle
PPP	Public Private Partnership
PPU	Palestinian Polytechnic University
PSI	Private sector involvement
PTUK	Palestine Technical University Kadoorie
PWA	Palestinian Water Authority
R&D	Research and development
SEBAL	Surface Energy Balance Algorithm for Land
SMD	Soil moisture demand
SPV	Special purpose vehicle
WWT	Wastewater treatment
THM	Trihalomethane
TUD	Technical University Delft
UASB	Up flow anaerobic sludge blanket
USA	United States of America
VFA	Volatile fatty acid
VSS	Volatile suspended solids
WASH	Water, sanitation and hygiene
WH	Water harvesting
WHO	World Health Organization
WOM	Weighted overlay method
WOSP	Weighted overlay summation process
WSRC	Water Sector Regulatory Council

Notes

1 The presentation of the research projects is partially based on the Final Narrative Report of the PADUCO project (Ozerol et al., 2016) and on the abstracts of the different papers.

2 Ten Palestinian and Dutch universities participate in the consortium: Birzeit University, An-Najah National University, Al-Quds University, Palestine Polytechnic University, Palestine Technical University Kadoorie, Maastricht School of Management, University of Twente, Technical University of Delft, UNESCO-IHE and Wageningen University.

3 The project and ran from 2013 till April 30, 2016.

4 For the final conference 80 abstracts were received, about 60 were asked to submit a paper. Roughly 40 papers were submitted, 30 selected to present and about 15 have been included in this special issue after extensive reviewing and rewriting.

5 The PADUCO research project had eleven subprojects.

6 According to Wikipedia, the Geneva initiative (also known as the Geneva Accord), is a draft Permanent Status Agreement to end the Israeli-Palestinian conflict, based on previous official negotiations, international resolutions, the Quartet Roadmap, the Clinton Parameters, and the Arab Peace Initiative. The document was finished on 12 October 2003 (consulted 22 July 2016).

7 Results and lessons learned from this assessment were presented and shared with the main actors of the Palestinian water sector in a workshop where policy changes and needs of the sector were discussed.