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Faculty of Graduate Studies

Integrated Water Resources Planning for A water-Stressed Basin in Palestine

By

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This thesis was defended successfully on July, 2006 and approved.

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DEDICATION

I recognize and appreciate the life-long influence of my mother and father. This thesis is dedicated to both of them

ACKNOWLEDGMENTS

I am deeply indebted to many people who have made the success of my research possible.

I would like to express my sincere gratitude to my teacher Dr., Anan Jayyousi, for the opportunities that he has made available to me, whose stimulating conversations have been inspirations. I am grateful for the time and energy that, Professor Marwan Haddad has given. Both have advised me on many occasions and provided feedback and expert advice that have lifted the thesis to a level I never would have reached on my own. Special thanks go to the Water and Environmental Studies Institute at An Najah National University.

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Above all, I thank GOD; for it is through Him all things are possible. My life has been truly blessed.

Aya R. Arafat

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ABSTRACT

In Palestine, failure to account for long-term scenarios of water availability is a concern given the potential for severe drought and the continuing misallocation of water rights and water distributions as well as the lack of policies to support integrated water resources management. Analysis to assess how to design future water resources, facilities, and management scenarios based on future measures and management practices as well as rainfall patterns for Palestine are investigated.

This research focuses on building an IWRM model for Al Far'a catchment using WEAP program. After collecting all the required data and studying the existing situation, different scenarios are suggested here. Population growth was taken in to account in this work. The burgeoning population growth in Palestine is crucial to integrated water resources planning and management and is expected to increase the stresses on the already scarce water resources. The last step was calibrating the model to get the best fit model and better accuracy. Projection of these data into the future was approximated through many strenuous built-in relationships in WEAP model to assess the future water states. Thus, annual, and decadal future water availability is projected, characterized, and examined to support efficient and effective scenarios to sustain water resources

management. This analysis of scenarios assessment and best management practices evaluation is performed for Al-Far'a watershed. Wherein, integrated water resource planning models that can simultaneously aggregate and process hydrologic and management elements are of paramount importance to aid decision planners evaluate the tradeoffs and priorities under different hydrologic realities and management objectives.

The utility of the analysis to highlight the need for alternative water supplies; to quantify groundwater recharge; to evaluate water conservation and fair water allocation policies; and to provide guidelines for future non-traditional water supply projects are also presented and discussed.

CHAPTER I

INTRODUCTION

General Introduction

Water has been harnessed in support of the achievement of social goals for thousands of years. Nevertheless, it is evident that many efforts to utilize water have been inadequate or misdirected [NRC, 2001]. In the future, moreover, available water resources will be subjected to greater pressure in the face of burgeoning demands and misallocation [Abu Zahra, 2001]. Thus, there is a growing need to more intensively manage water in order to achieve an increasingly diverse set of water-related social goals [Postel, Daily, and Ehrlich, 1996; Gleik, 1993].

However, successful management of water requires systematic, comprehensive, and coordinated approaches that will provide decision-relevant information at an affordable cost to water managers. Management of river basins will require approaches that will need more-and better quality-information about the current and potential future states of the water resources systems we manage. Therefore, to meet the growing information needs of water management and water resources research, efficient modeling techniques are required that have high power for long and short term assessment in order to be able to devise smart decisions.

Scenarios are alternative sets of assumptions to mitigate the future risks taking into accounts supply sufficiency, cost, and sensitivity of results based on uncertainty to key variables. There are many facets for formulating a scenario; these could include reductions in water demand due to demand side management, assumptions of rates of growth, incorporation of technical innovation, changes in supply. For instance, a scenario to reuse the waste water has a great potential in Palestinian territories to alleviate shortages in water supplies [Attili, 2004; Mimi and Marei, 2002; Mimi, et al., 2003].

This study examines the impacts of population growth on the water supplies of Palestinians under status-quo conditions. From this baseline, several scenarios are developed that describe conditions in 2000 and 2015. Several indicators are used to measure the positive and negative effects of these conditions. The indicators reveal extreme water resources stress among Palestinians as well as potential environmental degradation as population growth depletes natural water supplies

WEAP model as a water planning and evaluation tool has gained some credence in recent times but it has not been established as praxis in current water policy and decision-making frameworks. The results of this study were able to provide insights into potential management tools that will be useful for scenarios and planning evaluation schemes in basins where water resources are already highly stressed basin. In other words, these tools will provide techniques to improve water resources management by providing reliable assessment in a risk avert manner. [Raskin, et al., 1992; Strzepek, et al., 1999; Yates, et al., 2005b].

This thesis was successfully crafted to fulfill the following goals: to investigate the impact of different “what if” questions that are posed to enhance multiple water resources management problems; to develop a framework for the actions to be taken in decision making process and to evaluate the applicability of WEAP on real-life tasks related to water resources issues in Palestine.

The general structure of the thesis is as follows. Chapter I introduce the research and provide general explanation, justification, and background about the research objectives, research contributions, research motivations. Chapter II provides a review of the related literature and describes the general tradeoffs in scenarios modeling and assessment framework, general view about WEAP software and why to choose it in the modeling. Chapter III shows a general view of water resources in Palestine; surface and groundwater resources in West Bank, Palestine geographical location, climate change and rainfall in the area, in addition to Palestinian water use and demand, municipal, and irrigation water use and demand. Chapter IV details the integrated water resources planning and management, description of the case study in this research (Al-Far'a catchment). literature studies on Al-Far'a watershed, also identification of water sources in the catchment. Chapter V demonstrates the applicability of water evaluation and planning (WEAP) model in designing efficient scenarios for Al-Far'a catchment, model setup, and discussing the output results for the different suggested scenarios. Finally, chapter VI summarizes the findings of the research, describes the important inferences derived from this research, and presents conclusions and recommendations.

Integrated Water Resources Planning and Management (IWRP)

The general objective from IWRP and management is to get a reasonable development level. In order to move towards this general objective, decisions have to be taken finally by politicians and other types of decision makers. Also, public participation should play an important role in watershed management polices definition.

But, in the process of taking good decisions, adequate information has to be handled and analyzed about the feasible alternatives, their impact on the multiple objectives, the tradeoffs among them, as well as the risk associated with them. In order to elaborate and analyze such information, sound science, technology, and expertise have to be implicated. Frequently, policymakers and stakeholders are not prepared to produce and understand such information. Therefore, a transfer of technology from scientists to decision makers is needed. But it has to be an effective transfer in the science that decision makers be able to apply the technology easily and in a repeatable and scientifically defensible manner [NRC, 1999].

Of course, this is not an easy task at all. Many aspects are involved in watershed management (e.g, physical, hydrological, chemical, biological, socioeconomic, institutional, legal, etc.) and all are expected to be integrated in the analysis. Development of models in order to study all these aspects has been a duty carried out by the scientific community for many years. But, an additional effort is required to make these tools available to decision makers. Better and more user-friendly tools have to be produced in order to include most components of extremely complex watershed systems to estimate the effect of management alternatives on all the criteria of interest.

The goals of the IWRP are summarized as follows:

A clear consensus of support for policy, program and capital project recommendations resulting from a public outreach process that establishes and maintains effective communications with the District Board of Directors, staff and stakeholders throughout the IWRP process

A vision for District decision-makers that provides clear guidance and direction for all future resource management policies, programs and capital projects through full build-out of the District's water and wastewater service areas.

A comprehensive, forward-looking and fully-integrated planning document that includes the following:

- A "state-of-the-art" Water Use Efficiency (Water Conservation) Plan which, together with all other District demand management measures, is a fully integrated component of the IWRP.

A Drought Contingency Plan that ensures a safe and reliable water supply during dry year and multiple dry-year.

A balanced portfolio of water supplies that optimizes the District's goals of providing the best quality service to its customers at the lowest possible cost.

The successful development and implementation of an Integrated Water Resources Plan (IWRP) are crucial steps for the realization of this vision. The primary purpose of the IWRP will be to develop the policies, programs and capital improvement plans necessary to fully achieve the District's water resource management goals.

Water -Stressed Areas

Water stress results from an imbalance between water use and water resources. Water Stress Index is the number of hundreds of people who must share one million cubic meters of annually available renewable water. A higher value indicates a greater degree of water stress. Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use.

The World Bank experts have a standard definition of water stress index: "The water availability index (WAI) is a global measure of water available for socio-economic development and agricultural production. It represents the accessible water diverted from the runoff cycle in a give country, region or drainage basin, expressed as volume per person per year; m^3/p/y. Critical values of the water stress index (WSI) identify various ranges of water scarcity. Present critical indexes are between 1700 m^3/p/y and 1000 m^3/p/y.

Q/P == the same Quantity of water/ Population

If it is less that 1000 then it is severe stress. If it is between 1700-1000 it is critical.

The water stress indicator in Figure 1 measures the proportion of water withdrawal with respect to total renewable resources. It is a criticality ratio, which implies that water stress depends on the variability of resources. Water stress causes deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.) The value of this criticality ratio that indicates high water stress is based on expert judgment and experience (Alcamo and others, 2003). It ranges between 20 % for basins with highly variable runoff and 60 % for temperate zone basins. In this map, an overall value of 40 % to indicate high water stress is taken. It is seen that the situation is heterogeneous over the world.

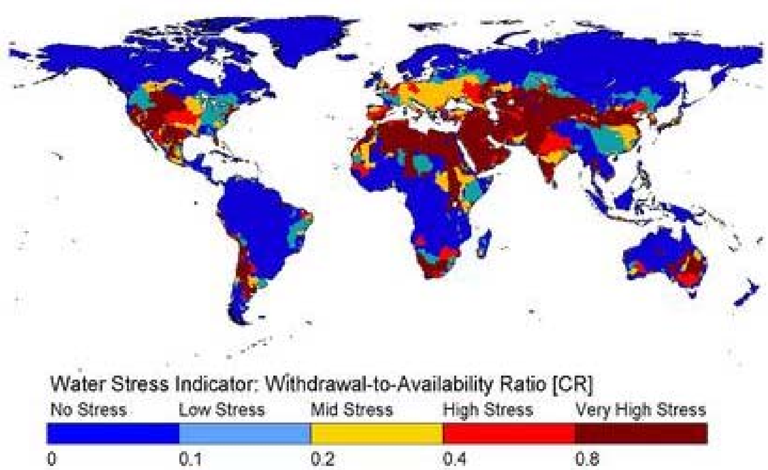


Figure 1: Water tress indicator map.

Research Objectives

Efficient water resources management requires reliable prediction models integrated with decision support systems. Rapid advances in computer technologies, data fusion concepts, and learning algorithms (i.e., computational learning theory and data-driven modeling) have the potential to revolutionize water management. These techniques will serve as the foundation for providing estimates of the uncertainty in real-time forecasts of future water system behavior, and could potentially play a significant role in structuring integrated decision support systems for providing better real-time information for water management decisions. This research is done in order to develop an integrated water resource management (IWRM) model using WEAP software, evaluate the existing scenario and other expected future scenarios taking into account different operating policies, costs, and factors that affect demand such as demand management strategies, alternative supply sources and hydrologic assumptions.

The purpose of the proposed research is to evaluate the plausibility of WEAP as complementary or an alternative to the traditional techniques used to solve decisions making processes for water systems settings.

The main objective behind this work is to develop an integrated water resource management (IWRM) model using WEAP software, Evaluate the existing water management scenarios and other expected future scenarios taking into account different operating policies, costs, and factors that affect demand such as demand management strategies,

1. Evaluate alternative supply sources and hydrologic assumptions.

2. Test and evaluate the use of WEAP and GIS programs as water demand management tool and how to apply them in solving IWRM problems using data and conditions of this case study.

3. Make the required calibration for the output data resulted from WEAP model if it is needed.

4. And demonstrate the expected performance benefits of the proposed scenario in appropriate practical application domains in Al-Far'a basin in Palestine.

CHAPTER II

REVIEW OF WATER RESOURCES IN PALESTINE

Introduction

Next to issues of land, refugee, right of return, and so forth, water resources are the major issue of contention in the peace negotiations between Palestinians and Israeli. Palestinians demand the re-apportioning of water resources. The Palestinians contend that the facts created on the ground unilaterally by Israeli during the last 50 years, namely the agricultural development and the high water consumption by the Israeli urban sector leave them without resources necessary for their development as a modern society [Eckstein and Eckstein, 2003]. Due to this misallocation per capita annual renewable freshwater in the region is amongst the lowest in the world. The issue of water is complicated by glaringly wide disparity in per capita water consumption between the two parties. While borders may separate the two nations with conflicting territorial ambitions, apportioning of groundwater between the indigenous Palestinians and the newly established Jewish State continues to be one of the most intractable issues in the Middle East Peace Process. Israelis claim water rights of groundwater in the aquifers mainly recharged at the uplands of the Upper Cretaceous partly karstified carbonate formations of the West Bank. At the same time, a case of flagrant contradiction, neither international nor domestic law provides an adequate answer to questions of ownership or rights [Eckstein and Eckstein, 2003; Kohn, 2003; McWhorter, et al., 2004; Pearce, 2004; Wouters, et al., 2004].

Here, we outline the water resources states and situation in Palestinian territories to further highlight the need for nontraditional water use and for fair allocation of water resources. We present the numbers and the data to bring up the urgency of the need for best management practices analyses where the implications of being able to anticipate drought, or assess the probability of management scenarios and/or drought are considerably greater for the human population, including of course the potential for enhanced conflict.

Palestine Geographical Location

Palestine is located in southern east of Asia, in southern east corner of Mediterranean Sea and in north and northern east of The Red Sea (see Figure 2).

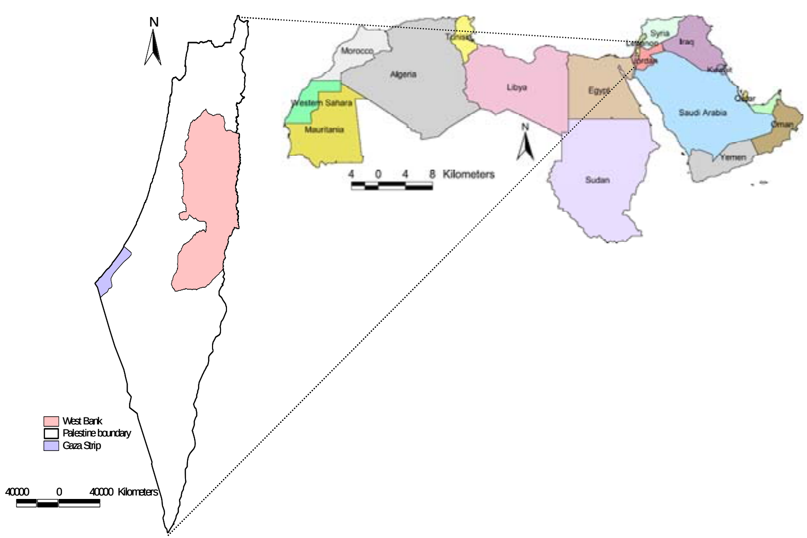


Figure 2: Palestine Geographical location with respect to the Arab World.

Water resources in Palestine are characterized with regional and local interferences. On regional basis, many countries are considered as riparian states to Jordan River basin, and on local basis, the common aquifer basins between Palestinians and Israeli is a complicated issue. In addition to this, the geographical separation between West Bank and Gaza Strip (hereinafter referred to as Palestine) and the suspension of peace process are considered as additional complexity factors.

Palestine is mainly divided into two parts; West Bank and Gaza Strip. The total area of West Bank is 5845 sq km with a length of about 130 km and a width of about 50 km. It is divided administratively into 10 districts: Nablus, Jenin, Tulkarem, Qaliqilya, and Tubas are considered the Northern Districts; Jerusalem, Ramallah, and Jericho are considered as Middle Districts; Bethlehem, and Hebron are considered as South Districts [PCBS–Geographic Statistics 2000]. Gaza Strip is located on the coast of Mediterranean Sea with a length of 40 km and a width ranges between 6 km in the north and 12 km in the south. The area of Gaza Strip is 365 sq km. It is divided administratively into 5 districts: North Gaza and Gaza (Northern). Deir Al-Balah (Middle). and Khan Yunus and Rafah (Southern).

Climate and Rainfall

The climate in Palestine varies from Desert to sub-tropical. In Palestine, temperature ranges from few degrees centigrade in winter to 43°C in summer especially in Jordan Valley [PCNI, 2003]. In general, Palestine has a Mediterranean climate characterized by long, hot, dry summers and short, cool, rainy winters. Palestine is located between the subtropical aridity of Egypt and subtropical humidity of the Eastern Mediterranean.

The watershed of the mountain range that divides the northern from the southern West Bank represents a natural division between rainy western slopes and semi-arid eastern slopes. Though relatively small in area, West Bank enjoys diverse topography, soil structure, and climate conditions. Such characteristics offer a tremendous opportunity for agricultural variation; olive groves cover most hilly mountains [ARIJ, 1994].

Rainfall, which is the main source of water in Palestine, recharges the groundwater aquifer basins, streams, valleys, and runoff water, and it is also used in rain-fed agriculture. Rainfall is limited to winter months starting with October and ending in May, while summer is completely dry. The strongly seasonal hydrologic cycle defines the water year beginning with a dry season that typically extends from May to October as shown in Figure 3. The wet season begins when rainfall increases in late October, the largest proportion of total annual rainfall occurs from December through April. Figure 3 also shows the tremendous variability of precipitation in Palestine.

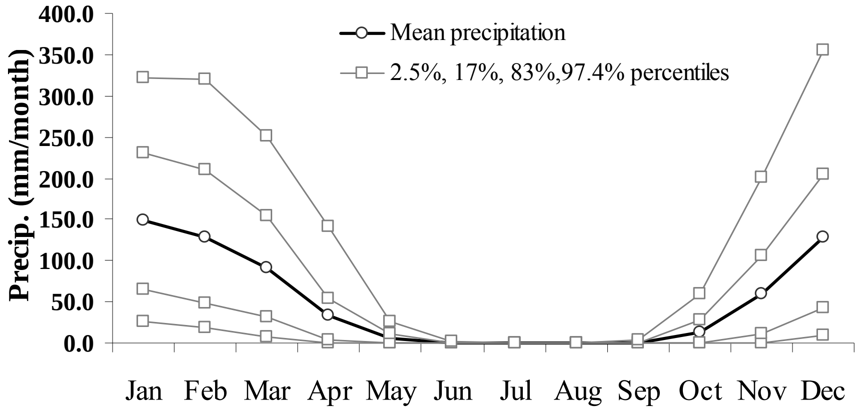


Figure 3: Variation in Jerusalem precipitation (from January 1846 to present) with a noticeably significant annual hydrologic cycle.

