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Impacts of Climate Change on Water Resources Availability and Agricultural Water Demand in the West Bank

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Abstract Global climate change is predicted as a result of increased concentrations of greenhouse gasses in the atmosphere. It is predicted that climate change will result in increasing temperature by 2 to 6°C and a possible reduction of precipitation of up to 16% in the Mediterranean basin. In this study, the West Bank is taken as a case study from the Mediterranean basin to evaluate the effects of such climate change on water resources availability and agricultural water demands. Due to the uncertainty in climate change impacts on temperature and precipitation, a number of scenarios for these impacts were assumed within the range of predicted changes. For temperature, three scenarios of 2, 4 and 6°C increase were assumed. For precipitation, two scenarios of no change and 16% precipitation reduction were assumed. Based on these scenarios, monthly evapotranspiration and monthly precipitation excess depths were estimated at seven weather stations distributed over the different climatic and geographical areas of the West Bank. GIS spatial analyses showed that the increase in temperature predicted by climate change could potentially increase agricultural water demands by up to 17% and could also result in reducing annual groundwater recharge by up to 21% of existing values. However, the effects of reduced precipitation resulting from climate change are more enormous as a 16% reduction in precipitation could result in reducing annual groundwater recharge in the West Bank by about 30% of existing value. When this effect is combined with a 6°C increase in temperature, the reduction in groundwater recharge could reach 50%.

Keywords Climate change · Water resources availability · Agricultural water demand · West Bank · Evapotranspiration · Precipitation · Mediterranean basin · Groundwater · Natural recharge · Precipitation excess

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Abbreviations

ASCE	American Society of Civil Engineers
ET	Evapotranspiration
FAO	Food and Agriculture Organization
GIS	Geographic information systems
h	Hour
IPCC	Intergovernmental Panel on Climate Change
MCM	Million cubic meters
MoT	Ministry of Transportation
P	Precipitation
PCBS	Palestine Central Bureau of Statistics
PWA	Palestine Water Authority
s	Seconds
WGI	Working Group I of the Intergovernmental Panel on Climate Change

1 Introduction

The West Bank, with an area of 5,655 km^2 (PCBS 2005), extends for approximately 155 km in length and 60 km in width. The West Bank is longitudinally divided into three main topographical regions running roughly north–south: the semi-coastal plains in the west, the mountains in the center and the Jordan rift valley in the east.

Groundwater is the main source of water in the West Bank. The annual recharge of groundwater aquifers in the West Bank is estimated at 688 MCM (PWA 2005). As the total population of the West Bank is estimated at 2.3 million (PCBS 2005), the amount of water that could be theoretically made available will be about 300 m^3 per capita per year. Due to various restrictions on water use and other political constraints, the amount of water available and consumed by Palestinians in the West Bank is about 146 MCM annually (PCBS 2005). Therefore, the per capita water availability in the West Bank is about 63 m^3 per year. This makes water scarcity very severe and any additional reduction on water availability will have severe socio-economic and possibly health impacts on the people.

In the West Bank, agriculture has been playing an important role in the Palestinian economy. Agriculture is responsible for employing 18% of the labor force and for 13% of the gross domestic product in the West Bank (PCBS 2005). Although irrigated agriculture utilizes only 5% of the cultivated area of the West Bank (PCBS 2005), it contributes about one third of the total agricultural production. However, agriculture also utilizes about 52% of the water resources.

As a result of existing 3 to 4% annual population growth rates and other socio-economic factors, domestic water demands are increasing in the West Bank as well as in the rest of the Middle East. The increase in water demands and the limited availability of water resources are resulting in increasing the water shortages in the region. The increases in water shortages are yielding to over exploitation of existing water resources and thus limiting the sustainability of their use. It is also resulting in deteriorating water quality and inducing salinity problems in water resources. In addition to depletion of water resources and the deterioration of water quality, the increase in water shortages could also escalate existing conflicts and tensions in the region.

Many previous studies showed that climate change will result in increasing temperature and negatively affecting water availability in the Mediterranean and the Middle East (Iglesias et al. 2007; El-Fadel and Bou-Zeid 2001). Irrigated agriculture is expected to be affected by climate change by reducing water availability and increasing its demand for water. Therefore, there is a need to evaluate and to quantify the impacts of climate change on water availability and on agricultural water demands. In this paper, the West Bank is taken as a case study of a Middle Eastern and Mediterranean country to evaluate the impacts of global warming and climate change on water availability and agricultural water demands. Since there is still some uncertainty on the amount of level by which temperature will increase as a result of climate change, several scenarios were simulated. Each increase in temperature (within the range of predicted changes in the Mediterranean basin) is simulated to estimate its effects on evapotranspiration. Based on the increased values of evapotranspiration, changes in natural recharge of groundwater and crop water requirements were estimated to assess the impacts of climate change on water availability and agricultural demands.

