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Climate change and agricultural water demand: Impacts and adaptations

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Global climate change related to natural and anthropogenic processes has been the topic of concern and interest world - wide. One of the most significant impacts of the 'greenhouse effect' is anticipated to be on water resources. Thus, the impact of climate change appears to be an additional component on top of the large number of existing water-related problems. The objective of the present paper is to analyze the climate change impacts on crop and irrigation water requirements, applying the CROPWAT model to several incremental climatic change scenarios for the West Bank governorate of Jericho and Al-Aghwar as a case study. The results clearly show that the greatest threat occurs if a temperature rise of 3°C is accompanied by 20% decrease in precipitation levels. For that scenario, there is a need to increase the amount of water for irrigation by 2.9 MCM/Y. A number of possible adaptation measures (at both sector/policy level and farm level) were evaluated. The evaluation was based on analysis of the relevant literature and stakeholder participation with respect to the following issues: adaptive capacity, technical feasibility and potential costs of implementation.

Key words: Climate change, agricultural water demand, adaptation, Palestine.

INTRODUCTION

One of the major issues in the present century is global warming. Studies on global warming and its effect on climatic change are being pursued vigorously as a multi - disciplinary problem. Global warming due to enhanced greenhouse effect is expected to cause major changes in various climatic variables such as absolute humidity, precipitation and net terrestrial and global solar radiation etc. Atmospheric temperature is probably the most widely used indicator of climatic changes both on global and regional scales (Jones and Briffa, 1992). Climate change will lead to an intensification of extremes of the global hydrological cycle and could have major impacts on water resources, affecting both ground and surface water supply for domestic and industrial uses, irrigation and in-stream ecosystems. Changes in the total amount of precipitation and in its frequency and intensity directly affect the magnitude and timing of runoff and the intensity of floods and droughts (IPCC, 2007).

Climate change is projected to have significant impacts on conditions affecting agriculture. While some aspects of climate change such as longer growing seasons and warmer temperatures may bring benefits (in cold regions), there will also be a range of adverse impacts, including reduced water availability, greater water need, and more frequent extreme weather. These impacts may put agricultural activities at significant risk (AEA Energy and Environment, 2007; Eitzinger and Kubu, 2009). According to climate models for the Mediterranean region there would be an increase in winter temperature combined with changes in rainfall amount and distribution (Ben-Gai et al., 1998). These climate changes are likely to affect the agricultural production (Schlenker et al., 2007). So the great challenge for the coming decades will be the task of increasing food production with water

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Abbreviations: GCMs, General circulation models; **CWR,** crop water requirement; **IWR,** irrigation water requirement; ET_o, reference crop evapotranspiration, ET_{crop}, crop evapotranspiration; **CROPWAT,** a computer program for irrigation planning and management; **P,** relative precipitation; **T,** temperature.

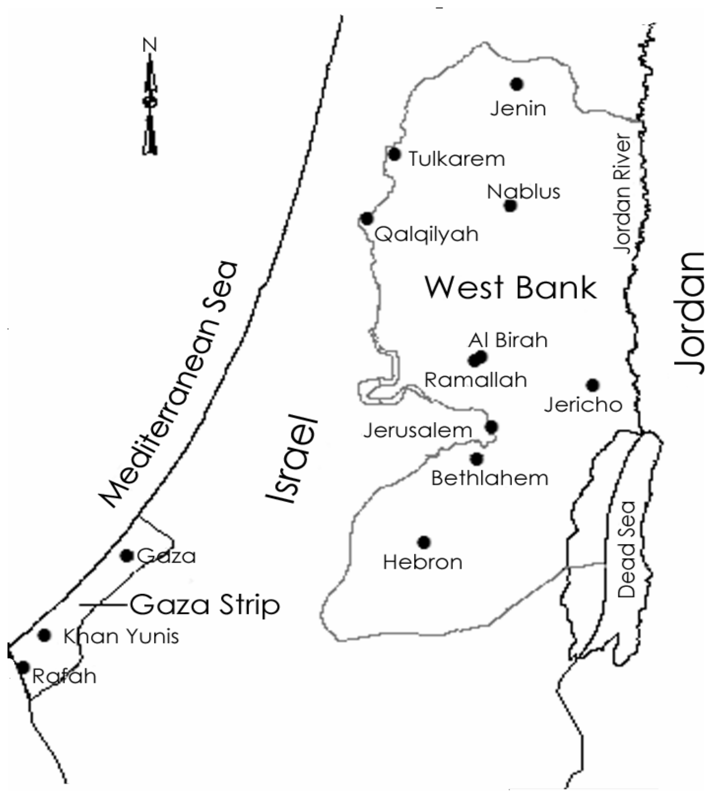

Figure 1. West Bank location map.