The amount of rainfall fluctuates from year to year, and from area to area depending on the location and the topography of the area. The climax of precipitation is usually recorded from December to March. In general, the average annual rainfall in West Bank is 450 mm. The precipitation varies from 70-100 mm/year in Dead Sea, 500-600 mm/year in the western slope, to 100-450 mm/year in the eastern slope. The annual precipitation in West Bank is equal to 2700 – 2900 MCM [PCNI, 2003], While the annual evaporation is estimated by 1900 and 2600 MCM in Semi coastal and Dead Sea areas respectively [MoA, 1999].

Surface Water Resources in West Bank

Surface water is provided by runoff water, streams and seasonal rivers inside the West Bank, Jordan River (the chief source) and Dead Sea. Runoff water is estimated by 71 MCM/Y [GTZ, 1996]. Lebanon, Syria, Jordan, and Palestine are considered as riparian areas in the Jordan River basin, therefore, all of these areas have the right to utilize the water from this river (with conservative of Israeli right). Jordan River originates at the slopes of Mount Jabal Al-Sheakh, located totally in Syria and Lebanon, and empties into the Dead Sea as shown in Figure 4.

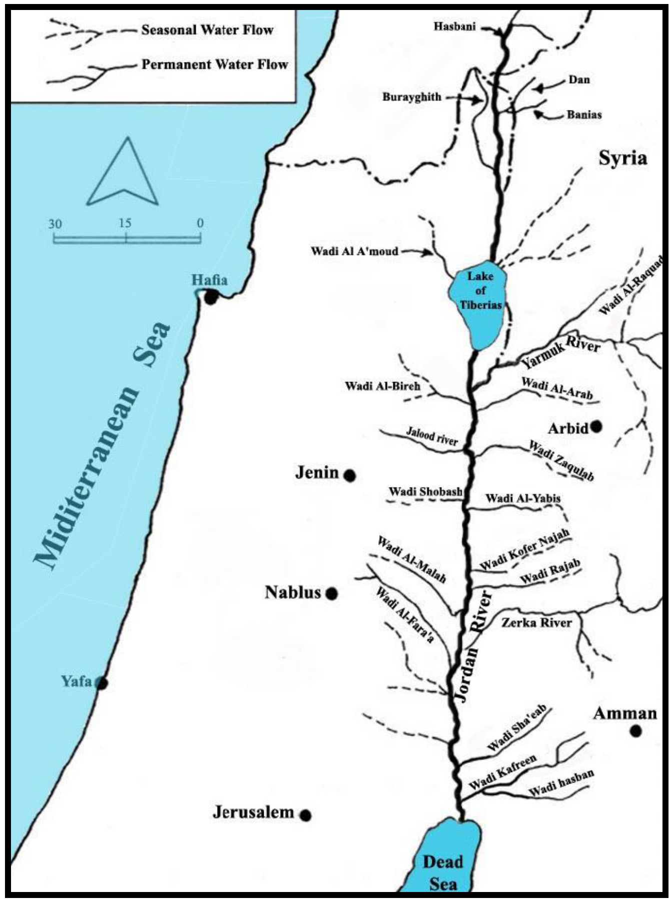


Figure 4: Jordan River Tributaries, [A'bed & Washahi, 1999**].**

The Dead Sea itself is an inland lake at the end of the river that drains an area of 40,000-47,000 sq km. It is replenished by the Jordan River, the main feeder, floodwater, saline, mineral spring from Jordan in the east and from Israel and the West Bank in the west, spring, and rainfall.

The average annual flow of this river is about 1,320 MCM. The utilization of the water resources in the Jordan River is shown in Figure 5 [A'bed & Washahi, 1999].

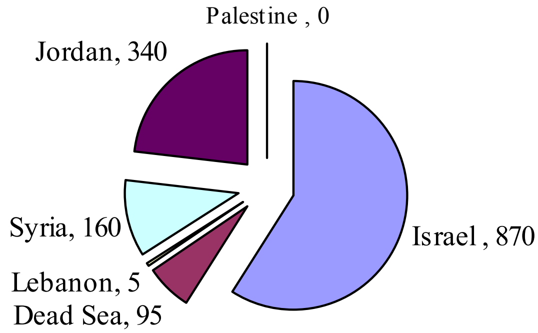


Figure 5: Riparian Utilization of Water in Jordan River Basin (MCM/Y). [PWA, 2002].

Springs and Wells

The geographical distribution of springs indicates that 90% of springs are located in north and middle of Palestine. In addition, plenty of rich springs of fresh water are found in the north, lower numbers of weak springs are found in the middle, and rare springs with saline water are found in the south. The reverse picture for the distribution of springs can be noticed but for agriculture land or land that can be reclaimed, the plain of good soils is wider and plenty in the south if it is compared with the north [Palestinian Encyclopedia, 1990].The number of measurable springs in the West Bank is 146 with discharge of 63.87 MCM/Y, and the number of non-measurable springs, hardly reached or low discharge (less than 0.1 liter per second). is 163 [PWA, 2002].

There are 561 wells; 519 Palestinian wells and 42 wells under Israeli control. Out of Palestinian wells, only 353 are in order with a discharge of 62.08 MCM/Y. There are 18 new wells and 148 wells out of order. Out of the working wells, 308 wells are used for irrigation with total discharge of

34.41 MCM/Y (55.4%). and the rest 27.67 MCM/Y (44.6 %) are used for domestic purposes [PWA, 2002].

Regarding the quality of water, In general, the concentration of chloride ions in water for all wells is acceptable according to the specification proposed by WHO, which should be less than 250 mg/l, while only 70% of wells producing water with acceptable concentration of Nitrate (less than 50 mg/l) according to the specification proposed by WHO [PWA, 2002].

It is important to notice that water resources in Palestine is not maintained and is heavily subjected to diverse set of contamination due the lack of suitable institutions and provisions [Abu Zahra, 2001; Assaf, 2001; Qannam, 2000].

Groundwater

Groundwater provides one-third of the world's drinking water. Since surface water is largely allocated, demand on the finite groundwater resources is increasing. However, groundwater is highly susceptible to contamination. This vulnerability can limit the value of the resource to society as a whole. Groundwater can be contaminated by localized releases from waste disposal sites, landfills, and underground storage tanks. Pesticides, fertilizers, salt water intrusion, and contaminants from other non-point source pollutants are also major sources of groundwater pollution.

In Palestine, Most of West Bank is characterized by limestone, dolomite and marl and chalky limestone upland, cut-up by narrow steep-sided valleys through which surface water usually flows in the rainy season. One property of these rocks is the high absorbent capacity, which leads to a reduction in evaporation of water, an increase in water percolation deeper into the subsurface layer, and consequently a reduction in water runoff. After considering the effective recharging area, the average recharging of the mountain aquifers are estimated with 679 MCM/Y according to Oslo agreement as shown in Table 1.

The mountain aquifers are divided into three aquifers; (North Eastern Aquifer Basin NEAB, Western Aquifer Basin WAB, and Eastern Aquifer Basin EAB) describes the water replenishment rates from these aquifers and the distribution between the Palestinian and the Israeli according to Oslo Agreement signed in 1993.

Table 1: Water Production in MCM/Y by Palestinian & Israeli from the aquifers according to Oslo Agreement

Aquifer	Israeli share	Palestinian from wells	Springs	Aquifer Safe Yield
WAB	340	20	2	362
NEAB	103	25	17	145
EAB	40	24	30	172
Total	483	69	49	679

According to Oslo Agreement, the permitted amount of water to be discharged is the available water resource for the Palestinian in the West

Bank. It is important to mention that the yields of these aquifers are not certain because of the lack of understanding of the possible cross-boundary fluxes amongst these basins. Moreover, there is an inter-aquifer flow within each aquifer. The amounts mentioned in Table 1 are uncertain and remain to be verified upon the finding of future studies, especially the modeling studies shows the groundwater basins in Palestine which are shown in Figure 6.

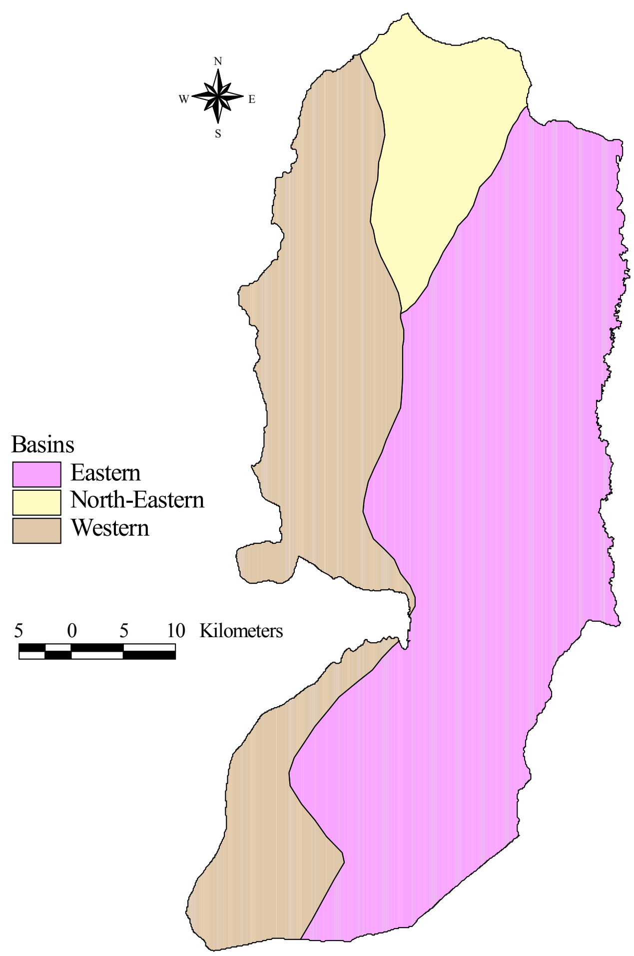


Figure 6: Basins in West Bank**.**

West Aquifer Basin (WAB)

It is considered as the richest aquifer in Palestine extends over an area of 11,862 sq km. The total thickness of the WAB system is in the range of 600-900 m and it includes two aquifer systems. The recharging area for this aquifer is estimated with 1600 – 1800 sq km, 90% of it lies within the West Bank land. The safe yield of this aquifer, as the experts in Oslo negotiation sessions estimated it, is 362 MCM/Y. The Palestinian utilizes 23.64 MCM/Y [PWA, 2002] and this amount equivalent to 6% out of the safe yield, while the Israeli are using 94%.

The number of Palestinian wells on this aquifer is 144 discharging 21.3 MCM/Y; out of them, 123 are agricultural wells constituting 40 % of total agricultural wells in West Bank and the rest are used for domestic usage. There are 4 Israeli wells inside the West Bank territories discharging 2.8 MCM/Y and 518-600 wells outside the West Bank discharging 542 MCM/Y. So, it is noticed that the quantity of water extracted by the Israeli is higher than the safe yield of the aquifer. For Palestinian springs, there are 144 measurable springs discharging 2.35 MCM/Y and 54 non-measurable springs. According to World Bank estimation, over-extracting from this aquifer by Israeli will lead to adverse hydrological consequences.

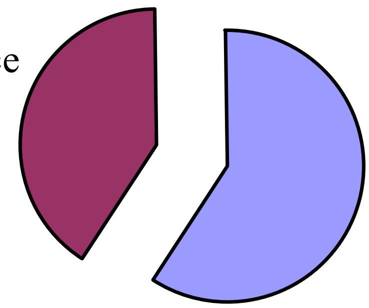


Figure 7: Imbalance in Western Aquifer Basin [Abu Zahra, 2001]**.**

To compare the safe yield of this aquifer (362 MCM/Y) with actual discharge (621 MCM/Y). an imbalance of –172 % will be accounted as shown in Figure 7 [Abu Zahra, 2001]. The WAB is heavily pumped by wells leading to diminishment in springs flow to a small percentage of the pre-use conditions. The imbalance in this aquifer is two times as high as the imbalances in the EAB and NEAB as it will be shown later, therefore, we have strong case of an actual over pumping of this aquifer.

Northeastern Aquifer Basin (NEAB)

It is considered the smallest aquifer basin in West Bank. Its area is about 1424 sq km. The replenishment rate of this aquifer as it has been agreed upon in Oslo Agreement is 145 MCM/Y, but the actual discharge is 184 MCM/Y [PWA, 2002]. The number of Palestinian wells on this aquifer is 82 discharging 15.84 MCM/Y; out of them, 70 are agricultural wells constituting 23% of total agricultural wells in West Bank, and the other 12 wells are used for domestic usage. The Israeli authority has forbidden the drilling of any new agricultural wells and allowed the drilling of 3 wells for household consumption. There are 4 Israeli wells inside the West Bank territories discharging 10.37 MCM/Y (12.9 MCM/Y according to World Bank records) and unknown number of wells outside the West Bank discharging 59.1 MCM/Y.

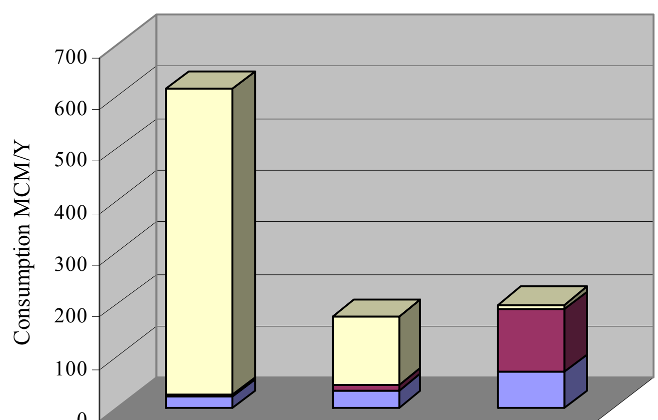
Regarding the Palestinian springs, there are 47 measurable springs discharging 16.76 MCM/Y and 41 non-measurable springs. Discharging from Israeli springs, located outside the West Bank, is 75.2 MCM/Y [PWA, 2002].

The Eastern Aquifer Basin (EAB)

It covers the eastern Part of West Bank located within structural and hydrological boundaries. The EAB System is composed of many separated groundwater flow systems.

The recharge to the Eastern Aquifer Basin as a whole occurs predominantly in the outcrop regions in the mountains of West Bank, where most of the rainfalls are precipitated. The depth of this aquifer is 650 – 800m and the safe yield is 172 MCM/Y as it was agreed upon in Oslo agreement. Currently, the Palestinians utilize 70 MCM/Y from this aquifer, 25 MCM/Y from 127 wells and 45 MCM/Y from 55 springs. The 127 wells are divided into 115 wells used for irrigation, which equal to 37% of total number of agricultural wells in West Bank and 12 wells used for domestic and other usages. Other immeasurable springs in West Bank are 68 due to low discharge capacity (less than 0.1 liter/second) and location difficulties. The Israeli Authority has permitted the Palestinians to drill 15 new wells instead of 12 old and unusable wells [PWA, 2002].The Israeli water discharges from the EAB is 130 MCM/Y from 30 wells with discharge capacity of 31.3 MCM/Y and 11 springs with discharge capacity of 96.6 MCM/Y (88.3 MCM in West Bank and 8.3 MCM outside West Bank [PWA, 2002]. The actual discharge, according to World Bank records is 205 MCM/Y.

In sum, Palestinians utilize 35%, 18%, and 4% of safe yield for the EAB, NEAB, and WAB respectively, while the Israelis utilize 65% from the EAB (60% inside the West Bank and 5% outside the West Bank). 82% from the NEAB (6% inside West Bank and 76 outside West Bank). and 96% from the WAB mostly from 600 wells found on the boundary of West Bank inside the green line, with the exception of 0.3% inside the West Bank land as shown in Figure 8 [Abu Zahra, 2001].



	Western	Northeastern	Eastern
Israel outside WB	589	134	10
Israel in WB	3	10	120
Palestine	24	33	70

Figure 8: Distribution of Palestinian & Israeli Water Consumption in % and Quantity MCM/Y

Palestinian Water Use and Demand

Due to the political situation, the Palestinians haven't been able to practice their sovereignty over the natural resources, and the primary, if not only, available source of water is the groundwater. With the usage of the limited amount of water, the minimum levels of Palestinian society demands for domestic, irrigation, and industry sectors were supplied. The total amount consumed in West Bank and Gaza Strip is 285 MCM/Y [GTZ, 1996]. In late 1980s and early 1990s, the average water use per capita for Palestinian was 82 CM/Y while the Israeli use per capita was 390 CM/Y [Al-Majthoub, 1998]. These averages have been changed especially after the foundation of Palestinian Authority, into 95 CM/Y and 328 CM/Y for Palestinian and Israeli respectively. According to the Israeli allegation, the reduction of Israeli water use per capita was justified by the shortage in water resources and the increases in population due to growth and immigration of Jews to Israel.

Municipal Water Use and Demand

The total water use by the domestic and municipal sectors in the West Bank and Gaza Strip during 1999 was estimated to be 101.3 MCM/Y. An amount of approximately 52.3 MCM/Y was used in the West Bank, whereas a total of approximately 49 MCM/Y was used in Gaza Strip [PWA, 2002]. The municipal water use includes usage for domestic, public, livestock, and commercial needs. The average water supply per capita is estimated with 82 l/d and this figure is not the real average of consumption because the losses of water are not considered. The total water consumption for domestic purposes in the West Bank has been estimated in the past based on estimated loss rates for the various districts and the above-mentioned supply rate. The overall loss or unaccounted-for-water rate was estimated to vary between 25% (in Ramallah) and 65% (in Jericho). with an average of 44% of the total supply. The loss rate in un-piped areas was assumed to be 25%. Unaccounted-for-water rate in piped areas includes physical losses at the source, in the main transmission system and distribution network, unregistered connections, and meter losses.

Domestic water consumption rates were grossly estimated varies with an average of about 50 l/c/d [PWA, 2002], these estimated domestic water consumption rates are substantially lower than the WHO minimum value of 100 l/c/d.

The total municipal water use in Gaza Strip in 1999 is 49 MCM/Y approximately. The per-capita domestic consumption rate was estimated to be approximately 80 l/d after considering the overall losses, which is estimated with 45% [PWA, 2002].

<u>Industrial Water Use and Demand</u>

Due to the constraints imposed on this economic sector in Palestine during the years of Israeli occupation, the industrial sector had a limited contribution to the overall economic development especially in the period preceding the foundation of Palestinian Authority. Types of existing Palestinian's industries range between quarries, food processing and others.

The total area of the industrial zones that are in operation in the West Bank is around 7 sq km.

According to several studies, based on the suggestions and proposals by Palestinian ministries and institutions, it was found that the present industrial water demand in Palestine represents about 8% of the total municipal water demand, while the accepted ratio is 16% according to WHO [PWA, 2002]. The future demand for this sector is estimated with 41 MCM/Y by year 2005 and 48 MCM/Y by year 2010 [PWA, 2002].

