EVALUATION OF WATER MANAGEMENT OPTIONS FOR MORE FOOD SECURITY IN PALESTINE

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ABSTRACT

Water management options for more food security in Palestine were evaluated using WEAP simulation model. A water management structure consisting of eight interrelated modules covering all aspects of water management was used. Three potential future political scenarios were tested: the current, a consolidate, and an independent State order. Simulations indicated that political status has decisive impact on water availability and the level of unmet demand and accordingly on present and future food security in Palestine. Water management, water trading, and water cost modules resulted in reductions in future water demands and therefore have positive impact on food security in Palestine.

Keywords: Food Security; Water Management; WEAP; Palestine

INTRODUCTION

Food is a basic human need. Governments, especially in developing countries, work hard to secure sufficient food supply for their population to sustain and grow. Food security for human beings and/or a society is described through the trends in social, economic and physical access to sufficient, safe and nutritious foods and in the availability, stability and distribution of food supplies (FAO 2003)

Worldwide, hunger strikes more than 840 million people and food insecurity is becoming a major worldwide problem. Hunger saps strength and dulls intelligence. It destroys innocent lives, especially children. Approximately 160 million children under the age of five are malnourished. Also by weakening a nation's workforce, hunger cripples a nation's growth (SOFI 2005 and IFPRI 2001). It was found, in a food hunger map, that most hunger affected countries were located in Africa, south east Asia, and the Middle East with much Moslem population (FAO, 2006).

The continuous enhancement and development of technical, managerial, and financial capacities in the agricultural sector is critical to the national survival. This enhancement and development include water management in agriculture as a prime element.

Palestine or the occupied Palestinian territory (OPT) as presented in this paper consists of the West Bank including East Jerusalem and the Gaza Strip. The West Bank and the Gaza Strip are those parts of Historic Palestine which were occupied by the Israeli army during the 1967 war between Israel and Egypt, Syria, and Jordan (see Figure 1).

Figure 1. General location Map

Palestine and due to the prolonged Israeli military occupation of Palestinian land and natural resources, access and mobility to national water resources for all purposes lies in the hands of Israeli authorities. Accordingly, Palestinians are living under conditions of restricted water supply and demand.

In Palestine, water management and food production enhancements has more specificity than any other areas in the world, it is connected not only to securing food or sustenance but also to Palestinian struggle to exist in Palestine and to protect Palestinian land from being colonized by foreign Jewish immigrants.

FAO, 2003 found that the OPT is not self sufficient in food and relies upon commercial imports to supply domestic demand. It was also found that with rising poverty and unemployment, the food security situation has considerably deteriorated over the past three years, with four out of ten Palestinians food insecure. Food insecurity is a reality for 1.4 million people (40 percent of the population) and a near constant worry for an additional 1.1 million people (30 percent) who are under threat of becoming food insecure should current conditions persist. People's physical access to food and farmer's physical access to the inputs and assets to produce food have been severely affected by restrictions on the movement of people and goods and the damages to personal property.

Because of fast growing population and rapid urbanization, food security and water management in Palestine are getting higher importance. However, as competition for fresh water grows among users and sectors under continuing limitations of water availability and/or accessibility, the call for limiting the size of agricultural sector in favor of domestic and industrial sectors is getting higher preference and acceptance by decision makers. On the other hand, because agriculture played and still plays central role in Palestinian economy, culture and life another popular call is advancing in support of farmers and agriculture. In this regard, it is important to note that for Palestinians not only ensuring sufficient food to Palestinian population is important, but also if not more enhancing Palestinian's attachment to their land and preventing its colonization.

This second call is supported by a conclusion by FAO that in the medium to longer term there should be increased investment in Palestinian agriculture along with other sectors as it is pro-poor in that it creates labor intensive employment, provides food of a range and variety for promoting dietary diversification, encourages women's participation in the development process and prevents further asset depletion and welfare dependency (FAO 2003).

This paper assess both calls by identifying, evaluating, and optimizing Palestinian water management options and scenarios to ensure secure food production in Palestine. Because irrigated agriculture in the Gaza Strip is minor compared to that in the West Bank, West Bank will be emphasized in this study. Water Evaluation and Planning System (WEAP) computer model was used for this purpose as a management and decision support tool.

BACKGROUND: PALESTINE, WATER, AND AGRICULTURE

The land area of the West Bank is estimated at 5572 km^2 extending for about 155 km in length and about 60 km in width. The Gaza Strip, with an area of 367 km^2 extending for approximately 41 kilometers in length and approximately 7 to 9 kilometers in width (see Figure 1, Abdel Salam 1990, and Haddad 1998).

Palestinian population projections reveal that mid year population in 2003 totaled 3,634,495 persons, of whom 2,304,825 in the West Bank and 1,329,670 in Gaza Strip (PCBS, 2003 and 2004). According to the official list of local authorities adopted by the Palestinian Central Bureau of Statistics (PCBS, 2003) and the ministry of local governments, there are 686 localities in Palestine. The localities are distributed by type as 54 urban, 603 rural, and 29 refugee camps. These localities distributed by type of authority as 107 municipalities, 11 local councils, 374 village council or project committee, and 29 director of refugee camp (additional 76 rural localities are either not inhibited or joined to larger locality).

Palestine is characterized by Mediterranean climate with hot, dry summers and wet cold winters with short transitional seasons. The eastern and southern parts of the region have a semi-arid to arid climate. In the Jordan rift valley climate is arid all year long and can be classified as desert climate. The area experiences extreme seasonal variations in climate. Characteristics of the Middle East in general is a high variability of precipitation; both temporary and spatially.

a. Water Supply and Demand

The estimated average annual ground water recharge in Palestine is 698 to 708 mcm/yr (648 mcm/yr in the West Bank and 50 – 60 mcm/yr in the Gaza Strip). The only surface water source in the West Bank is the Jordan River and its tributaries. In the Johnston plan, the Palestinian share in the Jordan River of 257 mcm/yr was considered as part of the Jordanian share of 774 mcm/yr as the West Bank was under the Jordanian rule. Since 1967 war and until present, Palestinians were prohibited by the Israeli army from using the Jordan River water and their lands and farms located along the western side of the river were confiscated and the area was declared as a restricted military security zone (Haddad 1993).