2 Global Climate Change

Global atmospheric concentrations of greenhouse gasses such as carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 (IPCC-WGI 2007). The increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture. The changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and inland surface properties, alter the energy balance of the climate system. The net effects of such changes are expected to cause climate change and global warming. Recent trends and analyses of direction of trends, show phenomenon such as: warmer and fewer cold days and nights over most land areas, warmer and more frequent hot days and nights over most land areas, warm spells and heat waves, severe fluctuations in precipitation events, increased frequency of droughts and flooding in addition to increased incidence of extreme high sea levels (IPCC-WGI 2007).

Global warming is now generally agreed to be inevitable, though there are many differing assessments as to how much temperatures will rise and at what rate. Climate change due to greenhouse gasses has been at the forefront of current research efforts in the past decade (IPCC-WGI 1996a, b). These research efforts used different general climatic models to predict climatic changes using different scenarios for the emission and concentration assumptions for greenhouse gasses. The latest report by IPCC (IPCC-WGI 2007) states that “continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century”. Based on different emission scenarios, best estimates for global average surface air temperature increase is predicted to range from 1.8 to 4°C by the end of the 21st century relative to 1980–1999 (IPCC-WGI 2007). Based on different emission scenarios, the likely range of change in global surface temperature is predicted to be between 1.1 and 6.4°C (Meehl et al. 2007). For a future warmer climate, the current generation of models indicates that precipitation is predicted to increase in the tropical regions and to decrease in the subtropics. Globally averaged mean water vapor, evaporation and precipitation are projected to increase (Meehl et al. 2007).

3 Climate Change in the Mediterranean Region

The main and most important climate changes in the Mediterranean region are those related to temperature and to precipitation. Although global climate change might result in a small increase in global annual precipitation rates, annual precipitation is very likely to decrease (Christensen et al. 2007) in most of the Mediterranean areas. The most critical months in the Mediterranean related to precipitation are those months with high precipitation rates which are December, January, and February. In these months, precipitation usually is greater than evapotranspiration and thus recharge of groundwater aquifers usually occurs in these months. Therefore, reduction of rainfall in these months will significantly affect recharge of groundwater aquifers and thus water availability. Table 1 shows projections for temperature and precipitation response to climate change in the Mediterranean areas. Table 1 shows that precipitation is expected to reduce by 6% during December, January and February; this reduction rate could increase to possibly 16%.

In the Mediterranean coast, the median temperature increase lies between 3°C and 4°C, roughly 1.5 times the global mean response (Christensen et al. 2007). The maximum increase in temperature is expected to be in June, July, and August. This increase is expected to increase crop water demands in these months.

For wind speed, the northward shift in cyclone activity tends to reduce windiness in the Mediterranean areas (Christensen et al. 2007). On the other hand, simulations with little change in the pressure pattern tend to show only small changes in the mean wind speed. Therefore, wind velocities are not expected to change significantly as a result of climate change in the Mediterranean basin.

4 Existing Climate in the West Bank

The existing climatic conditions of the West Bank are described using climatic data obtained from seven weather stations located at the main cities and geographical locations in the West Bank (MoT 1998). These stations are distributed over all climatic and geographic zones prevailing in the West Bank (semi-coastal, mountainous, and Jordan rift valley climates) as shown in Fig. 1a. Climatic data from these

Table 1 Temperature and precipitation response to climate change in the Mediterranean areas (Christensen et al. 2007)

Season	Temperature response (°C)			Precipitation response (%)		
	Minimum	Median	Maximum	Minimum	Median	Maximum
December, January, February	1.7	2.6	4.6	−16	−6	6
March, April, May	2.0	3.2	4.5	−53	−16	−2
June, July, August	2.7	4.1	6.5	−29	−24	−3
September, October, November	2.3	3.3	5.2	−27	−12	−2
Annual	2.2	3.5	5.1	−27	−12	−4