Summary

From previous research, we can get the following conclusions:

The most important factor that threatens water availability in Palestine is the Israeli power on water resources in the area. Since they put forceful constraints on Palestinians and on their consumption of water, they don't allow Palestinian to achieve their development as a modern society.

Water scarcity is not the only challenge that threatens water resources in Palestine since it is also threatened by contamination due the lack of suitable institutions and provisions.

Israeli performs the terrible in water availability in the region since they utilize the majority of aquifer's capacity, and they extract quantities of water higher than the safe yield of the aquifer, which leads to disputes in the aquifers, although they know that this over-extracting from this aquifer will lead to adverse hydrological consequences. As discussed earlier, The

Palestinian utilizes 6% out of the safe yield, while the Israeli are using 94% from the West Aquifer Basin, although 90% of it lies within the West Bank land

The same problem is appear in the Northeastern Aquifer Basin, since the replenishment rate of this aquifer as it has been agreed upon in Oslo Agreement is 145 MCM/Y, but the actual discharge is 184 MCM/Y, and this Israeli over extracting threatens the water level in the aquifer.

It is shown that Palestinian don't get their minimum requirements from water, their average water use per capita is 95 CM/Y while for Israeli is 328 CM/Y, and still this quantity is not the real average of consumption because the losses of water are not considered (total losses are on average 40%). Domestic water consumption rate is about 50 l/c/d which is lower than the WHO minimum value of 100 l/c/d.

It is clear that Palestinian can't develop their industry since the available industrial water demand in Palestine is about 8% of the total municipal water demand, while the accepted ratio is 16% according to WHO.

CHAPTER III

CONCEPT OF WEAP MODEL AND DATA REQUIRMENTS

Introduction

Proper water resources management requires consideration of both supply and demand. The disparity of supply and demand over time and space has motivated the development of much of the water resources infrastructure that is in place today.

The goal of sustainable water management is to promote water use in such a way that society's needs are both met to the extent possible now and in the future. This involves protecting and conserving water resources that will be needed for future generations [Khalil, et al., 2005].

Planning, developing and managing water resource systems to ensure adequate, inexpensive and sustainable supplies and qualities of water for both humans and natural ecosystems can only be successful if such activities address the causal socio-economic factors, such as inadequate education, population pressures and poverty.

Water resources professionals have learned how to plan, design, build and operate structures that, together with non-structural measures, increase the benefits people can obtain from the water resources contained in rivers and their drainage basins. However, there is a limit to the services one can expect from these resources. Rivers, estuaries and coastal zones under stress from overdevelopment and overuse cannot reliably meet the expectations of those depending on them. Water resources planning and management activities are usually motivated. In general, the main goal from this management is to obtain increased benefits from the use of water and related land resources. These benefits can be measured in many different ways. Inevitably, it is not easy to agree on the best way to do so, and whatever is proposed may incite conflict. Hence there is the need for careful study and research, as well as full stakeholder involvement, in the search for a shared vision of the best compromised plan or management policy. Modeling provides a way, perhaps the principal way, of predicting the behavior of proposed infrastructural designs or management policies. Developing models is an art. It requires knowledge of the system being modeled, the client's objectives, goals and information needs, and some analytical and programming skills. Models are always based on numerous assumptions or approximations, and some of these may be at issue. Applying these approximations of reality in ways that improve understanding and eventually lead to a good decision clearly requires not only modeling skills but also the ability to communicate effectively. It could be concluded that to engage in a successful water resources systems study, the modeler must possess not only the requisite mathematical and systems methodology skills, but also an understanding of the environmental engineering, economic, political, cultural and social aspects of water resources planning problems [Yates, et al., 2005b].

To achieve this required integrated water resources model, PEST and WEAP software are used since WEAP is known for its special capabilities and abilities to realize management goals. WEAP is a microcomputer tool for integrated water resources planning that attempts to assist rather than substitute for the skilled planner. It provides a comprehensive, flexible and user-friendly framework for planning and policy analysis. A growing number of water professionals are finding WEAP to be a useful addition to their toolbox of models, databases, spreadsheets and other software.

PEST is a unique program that can be used with any pre-existing model for data interpretation or model calibration.

It is powerful. It has successfully calibrated models with hundreds of parameters on the basis of thousands of observations and it is easy to use. No programming is required to interface an existing model with PEST because PEST communicates with the model through the model's own input and output files.

The flexibility engendered through this approach allows ingenious calibration methodologies to be developed, for the "model" can actually be a batch file running many programs in succession. PEST can communicate with some or all of these individual programs.

It depends on nonlinear parameter estimation techniques which allow you to exercise greater control over model calibration and/or data interpretation. Yet PEST can clearly indicate where further complexity is non-sustainable, given the current dataset. Contrast this with the manual calibration process where the modeler simply "gives up" when he/she no longer has the strength or the time to carry out yet another model run. So, PEST is used in this research besides using WEAP model in order to make calibration for the results get from WEAP model.

Estimating Linear and Nonlinear Models

Technically speaking, Nonlinear Estimation is a general fitting procedure that will estimate any kind of relationship between a dependent (or response variable). and a list of independent variables. In general, all regression models may be stated as:

$y = F(x_1, x_2, \ldots , x_n)$

In most general terms, the focus is on whether and how a dependent variable is related to a list of independent variables; the term F(x...) in the expression above means that y, the dependent or response variable, is a function of the x's, that is, the independent variables. An example of this type of model would be the linear multiple regression model as described in Multiple Regression. For this model, it is assumed the dependent variable to be a linear function of the independent variables, that is:

$y = a + b1*x1 + b2*x2 + \ldots + bn*xn$

Nonlinear Estimation allows specifying essentially any type of continuous or discontinuous regression model. Some of the most common nonlinear models are probit, logit, exponential growth, and breakpoint regression.

In general, whenever the simple linear regression model does not appear to adequately represent the relationships between variables, then the nonlinear regression model approach is appropriate.

For calibration purposes here, PEST (Parameter ESTimation) is used. It is a general-purpose, model-independent, parameter estimation and model predictive error analysis package developed by Dr. John Doherty. PEST is the most advanced software readily available for calibration and predictive error analysis of groundwater, surface water, and other environmental models. Using PEST we can:

1. apply advanced and efficient regularization techniques in calibrating your models to extract maximum information content from your data,
2. undertake linear and nonlinear predictive error analysis of model outputs,
3. simultaneously parameterize several models using multiple datasets,
4. accommodate heterogeneity using advanced spatial parameterization,
5. combine PEST with stochastic field generation to explore calibration non-uniqueness,
6. conduct parallel model optimization runs across PC or UNIX networks,
7. compare the worth of different proposed data acquisition strategies in reducing model predictive error thereby optimizing resources allocated to such tasks,

8. quantify the contributions to model predictive error made by different parameter types,

9. establish the irreducible uncertainty of a model prior to calibrating that model,

10. quantify the reduction in predictive uncertainty accrued through model calibration.

Concepts and applications of WEAP model

WEAP computer model is a water demand and supply accounting model (water balance accounting). which provides capabilities for comparing water supplies and demands.

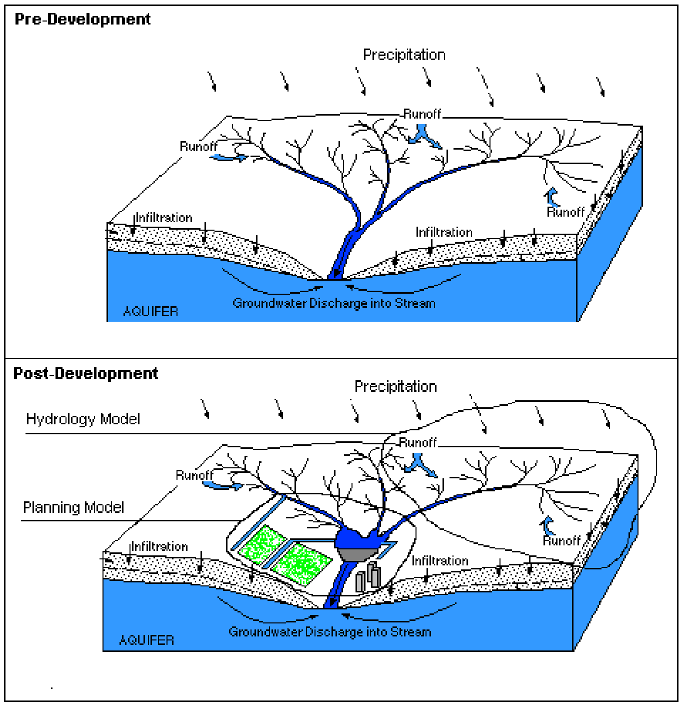


Figure 9. Schemata to show WEAP capabilities in integrating watershed hydrologic processes with water resources management.

As demand for quality water increases with burgeoning population and spawning of socio-economic activities; the lacking for integrated modeling scheme that accounts for physical, structural, and human aspects of the issue could not be further justified [Collado, 1998]. WEAP capabilities to address the multi-faceted aspects of comprehensive water resources brings forth to the decision makers the desirability to employ such model [Yates, et al., 2005a; Yates, et al., 2005b]. As shown in Figure 9, the integration of hydrological physics and the enacted scenarios is dealt with as one component in WEAP. This underscores the anthropogenic interaction with the physical attributes of the watershed. It also implies the appropriate application of water in each use, the administration of the institutional body that manages it, the appropriation of better technologies for planning, assignment, and management, and the assimilation of a new water culture [Collado, 1998; Daibes, 2000].

This anthropogenic dimension entails the influence of human and population on the biosphere. Water resources planning must acknowledge humans as the catalyst for increasing prudence in management, for adding stress on the available water resources, and for land-use change. Adverse anthropogenic impact over water resources stems from mismanagement and misallocation of the available water. Overexploitation of available groundwater, excessive use and misuse of agricultural lands to the extent that the land lose its fertility as well as, the lack of mechanisms for best management practices and water conservation that preserve the water quality are examples of anthropogenic interactions. In sum, it is the extra stress induced by human overexploitation of a limited resource and the lack of stewardship of our natural resources.

Anthropogenic interactions reflect the impact of human and population growth, and industrial growth on the natural resources. For example, climate change is anthropogenic because it is due to an increased industrial activities and increased release of CO_2.

In specific, the following tasks and activities could be performed using WEAP system:

1- identify and evaluate the impacts of climate change on water for agriculture, recreation, hydropower generation, water for municipal and industrial use, habitat function and health, biodiversity, water purification;

2- Simulates water demand, flows, and storage, and pollution generation (environmental assessment capability). treatment and discharge;

3- Provides through its graphical interface a simple yet powerful means for constructing;

4- Viewing and modifying the system and its data (database management, forecasting, and analysis.);

5- Detailed supply demand modeling (forecasting, planning and evaluation);

6- Assess current patterns of land development and modification (land use/land cover and population changes);

7- Examine alternative water development and management strategies including adaptation strategies.

8- Explore the physical, social, and institutional aspects that impact watershed management integrated water resources planning that may impact the water conservation policies.

The precipitation forecasts and future risk scenarios generated by the lack of proper management of proposed scenarios will be integrated into the WEAP, water evaluation and allocation planning management tool, (developed by the Stockholm Environmental Institute, www.WEAP21.org) to generate scenarios of future water availability and to compare different options for management. WEAP model components are shown in Figure 10.

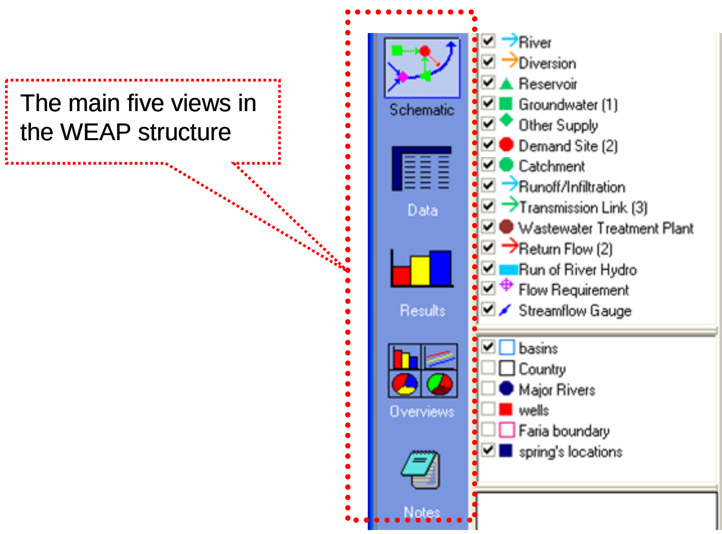


Figure 10: Schematic of the WEAP mode component.

The WEAP model is a basic mass balance model where supply is set equal to demand and water is allocated based on user-defined priorities. It has a GIS-based graphical user interface which makes it an ideal tool for presenting results of various scenarios to non-technical stakeholders and policy makers. The hydrological sub-unit can divide the watershed unit into

N fractional areas of climate.

WEAP Model

The Water Evaluation and Planning (WEAP) model has a long history of development and use in the water planning arena. The model was first used by [Raskin, et al., 1992; Yates, et al., 2005b] to a study on the Aral Sea water allocation and water management issues. The WEAP model was very limited by then due to the poor allocation scheme that treated rivers independently and gave priority to demands on upstream sites over downstream sites [Yates, et al., 2005b].

The advancements of WEAP21 version have been based on the premise that at the most basic level, water supply is defined by the amount of precipitation that falls on a watershed or a series of watersheds with this supply progressively depleted through natural watershed processes, human demands and interventions, or enhanced through watershed accretions. Thus, WEAP21 adopts a broad definition of water demand, where the watershed itself is the first point of depletion through evapotranspiration via surface-atmosphere interactions [Mahmood and Hubbard, 2002].

Figure 11 shows Schematic of the WEAP approach to water resources planning.

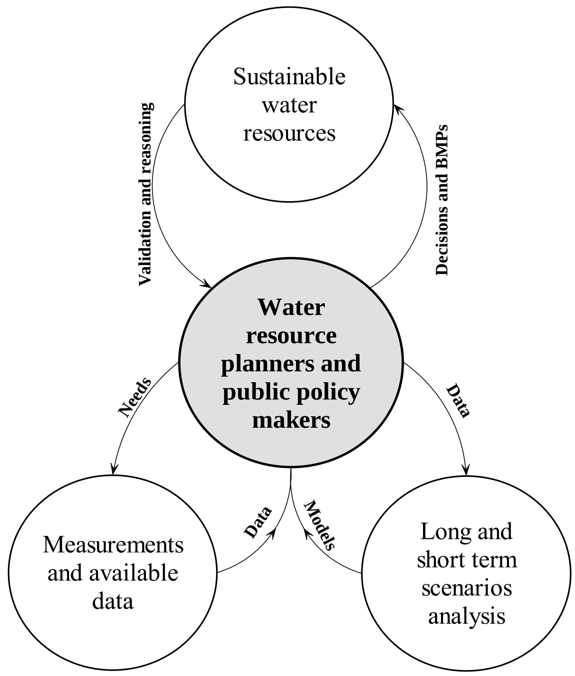


Figure 11: Schematic of the WEAP approach to water resources planning, management of quantity, quality, timing of the flow, and regulations involved requires data models and decisions and scenario analysis.

Thus, WEAP21 adopts a broad definition of water planning and management, and it embodies high flexibility for testing best management practices and accounting for scenario analysis based on data availability, needs, demands, and modeling capabilities. Specifically, in formulating demand mechanisms, the watershed itself is considered the first point of depletion through evapotranspiration via surface-atmosphere interactions. The residual supply, after the satisfaction of evaporative demands throughout the watershed, is the water available to the management system, which is typically the head flow boundary condition of a water planning or operations model. In addition to streamflow generated via hydrologic simulation, the user is free to prescribe time series of head flows for the surface water system and groundwater recharge for focusing solely on water management. By time a lot of developments done on WEAP, now the new version of WEAP released, has numerous and great properties, such as; Hydrologic models; WEAP can model runoff, infiltration, baseflow, evapotranspiration, irrigation requirements and crop yields from catchments. There are two hydrologic models are available; a simplified model using the FAO crop requirements method and a more detailed model which tracks soil moisture in two soil layers via a lumped-parameter hydrologic representation [Levite, et al., 2003; Raskin, et al., 1992; Strzepek, et al., 1999; Yates, et al., 2005b].

Methodology

WEAP program will be used to build an IWRM model taking Al-Far'a catchment as a case study. This will be done after preparing needed maps such as the catchment location within West Bank, topography, and land use; using GIS software, then collecting the required data such as the rainfall data recorded by the different stations of Al-Far'a catchment which analyzed for typical and maximum rainfall intensities, since they will be used as a tool to describe the point station data to the catchment rainfall.

The following summarize the main steps to be followed:

1. Collect all data and information needed from national and local agencies.
2. Setup GIS-based data as input for the model.
3. Suggest future scenarios related to the population growth, supply and

demand changes, and other factors.

4. Build the IWRM model using WEAP Program.

5. The final results of the modeling have been formulated in a form of figures, tables and maps.

6. Make needed calibration for the output data resulted from WEAP model for the catchment.

7. Set the general comments and recommendations.

In order to get our main goals from this research, it is necessary to make some steps;

1. Prepare the required information and all the input data for WEAP software to develop an integrated water resource management (IWRM) model,

2. Be a good decision maker to decide what the suggested scenarios will be after studying the catchment and what it needs to prevent water scarcity or high reduction in water level in the catchment since will help in evaluating the existing water management scenarios and other expected future scenarios taking into account different operating policies, costs, and factors that affect demand such as demand management strategies,

3. Get the output results and study their accuracy and check if they are very close to the reality in order to test and evaluate the use of WEAP

as water demand management tool and check if it can be applicable in solving IWRM problems using data and conditions of this case study and do the needed calibration.

CHAPTER IV

INTEGRATED WATER RESOURCES PLANNING AND MANAGEMENT AND DESCRIPTION OF FAR'A CATCHMENT

Abstract

Water is the major element that sustains and nurtures life. Water has been harnessed in support of the achievement of social goals for thousands of years. Despite the fact that three-quarters of Earth are submerged in this extraordinary compound, water scarcity is among the dangers contemporary world-watchers accuse of endangering the development of several of today’s human communities. In addition, it is evident that many efforts to utilize this scarce resource have been inadequate or misdirected. Only 2.5% of the water on earth is fresh, and two-thirds of that is frozen in Antarctica and Greenland. The world’s human population, now approaching six billion, must survive on the same fixed total amount of fresh water each year. Sustainable water management intends to enhance the water situation as a resource and maintain it for the generations to come. The sensitivity of water resources to a multitude of factors makes it highly vulnerable to diverse set of risks. Decisions to assess water sensitive to a given management mechanism conditioned on external variability are the primary key to endorse sustainability. Information to aid efficient policy making to insulate water resources against detrimental impacts is one of the milestones to ensure that Palestinians scarce resources are maintained and stretched to

provide maximum future utility.