The total amount of water supply delivered to the West Bank is 78 MCM for municipal and industrial uses and 75 MCM for agricultural purposes. The per capita annual domestic water consumption was estimated at 27.203 m^3/cap/yr.

Most of the Palestinian population are served by water networks, about 90% of population have access to network through municapilities and the others don't have network and depend upon rainfed cisterns and private water tankers. It was found that only 36% of the communities having network with a good network, and the others have a bad network. This indicates a high percentage of losses (PHG, 2004). At present, conveyance between districts is not existed, i.e., ther is no national water supply grid in Palestine.

b. Agriculture and Agricultural Production

In Palestine agriculture is the dominant economic sector and it plays a central role in ensuring Palestinian food security. Despite the small size of the West Bank the area enjoy a diversity of climatic regions, which makes it possible to grow almost anything, all year round. Rain-fed cultivation forms the largest cultivated area, using more than 90% of the West Bank total cultivated land. Almost 92.7% of the total irrigated areas in the West Bank are concentrated in the two agro-ecological areas, the semi-coastal region and the Jordan Valley. Vegetables constitute 67% of the total irrigated areas. Fruit trees form about 26.5% mainly olives, while field crops constitute 6.5%. Nearly 97.3% of the fruit trees are cultivated under rain-fed conditions, irrigating the remaining. Although irrigated fruit trees occupy limited areas, they contribute approximately 37% to the total fruit tree production (PCBS, 2003).

During the period 1967 through 1995 a mix of economic and political considerations shaped Palestinian agricultural practices. In irrigated agriculture, economic issues forced Palestinians to shift from fruit trees to high cash value crops such as vegetables. In rain-fed farming, Palestinians shifted from field crops to olives, because the income from field crops is low, Olives do not require a lot of work, and the planting of olives indicates that the land is cultivated, which protects it from the Israeli assaults (Butterfield, 2000). As a result, the country has moved away from agricultural food security. Palestine has not been self-sufficient in producing field crops and livestock products, mainly red meat and milk. Table 1 summarizes total area cultivated with total yield (PCBS, 2003).

Total Quantities of Exported and Imported agricultural products to Palestine (West Bank and Gaza Strip) in 2003 are summarized in Table 2 (PCBS, 2003).

Table 1: Area and Total Yield a of Crops in the West Bank, 2003\2004

Product	Area (dunums)	Production (Tonns)
Irrigated Wheat	5,319	2,685
Rainfed Wheat	346,103	69,942
Irrigated Citrus	23,787	61,691
Irrigated Fruits	10,197	23,158
Rainfed Fruits	164,153	89,405
Irrigated Olives	23,010	13,438
Rainfed Olives	877,878	71,986
Irrigated vegetables	36,858	311,824
Rainfed vegetables	42,796	24,333

Source: PBCS, 2003\2004 (Environment statistics in Palestine)

Table 2: Agriculture import and export

Product	Import (1000 tons)	Export (1000 tons)
Flour of Wheat	235	
Fruits	88	2.6
Rice	48	
Sugar	86.3	
Wheat	72	
Meat	5.8	
Olives		31.3
milk		171

Source: FAO, 2006

METHODS

a. The WEAP Model

WEAP, water evaluation and planning system developed by the Stockholm Institute (SEI, 2005), is an adaptable water resource planning model that is scalable depending on the complexity of the system under investigation. WEAP is a water demand and supply accounting model (water balance accounting), which provides capabilities for comparing water supplies and demands as well as for forecasting demands under various management scenarios. It has an accessible interface and transparent data structure that make it suited as a tool for deliberations between a diverse group of stakeholders.

WEAP has an integrated approach to simulating both the natural inflows and engineered components of water systems. This allows the planner access to a comprehensive view of the factors that must be considered in managing water resources for present and future use. This enables us to predict the outcomes of the whole system under different scenarios, and carry out comparisons between the different alternatives to evaluate a full range of water development and management options. (SEI, 2005).

In WEAP, (1) a current account of the water system under study is created, (2) a reference scenario is established based on a variety of economic, demographic, hydrological, and other trends, and (3) one or more policy scenarios are developed with alternative assumptions about future developments. WEAP through the scenarios management option can address a broad range of "what if" questions. These scenarios may be viewed simultaneously in the results for easy comparison of their effects on the water system.

WEAP also evaluates a full range of water development and management options. This approach places development objectives at the foundation of water analysis, and allows an evaluation of effects of improved technologies on these uses, as well as effects of changing prices on quantities of water demanded. In addition, priorities for allocating water for particular demands or from particular sources may be specified by the user.

WEAP can account for the requirements of aquatic ecosystems. It can provide a summary of the pollution pressure different water uses impose on the overall system.

The applicability and suitability of WEAP as water management DSS tool was tested and approved to be used for further analysis by applying the model to Tulkarem district (Haddad et. al.,2006) and The West Bank Water Resources systems (Abu Hantash, 2007) as two case studies in the Palestinian localities.

b. Database Structure and Input Data /the Current Accounts

Establishing the Current Accounts in WEAP represent the core of the simulation process and the basic definition of the water system, as it currently exists. In this case, the year 2003 is selected as the current year. The model simulation period is taken from 2003 -2025.

Current water uses: Existing water uses can be classified to the following: Municipal and industrial (domestic, industrial) water demands, Agricultural demands.

The municipal demnad consists of domestic and industrial demands. The population census for 2003 obtained from PCBS indicate a population of 2,163,515 with a growth rate of 3.2%. Palestinians are currently consuming an average of 74.5 L/c/d for municipal uses. Two levels of domestic Water Needs were set (1) by the amount of clean water required to maintain adequate human health which is (1) 100 L/c/d as minimum considering the continuation of the current political situation, and (2) 150 L/c/d as WHO Standards for acceptable quality of life (WHO, 2006).

Industrial demand shares about 7 percent of total municipal and industrial demand. (CH_2M HILL, 2003). Agricultural demands are represented by agricultural and livestock food products. Agriculture production and consumption is summarized in Table 3.