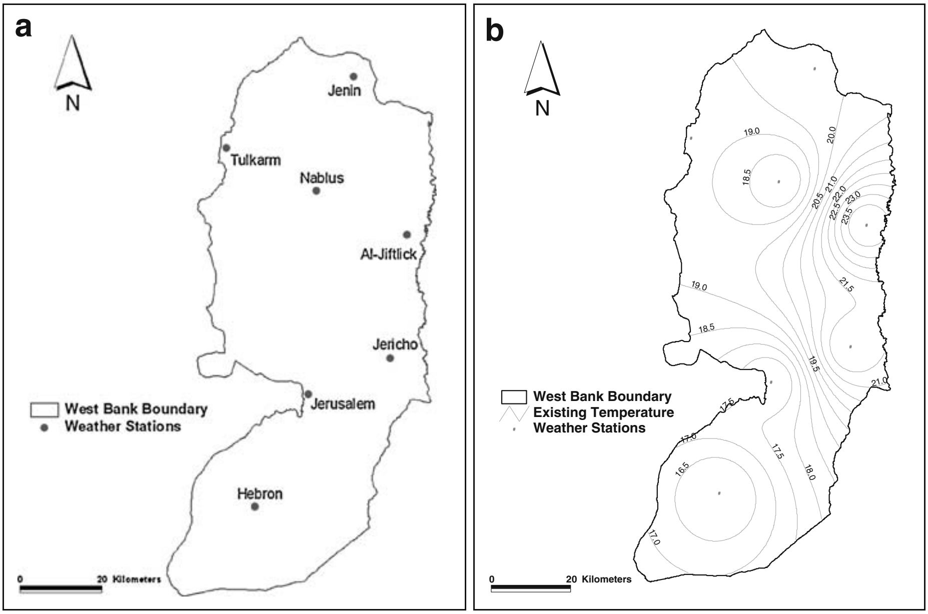

Fig. 1 **a** Location of the seven weather climatic stations describing weather conditions in the West Bank. **b** Spatial distribution of existing annual average temperatures in the West Bank

stations included average monthly maximum and minimum temperatures, relative humidity, wind speed, precipitation and sunshine hours. Average monthly values of climatic data for the West Bank were determined from the seven weather stations and shown in Table 2. Figure 1b shows spatial distribution of existing average annual temperatures in the West Bank.

Table 2 Average climatic conditions in the West Bank based on climatic data from the seven weather stations under consideration

Month	Maximum temperature °C	Minimum temperature °C	Average temperature °C	Wind speed (km/h)	Relative humidity (%)	Precipitation (mm)	ET (mm)
January	14.9	6.9	10.9	7.6	71.9	103	61
February	16.0	7.4	11.7	8.4	71.9	96	70
March	19.2	9.4	14.3	8.7	65.4	74	112
April	24.4	12.3	18.3	8.5	56.9	19	155
May	28.3	15.7	22.0	8.3	50.9	3	197
June	30.7	18.4	24.6	8.6	53.6	0	210
July	32.1	20.2	26.2	9.4	56.1	0	229
August	32.2	20.8	26.5	8.6	59.6	0	215
September	30.9	19.7	25.3	7.6	58.3	1	173
October	28.1	17.1	22.6	5.9	58.4	15	128
November	22.4	12.9	17.6	6.2	60.7	57	87
December	16.7	8.8	12.7	6.6	69.7	110	62
Annual	24.6	14.1	19.4	7.9	61.1	479	1,700

Table 1 shows that average monthly temperatures range from 10.9 to 26.5°C. However, there is a significant spatial variability in temperature in the West Bank. Figure 2 shows that highest temperatures are observed in the Jordan rift valley area (Jericho) while lowest temperatures are observed in the central southern mountain areas (Hebron).

Spatial and monthly variations are also observed in the values of relative humidity, wind speed, precipitation and evapotranspiration. Wind speed values observed at the West Bank weather stations vary from 2 to 16 km/h with highest wind speeds in the central areas and the lowest in the Jordan rift valley. Highest values of relative humidity are observed in the western areas of the West Bank and they tend to reduce to their lowest values in the Jordan rift valley to the east. Table 1 shows that overall monthly relative humidity ranges from 50 to 70% which reflects a relatively small monthly variation in relative humidity.

The variations in precipitation are high over space and time in the West Bank. Annual precipitation ranges from 166 mm in Jericho (Jordan rift valley) to about 660 mm in Nablus (central northern mountains). Average annual precipitation in the West Bank is estimated at 480 mm from the data obtained for the seven weather stations under consideration. Precipitation usually occurs between October and April with nearly dry summer months (from May to September) in all of the West Bank (Fig. 3).