Factors of both palliative and aggravating nature will be assessed through scenario analysis.

The utility and practicality of this a proposed approach to address the water resources in Far'a watershed in Palestine is demonstrated with an application in a real case study involving multi-scale operation of demand, use and supply.

Introduction

For millennia, water has been harnessed in support of the achievement of social goals. Nevertheless, it is evident that many efforts to utilize water have been inadequate or misdirected [NRC, 2001]. In the future, moreover, available water resources will be subjected to greater pressure in the face of increasing demands. Thus, there is an increasing need to more intensively manage water in order to achieve an increasingly diverse set of water-related social goals [Postel, Daily, and Ehrlich, 1996; Gleik, 1993]. Therefore, successful management of basins will require more systematic, comprehensive, and coordinated approaches that will need more –and better quality– information about the state of the water resources systems we manage. The steps for integrated water resources planning and management in Al-Far'a are shown in Figure 12. These steps are as follows: 1) the specification and attributes of the watershed and the sub-watersheds are identified and the points of demand and supply are also pinpointed; 2) identify the types of water demands and the associated seasonality across space and time, this will include specifying the land uses and the pertaining type of water use, the seasonality will also account for the variation in crops demand throughout the year; 3) perform exploration of the future determinants of water supply and demand, the projection in the future of significant determinants could be hypothesized in the selected scenarios to measure and test efficiency and effectiveness; 4) consistently test the supply, demand, use condition, this monitoring is a necessity for the integrated water resources planning and management and plays as the guidelines to formulate adequate scenarios in touch with the reality and the conditions on the ground; 5) continuous tuning of the system factors to minimize losses and cost, maximize efficiency, expand for grows and increasing need requires a diligent and systematic monitoring, control, and adaptive management; 6) seek alternative water supplies (i.e., traditional or nontraditional) to suffice the increase in demand; and 7) enact institutions, measures, and provisions to mitigate water stresses through both long and short term decision making and joint planning.

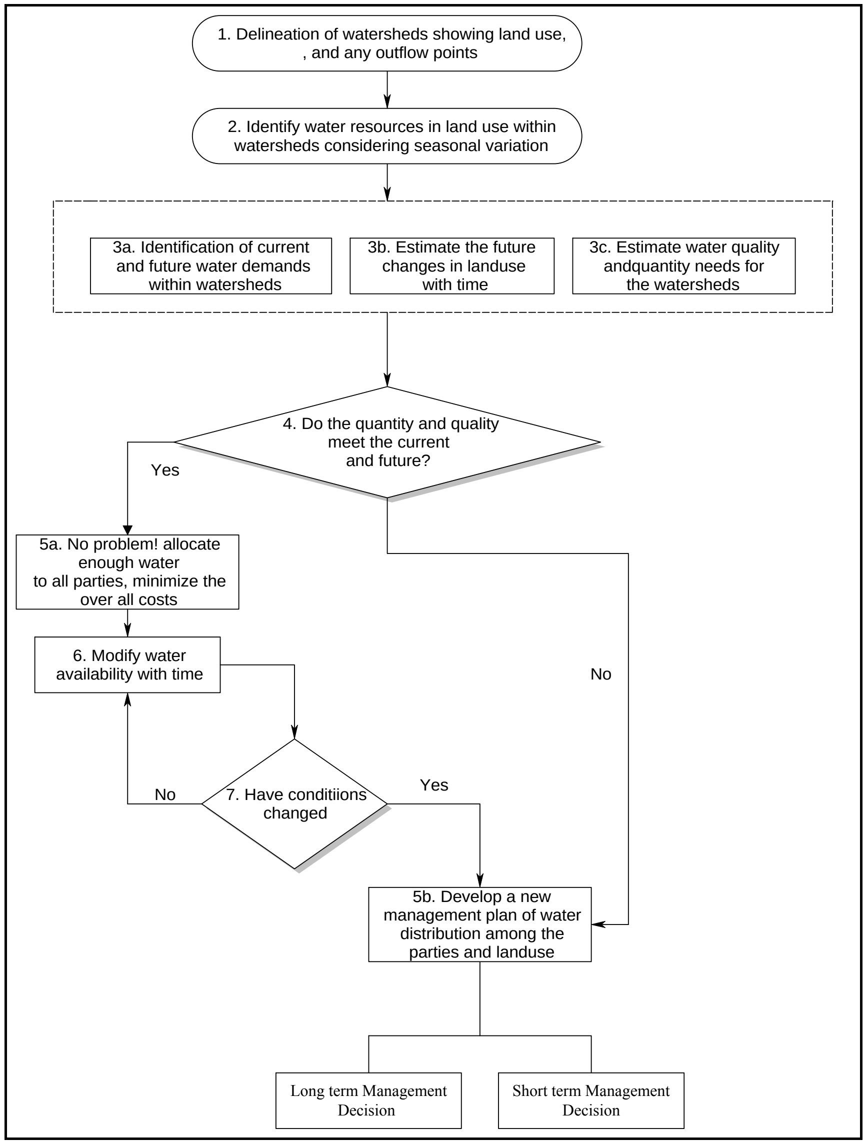


Figure 12: Flowchart for integrated water resources management.

The paradigm formulated here emerges from holistic modeling procedure where the physical modeling, institutional planning, and scenario analysis are all accounted for simultaneously. This should have wide application potential in water resources research and management; that have the capability to identify and reflect new behavioral characteristics of the system, which, in a broader sense, might be interpreted in physically or operationally meaningful contexts.

Description of Al-Far'a Catchment

In this chapter we focus our analysis on Al-Far'a catchment to further enhance sustainable water management and operations along the presented guidelines. Al-Far'a catchment is located in the northeastern part of the West Bank in Palestine as shown in Figure 13. Al-Far'a overlies three major districts and those are Nablus, Tubas, and Jericho. The catchment area of Al-Far'a is approximately 334 sq Km. Al-Far'a catchment lies within the eastern aquifer, which is one of the three major groundwater aquifers forming the West Bank water resources.

Al-Far'a watershed area overlies three districts of the West Bank, these are: Nablus, Tubas and Jericho. The watershed area includes about twenty communities within its borders. Ten of these communities are located around Al-Far'a stream in the area of the watershed known as Al-Far'a valley or Al-Far'a Wadi. These are: (1) Ras Al-Far'a, (2) Al-Far'a camp, (3) Wadi Al-Far'a, (4) Al-Bathan, (5) Al-Aqrabaniyya, (6) An-Nassariyya, (7) Beit Hassan, (8) Ein Shibli, (9) Froush Beit Dajan, and (10) Al-Jiftlik. In addition to these communities, there are three small communities namely, Khirbat Qishda, Khirbat An-Nawaji and Khirbat Tall El-Ghar. Also, there are numbers of scattered families of Bedouins who travel continuously in the watershed and live in few tents.

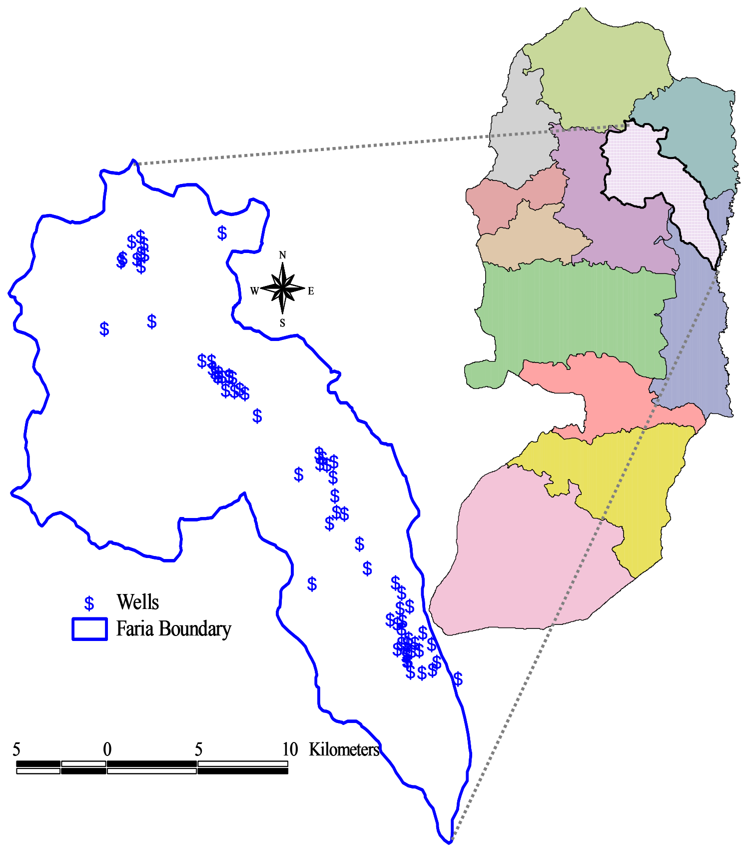


Figure 13: Location of Al- Far'a Catchment within the West Bank Population and Growth

The population of Wadi Al-Far'a is distributed mainly in small villages. The rural population of the area in 2004 is estimated at 20,261 people living in poor economic and environmental conditions. Population growth rate is estimated to be about 3.5% annually (averaged for projected rate of growth by PCBS, 2004). which means that population doubles in nearly 16 years. Therefore, the population of the catchment is expected to reach 36,393 people by the year 2020 as presented in Table 2. The population in the Wadi is classified as a young society because of the high percentage of young hood ages. Children under fifteen represent 36% of the whole population in the area. This young population is in need for housing, educational and health services.

The housing density ranges from 6.5 in Ras Al-Far'a to about 15 people per house in Froush Beit Dajan. The highest density of population was found in Froush Beit Dajan and Al-Jiftlik where housing density exceeds that of Al-Far'a camp. The high housing density there is a direct result of the restrictions on housing for the Palestinians imposed by the Israeli military authorities.

Table 2: Population Estimates and Forecast for Wadi Al-Far'a Area [PCBS, 2004].

Projected year	2004	2010	2015	2020
Total Population	20261	25845	31105	36393

<u>Literature Studies on Far'a Watershed</u>

Few reports and researches are done on Al-Far'a catchment, but there are number of Master researches done on the catchment, such as; Shadeed and Wahsh studied the runoff generation in the upper part of Al-Far'a catchment using synthetic models [Shaded and Wahsh, 2004]. Bashir (2002) studied rainfall data in Al-Far'a catchment and developed approximate IDF curves for Beit Dajan station. [Shaded, 2004] studied the hydrological aspects in the catchment especially the runoff, rainfall using GIUH model and GIS software.

Calvin College and Birzeit University did spread work on the catchment, since they proposed the development of an institutional partnership through the implementation of the proposed water development of the Wadi Al-Far'a. They aim to understand the history of site management and the state of archaeology and archaeological site provides a context for the team's recommendations. Also, agricultural data are provided through this work, it is needed in order to make recommendations on the agricultural land use of the Wadi Al-Far'a. Land units are delineated in hierarchical sensitivity in relation to agricultural parameters of climate, temperature, to determine different degrees of value for land use and protection. The most sensitive land units are recommended for protection. Also, they focus on the land use, agriculture, pollution and health, soil, and other numerous sides

From all works done on Wadi Al-Far'a, it is concluded that it is one of the most prominent wadis in the West Bank; it is a significant agricultural resource. It has ecological as well as landscape diversity from source to mouth. It provides significant amounts of water to the inhabitants of the region, who use it both for household needs and agricultural irrigation.

Identification of Water Sources

In Al- Far'a region the main water consumption is for irrigation where both surface and ground water are utilized for irrigation activities. There are 70 groundwater wells and 13 fresh water springs to provide the necessary water supply as shown in Figure 14. The fertile alluvial soils, the availability of water through a number of springs and the meteorological conditions of the catchment made the catchment one of the most important irrigated agricultural areas in the West Bank. The Far'a basin extends from the ridges of Nablus Mountains down the eastern slopes to the Jordan River bounding the West Bank from east.

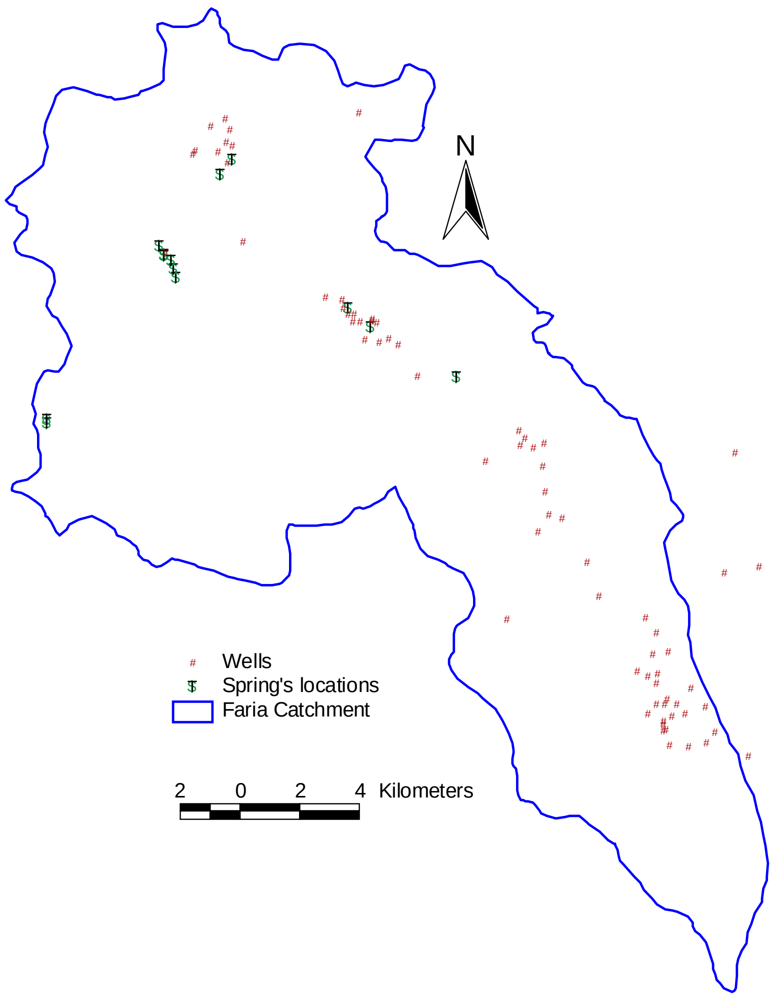


Figure 14: Wells and springs within Al- Far'a Catchment.

Water resources are either surface or groundwater. It was estimated that the city of Nablus discharges about 1.0 MCM/year of untreated industrial and domestic wastewater effluent to Wadi Al-Far'a. Storm water runoff within the Wadi was estimated at 4 MCM/year making a total runoff of about 5 MCM/year.

There are 70 wells in Al-Far'a basin; of which 62 agricultural wells, 3 Domestic and 5 Israeli wells. Based on the data available, the total utilization of the Palestinian wells ranges from 4.5 to 11.5 MCM/year. Water from irrigation wells is used in conjunction with spring discharge in most of the Wadi. During wet years when the spring discharge is high, abstraction from wells reduces while pumping increases in dry years. Palestinian agricultural wells are usually small wells with shallow depths. The deepest and largest wells for Palestinians are the two domestic wells for Nablus municipality which produce about 4 MCM/year. However, Israeli wells in the area are usually deeper, larger and their average production is about 2 MCM/year per well. Thus the 5 Israeli wells produce about 10 MCM/year which is more than the 61 Palestinian agricultural wells combined.

Domestic water supplies to the villages and towns in Wadi Al-Far'a are obtained from existing springs and wells in the area. Ras Al-Far'a and Wadi Al-Far'a villages don’t have domestic pipe networks.

Pumping records from wells in the area showed that the biggest domestic water consumer is the city of Nablus which consumes from Wadi Al-Far'a area about 4 MCM/year. This quantity varies from one year to another depending on the availability of water from other sources for the city of Nablus. It was estimated that the per capita consumption in Nablus is about 88 Liters/day which is lower than the minimum recommended by the WHO. The per capita consumption is much less in the rural areas of Al-

Far'a Wadi and rarely reaches 50 Liters/day. Economic and social development in addition to population growth will result in significant increases in domestic water consumption in the area.

Domestic and agricultural water supply system

- Domestic water supply systems: There are three distinguished domestic supply systems in the area. These systems include: Nablus municipality, Tubas municipality and Al-Far'a camp systems. The Nablus municipality supply system utilizes two water wells in the watershed in addition to two small springs in the upper parts of the watershed within the city limits of Nablus. These wells and springs are considered an important part of a much larger supply system for Nablus, which provides water for more than 200,000 people in Nablus city and few villages around it. Since Nablus utilizes several water resources many of which are outside Al-Far'a watershed it will be hard to clearly define its demands from Al-Far'a watershed. However, the amounts of water supplied to Nablus from Al-Far'a are restricted by the discharge capacity of the main trunk pipeline carrying water to Nablus, which is estimated at 500 m3/hr.

- Agricultural supplies are from either springs or from wells. Supply data from irrigation wells are available from the pumping rates of wells. Irrigation wells supply water through a number of small pipe networks, which are not connected with each other. Therefore, the areas that can be irrigated from these wells are not well defined which makes demand harder to estimate.

Climate perspective

The data on climate condition prevailing in Al-Far'a watershed were obtained from Palestine Climate Data Handbook published by the MOT (Meteorological Office of the Ministry of Transport) in 1998. Climatic data included mean wind speed, average monthly values for maximum and minimum temperature, mean relative humidity, pan evaporation and mean rainfall for Nablus and Al-Far'a stations.

The main wind direction is from west, southwest and northwest. Variation during winter is associated with the pattern of depressions passing from west to east over the Mediterranean [Al-Khatib, et al., 2003; Nashashibi and vanDuijl, 1995]. Al-Far'a catchment is characterized by high temperature variations over space and time. Temperatures reduce with increasing elevation in the catchment. The mean annual temperature changes from 18 ^{o}C in the western side of the catchment in Nablus to 24 ^{o}C in the eastern side of the catchment as shown in Figure 15.

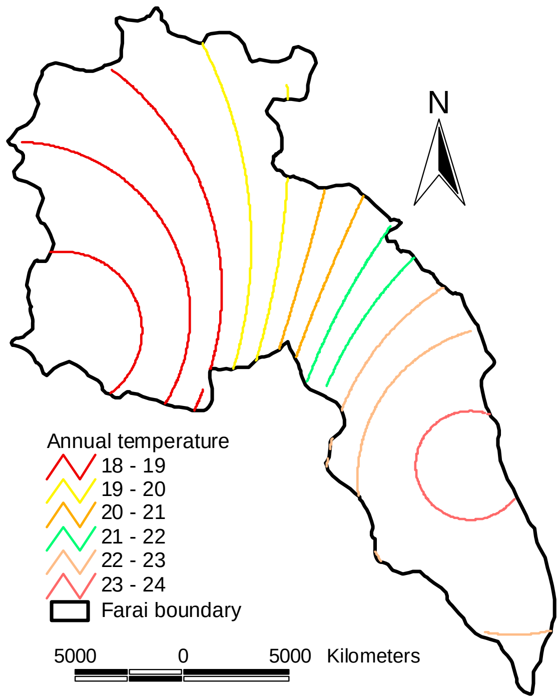


Figure 15: The annual temperature in Al-Far'a Catchment.