shortage and climate changes under the restricted cultivated lands. The aim of this paper is to evaluate the potential impacts of climate change on crop and irrigation water requirements under different suggested incrementtal climatic change scenarios for the Jericho and Al-Aghwar governorate located in the West Bank, Palestine as a case study. Moreover, the paper will identify and evaluate possible adaptation measures to those potential impacts.

STUDY AREA

The emerging Palestinian State is located in Southwest Asia on the Eastern shore of the Mediterranean. It is composed of two separate areas, Gaza Strip and the West Bank. The eastern boundaries of the West Bank are the Jordan River and the Dead Sea; the western, northern and southern are Israel as shown in Figure 1. There are two distinctive climatic seasons a wet winter and a dry summer. Annual average rainfall in the West Bank and Gaza is approximately 450 and 400 mm respectively. The Jordan River system is the only surface water resource in the West Bank. There are two aquifers shared by Palestine and Israel: the Mountain Aquifer underlying the West Bank and the Coastal Aquifer underlying Gaza. The present problems related to water are many and varied. Palestine, Israel, Jordan, and most other mid - eastern countries, which are generally characterized by aridity have very limited water resources. They have experienced in the last three years a serious recurrent winter drought. The 2007/2008 winter has seen a drastic drop in rainfall for the entire Palestine. (Ministry of Agriculture, 2008). Palestine has one of the lowest per-capita water availability levels world-wide. Continuing population growth, predictions for climate change within the region, changes in rainfall amount and distribution of reduced precipitation will intensify these problems. Palestine will experience serious deficit in water; the shortage was predicted to be 271 MCM for the year 2020 (Mimi et al., 2003). Weather changes mainly affect the start and duration of the different seasons, and the quantity of rainfall. This has two effects: firstly, periods of heavier rainfall are concentrated in a shorter time, with consequent of increased run - off, erosion and decreased absorption capacities of the soil. A decreased quantity of retained water results in a lower pasture production, which forces herders to anticipate the purchase of fodder. Secondly, on the other hand, poorer rainfall results in a lower quantity of water harvested and stored in cisterns, which forces herders to anticipate the purchase of tankered water.

A study by Ben-Gai and others (1994) showed that the annual rainfall in southern Israel has increased by up to 30% over the past 30 years. A further study (Steinberger and Gazit-Yaari, 1996) revealed that rainfall amounts have decreased in the area to the north of Tel Aviv. They showed that, in the coastal area south of Tel Aviv and western slopes of the West Bank Mountains, the rainfall had increased. These increases are characterized by an increase in rainfall at both ends of the rainy season (that is in October and April), predominantly at urban locations (Otterman et al., 1990). It is not known whether this trend affects the West Bank itself, as insufficient observational data from the West Bank have been used in the studies to date and the region lies between the zones of most marked increase and decrease (SUSMAQ, 2003).

Increases in seasonal temperature variability, storminess and frequency of temperature extremes may endanger cold - and heat - sensitive crops. Greater rain intensities and resulting floods may damage crops. Drought damages are also expected to increase with the anticipated decrease in water availability, hotter

Table 1. Range of climate change.