Agricultural Water Needs: water requirement was estimated based upon the area of culltivated land, amount of water applied, and total agricultural production. It was assumed that livestock fodder will be purchased accordintig to the current practise in Palestine, in case it needs additional quantities of water to produce it (see Table 4).

Table 3: Production, consumption, and surplus/deficit of Palestinian agriculture 2003

Product	Produc-tion (ton)	VW produced (MCM)	Consump-tion (kg/capita/yr)	Total Consump-tion (ton)	VW requirement (MCM)	Surplus/ deficit (ton)	VW needed (MCM)
Field Crops	72,627	73	115.00	248,804	249	-176,177	-176
Citrus	61,691	31	15.00	32,453	16	29,238	15
Fruits	112,562	56	50.00	108,176	54	4,387	2
Olives	85,424	171	25.00	54,088	108	31,336	63
Vegetables	336,157	168	200.00	432,703	216	-96,546	-48
Red meat	5,517	55	17.00	36,780	368	-31,263	-313
Poultry	4,868	17	15.00	32,453	114	-27,585	-97
Eggs	11,953	44	6.50	14,063	52	-2,109	-8
milk	21,950	22	68.00	147,119	147	-125,169	-125
Sum (MCM)		637			1324		-687
VW content (m^3/person/d)		0.81			1.68		-0.87

Source:
1: PCBS, 2003 (Environment statistics in Palestine)
2: Personal estimation based on different previous studies in the West Bank

MODEL APPLICATION AND SIMULATION RUNS

a. Water Management Structure

The structure of the water management concepts were developed and detailed in a previous work (Haddad et al. 2006). The previously developed management structure is used in this study and consists of eight interrelated modules (see Figure 2). In setting the data for the simulation of any of the eight modules, the impact of any data element on the other seven modules with their sub-elements was considered and estimated.

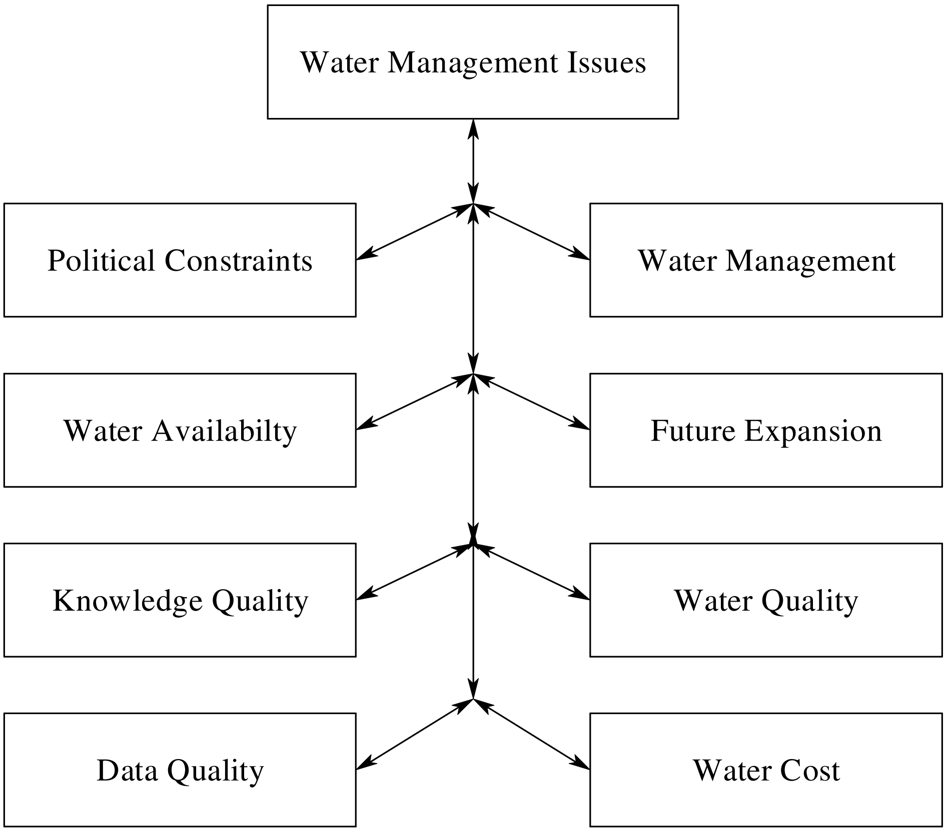

Figure 2 Modules of Water Management Structure

Table 4: Agricultural water supply requirement

Product	Area (dunums)	Production (Tons)	Water requirement (m^3/kg)
Irrigated Wheat	5,319	2,685	1.3
Rainfed Wheat	346,103	69,942	0
Irrigated Citrus	23,787	61,691	0.5
Irrigated Fruits	10,197	23,158	0.3
Rainfed Fruits	164,153	89,405	0
Irrigated Olives	23,010	13,438	1.2
Rainfed Olives	877,878	71,986	0
Irrigated	36,858	311,824	0.092
Rainfed	42,796	24,333	0
Red Meat	-	3,605	0.85
Poultry	-	4,650	0.005
Eggs	-	1,965	0.002
Milk	-	21,950	0.005

Source:
1 Calculated from the water supply (PWA, 2003) and production (PCBS, 2003)
* Personal estimation from previous studies

b. The Reference Scenario

This scenario represents the changes that are likely to occur in the future, in absence of any new policy measure. The population growth at a rate of 3.2 (PCBS, 2003), with existing water allocation and polices.

Industrial and Agricultural development in Palestine has been obstructed by Israeli Occupation. The amount of water available for development purposes is insufficient that restricted food production to the existing. Present water supply has been limited due to severe political constraints and restrictions. It was assumed that the water supply quantities will remain static.

Reference scenario results indicate that total water demand will increase from 155 MCM in base year 2003 to 234 MCM at the end of 2025. This increase is due to population growth only (see Figure 3).

Unmet demand was predicted at 53.2 MCM in 2005 and increased to 129.29 in 2025 (see Figure 4). This is due to demand increase while the water supply still unchanged due to the Israeli constraints.