The mean annual relative humidity of Nablus area is 61%. The minimum value of relative humidity is 51% which occurs in May during the Khamaseen weather, while the maximum relative humidity of 67% is usually registered in December, January and February. Relative humidity is in general low in the entire catchment especially in summer months because the catchment is located on the eastern side of the West Bank Mountains. The source of humidity in the region is the Mediterranean Sea, where the western winds bring humidity to the catchment. Eastern winds coming from the desert are usually dry.

The West Bank is considered as semiarid and has the Mediterranean type climate. Regionally, the winter rainy season is from October to April in the catchment. Rainfall events predominantly occur in autumn and winter to account for 90% of the total annual precipitation events. Although the summer months are dry, some rain events occur occasionally and a high-pressure area governs the weather over the Mediterranean. Figure 16 shows the annual rainfall in Al-Far'a catchment.

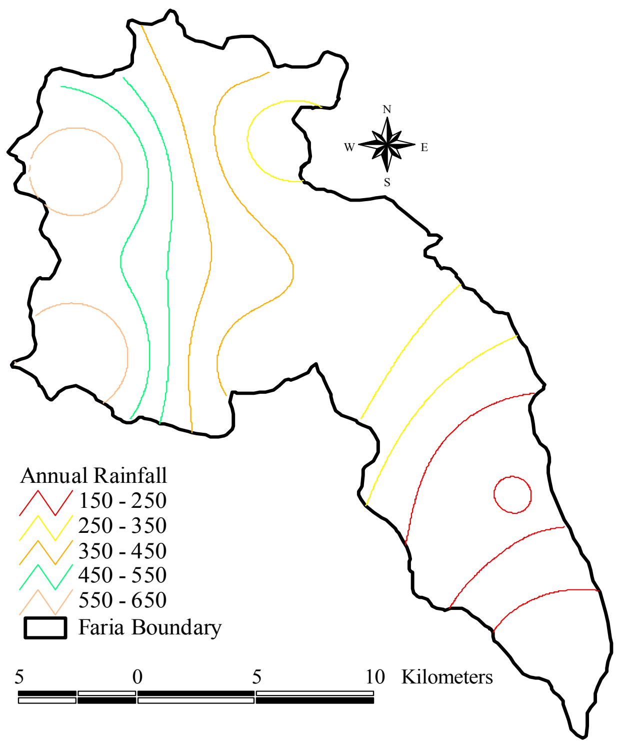


Figure 16: The annual rainfall in Al-Far'a Catchment

Evaporation rates in Al-Far'a regions are measured from a US Class A pan at Nablus station. The average annual evaporation measured at Nablus station is about 1682 mm. Evapotranspiration is usually smaller than pan evaporation. Evaporation rates should be multiplied by a pan coefficient (less than 1) to estimate evapotranspiration rates. A more accurate way to estimate evapotranspiration is from climatic data. The average annual potential rate of Evapotranspiration in the catchment is about 1474mm, and the average annual rainfall is 420mm.

The annual average Precipitation ranges between 150 and 660 mm in Al-Far'a watershed. Figure 16 presents a spatial representation of the rainfall data. Regionally, the winter rainy season is from October to April in the upper zone, while in the central and lower zones, rainfall events usually occur between November and April. Rainfall events predominantly occur in autumn and winter to account for 90% of the total annual precipitation events. Rainfall measurement within the Wadi Al-Far'a basin is highly varied because of the relationship to the topography. Nablus, in the western parts of the watershed is at a topographic high (about 900 m above sea level) the average annual precipitation exceeds 600mm, and the Jordan Valley is at a topographic low (-250 m) the average annual precipitation reaches 160mm while at the central zone (about 100m below sea level) the average annual precipitation reaches 230mm (Table 4.4). There is a large variability in annual precipitation especially in the eastern sides of the watershed. Therefore average precipitation values depend on the periods used in estimating average precipitation. Published data by the Metrological office of the department of Transportation showed that for the period of 1969 to 1981, average precipitation in Al-Jiftlik was 225 mm, for Nablus an average of 660 mm was estimated for the period of 1975 to 1997. However, in this study precipitation values for longer periods of time were collected and the average values were estimated and shown in Table 3. In all the three zones, June, July and August are completely devoid of rain.

Table 3: Annual Precipitations for the Different Climatic Zones of Al-Far'a Watershed

Station name	Climatic zone	Average annual precipitation (mm)	Years of record
Talluza	Post upper zone	630.5	1964-2002
Nablus	Post upper zone	642.6	1947-2002
Tubas	Upper Zone	415.2	1968-2002
Bait Dajan	Upper Zone	379.1	1953-2002
Tammoun	Central Zone	322.3	1967-2002
Al-Jiftlik	Lower Zone	198.6	1953-1989

Source: Based on PWA database and Tubas Municipality for Tubas data.

Evaporation rates in Al-Far'a regions are measured from a US Class A pan at Nablus station. The average annual evaporation measured at Nablus station is about 1682 mm. Evapotranspiration is usually smaller than pan evaporation. Evaporation rates should be multiplied by a pan coefficient (less than 1) to estimate evapotranspiration rates. A more accurate way to estimate evapotranspiration is from climatic data. The average annual potential rate of Evapotranspiration in the catchment is about 1474mm, and the average annual rainfall is 420mm.

Surface runoff in the eastern slopes of the West Bank is mostly intermittent and occurs when rainfall exceeds 50mm in one day or 70mm in two consecutive days (Bestir, 2002). Rofe and Raffety (1965) studied runoff in the West Bank through monitoring and studying runoff data from seventeen flow gauging stations within the boundaries of the West Bank. They concluded that surface runoff constituted nearly 2.2% of its total equivalent rainfall. Surface runoff of Wadi Al-Far'a is high compared to other Wadis in the West Bank because of the steep slopes of the area.

Runoff decreases from west to east as the slope becomes relatively more gentile eastward down the Wadi and rainfall rates reduce.

The stream flow of Wadi Al-Far'a is a mix of:

- Winter storm runoff water of about 4 MCM/year. This includes urban runoff from the eastern side of the city of Nablus and other built up areas in the watershed.
- Untreated wastewater of eastern part of Nablus and Al-Far'a camp which is about 1.0 MCM/year.
- Fresh water from springs which provides a base flow for the stream preventing it from drying up in the summer.

Part of this surface runoff of the stream recharges the shallow unconfined aquifer in the Wadi. Farmers use part of this water for irrigation while the rest is discharged into the lower Jordan valley or lost through evaporation.

CHAPTER V

SCENARIOS ASSESSMENT AND ANALYSIS

Model Setup and Preparation

WEAP applications generally involve the following steps: 1) problem definition including time frame, spatial boundary, system components and configuration; 2) establishing the current accounts which provides a snapshot of actual water demand, resources and supplies for the system; 3) building scenarios based on different sets of future trends based on policies, technological development, and other factors that affect demand, supply and hydrology; and 4) evaluating the scenarios with regard to criteria such as adequacy of water resources, costs, benefits, and environmental impacts.

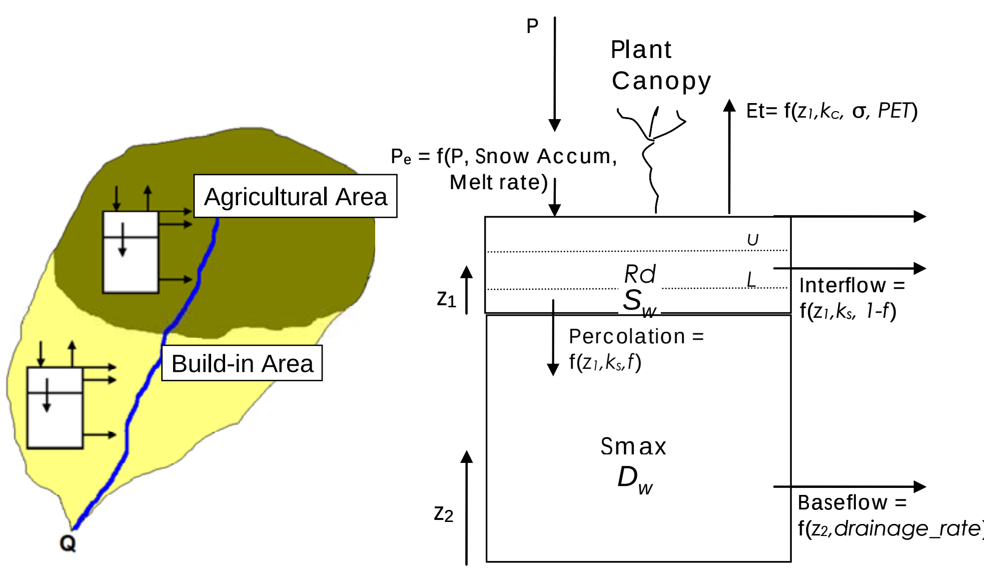


Figure 17: Reservoir model represents how WEAP translates precipitation into surface runoff, interflow, and baseflow.

Figure 17 shows the stylized limited parameter hydrologic model. We are computing a watershed mass balance in a stylized way. Runoff from the upper storage occurs as direct, surface, and interflow, whereas baseflow originates only from the lower storage. As shown in Figure 17 the hydrologic model takes into account many physical attributes like Precipitation (P). evapotranspiration (E_t). effective precipitation (P_e). upper storage capacity (root zone) (S_w). lower storage capacity (deep water zone) (D_w). average, long-term relative storage in the root zone (percentage of total available capacity; % of S_w) (Z_1). and average and long-term relative storage in the deep water zone (percentage of total available capacity; % of D_w) (Z_2).

The model evaluation criteria could be any of the following: flows along mainstem and tributaries; reservoir storage and release; water diversions from other basins; agricultural water demand and delivery; municipal and industrial water demands and deliveries; and groundwater storage trends and levels.

In this chapter, we will try to seamlessly link water modeling schemes directly to the adopted panning strategies. Although WEAP is mainly a river basin model that looks at supply, demand, and infrastructure, it also has a hydrologic model that can determine runoff along with irrigation type modeling capabilities.

Objectives of WEAP Application

The objective of this chapter is to answer the following questions:

How should water be allocated to various uses in time of shortage? How can these operations be constrained to protect the services provided by the river? How should infrastructure in the system (e.g., dams, diversion works, or even wastewater treatment plant) be operated to achieve maximum benefit? How will allocation, operations, and operating constraints change if new management strategies are introduced into the system?

Data Requirements (inputs and assumptions)

The following input data and assumptions are used in WEAP model for Al-Far'a catchment;

1. Total area of the catchment is 334 sq km, the agricultural areas and the domestic areas form about 88.2%, 8.2% respectively from the total area.

2. Water consumption in the catchment for the years between 1977 up to 2003 is used as a yearly input data.

3. The annual safe yield of the Eastern Aquifer is 70 MCM (since Palestinian utilizes 70 MCM according to Oslo agreement) and for Al-Far'a catchment is 20 MCM. (WESI, 2003).

4. Average annual runoff is about 8.5 MCM.

5. The population in the catchment in 2004 is 20,261 people, and the population growth is 3.5%.

6. It is assumed that the agricultural and the domestic demand sources have the same degree of priority.

WEAP MODEL FOR AL-FAR'A

The initial tasks in the modeling with WEAP are to set the main components of the system; area location, catchment size, supply and demand locations, basins or any other source of groundwater, surface water sources. Figure 18 shows the WEAP model for Al-Far'a catchment.

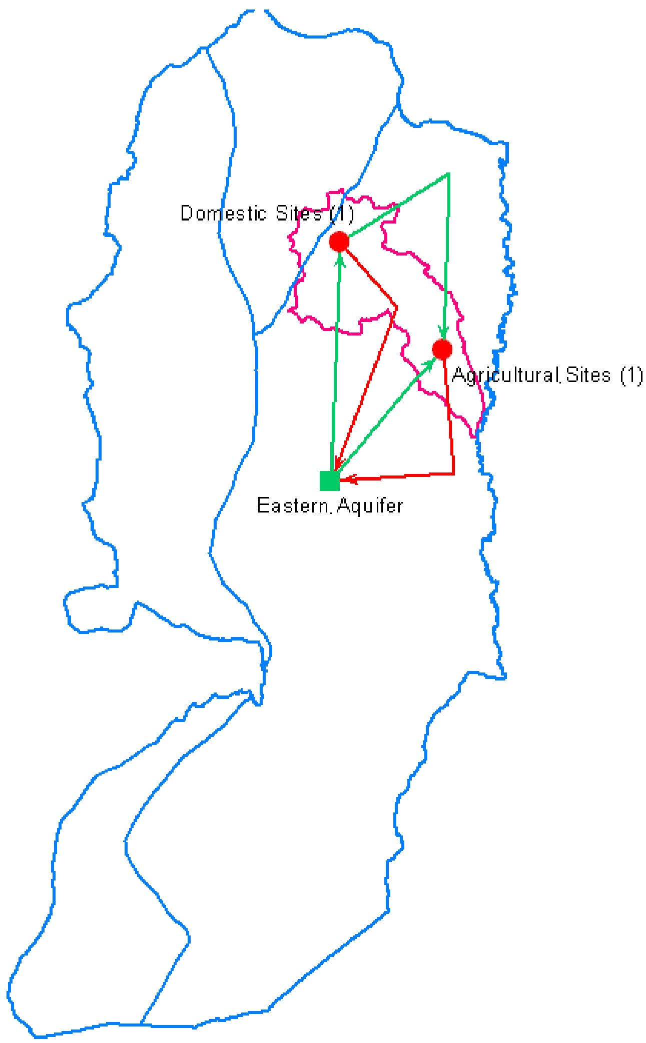


Figure 18: WEAP model for Al-Far'a Catchment.

As shown in Figure 18, Al-Far'a catchment is divided in to two main demand sources; agricultural demand sites and the domestic demand site. The agricultural areas form about 88% from the total area of the catchment while the domestic sites form about 8.2%. Figure 19 shows the landuse for Al-Far'a catchment. From this simple statistics it is concluded that the main factor that affects the water availability in the catchment is the agricultural consumption of water. So, this study will focus on the agricultural water consumption more than municipal one. For these demand sites the annual data are available from 1977 up to 2003 [PWA, 2003] Also, population data are available from PCBS census. See the Appendix.

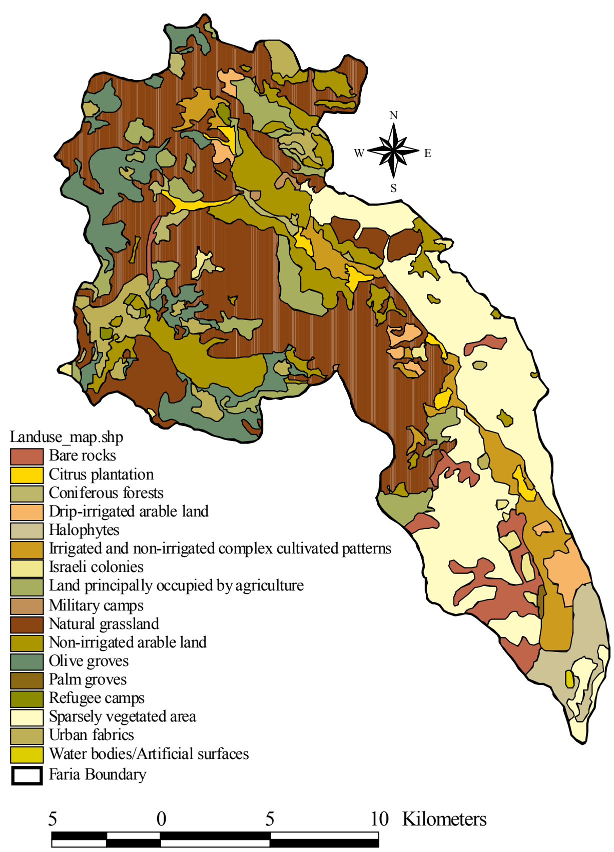


Figure 19: Al Far'a catchment landuse map

The supply input elements related to the water balance in the catchment were studied. Data related to groundwater recharge rates, its initial storage, its specific yield, and the maximum withdrawals allowed according to annual renewal was collected and calculated based on yearly time steps for the period 1977-2003 according to the water balance equation. The major water resource in the catchment is the groundwater; specifically the Eastern aquifer, extraction of water is mainly through wells and springs. The storage capacity is unlimited. The safe yield is 172 MCM/Y as agreed upon in Oslo agreement but currently, the Palestinians utilize 70 MCM/Y from this aquifer. This research will base on the safe yield of Al-Far'a catchment which is 20 MCM/Y. Figure 20 shows water demand and supply sources in the catchment.

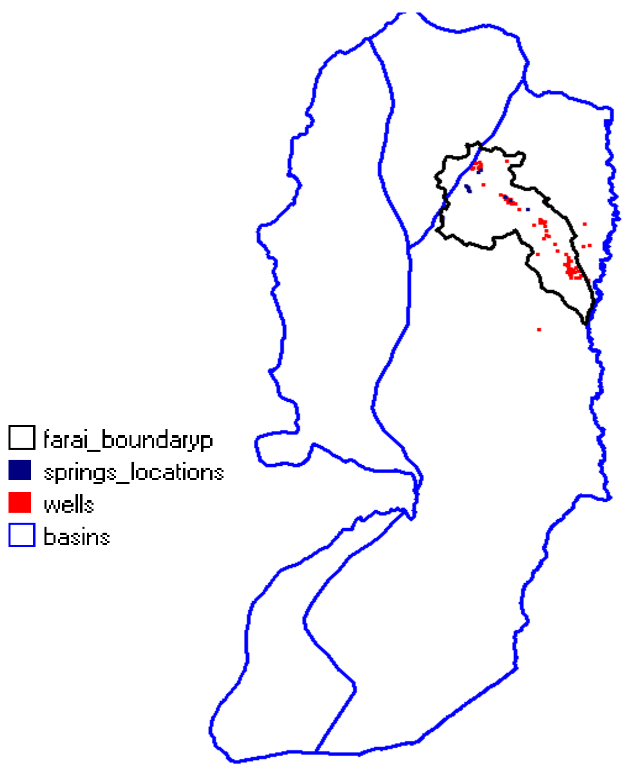


Figure 20: Water demand and supply sources in the catchment**.**

WEAP Setup

First of all, the basic parameters were defined: the current account year and forecast intervals. Figure 21 shows the main concepts of WEAP.