Phenomena	Projection of probable global annual average change	Regional average distribution of change	Confidence of projection for global (G) and regional (R) averages
Temperature	+2 to 5℃	-3 to +10℃	G- High; R- Medium
Sea level	+10 to 100 cm		G- High; R- Medium
Precipitation	+7 to 15%	-20 to +20%	G-High; R- Low
Evapotranspiration	+5 to 10%	-10 to +10%	G-High; R- Low
Runoff	Increase	-50 to +50%	G-Medium; R-Low

Source: Waggoner (1990).

temperatures and shorter winters. More pests and pathogens will not only increase crop diseases but also their sensitivity to drought and loss of biodiversity may reduce the natural control of agricultural pests. A delayed growing season will cause Palestine to lose its advantage over countries in colder climates in early exports of flowers, fruits and vegetables (Ministry of Agriculture, 2008). As a result of these climate changes and ensuing difficulties, the rural areas have experienced a progressive socio-economic deterioration. Palestinian farmers in the West Bank will face greater challenges to mitigate the impact of decreased water availability on the agricultural economy. The livelihood of these communities is always threatened since these sources are directly affected by rainfall and drought incidence, and climate changes threaten to exacerbate this threat. Water shortages in the West Bank are not solely the result of natural phenomena, whether influenced by climate change or not, but are exacerbated and perpetuated by Israeli policies and practices in the West Bank. These constraints include reduced accessibility of water and sanitation through denial of control over and development of water resources, and denial of permission to construct water and sanitation infrastructure (CROHI, 2008).

METHODOLOGY

The effects of climate change on Crop Water Requirement (CWR) and Irrigation Water Requirement (IWR) under different suggested climatic scenarios will be explored using the CROPWAT model for Jericho and Al-Aghwar governorate as briefly described below:

Incremental climatic change scenarios

A climatic scenario is defined as a plausible future climate that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change (IPCC, 2001; Abu-Taleb, 2000). Current predictions from General Circulation Models (GCMs) show significant decreases in annual rainfall over the region by the 2050s. This is combined with an increase in temperatures, causing higher losses from evapotranspiration and changes in snow accumulation and melt. A global - scale scenario cannot be reliably applied to the West Bank, because of the small size of the country, the coarse resolution of current models and the great spatial inaccuracy of global models. When projecting local scenarios from global trends, climatic models tend to display spatial inaccuracy of certain climatic mechanisms, especially precipitation (Wigley, 1992; Mirza et al., 1998). In view of the uncertainties associated with future projections of climate change, a number of climatic scenarios will be examined. Incremental climatic change scenarios were constructed from a range of climate change (Table 1) by applying relative precipitation (P) and Temperature (T) changes values respectively (that is P -20%, P -10%, P +10%, P +20%, T+1℃, T+2℃, and T+3℃). For each climatic scenario, reference crop evapotranspiration, CWR and IWR will be calculated.

CROPWAT model

CROPWAT model will be used in this research to calculate CWR and IWR for the case study area. There are many formulas and approaches to calculate CWR and IWR. No attempt is made here to exhaust this research, as it is fully covered by the following references: FAO (1986), (1992), (1993), and ARIJ (1998). These references explain how to apply CROPWAT model, identify approaches to CWR and IWR evaluation and present the underlying calculation procedures:

Reference crop evapotranspiration

To calculate Reference Crop Evapotranspiration (ET_o), it is necessary to collect and evaluate available climatic and crop data based on the available meteorological data. The Modified Penman-Monteith method will be used for calculating reference evapotranspiration. The equation is:

$$ET_0 = \frac{0.408\,\Delta\,(R_n - G) + \gamma\,\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

Where:

ET_o reference evapotranspiration [mm/day]
R_n net radiation at the crop surface [MJ m^{-2}/day]
G soil heat flux density [MJ m^{-2}/day]
T mean daily air temperature at 2 m height [℃]
u_2 wind speed at 2 m height [m/s]
e_s saturation vapour pressure [kPa]
e_a actual vapour pressure [kPa]
$e_s - e_a$ saturation vapour pressure deficit [kPa]
Δ slope vapour pressure curve [kPa/℃]
γ psychrometric constant [kPa/℃]

The equation uses standard climatological records of solar radiation (sunshine hours), air temperature, humidity and wind speed. The procedures to calculate ET_o may seem rather complicated. This is due to the fact that the formula contains components that need to be derived from measured climatic data when no direct measurements of needed variables are available. For instance, for places where no direct measurements of net radiation are available, as in the case of the West Bank, these can be obtained from measured solar radiation, sunshine duration or cloudiness observations, together with measured humidity and temperature. FAO (1993) and (1998) present useful formulas that can be used in the absence of collected information on needed climaticdata.