Based on climatic data obtained from the seven weather stations under consideration in the West Bank, monthly values of evapotranspiration were estimated using FAO Penman–Monteith approach through CropWat for Windows Version 4.2 model (FAO 1998). The FAO Penman–Monteith method was used because it has been recommended as the sole standard method for computation of evapotranspiration (Allen et al. 1998). ASCE and European studies indicated that FAO Penman–Monteith is relatively accurate and has consistent performance in both arid and humid climates (Allen et al. 1998). In this method, reference evapotranspiration (ET) is defined as the rate of evapotranspiration from a hypothetic crop with an assumed crop height of 12 cm, a fixed canopy resistance of 70 s m^{-1} and an albedo of 0.23. This is closely resembling the evapotranspiration from an extensive surface of

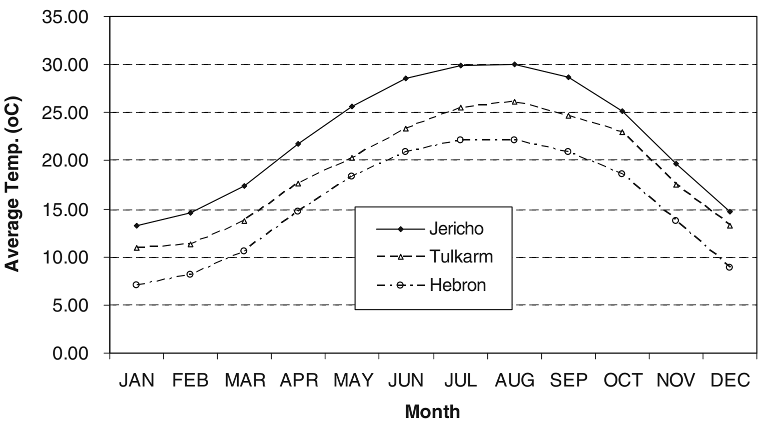

Fig. 2 Monthly variations of average temperature at different locations in the West Bank

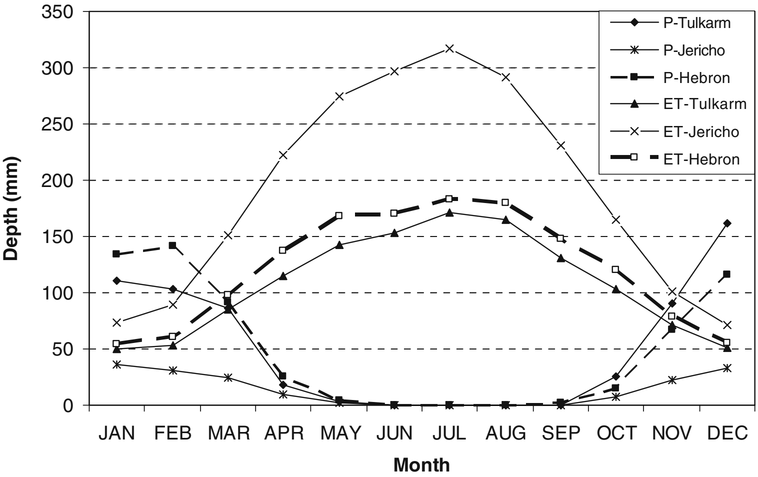

Fig. 3 Monthly evapotranspiration and precipitation at three weather stations in the West Bank

green grass of uniform height, actively growing, completely shading the ground and not short of water. The Penman–Monteith approach utilizes a formula combining aerodynamic and radiation terms for estimating ET.

Figure 3 shows the variations in monthly evapotranspiration and precipitation at three weather stations in the West Bank. The variations in the values for these weather stations reflect the spatial variations in the West Bank. The lowest precipitation and highest evapotranspiration are observed in Jericho which is located in the Jordan rift valley. The lowest evapotranspiration is observed in Tulkarm on the western side of the West Bank which is the closest station to the Mediterranean Sea. Figure 3 shows that precipitation exceeds evapotranspiration during December, January, and February in Tulkarm and Hebron weather stations which represent climatic conditions in the central and western areas of the West Bank. These areas are the recharge zones for the groundwater aquifers of the West Bank. Therefore, any changes in precipitation and evapotranspiration during December, January, and February at the central and western areas of the West Bank will have direct impacts on the availability of water in the West Bank. Changes in evapotranspiration and precipitation will also impact agricultural water demands and agricultural production of rainfed crops in the West Bank.

In addition to irrigated agriculture, rainfed agriculture is also important in the socio-economic conditions of the rural areas in the West Bank. Rainfed agricultural patterns include olive and grape trees, field crops and vegetables. These crops cover about 1,300 km^2 or 23% of the West Bank (PCBS 2005). Precipitation depths in March and November usually exceed 60% of evapotranspiration in most central and western areas of the West Bank. This makes precipitation in these months highly essential in extending the winter cropping season for rainfed agriculture in these areas. Precipitation in March is essential to provide moisture during the flowering season for rainfed agricultural crops. Therefore, a reduction in rainfall or an increase in evapotranspiration in March will have serious effects on the productivity of rainfed agricultural crops. The eastern areas of the West Bank are usually considered poor rainfed agricultural areas or marginal lands because of the small amounts of rainfall occurring in these areas especially in March. Increasing temperature and reducing precipitation resulting from climate change could easily yield to extending the area of marginal lands in the West Bank in addition to reducing available water resources.