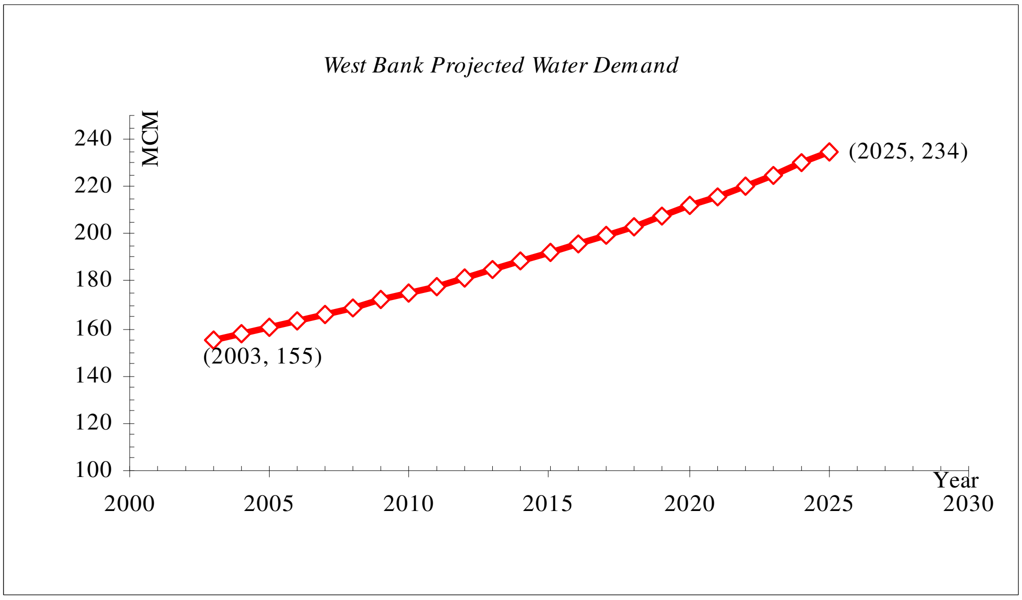

Figure 3: Projected Palestinian water demand for the reference scenario

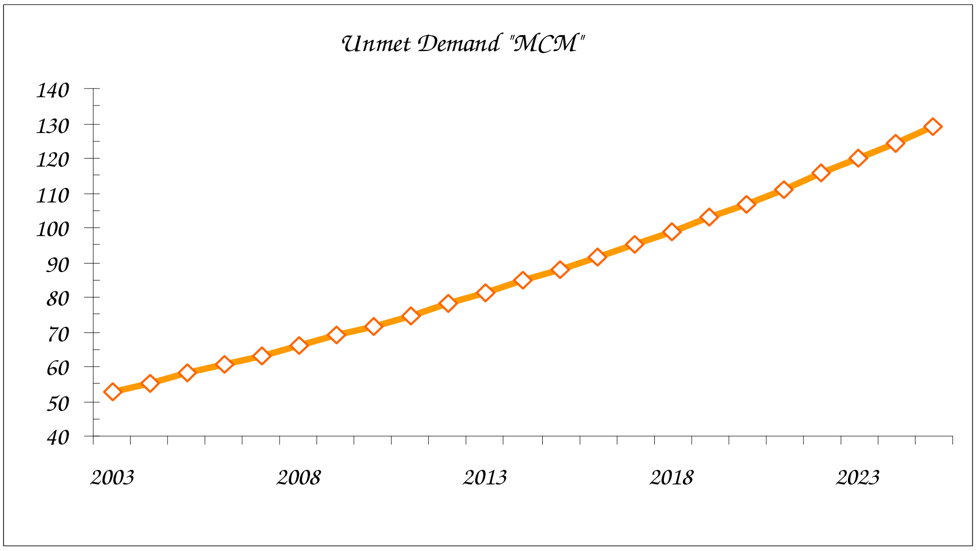

Figure 4: Unmet water demand for the Reference Scenario

c. Future Political Scenarios

For the West Bank situation, the political aspects were key factors in developing water resources management options for the West Bank. Accordingly, three main political scenarios were assumed and considered and used in the eight modules simulation runs including: (1) Current state of occupation and closures, (2) Consolidate State when peace process moves on, and (3) Independent State of Palestine.

The following Paragraphs will briefly present the assumptions and data used in each of the future political scenarios:

c.1 Political Scenario 1: Current state of Occupation and Closures

Political Constraints Module (1):

The current political conditions of full Israeli control of Palestinian people, land, and natural resources along with all limitations will continue existing during this scenario.

Water Management Module (2):

- Intensive demand management program will be implemented to increase farmer's knowledge and awareness, and increase irrigation efficiency by appropriating new farming practices such as watering at field level, crop reallocation, and crop water allocation reduction techniques. It was estimated making use from pervious experiments in communities similar to the West Bank, that water can be saved as much as 20 %.
- Wastewater treatment and reuse: Wastewater generated by municipalities will be treated, 39 MCM/yr of treated water will be used for agricultural purposes.

- Implement rainwater harvesting simple techniques for agricultural uses to support land productivity, this will increase water available to irrigate wheat and fruits by 31.5 MCM.
- Changing people diet: Table 5 below shows the Palestinian food consumption that representing their diets. As aforementioned; food energy and protein consumption by Palestinians was essentially equal to the levels considered sufficient for food security (FAO, 2006).

Accordingly four sub scenarios were assumed, from consuming full diet as presented in Table 5, to a Vegetarian diet taking into consideration that Palestinians will produce the food themselves:

- Sub scenario 1 : Full diet
- Sub scenario 2 : 50% replacement of animal products by vegetables
- Sub scenario 3 : 50% reduction in animal products
- Sub scenario 4 : Vegetarian

Table 5: Palestinian Food Consumption

Product	Production (ton)	Consumption (kg/capita/yr)	Total Consumption (ton)	Surplus/deficit (ton)
Field Crops	72,627	115.00	248,804	-176,177
Citrus	61,691	15.00	32,453	29,238
Fruits	112,562	50.00	108,176	4,387
Olives	85,424	25.00	54,088	31,336
Vegetables	336,157	200.00	432,703	-96,546
Red Meat	5,517	17.00	36,780	-31,263
Poultry	4,868	15.00	32,453	-27,585
Eggs	11,953	6.50	14,063	-2,109
Milk	21,950	68.00	147,119	-125,169

Source: FAO, 2006

Water Availability Module (3):

Water availability will increase by 70 MCM, 39 MCM/yr of treated water and 31.5 MCM by implementing rainwater harvesting simple techniques.