Figure 21: shows the main concepts of WEAP

While, Figure 21 shows WEAP model for Al Far'a region and the water demand.

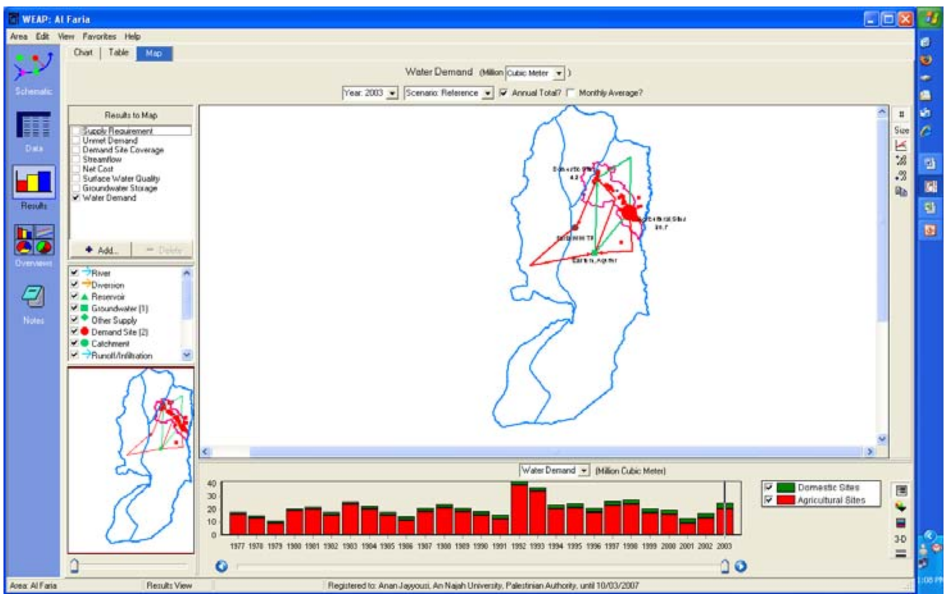


Figure 22: WEAP model for Al Far'a catchment

The current account set corresponds to 1977 while the forecast interval is 2004-2029 as shown in Figure 22.

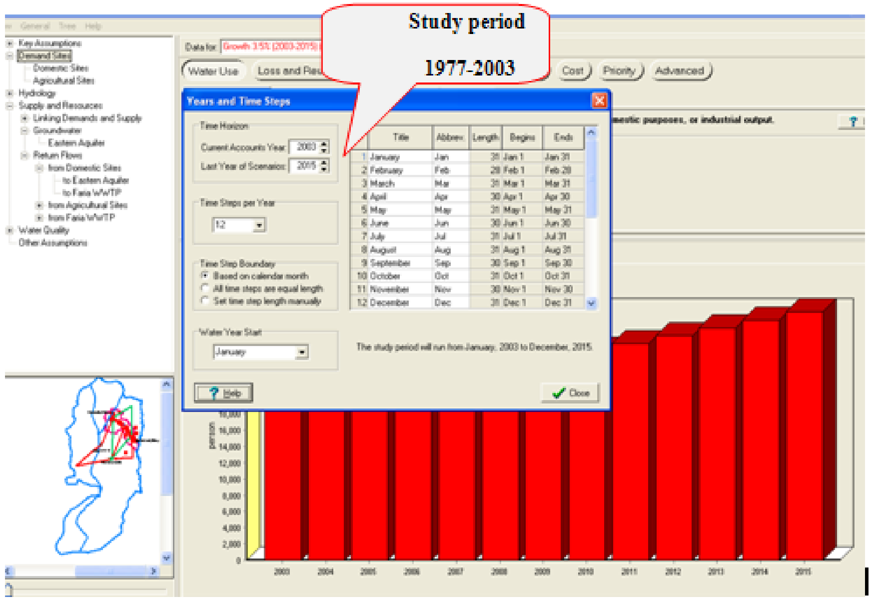


Figure 23: The study period and input annual demand in the WEAP window.

Then set the priorities. Priorities can range from 1 to 99, with 1 being the highest priority and 99 the lowest. These priorities are useful in representing a system of water rights, and are also important during a water shortage, in which case higher priorities are satisfied as fully as possible before lower priorities are considered. If priorities are the same, shortages will be equally shared. Figure 24 show the concept of priorities in WEAP.

Figure (a)** **Figure (**b)**

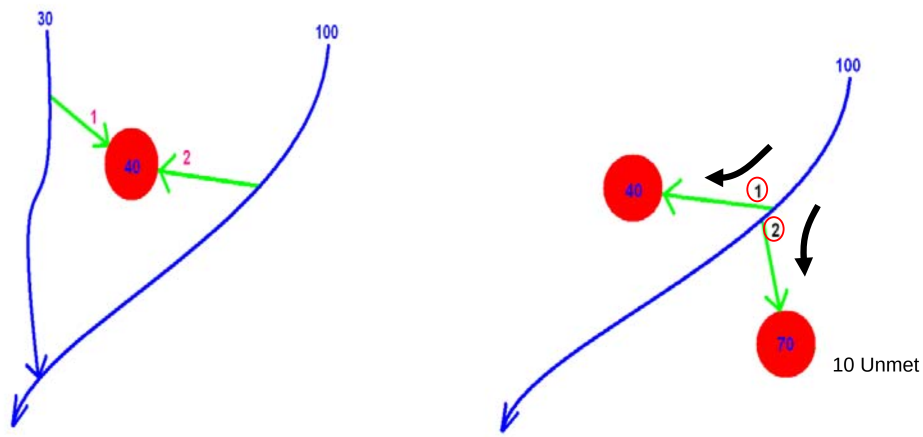


Figure 24: WEAP concept of priorities.

Then enter all required input data and check all units used, run the model will be done without errors or difficulties. Usually, it is possible to get results in form of tables, graphs or maps. Here, some outputs for the existing scenario are shown.

Annual Demand

Figure 25 shows the annual water demand for the agricultural and domestic sites. From this graph it is shown that main source of consuming water is the agriculture. From the land use map, it can be shown that the agricultural areas form approximately 88.2% from the total area. That means agriculture has a great effect on the water consumption and this is what exactly shown in this figure since agriculture utilizes the noticeable amounts compared with the domestic ones. As a conclusion, it could be recognized that if the agricultural crops are controlled well and effectively like how to choose types of crops, what seasons are better for each type, and amount of water needed for each crop, since this will manage the consumption of water.

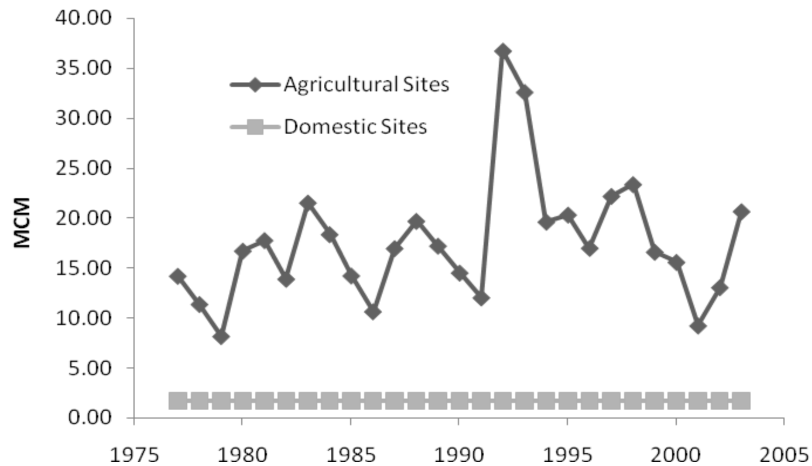


Figure 25: Annual water demand for agricultural and domestic sites.

Annual Groundwater Inflows and Outflows

Figure 26 shows the annual groundwater inflows and outflows. It could be noticed that there are a lot of hydrologic processes occur within the aquifer; inflow, outflow, recharge which cause changes in storage as the time pass, but at the end the equilibrium set and the physical sum of all these processes goes to zero. That means the inflow equals to the outflow which is the main concept in WEAP model. (Positive sign in WEAP charts shows the inflows while the negative sign shows the outflows).

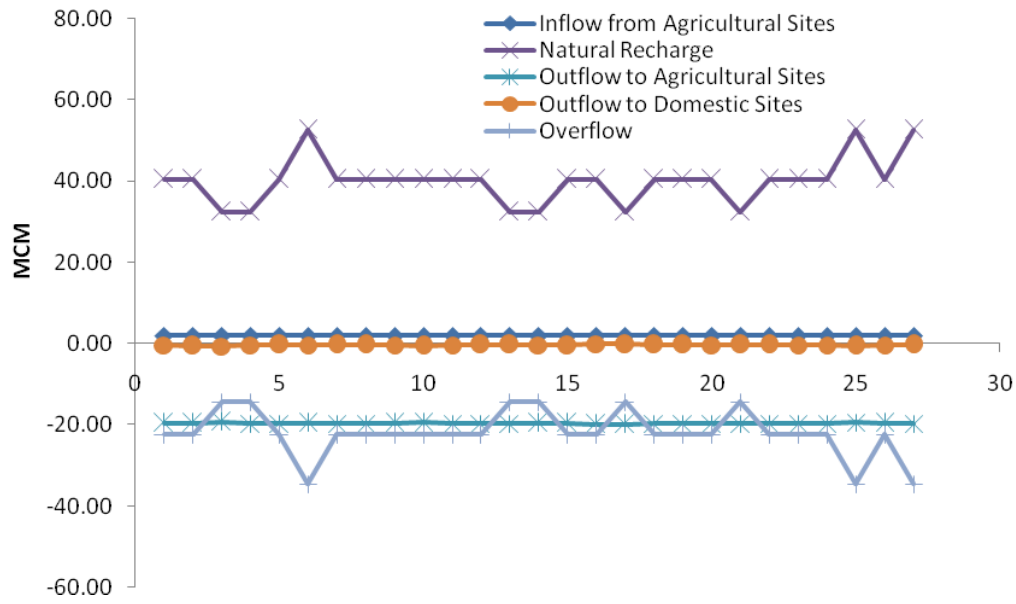


Figure 26: The annual groundwater inflows and outflows**.**

Proposed Scenarios

Scenarios are formulated by considering a set of alternative assumptions about future impacts of the adopted policies. For instance, a policy to enhance the irrigation mechanisms and advancing the irrigation strategies will save water. A decision to embrace scenario is a function of cost, climate considerations, water status in the sense of demand and supply, and water quality. These decision variables should be explored in order to design scenarios efficiently and effectively. Scenarios are used to explore the model with enormous range of "what if" questions, such as:

1. What if the population growth and the economic development patterns change?

2. What if groundwater is more fully exploited?

3. What if water conservation is introduced?

4. What if more efficient irrigation techniques are implemented?

5. What if the mix of agricultural crops changes?

6. What if climate change alters demands and supplies?

Scenario One

This scenario is the “Do-no-thing Scenario”. What is done till now shows the reference scenario that reflects the existing conditions. The next step is to suggest the future expected scenarios that coincident with the nature and hydrology of the catchment. In the coming sections we will build scenarios based on different sets of future trends.

Following are the WEAP inputs and outputs for the existing situation:

Water agricultural and domestic demands for the catchment

Figure 27 shows water agricultural and domestic demands for the catchment between the years 1977-2003.

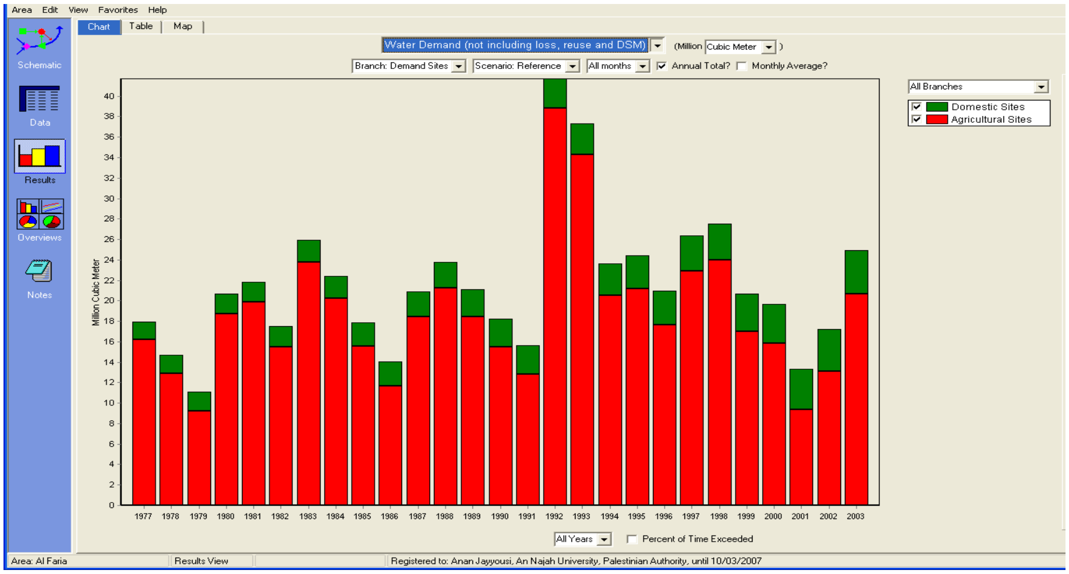


Figure 27: Annual agricultural and domestic demand sites.

Figure shows the unmet demand for the catchment. It shows that there is a shortage in the water needed for both agricultural and domestic sites in the region. There is variability in the amount of the water shortage with a maximum agricultural unmet demand happened in 1992. The agricultural unmet demand is always larger than the domestic one since always the amount of water needed for the agricultural uses is more than domestic uses as shown in

Figure 28.

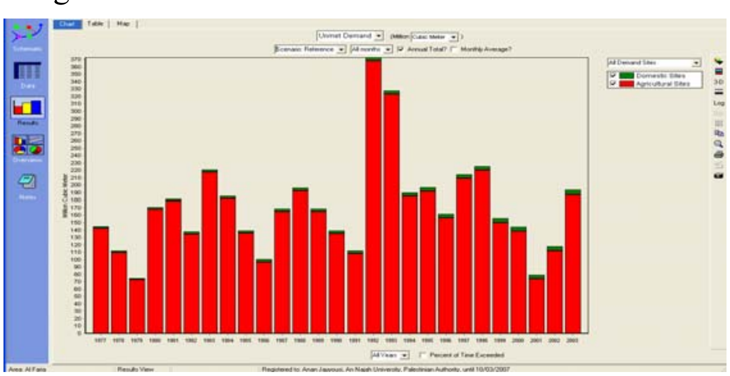


Figure 28: The unmet demand for the region.

Scenario Two

Projects related to wastewater treatment or reuse, are rare in Al-Far'a area due to lack of proper or adequate wastewater collection systems there. However, some initiatives are in the phase of planning or initial implementation phases.

A major project for the treatment and reuse of wastewater discharged from the eastern part of Nablus is being studied for the past few years. Such project is expected to treat about 40% of wastewater generated from the city which is estimated to reach about 1-1.5 MCM/year. The proposed plans assume that the location of treatment plant and the area of reuse to be in the upper area of the watershed. Therefore, there will not be any potential increase in water amounts in the middle or downstream areas. However, the positive effects of such project will include the elimination of the main wastewater source polluting the fresh water resources in the area.

Other small scale projects are being implemented by local NGO's through foreign funding to wastewater treatment units at the household level. The Palestinian Agricultural Relief Committees (PARC) is implementing this project with the assistance of Water and Environmental Studies Institute of An-Najah National University. Their plan is to construct 100 units in the area of Al-Far'a and Tubas. These units will be situated in households that possess a garden or irrigated area of at least 100 square meters and are assumed to be capable of treating black wastewater from these households. The treated effluents will pass through a sub-surface irrigation system to minimize potential health risks associated to wastewater reuse.

In this scenario, it is suggested to establish wastewater treatment plant (WWTP) in the catchment to reuse water from agricultural and domestic sites. The same assumptions in the existing scenario are used here in this scenario, in addition to establish the WWTP, and the population growth of 3.5% for the years 2003-2015. The following output results produced from WEAP. From Figure 29, it is clearly noticed that creating a WWTP in the catchment will affect and reduce the agricultural demand. In this case, the maximum expected amount of water consumed by the agricultural sites is less than 25 MCM in 2024 while in the existing scenario the maximum is more than 35 MCM, and main consumption is the domestic sites almost the same although there is a population increase of 3.5%. This means establishing WWTP is recommended and powerful.

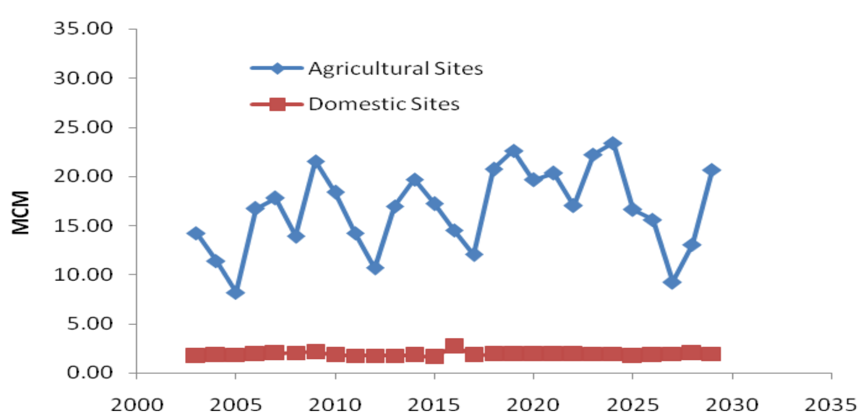


Figure 29: Annual demand for the agricultural and domestic sites**.**

Annual outflows from the catchment

Figure 30 shows the Different outflows from the area. As shown in this figure, the average agricultural outflow in the catchment is about 17 MCM, while the domestic one is about 1 MCM. It is very clear that the area and what we need is to control the type of crops grown in the catchment, amount of water consumed by agricultural lands and control the size of the land used for agriculture.

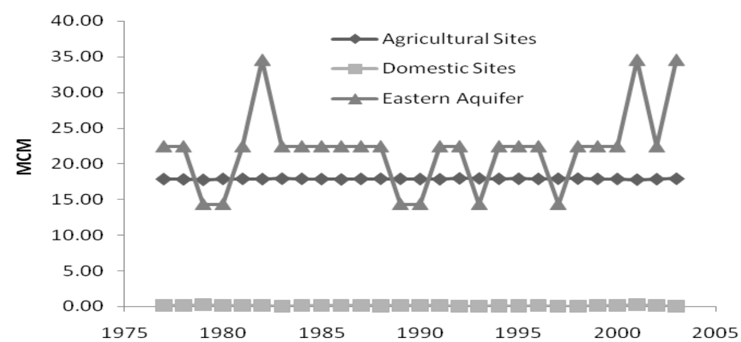


Figure 30: Outflows from the area.