5 Simulated Climate Changes

Since the concern of this study was to assess the effects on water availability and water demands, changes with direct effect on evapotranspiration and precipitation were considered. Temperature changes for the Mediterranean areas as predicted by different climate models are shown in Table 1. The increase in temperature is predicted to range from 1.7 to 6.5°C (Christensen et al. 2007) with small monthly variations. Since there is still a lot of uncertainty for climate change, the possible impacts of climate change on water resources availability and demand are predicted using a number of scenarios within the predicted range of temperature and precipitation changes. In this study, three scenarios within the predicted temperature changes are modeled. These scenarios are 2, 4, and 6°C increases in average monthly temperatures. Although there are small monthly variations in the predicted change, temperature increases were assumed to be uniform as the objective of this study is to assess the range of impacts of such climate change. For precipitation changes, two scenarios were assumed: one with no changes in monthly precipitation depths and the second assuming a reduction of 16% in average monthly precipitation depths. The 16% reduction is the maximum predicted reduction in precipitation depths in the Mediterranean basin as shown in Table 1 and represents the worse scenario predicted for climate change effects on precipitation.

Although wind speed, relative humidity and sunshine hours have an effect on evapotranspiration estimation, however predicted changes resulting from climate change on these variables are small and uncertain (IPCC-WGI 2007). Thus, the effects of possible changes in wind speed, relative humidity and sunshine hours are not considered in this study. Based on average values of these climatic parameters and the different scenarios for temperature changes above, monthly evapotranspiration depths were estimated using Penman–Monteith approach for the seven climatic stations under consideration in the West Bank.

The monthly evapotranspiration depths for the different weather stations under consideration were compared with monthly precipitation depths at these stations. The comparison was performed for both existing precipitation depths and the 16% reduced precipitation depths. Based on these comparisons, excess precipitation depths during winter months were estimated at the different stations. The precipitation excesses over evapotranspiration represent natural recharge depths for the groundwater aquifers. Theses depths were added at each station to calculate annual values at each station. GIS spatial analyses were performed to estimate spatial average effects on the entire West Bank. Changes in annual average natural recharge depths represent the predicted changes in the groundwater availability from the aquifers. These changes represent changes in the availability of water resources in the West Bank as a result of climate change.

The changes in monthly and annual evapotranspiration depths at the different stations represent changes in agricultural water demands. Another important change evaluated is the number of months when precipitation exceeds evapotranspiration. This number is highly important in rainfed agriculture as it indicates the feasibility of planting crops that depend on rainfall as the only source of water.

6 Results of Simulated Climate Changes

Figure 1b shows existing distribution of average annual temperatures in the West Bank. In addition to the topography, this distribution allows forming three climatic zones in the West Bank. These zones are the Jordan rift valley, the mountainous and the semi-coastal climatic zones. GIS spatial analyses of average annual temperatures in the West Bank shows a spatial average of 19.07°C. Figure 1b shows that a small increase in temperature of only 2°C could expand the climate of the Jordan rift valley to Jenin in the northern central West Bank. This will be a significant spatial expansion which will have effects on agricultural crops and cropping patterns there. This effect is also important on the mountainous areas as temperature in the southern mountains around Hebron will be nearly equal to those existing temperatures in the northern lower (in height) mountains around Nablus and Jerusalem. Therefore, such a small change in temperature will probably restrict the plantation and production of some current fruit trees requiring low winter temperatures in the Hebron Mountains. Figure 1b shows also that an increase of 6°C in temperature will have the temperatures of the mountainous areas reaching those of the existing Jordan rift valley temperatures. As a result of such change, the whole West Bank will have the