Future Expansion Module (4):

- Population growth rate 3.2%
- Domestic demand will be at minimum WHO standards. The aim is to provide a sustainable and reliable amount of water to reach 100 L/C/d in an equitable manner for all population in the West Bank to secure health.
- Irrigated areas will still as current
- Industrial demand will remain as current.

Knowledge Quality Module (5): No effect

Water Quality Module (6):

All wastewater generated by municipalities will be treated, 39 MCM/yr of treated water will be used to increase water availability for agricultural purposes.

Data Quality Module (7):

Risk of water data inaccuracy was not possible to consider due to model limitations and/or data availability

Water Cost Module (8):

There will not be any increase in water cost under this scenario.

c.2 Political Scenario 2: Consolidate State when Peace Process Moves on

Political Constraints Module (1):

The political situation will change with Palestinians obtaining some of their rights. These rights are limited with partial sovereignty, and partial water rights.

Water Management Module (2):

- Domestic Demand Management Program will be implemented to increase user awareness to use water saving technologies, save water by optimizing its use, and protect it from pollution; It was estimated making use from pervious experiments in communities similar to the West Bank, that water can be saved as much as 25 % (GWP, case studies)
- Agriculture Demand Management Program will be implemented to increasing farmer's knowledge and awareness, appropriate new farming practices such as watering at field level, crop reallocation, and crop water allocation reduction techniques, and introduce farmer's new agro technologies and economic incentives; this can save water as much as 20 percent (GWP case Studies).
- Three sub scenarios will be tested on the basis of virtual water concept. As aforementioned in Table 6, the virtual water required to produce all the food consumed by Palestinians is 1.68 m^3/cap/day, accordingly the following scenarios were assumed:
    - Sub scenario 1: Self sufficiency that Palestinians will their food locally.
    - Sub scenario 2: Food Trade (Import of low-cost water intensive products such as Wheat, export of vegetables, and olives, and keep citrus production to self sufficiency as it tradition plant in Palestine).
    - Sub scenario 3: Basic food security (Producing basic food needs locally to sustain survival during the state of critical issues).

Supply Management Assumptions:

- Local supplies in this stage are still the only feasible and reliable source of water to meet Palestinian needs and the most cost effective source. The Quantity that will become available for Palestinian use in the future is not defined subjected to the outcome of the final Status Negotiations. Under the terms of article 40 of the Oslo Interim Agreement, the Palestinians are entitled to develop an additional annual supply of 70-80 MCM from groundwater sources above current abstractions.
- Water utilization from wadis is estimated be developed by 75 MCM to be used for agricultural purposes.
- Only the wastewater generated by municipalities can be feasibly developed, so 78 MCM/yr of treated water will be used for agricultural purposes.
- Private sector will be engaged in water development activities in the West Bank to achieve development progress. This would enable projects sustainability and ensures more effective water supply management.

Water Availability Module (3):

Further development of additional 80 MCM form groundwater, 75 MCM from wadis, and 78 MCM treated water.

Future Expansion Module (4):

- Population projections are assumed as shown in Table 6 to reflect the improvement in the level of living.

Table 6: Population Projections

Period	Growth Rate
2003-2010	3.2%
2010-2015	3.0%
2015-2020	2.5%
2020-	2.0%

- Municipal demand will be at the average WHO standards 150L/C/d.
- Irrigated areas will be projected to achieve 0.12 dunum/c at the end of 2020 restricted to total area of irrigable lands, to secure the per capita basic food needs.
- Industrial demand will be increased to reach 10.5 percent of total municipal demand, and tourism will be developed to reach 2.5% of total municipal demand to achieve some reasonable level of economic development.

Knowledge Quality Module (5):

Consumer education and awareness level would affect his water use and practices, which could result in water demand reduction. It was assumed that there is an increase in education and awareness to a level that will result in a succeeded efficient DMP which can save 25% of domestic demand and 20 % of agricultural demand included within the Water management module.

Water Quality Module (6):

It was assumed that all Municipalities will have wastewater collection to improve the environment and treat the water to be used for agricultural purposes.

Data Quality Module (7):

Risk of water data inaccuracy was not possible to consider due to model limitations and/or data availability.

Water Cost Module (8):

Improving water tariff system leads to personal demand management practices which can reduce water demand to about 5% included into demand management program assumptions.

c.3 Political Scenario 3: Independent State of Palestine

Political Constraints Module (1):

Under this scenario the political situation will change with Palestinians obtaining all of their rights. These rights are including full Palestinian sovereignty over all aspects of life, over land, and over water. Therefore full water rights are assumed under this scenario.

Water Management Module (2)

- Water demand practices program will be implemented to increase user awareness of how to save water by optimizing its use, and protect it from pollution; this can save water as much as 25 % and assures equity for all.
- Agriculture water demand management: Increase farmer's knowledge and awareness, appropriate new farming practices such as watering at field level, crop reallocation, and crop water allocation reduction techniques, and introduce farmer's new agro technologies and economic incentives; this can save water as much as 20 percent.
- Implementing virtual water concept: The following sub-scenarios were assumed:
  - Sub scenario 1: Self production 100 % of the required food.
  - Sub scenario 2: Import 100% of required agricultural food products.

- Sub scenario 3: Import of low-cost water intensive products, and export of vegetables, and olives.

Water Availability Module (3):

Palestinian will gain their water rights and will develop all their needs. Development of Palestinian needs from aquifers 679 MCM, 250 MCM from Jordan River, 78 MCM of treated water, 100 MCM from wadis.