Crop coefficient

To calculate Crop Coefficient (k_c), it is necessary to select cropping pattern, determine time of planting or sowing, rate of crop development, length of crop development stages and growing period.

Crop evapotranspiration

Crop Evapotranspiration (ETcrop) can be determined using the following equation:

$$ETcrop = k_c \times ET_0 \quad (2)$$

Crop water requirement

Under optimal management and environmental conditions ETcrop is equal to the CWR. In other words, the amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. Although the values for ETcrop and CWR are identical, CWR refers to the amount of water that needs to be supplied, while ETcrop refers to the amount of water that is lost through evapotranspiration.

Irrigation water requirement

IWR of a crop is the total amount of water that must be supplied by irrigation to a disease free crop, growing in a large field with adequate soil water and fertility, and achieving full production potential under the given growing environment (FAO, 1998). IWR includes water consumed by crops (ETcrop) plus losses during the application of irrigation water and the quantity of water required for leaching. IWR basically represents the difference between the crop water requirement and effective rain. In order to determine irrigation requirements, the following variables are taken into consideration:

Effective precipitation

Effective rainfall is that proportion of the rainfall that can be used by the crop after rain. The amount of effective rainfall depends on the precipitation rate and soil moisture conditions. A simplified method developed by FAO (1992) has been useful for determining effective rainfall:

$P_{eff} = 0.6\ P_{tot} - 10$ for $P_{tot} < 70$ mm
$P_{eff} = 0.8\ P_{tot} - 24$ for $P_{tot} > 70$ mm

Where:

P_{eff}: effective rainfall (mm)
P_{tot}: total rainfall (mm)

Rooting characteristics

The moisture characteristics of the soil, the depth to which the plant roots extend and the densities of the roots determine the amount of soil moisture that is available to a plant.

Soil textures

Soil properties vary from region to region in the West Bank. In Jericho and Al-Aghwar governorate the dominant soil texture is sandy loam (ARIJ, 1995, 1996).

Leaching requirements

Leaching is the process of dissolving and transporting soluble salts by downward movement of water through the soil. The fraction of irrigation water that must be leached from the root zones to keep salinity of the soil below a specific limit is termed the leaching requirement (LR). Mathematically it can be expressed as (ARIJ 1998).

$LR = EC_I / (5\ EC_E - EC_I)$

Where:

LR: leaching requirement (ratio)
EC_I : electrical conductivity of irrigation water (mmhos/cm)
EC_E: electrical conductivity of the soil saturation extract for a given crop appropriate to the tolerable degree of yield reduction (mmhos/cm)

Irrigation efficiency

This is the ratio between water made directly available to the crop and that released at head - works, which includes field canal efficiency, water application efficiency, and water conveyance efficiency. In this study irrigation requirements were calculated based on 75% irrigation efficiency according to ARIJ (1998).

Gross depth per irrigation

The gross depth per irrigation should include sufficient water to compensate for system uniformity and allow for unavoidable losses or for the required leaching water. To keep the gross depth per irrigation at a minimum, systems should be well designed, accurately scheduled and carefully maintained. Gross irrigation requirements can be calculated with this formula:

$d_g = d_n / E_I (1 - LR)$

Where:

d_g : gross irrigation requirements (mm)
d_n : net irrigation requirements (mm)
E_I : irrigation efficiency (%)
LR : leaching requirements (fraction)
If $LR \leq 0.1$ use $d_g = d_n / E_I$

APPLICATION AND RESULTS

The climate of the Jericho and Al-Aghwar governorate is classified as arid, which has hot summers and warm winters with very rare frost incidents. The average maximum temperatures during January and August are around 20.7 and 38.8°C respectively. The average

Table 2. Monthly averages for the climatic parameters.