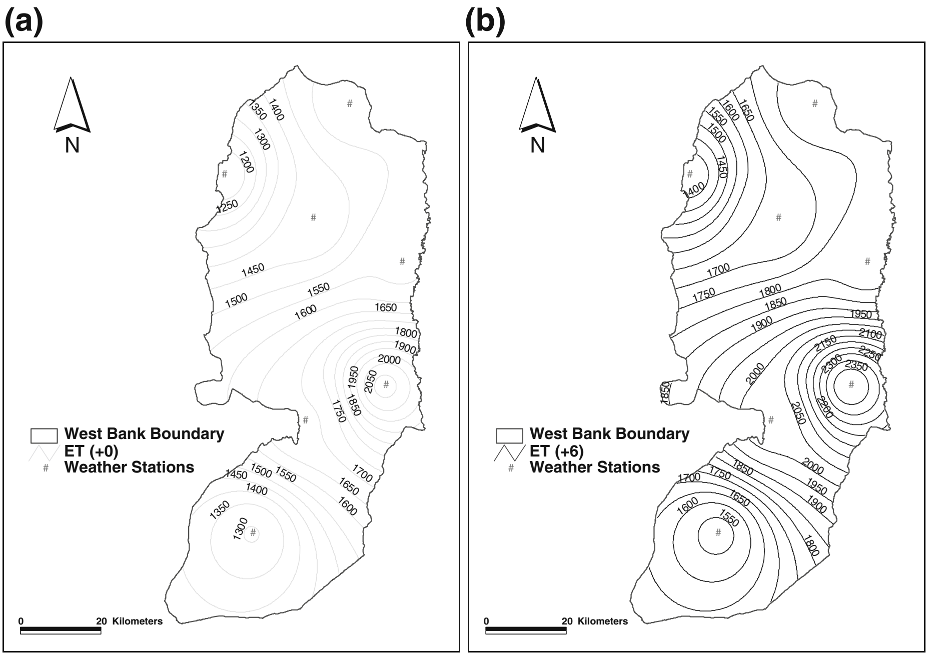

Fig. 4 **a** Spatial distribution of annual evapotranspiration depths (mm) estimated from existing climatic conditions in the West bank. **b** Spatial distribution of annual evapotranspiration depths (mm) estimated from 6°C increase in temperature in the West Bank

Jordan rift valley temperatures prevailing instead of the existing three climatic zones. This climate zone will be warm winters and very hot dry summers. Such changes are enormous weather changes and will result in large transformations of weather and agriculture all over the West Bank.

Existing annual evapotranspiration depths in the West Bank show a variation from 1,160 mm in the semi-coastal areas to more than 2,000 mm in the Jordan rift valley. Figure 4a shows the spatial distribution of annual evapotranspiration depths in the West Bank estimated from existing climatic conditions. Figure 4b shows the spatial distribution of evapotranspiration depths with 6°C increase in temperature. The increase in evapotranspiration represents increase in irrigation demands.

GIS spatial analyses of evapotranspiration data showed that the increase in temperature predicted by climate change will result in increasing evapotranspiration in the West Bank by 6 to 17%. Therefore, climate change will result in increasing agricultural water demands by up to 17%. It will be possible to plant some crops at earlier times in the season during cooler months to reduce their demand to water to adapt for temperature changes. However, such an option should be evaluated considering availability of water and other environmental and socio-economic conditions prevailing in the West Bank.

Natural recharge rates were estimated by comparing monthly evapotranspiration with monthly precipitation considering some losses in precipitation due mainly to runoff. Assuming that these losses remain constant, average natural recharge rates (precipitation excess) are estimated for both existing and future scenarios and shown