Future Expansion Module (4):

- Based on regional equity between Palestinians and Israelis, domestic Demand will be projected in Table 7.
- Industrial demand will be increased to reach 13 percent of total municipal demand, and tourism will be developed to reach 5% of total municipal demand to achieve some reasonable level of economic development.
- Irrigated areas will be increased to achieve the land requirement for national consumption needs at the end of 2020.

Table 7: Population-Demand Projection

Period	Growth Rate	Domestic Demand (m^3/capita/yr)
2003-2010	3.2%	27.03
2010-2015	3.0%	65
2015-2020	2.5%	75
2020-	2.0%	100

Knowledge Quality Module (5):

Consumer education and awareness level would affect his water use and practices, which could result in water demand reduction. It was assumed that there is an increase in education and awareness to a level that will result in a succeeded efficient DMP which can save 25% of domestic demand and 20 % of agricultural demand included within the Water management module.

Water Quality Module (6):

It was assumed that all communities with the district will have wastewater collection, treatment and reuse systems and plants. It was also assumed that only 78 MCM of collected and treated wastewater will be reused in agriculture.

Data Quality Module (7):

Risk of water data inaccuracy was not possible to consider due to model limitations and/or data availability.

Water Cost Module (8):

Improving water tariff system leads to personal demand management practices which can reduce water demand to about 5% included into demand management program assumptions.

SIMULATION RESULTS AND DISCUSSIONS

The results obtained from various WEAP simulation runs on the impacts of the three potential political scenarios and eight water management modules on food security in Palestine were summarized, discussed, and presented in the following sections.

a. Political Constraints Module (1)

Under this module the simulation runs were conducted for Palestinian water rights as transferred to water availability under the three potential political scenarios. Table 8 shows the predicted unmet water demand for the three scenarios assuming food security based on self sufficiency.

Table 8: Predicted Unmet Demand

Module \ Scenario	Scenario 1: Existing situation	Scenario 2: Consolidated State	Scenario 3: Independent State
Political Constraints	975.5	857	742
Water Demand Management	754.5	621	421
Water Availability versus existing	975.5	1090	1353
Future Expansion	0	+	+

As shown in Table 8 significant and direct relation between the political situation and the water availability or in other words the fulfillment of food security: as political situation improve towards the independent State as water availability and food self sufficiency increase. In scenarios 2 and 3, water availability and future expansion modules have significant positive effects on the unmet demand either as a reduction by increasing water availability or an increase as future needs will grow. Water demand management module has significant effects in reducing water gap in all scenarios during water shortages. All other management modules will have no/or slight effects.

b. Water Management Module (2)

By changing habitants' diet if the existing situation will continue, the annual per capita water demand is predicted to:

- 280 m^3 to achieve full diet using the referencescenario
- 267 m^3 by replacing 50% of animal products needed by vegetable products,
- 260 m^3 by 50 % animal production, and
- 254 m^3 for a vegetarian diet.

By implementing water trading and virtual water concept in the Independent state sub-scenario (3), the water demand will vary significantly from 1354 MCM for 100 percent self food production sub-scenario, to 752 MCM for import of low cost water intensive products scenario, and to 441 for 100 percent import of the required products. This result emphasizes the role of virtual water in water management in Palestine (see Figure 4).

Results of applying the consolidated state sub-scenario (2) indicated that the water demand will vary from 1123.5 MCM for fulfilling self sufficiency and 868 MCM for fulfilling basic needs only (see Figure 5).