Months	Rainfall (mm)	Temp $_{max}$ (c°)	Temp $_{min}$ (c°)	R.H (%)	Wind speed (km/h)	Sunshine (h/day)
January	34.4	20.7	8.2	70	5.3	5.8
February	30.6	20.4	8.4	65	5.9	6.6
March	23.3	23.5	10.9	57	8.1	7.6
April	4.7	29.4	14.8	45	9.3	8.9
May	0.1	34.5	18.9	39	9.9	10.2
June	0.0	37.0	21.5	40	9.6	11.8
July	0.0	39.2	23.6	41	9.5	11.8
August	0.0	38.8	24.0	45	8.7	11.4
September	0.0	36.6	22.1	47	7.8	10.2
October	2.6	33.1	19.3	52	6.4	8.4
November	18.5	27.3	13.9	59	5.1	7.2
December	31.7	20.7	10.0	70	5.5	5.6

minimum temperatures for the same months are around 8.2 and 24°C respectively. The average relative humidity is 53%. The governorate receives an average of 146 mm total rainfall with more than 80% of the total rainfall occurring during December, January, February and March. Precipitation, temperature, humidity, wind speed and solar radiation monthly records were taken from the Palestinian Metrological Center/Geographical Center for the governorate. Records were available with different periods for each parameter; for maximum and minimum temperatures records were available for 18 years, while for relative humidity, data were available for 38 years, with some missing years (1993, 1994, 1995 and 1996). Wind speed and sunshine duration records were available for 11 years and for rainfall 32 years record were available. These records were used to calculate the monthly average for each parameter until 2007 for Jericho and Al Aghwar district, and the results were as listed in Table 2.

Impact of climatic scenarios on CWR and IWR

Crops considered in this study are irrigated in open - field conditions; rain fed agriculture and greenhouses are excluded. Values for different crop parameters like rooting depth, yield response, allowable depletion, crop coefficients and length of individual growing stages were adopted from FAO (1986) and ARIJ (1998). The dominant soil in the governorate is sandy loam (ARIJ, 1995). Based on the details of soil strata from the FAO for different types of soil and typical soil water characteristics (FAO, 1998), the total available soil moisture data were taken as 100 mm/m depth of soil. The effects of climate change on CWR and IWR for Jericho and Al-Aghwar governorate was explored based on the methodology discussed earlier. Table 3 presents ET_O, CWR and IWR for some of the crops planted in the governorate based on the current monthly average temperature and precipitation. Table 4 presents IWR by applying relative temperature (T) changes of T+1°C, T+2°C, and T+3°C to the monthly average series of temperature and relative precipitation (P) changes of P-20%, P-10%, P+10% and P+20% to the monthly average series of precipitation. The results clearly showed that the greatest threat occurs for the most extreme scenario chosen, viz., a temperature rise of 3°C accompanied by 20% decrease in precipitation levels. The scenario resulted in an additional 2.9 MCM/Y which is required to overcome the water losses in evapotranspiration.

Adaptation measures

In order to reduce vulnerabilities, a timely adaptation to probable new environmental conditions under climate change becomes imperative. Adaptation can be defined as: ‘adjustments in human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities’ (IPCC, 2001). As noted above, Palestinian agriculture is already impacted by water scarcity, both natural and anthropogenic, and declining economic profitability. Adaptations to these are also adaptations to climate change impacts. The process of identifying potential adaptation measures involved two main stages:

i. Analysis of relevant literature and ongoing studies to characterize adaptation measures relating to the risks and opportunities identified in the impacts assessment (Anderson, 2008; AEA Energy and Environment, 2007; USAID, 2007).

ii. A stakeholder consultation exercise to obtain practical information on adaptation measures; this took the form of interviews with some farmers.

Adaptation practices may vary considerably among

Table 3. Reference crop evapotranspiration (ETo), crop water requirement (CWR) and irrigation water requirement (IWR) for some of the crops.