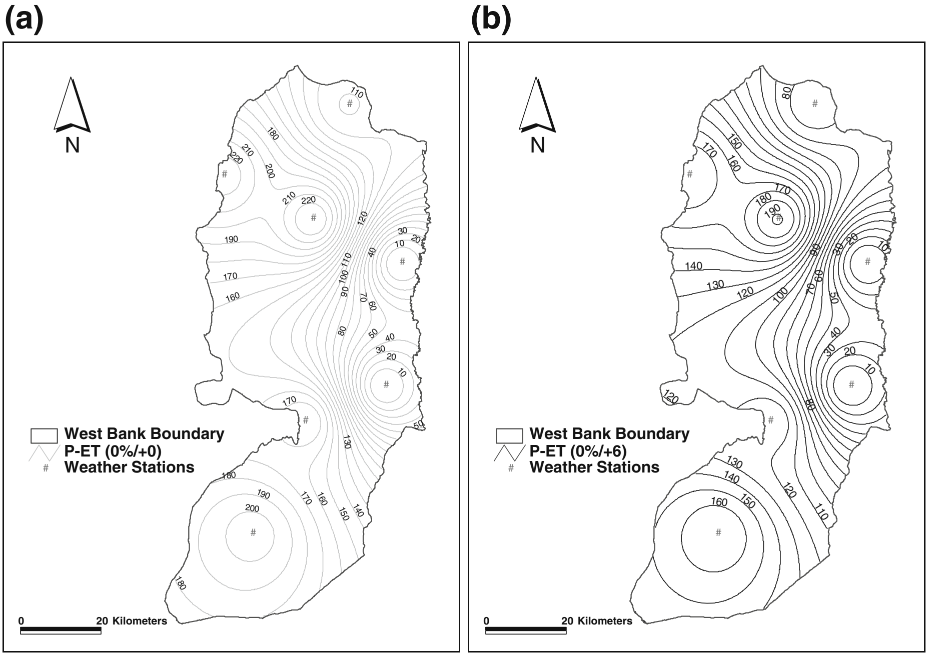

Fig. 5 **a** Spatial distribution of annual precipitation excess (P-ET) depths estimated from existing climatic conditions in the West Bank. **b** Spatial distribution of annual precipitation excess (P-ET) depths estimated from 6°C increase in temperature in the West Bank

in Fig. 5a and b. Figure 5b shows the distribution of annual precipitation excess (P-ET) depths with a 6°C increase in temperature in the West Bank. GIS spatial analyses showed that the predicted increase in temperature will result in reducing recharge depths from 7 to 21% assuming no reduction in precipitation. This means that natural recharge of groundwater aquifers could reduce by up to 21% as a result of 6°C increase in temperature.

Figure 6a shows the distribution of precipitation excess (P-ET) depths with existing temperatures and a 16% reduction in precipitation. Figure 6b shows the distribution of precipitation excess depths if the 16% reduction in precipitation is combined with a 6°C increase in temperature. GIS spatial analyses showed that a possible 16% reduction in precipitation will have severe effects on recharge rates of groundwater aquifers and thus on water resources availability in the West Bank. Even with no temperature changes, the reduction in recharge will be about 30% which is much higher than the effect of a 6°C increase in temperature. If the 16% possible reduction in precipitation is combined with a 6°C increase in temperature, the reduction in recharge and thus water availability will reach 50%. Such possibility will have tremendous effects on water availability, the socio-economics and the politics of the West Bank and its neighboring countries which might have similar impacts. This effect is not going to be unique to the West Bank since Mediterranean and Middle Eastern countries have similar climatic conditions which could have similar effects of climate change.

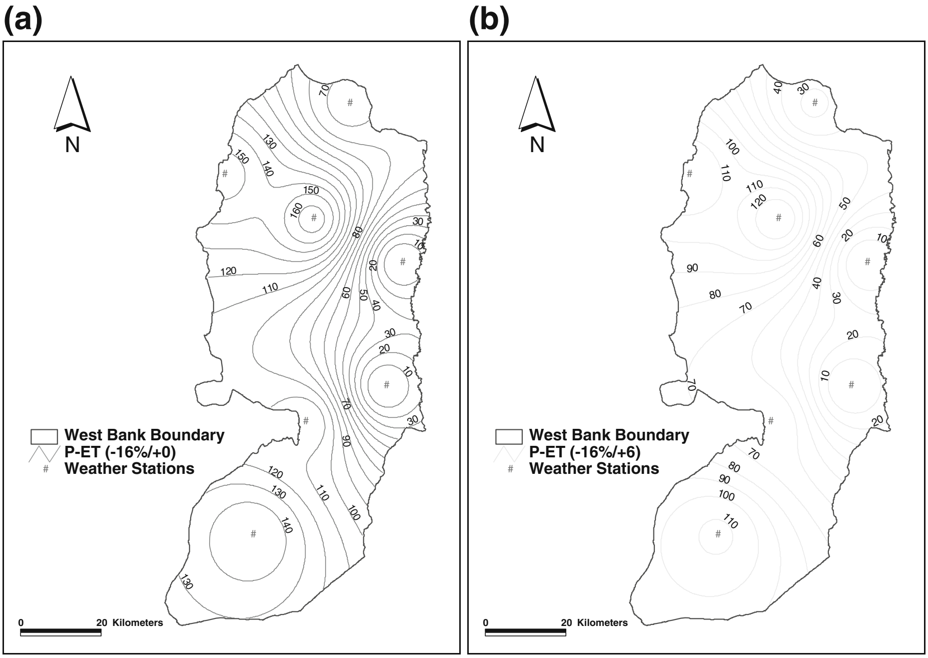

Fig. 6 **a** Spatial distribution of annual precipitation excess (P-ET) depths (mm) estimated from existing temperature and 16% reduction in annual precipitation in the West Bank. **b** Spatial distribution of annual precipitation excess (P-ET) depths (mm) estimated from 6°C increase in temperature and a 16% reduction in precipitation in the West Bank

Table 3 Summary of average impacts of increase in temperature and reduction in precipitation on the entire West Bank using GIS spatial analyses