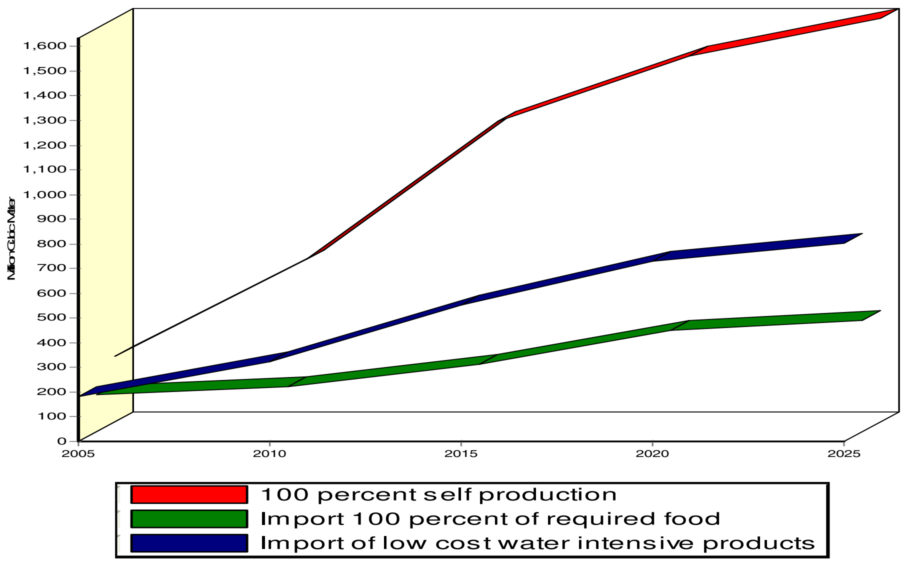

Figure 4: Predicted Water Demand for different scenarios

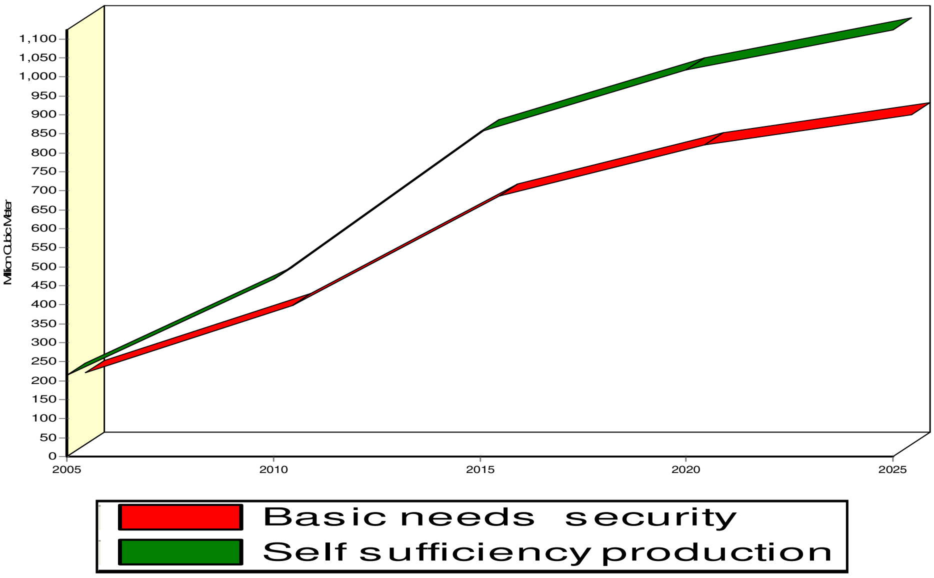

Figure 5: Predicted Demand under Water Trading Sub-Scenarios for Scenario 3

c. Water Availability Module (3)

As asumed in sub-scenario (3), the relayance on the recognition of Palestinian water rights will add more than 950 MCM of water availability at the end of 2025 to fulfill all developmental needs.

Unmet water demand for the three scenarios is presented in Figure 6. Having thier full water rights, Palestinians will fill most of the gap of water demand if they implement water trading. Even that water demand is kept at the minimum WHO standards and no further development in domestic water needs was assumed, the gap between water demand and supply will be more than 150 MCM if the existing situation continues (sub-scenario (1), see Figure 6).

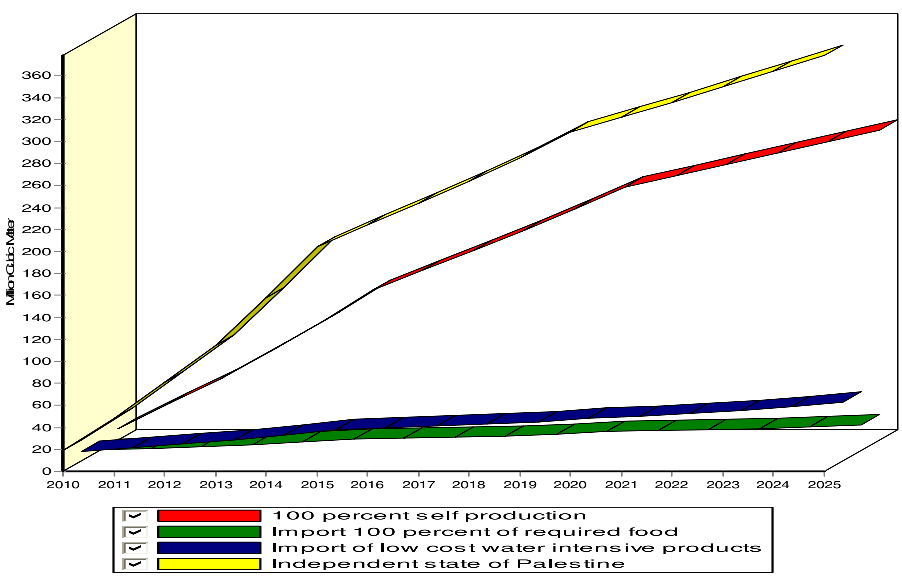

Figure 6: Predicted Unmet Demand under different scenarios

Adapting a climate change depicted in an increase in temperature of 2°C in summer and 1.7°C in winter and a decrease of annual rainfall of 50 mm at the end of 2040, would result in 14% increase in water demand and 25% decrease in water availability. During extreme water shortages, water supply priority will be given to satisfy the domestic uses by 150 l/c/d, and the remainder of available water will be directed to the agricultural sector. This situation will result in a decrease of water demand by 16 %. Applying the water trading between the sectors resulted in 42 % reduction of unmet demand in the year 2025 (See Figure 7).

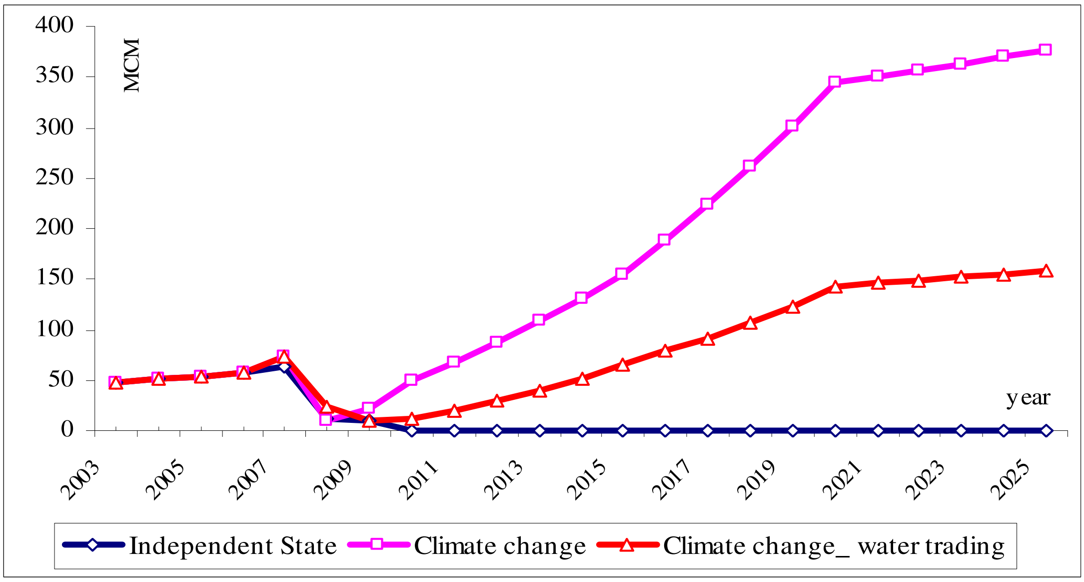

Figure 7: Predicted unmet demand under independent state climate change scenario

d. Future Expansion module (4)

Simulations predicted water demand decrease by the factor 7: 4.5:1 as the conditions in Palestine move from full production of food locally in the independent state scenario, to the intermediate status where some level of water availability and food productions is agreed upon, to the current situation or sub-scenario (1) (see Figure 8).