Groundwater inflows and outflows

Figure 31shows the groundwater inflows and outflows from the catchment.

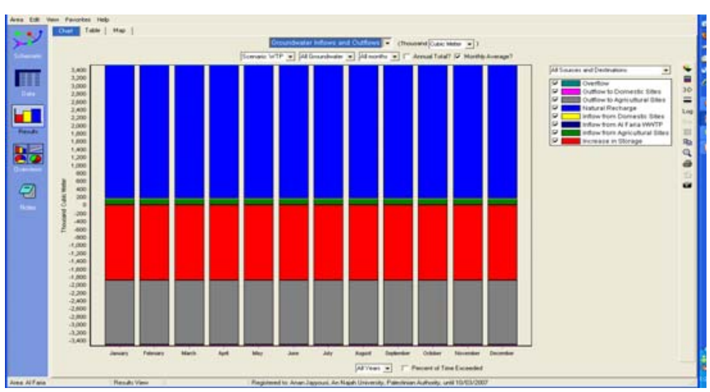


Figure 31: Groundwater inflows and outflows in the catchment

Scenario Three

Wadi Al-Far'a watershed is threatened by rapid population growth in the city of Nablus and several refugee camps. So, one of the suggestion is to project a population growth of 3.5% taking into account that all the assumptions in the existing scenario is applied here too.

Annual Demand

It is shown from Figure 32 that population growth has effect on the total demand in the catchment, so this growth must be taken into account. If we compare the amount of water consumed by domestic sites when the population growth wasn't taken in to account (about 1.7 MCM) with this case (the average amount is 15 MCM). then we can see the population growth effect on the total water consumption in the catchment. So, population growth can't be neglected.

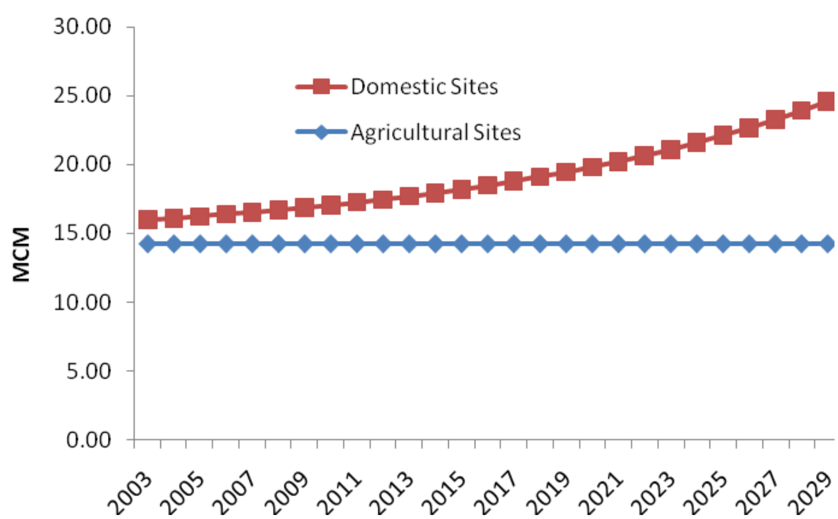


Figure 32: Annual demand for the agricultural and domestic sites.

Annual Groundwater Inflows and Outflows

From Figure 33, it is shown that all processes fall under the equilibrium theory, since after all changes during these 26 years, after all inflows, outflows, losses, the system stays in equilibrium.

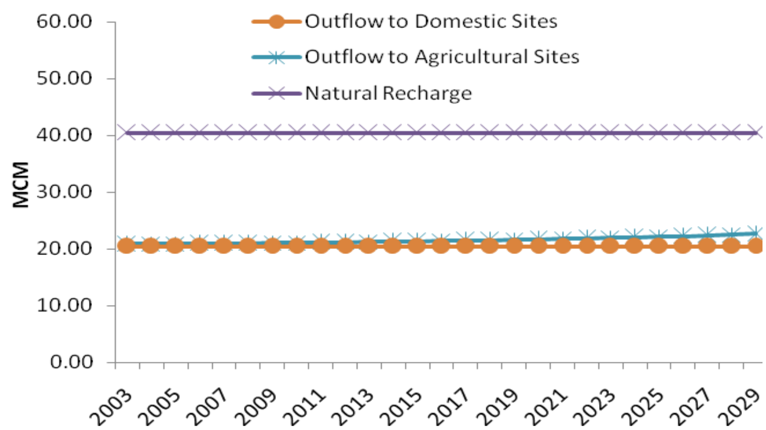


Figure 33: The annual Groundwater inflows and outflows.

Figure 34 shows the increasing groundwater storage by time during the study period.

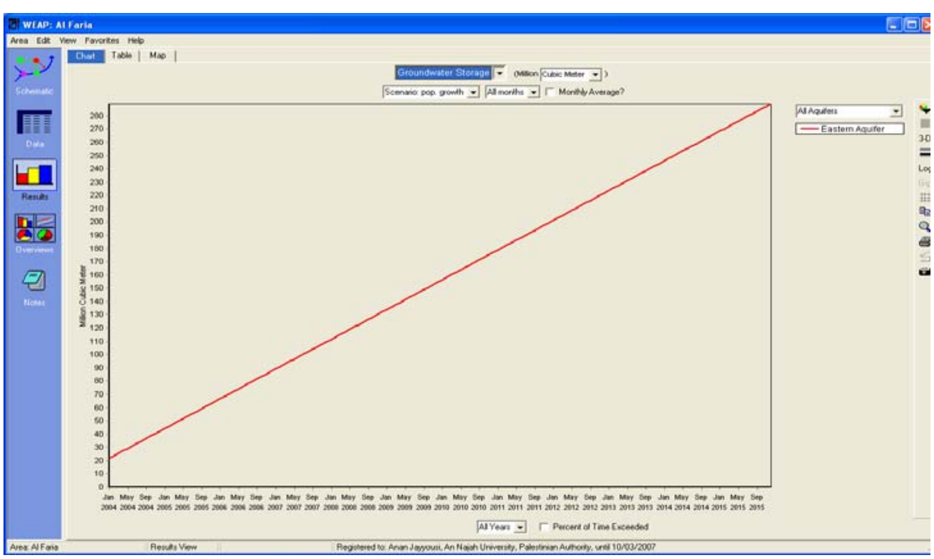


Figure 34: The groundwater storage.

Scenario Four

It is well known that the new techniques can save about 30% of the irrigation water through the reduction of water losses by conveyance system as well as evaporation from soil surface. Besides, modern irrigation systems increase the productivity and quality of crops, because the improved scheduling of irrigation quantities and times result in better and more efficient use of available water. So, it will be suggested to use new techniques in the agriculture to increase the supply up to 30%.

Annual Demand

Figure 35 shows that using new techniques in agriculture will reduce the water consumed through agriculture since in the year 2029 the maximum predicted amount of water consumed by agriculture will be less than 6 MCM, and this is highly affect the total annual amount of water consumed. And for the long term benefits, it will be a good suggestion to think about using new techniques to manage the amount of water available in the aquifer. For the domestic sites, water consumption increases since the population increases in the catchment with a maximum amount of 10 MCM.

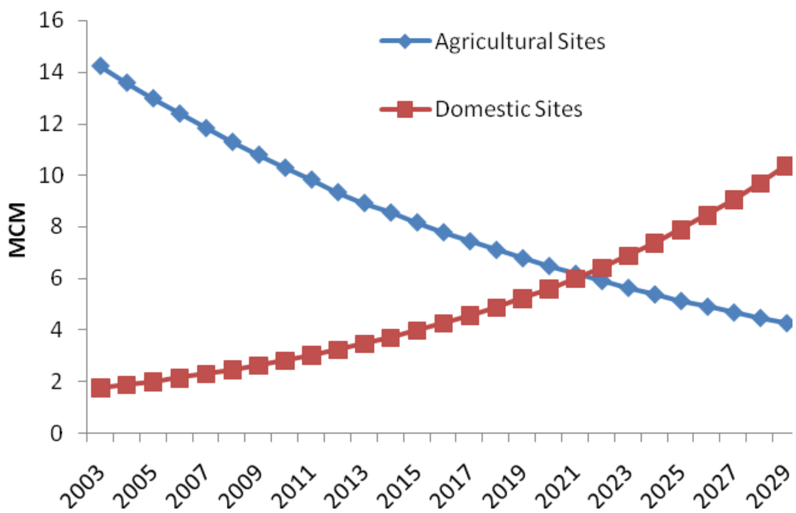


Figure 35: Annual demand for agricultural and domestic sites.

Figure 36 and Figure 37 show the Unmet Demand for the agricultural and domestic sources.

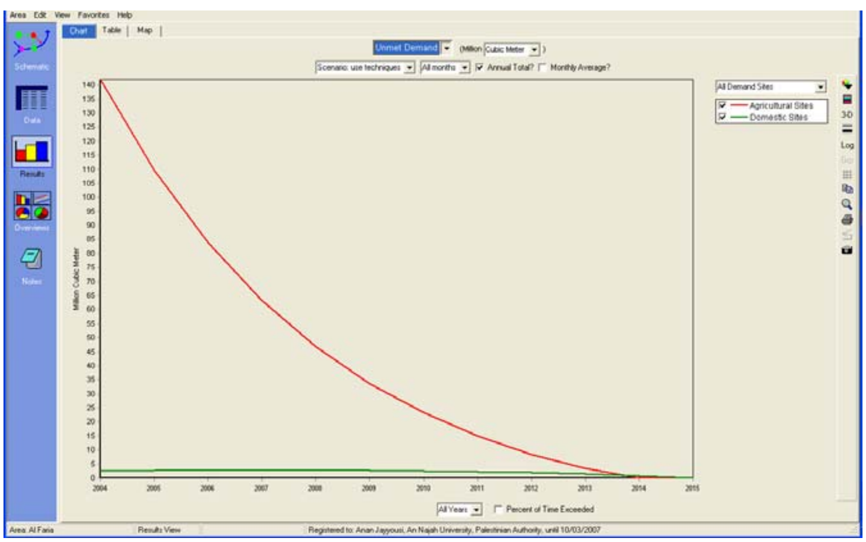


Figure 36: The groundwater inflows and outflows

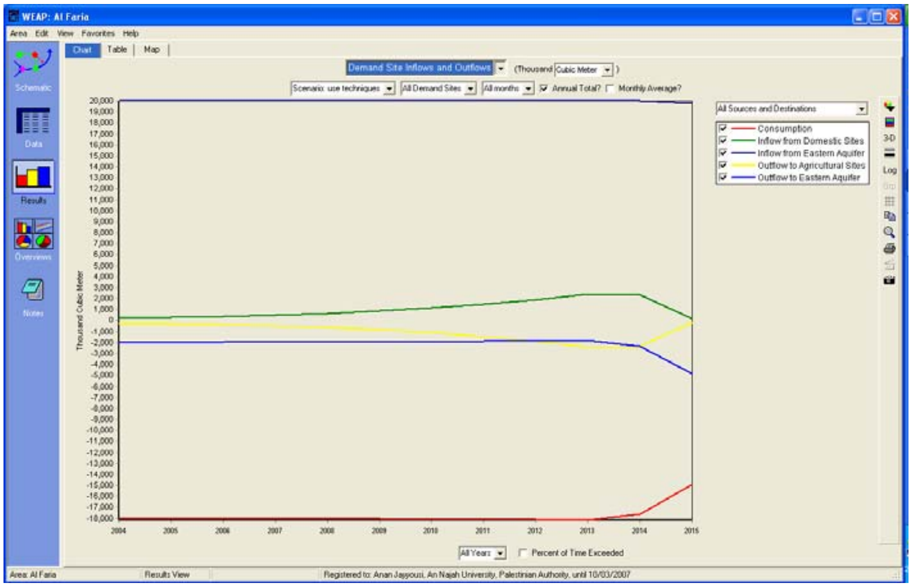


Figure 37: The groundwater inflows and outflows catchment

Studying the efficiency of the Conveyance System

Agricultural water supply systems are supplied from irrigation wells and springs. There is no comprehensive system to supply water for irrigation. Irrigation wells are privately owned and operated; therefore, each well has a separate pipe network to serve the farmers who own the well or those who buy water from it. There are no connections among the different wells. Usually steel pipes with diameters 4 to 6 inches are used to distribute water to farmers. The conditions of these pipes are usually not good as these pipes are not lined and without protective coating.

For springs, the only pipe network system is Al-Far'a Irrigation project which extends from Ein Shibli to Al-Jiftlik. However, most springs are located in the upper areas. In these areas water is conveyed through the natural stream and open ditches. The conveyance efficiency of these systems is usually low. No data was available for the conveyance efficiency of these systems. There are no effective farmers unions or water user associations to manage and operate the irrigation systems. Also, the water rights system in the area for spring water is not clear and without enforcement mechanisms. Therefore, the efficiency of water use in these areas is small.

Data for actual agricultural consumption and agricultural demands are not available for the area. Therefore, climatic data was analyzed to determine crop water requirements in the area utilizing the FAO irrigation model known as CROPWAT. Using this model, crop water requirements for the commonly irrigated crops were estimated. However, due to the climate of the area which allows planting vegetables in nearly all of the year, it was found that the crop water requirements are highly dependent on the time of plantation. Moving the time of planting a vegetable crop one month might result in increasing its crop water requirements by 30% or more.

The total irrigation demand in the watershed was estimated at about 15.25 MCM/year. Total amount of water available for agriculture from springs was estimated at 13.9 MCM/year and 6.3 MCM/year from agricultural wells on the average. One MCM/year of untreated wastewater is estimated to flow from the eastern part of Nablus to the Wadi. Thus, the total available water is about 21.2 MCM/year. However, about 2.1 MCM/year of that water are discharged during December and January when irrigation is not required in the upper area. In the lower area the estimated water requirements during these two months are estimated to be about 1.57

MCM (based on the water requirements of maize and the cultivated area of vegetables and field crops). An excess of about 0.5 MCM of winter spring flow is lost. The total efficiency of the conveyance system (including both springs and wells) will be about 72%. Assuming an efficiency of the conveyance system from wells to be about 90%, thus the efficiency of the springs system will be about 64%. This conveyance efficiency is very low and requires improvements. However, these estimates will require more data collection, measurements in the field and further analyses.

Agriculture is the most common economic activity in the area. In addition to agriculture, there are few small industrial and commercial activities in the area. The upper area has few touristic activities and touristic facilities. However, these activities were highly impacted by the closure of roads and the restrictions on travel.

Agricultural patterns in the area include rainfed and irrigated agriculture. Rainfed agriculture includes rainfed vegetables, field crops and rainfed trees. Rainfed agriculture is mainly in the upper areas as it is not feasible in the lower areas because of the small amounts of rainfall there. The most common rainfed crops are olive trees especially in the upper areas of Talluza and Al-Bathan where olives cover more than 10,000 dunums. Field crops cover approximately 5,000 dunums mainly in Al-Far'a and An-Nassariyya. Rainfed vegetables cover less than 1,000 dunums which are also in the upper parts of the Wadi. The economic returns of rainfed agriculture are much lower than irrigated agriculture. Irrigated agriculture is the most important economic activity in the Wadi. Irrigated agriculture includes open field vegetables, greenhouses and irrigated trees. Open field vegetables cover more than 20,000 dunums. The climate allows production of vegetables all year in the Wadi which made a very important area in the West Bank for the production of vegetables. Greenhouses usually have much higher returns than open field vegetables as the productivity under greenhouses is much more than that for open field crops. However, greenhouses require more investments. For irrigated trees, the most common irrigated trees in the Wadi are citrus trees which cover about 3,000 dunums. However, due to the high prices of water and the salinity of water especially in the lower areas, farmers are uprooting citrus trees to replace them by vegetables, grapes or palm dates.

Economical Analysis of Agricultural Water Supply Systems

Since the early days of human settlement history, food producers and nations have depended on irrigation to produce stable food supplies and meet the growing demand for agricultural products as the population grows and the standards of living also increase across the world (Arosoroff, S, 2002).

The product is not produced when the water is missing. The right cost of water should reflect the shadow price of its utilization or its economic value. When the cost of water is less than its economic value, farmers and households will utilize more water to produce more and to improve their welfare. Right prices of water include prices paid for its extraction from the existing resources.

Costs of water should reflect its value in production and its scarcity in nature. For a farmer to use an extra unit of water, this unit of water should produce a profit exceeding its cost. However, the cost of satisfying the demand of another user could be more than the profit that the first farmer is gaining from that unit of water. However, shifting water from a user to another to reach optimal allocation of water faces the political constraints of water rights and existing allocations of water. Therefore, an emphasis on improving the efficiency of water use is much more feasible and practical than looking on the economic efficiency of water use.

Surface irrigation systems usually have low technical efficiencies and consequently low economic efficiencies in water use. Such systems are not suitable for the Wadi as well as they are suitable for arid areas. Also, distributing water in open ditches results in high losses due to evaporation and seepage. Thus, open ditches should be replaced by closed pipes to minimize losses. Farmers in the Wadi still use surface irrigation systems and open ditches to distribute water. This is mainly because spring water utilized by these methods is distributed free of charge. However, areas irrigated from irrigation wells use water more efficiently because of the high costs of water there.

Marketing and trading issues play a critical role in the Palestinian agricultural economies. The major markets for agricultural produce in the area are the domestic Palestinian markets as well as Israeli and Jordanian markets. Marketing problems appear from time to time as a result of many reasons including:

1- Lack of clear marketing policy, which depends on the study of the requirements of both local and external markets.

2- The capacity of local markets to absorb all of the agricultural production is limited

3- Inadequate marketing infrastructure such as grading and packing centers, refrigerators, manufacturing and proper means of transportation.

4- The prevailing traditional cropping patterns as farmers are used to cultivate traditional crops such as tomatoes, cucumbers, eggplants and squashes, which leads to overwhelming supply which exceeds the demand sometimes. This causes a sharp drop in prices which sometimes becomes below original costs of production.

5- The closure of many of the traditional markets in the Gulf countries in front of the Palestinian products, especially after the second Gulf war.

6- Restrictions imposed by the Israeli authorities on the Palestinian people from time to time, such as curfews and closures. Delaying the products at the checkpoints and bridges due to the Israeli security measurements, causing decrease in the quality or damaging the products.

7- The political situation which led to the fact that Israeli products flow freely into the Palestinian markets while restrictions are imposed by the Israelis on the Palestinian agricultural products preventing them from entering Israeli markets.