	Crop	Area (10^3 m^2)	ET_0 mm/period	CWR mm/period	IWR	
					mm/period	MCM/Y
Fruit trees	Banana	2100	1376.8	1200.9	1125.0	2.4
	Date	1882	1727.5	1614.4	1482.5	2.8
	Pomegranate	70	1727.5	1073.4	941.5	0.1
	Grape	348	1727.5	879.9	751.1	0.3
	Citrus	1132	1727.5	1171.7	1039.8	1.2
	Olives	85	1727.5	1149.7	1017.9	0.1
Vegetables	Squash	9180	428.6	387.3	335.7	3.1
	Corn	6868	266.4	191.7	135.1	0.9
	Eggplant	4817	460.2	382.8	310.4	1.5
	Tomato	3468	460.2	382.8	310.4	1.1
	Green beans	1760	251.5	189.1	142.7	0.3
	Javabeans	835	369.76	272.21	163.36	0.1
	Cauliflower	994	266.4	224.2	167.6	0.2
	Jew's mallows	782	1727.5	1437.7	1305.8	1.0
	Cabbage	795	266.4	224.2	167.6	0.1
	Snake cucumber	586	274.1	244.2	182.3	0.1
	Pepper	569	319.3	254.0	165.5	0.1
	Chili pepper	499	319.3	254.0	165.5	0.1
	Okra	570	753.2	733.0	685.1	0.4
	Pumpkin	455	388.6	290.0	263.3	0.1
Field crops	Wheat	3980	957.3	804.1	687.2	2.7
	Barley	1180	248.1	177.3	68.5	0.1
	Vetch	89	1727.5	1297.6	1186.5	0.1
	Alfalfa	820	1727.5	1297.6	1186.5	1.0
	Onion (Dry)	256	640.3	586.5	454.6	0.1
	Total	44120				19.95

Table 4. Irrigation water requirement (IWR) under different incremental climatic change scenarios in MCM/Y.

(%)	T	T+1	T+2	T+3
P-20	21.05	21.63	22.23	22.83
P-10	20.24	20.82	21.42	22.01
P	19.95	20.53	21.12	21.71
P+10	19.66	20.24	20.83	21.42
P+20	19.38	19.96	20.54	21.13

regions, countries and social groups: all of these may react to climatic variability and change in different forms. Effective adaptation practices are responsive to a wide variety of economic, social, political, geographic and environmental conditions, so criteria for success may be context specific. From this perspective, it may thus seem appropriate to provide here a framework of concepts, linked together in a flexible manner, e.g. in the form of a tool that helps policy makers and practitioners in the design, implementation or evaluation of the usefulness and chances for success of adaptation strategies and measures. There are three types of adaptation options in the agriculture sector: technical (e.g. introduction of new cultivars), management (e.g. changes in cropping

Table 5. Potential consequences for agricultural production of the identified risks adaptation options, option category, level of implementation, adaptive capacity, technical feasibility and potential cost.

Consequences for agricultural production	Agricultural adaptation	Category [1]	Level [2]	Adaptive capacity [3]	Technical feasibility [3]	Potential cost [3]
Risks						
1. Crop area changes due to decrease in optimal farming conditions						
Main climatic causes of risk						
Changes in monthly precipitation distribution						
Increased temperatures in critical periods						
Increased erosion						
Loss of soil water retention capacity						
Farming optimal conditions altered resulting in increased risk to rural income	Livelihood diversification	M	S	M	M	M
	Strengthen local capacity to reduce sensitivity	M	S	M	M	M
	Irrigation					
	Changing cultivation practices	I	F	H	H	M
	Increased irrigation of main crops	M	F	M	H	H
	Change of cropping mix	M	F	H	H	H
	Switching to alternative crops	M	F	M	M	L
		T	F	M	M	L
Loss of indigenous species	Climate change resilient crops	T	F	M	M	L
Soils deterioration due to land use changes	Precision agriculture: improve soil and crop management	M	F	H	M	M
2. Decreased crop productivity						
Main climatic causes of risk						
Changes in monthly precipitation distribution						
Increased temperatures in critical periods (heat stress)						
Loss of soil water retention capacity						
Crop productivity decrease	Change in crops and cropping patterns	M	F	M	M	L
	Increased input of agro-chemicals					
	Irrigation	M	F	H	H	M
		I	F	H	H	H
Land abandonment	Design of regional adaptation plans	M	S	H	M	M
	Livelihood diversification					
		M	S	H	M	M
3. Increased risk of floods						
Main climatic causes of risk						
Increase of extreme events frequency						
Loss of soil water retention capacity						
Increased expenditure in emergency and remediation actions	Develop contingency plans	M	F	H	H	L
	Enhance flood plain management	M	F	M	M	M
Flash flood frequency and intensity increase	Increase rainfall interception capacity	M	F	H	H	L
	Reduce grazing pressures to protect against soil erosion from flash flooding	M	F	L	L	M
Flooding	Increase drainage	I	F	H	H	L

Table 5. Continued.