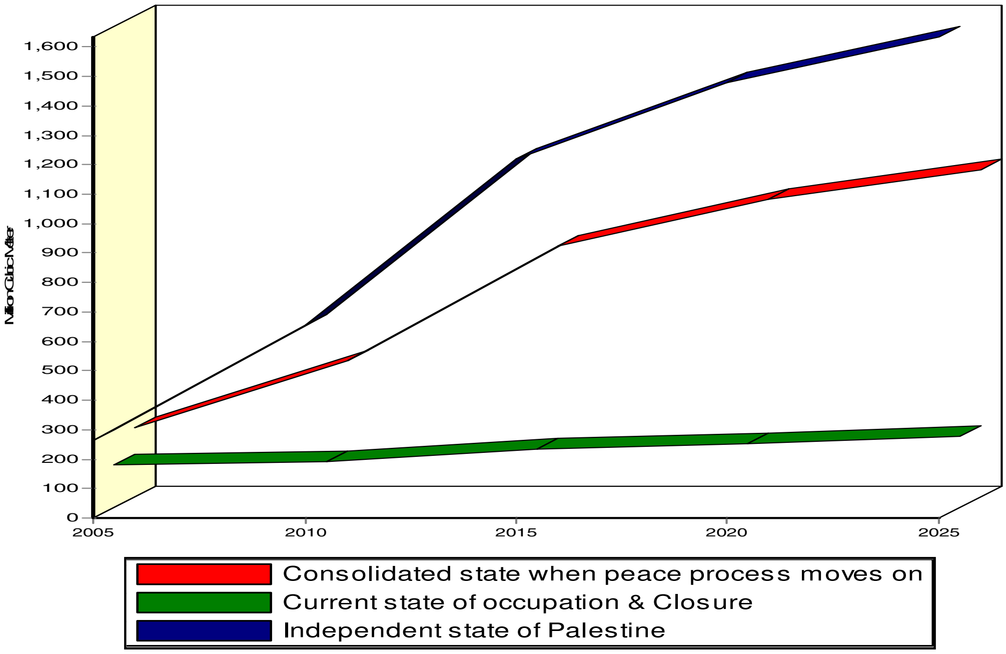

Figure 8: Predicted Water Demand

e. Knowledge Quality Module (5)

The change in water demand for this module is included in the water demand predicted under water management module .This result emphasized the strong relation between management and awareness where the increase in consumer knowledge and awareness resulted in higher water conservation and demand reduction.

f. Water Quality Module (6)

A decrease in pollution generation to a convincing level and an increase of water availability for irrigation purposes to 78 MCM was predicted under the Independent state subscenario (3). Accidental spills of hazardous wastes such as chemical or petrol spills could not be modeled in WEAP for groundwater.

g. Data Quality Module (7)

Risk of water data inaccuracy was not possible to consider due to model limitations and/or data availability

h. Water Cost Module (8)

Predictions for water cost indicated that water cost will increase slightly during the design period up to 2015 in the independent state scenario. However, a 0.250 US$ reduction in water cost and a 4% reduction in unmet water demand was predicted by the year 2025 under the same scenario (see Figure 9).

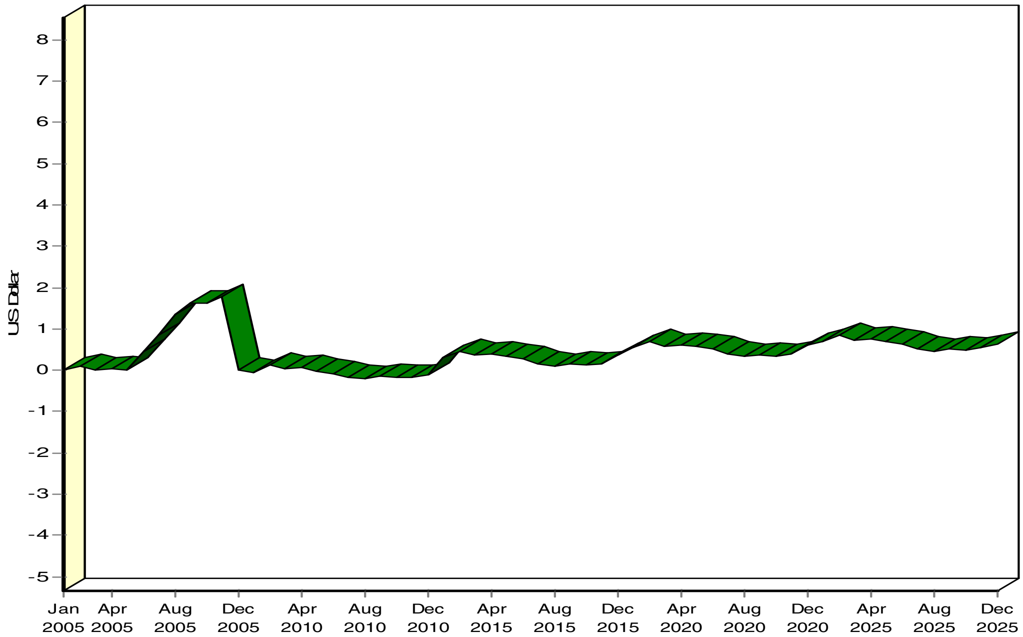

Figure 9: Predicted average cost

CONCLUSIONS

Based on the results of this study the following concluding points were reached:

- Full food self sufficiency in Palestine is possible only under the independent state scenario along with applying water trading. About 1600 MCM is needed to achieve national food security.

- Changing water tariff would have a noticeable effect on the total water cost or unmet demand on the long-term only.

- Agriculture will suffer most if a climate change or extreme event condition prevails in Palestine.

- Increasing public knowledge would increase water availability and lead to decreasing unmet water demand.

- Water trading and import in the form of virtual water can save a reasonable amount of water, while achieving a satisfactory level of food security.

- Changing people diets in Palestine will not save considerable amounts of water, since Palestinian diet is at the minimum.

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