		Increase in temp only			Reduction in precipitation and increase in temp.			
	Existing	2°C increase	4°C increase	6°C increase	Existing temp.	2°C increase	4°C increase	6°C increase
Average temp. °C	19.07	21.07	23.07	25.07	19.07	21.07	23.07	25.07
Precipitation (mm)	485	485	485	485	408	408	408	408
ET (mm)	1529	1616	1704	1794	1529	1616	1704	1794
Recharge (mm)	142.3	132.2	122.2	111.9	98.9	89.3	79.7	69.8
Change in Precipitation	0.0%	0.0%	0.0%	0.0%	−16.0%	−16.0%	−16.0%	−16.0%
Increase in ET	0.0%	5.7%	11.4%	17.3%	0.0%	5.7%	11.4%	17.3%
Reduction in recharge	0.0%	7.1%	14.2%	21.4%	30.5%	37.2%	44.0%	50.9%

Table 4 Changes in number of months with precipitation exceeding evapotranspiration for different climatic change scenarios

		No reduction in precipitation			16% reduction in precipitation			
	Existing	2°C increase	4°C increase	6°C increase	Existing	2°C increase	4°C increase	6°C increase
Al-Jiftlick	2	1	1	0	0	0	0	0
Tulkarm	5	5	5	5	4	4	4	3
Jenin	3	3	3	3	3	3	3	3
Hebron	4	4	3	3	3	3	3	3
Jericho	0	0	0	0	0	0	0	0
Jerusalem	3	3	3	3	3	3	3	3
Nablus	5	4	4	4	3	3	3	3

Table 3 shows a summary of the potential effects of increase in temperature and reduction in precipitation on evapotranspiration and precipitation excess depths representing natural recharge in the West Bank.

Another factor which will be important for agriculture is the number of months when precipitation exceeds evapotranspiration. This represents the length of time when plants are not water stressed and thus has a special agricultural importance. Table 4 shows the existing number of months when precipitation exceeds evapotranspiration as compared by those numbers for the different scenarios of climate change. Although Table 4 shows small reductions in the number of months with precipitation exceeding evapotranspiration, the effect of temperature increase and precipitation reduction will be high on the agricultural sector in the West Bank. The increase in evapotranspiration and reduction in precipitation during March and April will cause severe water stresses for crops during these two months. Also water storage in the soil will be less during March and April as a result of smaller precipitation excess in previous months. This will increase water stress during flowering months which will result in significant reductions of crop yield of rainfed crops.

7 Coping with Climatic Changes

As discussed above, the West Bank as well as many countries in the Mediterranean region already suffer severe water scarcity. However, increasing temperature and reducing precipitation as potential results of climatic changes would result in reducing water availability and increasing agricultural water demands. These effects enhance the need for national action plans to cope with climatic changes. These action plans should be developed to combat water shortages and desertification utilizing all available knowledge and experience including indigenous knowledge of the people in the region in adapting to the severe climatic variations. Adaptation plans and initiatives could include:

- Conservation practices for water and soil such as: conservation terraces, contour tillage, mulching, adopting efficient irrigation systems and efficient irrigation schedules, planting in controlled environment, selection of high yielding plant varieties and using efficient water distribution systems.
- Enhancing water supplies through water harvesting methods and artificial recharge of groundwater.

- Utilizing non-conventional water sources such as treated wastewater and brackish water, desalination of brackish and sea water and rainfall enhancement.
- Evaluating cropping patterns and adopting new patterns considering climatic changes.
- Regional cooperation on enhancing water supply and food safety issues

8 Conclusions and Recommendations

This study shows that climate change will have severe effects on available water resources and agricultural water demands in the West Bank. The study shows that the predicted increase in temperature could cause an increase in evapotranspiration from 6 to 17%. The increase in temperature alone could reduce natural recharge of groundwater aquifers by 7 to 21%. Therefore, temperature changes could reduce water availability by up to 21% and increase agricultural water demands by up to 17%. However, possible changes in precipitation will have more severe effects on water availability than the increase in temperature. This study shows a possible 16% reduction in precipitation could result in reducing recharge of groundwater aquifers by about 30%. If this effect is combined with an increase of 6°C in temperature, the reduction in groundwater recharge will reach 50%. Such reduction will have severe effects on the water availability in the West Bank. It requires more evaluation and analyses of the possible consequences of climate change especially on precipitation. It also requires adopting national plans to adapt to climate changes.

Although the analyses and evaluation conducted in this study were performed for the West Bank, the effects of climate change will be also as severe in many Middle Eastern and Mediterranean countries as they have similar climatic conditions. This emphasizes the need for regional cooperation in designing and adapting plans to cope with climate change.

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