4. Increased risk of drought and water scarcity						
Main climatic causes of risk						
Decreased annual and/or seasonal precipitation						
Increase in the frequency of extreme conditions (droughts and heat waves)						
Conflicts among water users due to drought and water scarcity	Set clear water use priorities	M	S	H	H	L
	Increase water use efficiency	M	F	H	H	H
Water supply reduced	Increase rainfall interception capacity (techniques for conserving soil moisture)	M	F	H	H	H
	Improve field drainage and soil absorption capacity	I	F	L	M	M
	Altering crop rotations to introduce crops more tolerant to heat/drought	M	F	H	M	M
5. Increased irrigation requirements						
Main climatic causes of risk						
Increased average and extreme temperature						
Increase of drought and heat stress conditions frequency						
Decreased precipitation						
Water availability decrease	Invest in irrigation equipment that helps reduce the severity and collects rain water	E	F	H	H	M
Water shortage in irrigated areas	Invest in water saving devices like trickle irrigation	E	F	M	H	H
	Irrigation during the night	M	F	H	H	L
	Water harvesting	I	F	H	H	M
	Extensive development of new water sources including water reuse and desalination	I	S	H	H	H

[1]Category = T: Technical, M: Management, I: Infrastructural, E: Equipment.
[2]Level of implementation = F: Farm level, S: Sector Level.
[3]Adaptive capacity, technical feasibility and potential cost = M: Moderate, H: High, L: Low.

patterns, soil, landscape, water), or infrastructural (e.g. changes in drainage, irrigation systems, access, buildings). The type of measure will largely determine the extent to which farmers can adopt them without additional assistance or coordination. Farmers should be able to carry out some changes in management measures without support. This will also be true, to a large extent, for technical measures, while infrastructural measures are likely to require significant capital investment.

A number of possible adaptation responses (at both sector/policy level and farm level) were evaluated based on the analysis of relevant literature and stakeholder participation with respect to the following issues: adaptive capacity, technical feasibility and potential costs of implementation. The full list of potential measures for the case study area and their evaluation is given in Table 5 (Anderson, 2008; AEA Energy and Environment, 2007; USAID, 2007). However, before many of these adaptation initiatives can be implemented, short-term measures involving policy development, knowledge transfer and establishing relevant partnerships must first be put in place.

Conclusion

Current predictions from general circulation models (GCMs) are for significant decreases in annual rainfall over the region by the 2050s. This is combined with an increase in temperatures. A global - scale scenario cannot be reliably applied to Palestine, because of the small size of the country, the coarse resolution of current models and the great spatial inaccuracy of global models. The level of confidence in using GCM output directly is very low, so more sophisticated methods of "downscaling" GCM output for Palestine must be performed - primarily using dynamical method, that is a high resolution regional model embedded within the GCM. Climate change is projected to have significant impacts on conditions affecting Palestinian agriculture. Although the results presented in the current study are estimates, they provide a preliminary idea about the potential impact of climate change on agricultural water demand, taking into consideration that these results present the impact on irrigated open field agriculture only, which means that the deficit in agricultural water demand will become greater when considering the impact of climate change on rain-fed agriculture and greenhouses.

As stated above, the results presented in the current study are estimates since they are considering one type of soil and relatively limited available climatic data in the CROPWAT calculation and the incremental climate scenarios do not reflect seasonal or monthly different shifts in temperature or precipitation which is an important limitation for the results. It is time for planners to think in terms of expected change in water requirement due to climate change while estimating the future water demands and planning for development of future water resources in Palestine. Climate change will have large impacts on the agricultural water demand, reliability and security of water systems in Palestine. Adaptation practices should be implemented after carefull evaluation. Effective adaptation practices are responsive to a wide variety of economic, social, political, geographic and environmental conditions, so criteria for success may be context specific. The process of identifying potential adaptation measures should involve two main stages: analysis of relevant literature and ongoing studies and a stakeholder consultation exercise to obtain practical information on adaptation measures. Many of the possible adaptation measures can be applied at farm level, with the majority of measures being management-related. This implies that these should be more easily orchestrated, with many categorized as applicable over a mid-term timescale (5 -10 years). However, before many of these can be implemented, short - term measures involving policy development and partnerships must first be put in place.

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