The reduction of prices due to marketing problems combined with the lack of agricultural industries that are able to absorb the surplus agricultural products in the area resulted in the creation of a situation where prices are reduced down into a level where it is no longer economically feasible to cultivate. Such situations usually result in severe losses to the farmers which force them to stop irrigating their crops and uprooting them. Therefore, solving marketing problems to the farmers is an essential step towards agricultural development and agricultural sustainability.

Model Calibration

Model calibration consists of changing values of model input parameters in an attempt to match field conditions within some acceptable criteria. This requires that field conditions at a site be properly characterized. Lack of proper site characterization may result in a model that is calibrated to a set of conditions which are not representative of actual field conditions. The calibration process typically involves calibrating to steady-state and transient conditions. With steady-state simulations, there are no observed changes in hydraulic head or contaminant concentration with time for the field conditions being modeled. Transient simulations involve the change in hydraulic head or contaminant concentration with time (e.g. aquifer test, an aquifer stressed by a well-field, or a migrating contaminant plume). These simulations are needed to narrow the range of variability in model input data since there are numerous choices of model input data values which may result in similar steady-state simulations. Models may be calibrated without simulating steady-state flow conditions, but not without some difficulty.

At a minimum, model calibration should include comparisons between model-simulated conditions and field conditions for the following data:

- Hydraulic head data,
- Groundwater-flow direction,
- Hydraulic-head gradient,
- Water mass balance,
- Contaminant concentrations (if appropriate).
- Contaminant migration rates (if appropriate).
- Migration directions (if appropriate). and
- Degradation rates (if appropriate).

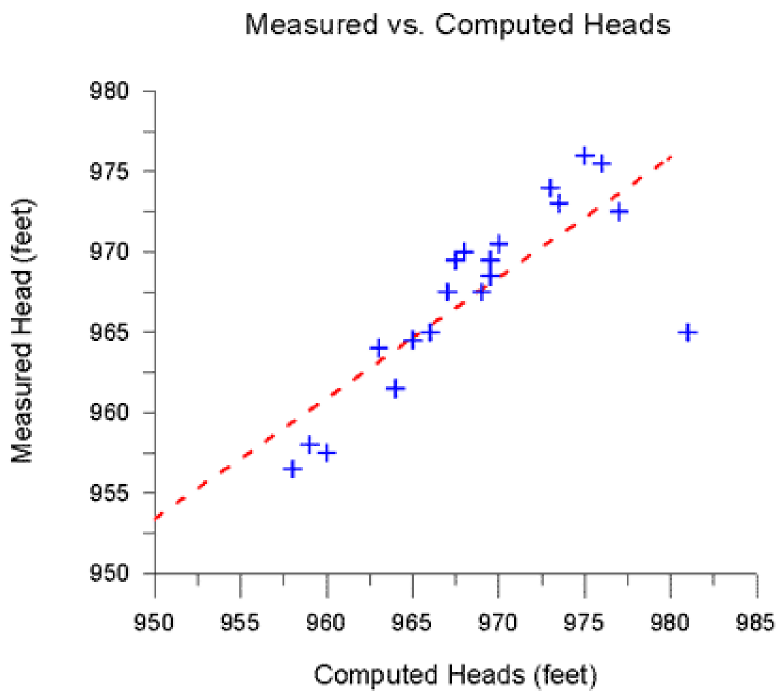


Figure 38: Comparison between measured and computed hydraulic heads

These comparisons should be presented in maps, tables, or graphs. A simple graphical comparison between measured and computed heads is shown in Figure 38. In this example, the closer the heads fall on the straight dashed line, the better the "goodness-of-fit". Each modeler and model reviewer will need to use their professional judgment in evaluating the calibration results. There are no universally accepted "goodness-of-fit" criteria that apply in all cases. However, it is important that the modeler make every attempt to minimize the difference between model simulations and measured field conditions. Typically, the difference between simulated and actual field conditions (residual) should be less than 10 percent of the variability in the field data across the model domain

Calibration work is necessary to show the difference between the collected data and the outputs from software models, and to fix the data resulted from the model in order to be closer and closer from the true values and reduce the error with higher degree of accuracy. Central to the decision making processes in water resources is the ability to build a model that can test many scenarios and derive diagnostic and prognostic inferences to enhance the system operation and also to avert potential risks.

The devised framework throughput this paper could be summarized as in Figure 39. In order to make reliable decisions one ought to rigorously test the model structures and validate the model parameters. The calibration process is essential to gin robustness in the tool and the formulated scenarios.

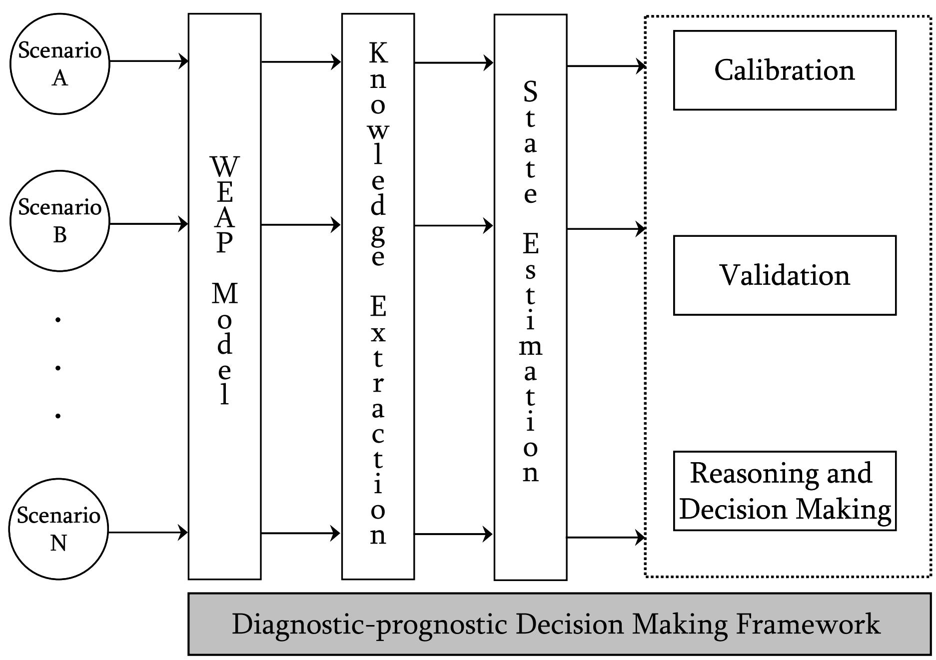


Figure 39: Decisions making framework and scenarios analysis.

Following the generic calibration flowchart in Figure 40, and owing to the simplicity of the WEAP model we opted to perform manual calibration. Multiple runs of trial-an-error were conducted to change the model decisions variables. Root mean square error criteria were selected to judge the model quality. There is no practical or theoretical evidence that a particular objective function is favorable over another for the purpose of calibration; therefore, it is useful to consider additional criteria in order to account for different characteristics of the discrepancy between the model-simulated and the observed outputs. The correlation measure was additionally used to judge the model performance too. For details on measures for calibration refer to [Legates and McCabe, 1999].

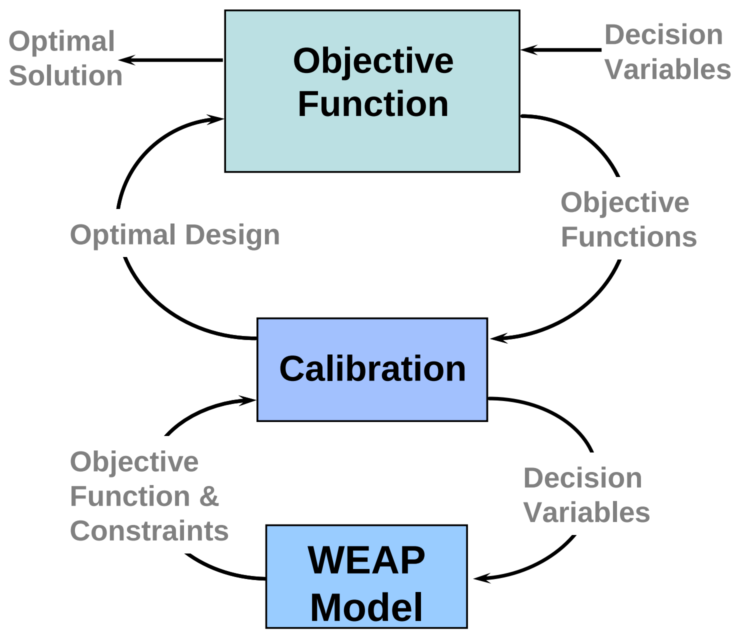


Figure 40: Generic flowchart of any calibration processes.

In this research, calibration model is made to show the variance between the resulted and the collected data as shown in Figure 41.

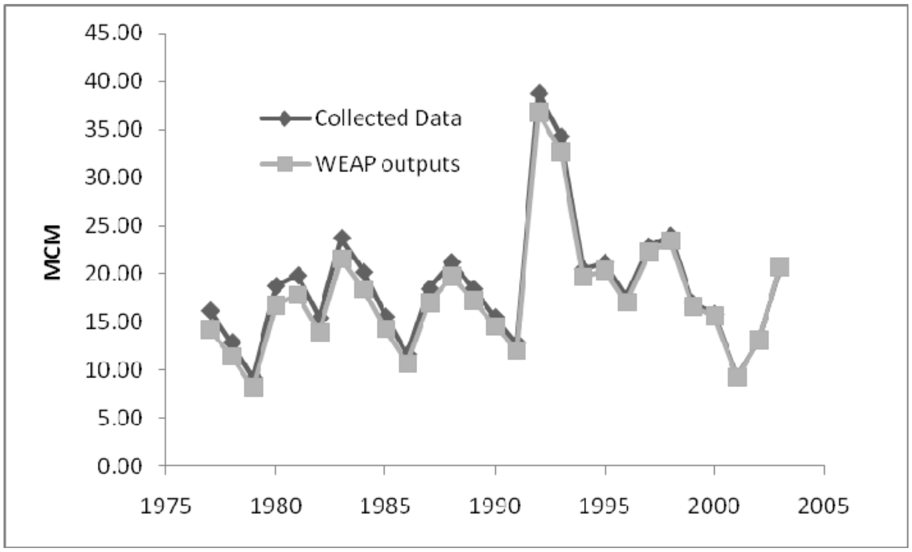


Figure 41: Calibration model for agricultural demand.

From Figure 41, it is clear that the output and the collected data are very close and there is no need to make calibration. But for the domestic demand, a little calibration is needed in order to make the collected and the output data closer and closer, some parameters will be changed such as % losses, % ET, and other parameters. Figure 42 shows the resulted graph after making calibration.

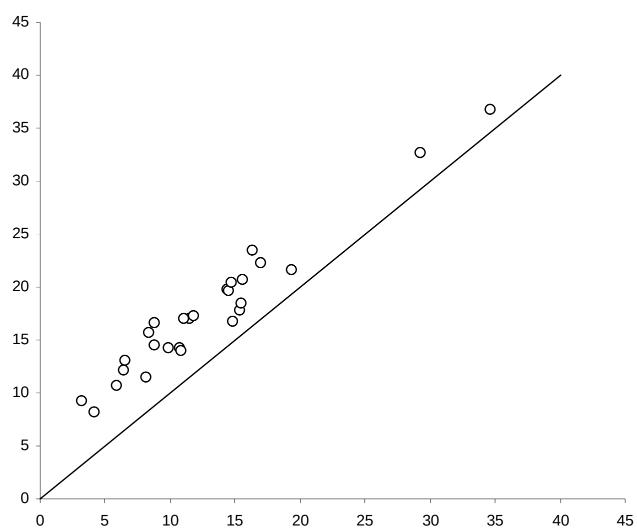


Figure 42: Resulted data after calibration.

CHAPTER VI

DISCUSSION, SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Chapters III to VI present the body of the work and the main scientific results of this thesis. Here, I summarize and emphasize the important conclusions and recommend avenues for future research.

Discussions

The following aspects are shown and concluded from our previous discussions;

1. Taking good decisions is the main step to achieve a successful IWRM. And for this effective IWRM models, so the main point is to be a good decision maker while suggesting the best fit scenarios which are logical, realistic, and applicable. Also, it is necessary to conclude both; the bio-physical and the socio-economic factors while taking decisions.

2. Effective IWRM models must address the two distinct systems that shape the water management landscape, some of these factors related to the system such as climate, topography, land cover, surface water hydrology, groundwater hydrology, soils, water quality, others related to management system, driven basically by human demand for water, shape how available water is stored, allocated, and conveyed within or across watershed boundaries.

3. Water is the limiting resource to human development. It is the key element for many physical and biological processes. So, it is one of the most important environmental management concerns.

4. From the suggested scenarios, it is shown that all of them are successful to control and manage the water consumption in the region, but the most effective scenario is to use new techniques in agriculture. But it should be noticed here that the financial side is not taken into account, so in order to get the most potent and powerful scenario, the cost of each of these scenarios must be calculated and then the evaluation and the comparison between these scenarios will be more valuable. But here in this research, the financial sides are not taken into account because of the lack of the available data.

Summary and Conclusion

The main challenge that threatens Palestinian water resources is that they don't have accessibility to obtain their water resources; 75% of the Occupied West Bank & Gaza Strip renewable water resources are used by Israeli who control the resources and provide Palestinian with less than the minimum requirements, since three million Palestinians are allowed to use 250 MCM/Y (83 CM/Y for each Palestinian) while six million Israelis enjoy the use of 2.0 BCM/Y (333 CM/Y). which means that one Israeli consumes as much water as do four Palestinians. Each Israeli settler is allocated 1,450 CM/Y. Although the World Health Organization's recognized minimum of domestic water consumption is 100 l/c/d. The current domestic water supply for Palestinians is only 57-76 l/c/d. From these numbers it is clear that Palestinian can’t make management to their water resources before getting their rights from water. But planners are always trying to manage the amount of water available for them in order to not to face challenges with water scarcity. In this research management of water resources in West Bank taking Al-Far'a catchment as a case study since it is one of the most important catchments in West Bank because of its wealthy agricultural land and water resources available within its area.

To achieve this goal, WEAP software is used to build an IWRM model on Al-Far'a catchment, examine alternative water development and management strategies including adaptation strategies, and to explore the physical, social, and institutional aspects that impact the integrated water resources planning that may impact the water conservation policies. So, different scenarios of management and strategies for Al-Far'a watershed are investigated to illustrate the impact on the water balance. The impact of different scenarios can be contrasted and evaluated leading to more informed management and decision-making. Finally, results present that there are many solutions and effective alternatives to manage the water demand in the region. One of these alternatives is to use new techniques in agriculture to minimize the agricultural water consumption since the agricultural lands form more than 85% from the total catchment.

After doing all the adequate research, building the model, setting the scenarios, and calibrate the output results, it is concluded that for successful planning and management, it is necessary to take into account all the surrounding factors that affect the model; water quantity and quality, climatic changes, vegetation, properties of watershed, land use, and seasonal variations since the region suffers from the lack of water and needs to solve the problem as soon as possible. After studying all the proposed scenarios, it is noticed that using new techniques, controlling the crops spatially and temporally, using good irrigation systems is the best option and solution for the bad situation there. Also, it would be great if we can merge two options or scenarios together like building WWTP and using new techniques since both of them is efficient in the region.

Based on the available and collected data, it is noticed that if agricultural demand is controlled and managed well, this will lead to a good water supply and demand system since the majority of both surface and ground water are utilized for irrigation activities.

Recommendations

Based on the concepts developed and the results demonstrated throughout this research, the following recommendations might be considered for future research: It is necessary to make water management in Palestine since the area is threaten by water scarcity and problems related to water quantity and quality.

Thriving IWRM is necessary step in solving water crisis at any region in the world, to achieve that models must be created, scenarios must be set and this required good decision-makers since it is not easy to obtain that.

Annual maintenance is recommended for the stations built in the catchment to insure getting accurate results and readings.

The catchment is a rich one with its agriculture and water sources, so; it deserves more care from authorities to benefit from it widely and effectively.

From all works done on Wadi Al-Far'a, it is concluded that it is one of the most prominent wadis in the West Bank; it is a significant agricultural resource. It has ecological as well as landscape diversity from source to mouth. It provides significant amounts of water to the inhabitants of the region, who use it both for household needs and agricultural irrigation.

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إعداد
آية عرفات

إشراف
أ. د. مروان حداد
د. عنان جيوسي

قدمت هذه الأطروحة استكمالاً لمتطلبات درجة الماجستير في هندسة المياه والبيئة، بكلية الدراسات العليا في جامعة النجاح الوطنية، نابلس _ فلسطين

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المخلص

إن فشل توضيح سيناريوهات طويلة المدى لتوفير المياه في فلسطين هو اهتمام أعطى لإحتمالية حدوث قحط شديد واستمرارية سوء تحصيص حقوق وتوزيع المياه تماماً كنقص سياسات دعم إدارة مصادر المياه الموحدة.

إن تحليلات تقييم تصميم مصادر مياه مستقبلية وتسهيلات وسيناريوهات الإدارة التي تقوم على إجراءات مستقبلية وممارسات إدارية كهطول المطر في فلسطين تبحث وتفحص.

هذا البحث يركز على بناء نموذج إدارة مصادر المياه الموحدة لمستجمع الفارعة باستخدام WEAP وهو برنامج تحليل الطاقة المائية وتقيمها وبعد تجميع كل البيانات المطلوبة ودراسة الوضع القائم، فإن سيناريوهات مختلفة تقترح في هذا الصدد. نمو السكان المزدهر في فلسطين هام جداً يؤخذ في الحسبان من أجل تخطيط مصادر المياه الموحدة، ومن المتوقع زيادة الضغوطات على مصادر مياه هي أصلاً نادرة. وقد اقتربت هذه البيانات المستقبلية من بعضها من خلال علاقات شاقة كثيرة في نموذج WEAP من أجل تحديد مناطق المياه المستقبلية. وهكذا، فإن وفرة مستقبلية سنوية وعقدية تبرر وتميز وتفحص من أجل دعم سيناريوهات فعاله وكفؤة. تحليل تقييم سيناريوهات وممارسات إدارية تقدم إلى مستجمع الفارعة.

وحيث أن نماذج تخطيط مصادر المياه يمكنها توحيد وعمل عناصر إدارية ذات اهتمام عالي في مساعدة مخططي القرار في تقييم الأولويات تحت وقائع هيدروليكية وأهداف إدارية.

وأن هدف هذا التحليل هو لتوضيح حاجة وتزويد مياه بديلة من أجل تحديد كمية المياه الجوفية وتقييم حفظ المياه وسياسات التحصيص وتزويد إرشادات مستقبلة لمشاريع مائية تقليدية تطرح هنا وتناقش.