Climate change mitigation opportunities in Palestine through the utilization of the renewable energy sources

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Abstract
The climate change scenario B1A for historical Palestine; as part of the east Mediterranean basin, over the period 2000-2045 suggests a decrease in annual precipitation, an increase in average seasonal temperature and an increase in frequent occurrence of extreme climate events. A climate change adaptation strategy is essentially required as the region is already experiencing acute shortage of fresh water resources associated with continuous widening of the dry land areas. On the other hand, the region is blessed with the availability of the renewable energy sources that may be harnessed well to tackle the possible adverse climate change impacts. In this paper the climate change trends and future scenario for the region will be presented based on a research done in the framework of the German funded GLOWA-Jordan River program. Opportunities for the possible utilization of the available renewable energy for mitigating the possible impacts are also presented together with other possible actions.

Keywords: Climate change, east Mediterranean basin, Palestinian Authority, Renewable Energy

1. Introduction
Palestine is part of the eastern Mediterranean basin, which is located between the mid-latitude storm rain-band and the Sahara Desert and influenced by a profound seasonal cycle with wet–cold winters and dry-warm summers. The land types of the basin are predominantly desert, grasslands, and rangelands and the Mediterranean Sea represents an important source of atmospheric moisture that affects the climate of the surrounding basin. The basin, which hosts a population that exceeds 100 million, has been experiencing, during the last 20th century, a rapid demographic and economical development coupled with increasing demands on both water and energy. Such increase in demand on affects the region's unique biodiversity of habitats and their flora and fauna. The effect may intensify as the region is already facing major problems such as water scarcity, food security, prevalence of diseases and rapid population growth. With a climate change trends that favour the increase in average air temperature and the decrease in precipitation; a trend suggested in the IPCC[1] report [1], the peoples of the region, including Palestinians, need to be prepared for worst possible scenarios. The climate development over Palestine is strongly influenced by the Israeli anthropogenic emissions. There is no statistics regarding Palestinian greenhouse gas (GHG) emissions. Palestinian generates very minimal electrical energy as they import over 90% of their electrical energy from Israel [2]. The statistics on GHG emission in Israel show that Israel emitted in 2007 more than 76 million tons of GHG per year (CO_2 equivalent) [3], which is considered a rise of 20% since 1996. Israel is ranked in the eighth place for countries with maximum CO_2 emissions [4] as seen in Figure 1. The anticipated further raise in energy consumption and GHG emissions forecasting a 63% increase in GHG emissions in the year 2025, under business-as-usual scenario. Such scenario when coupled with the population growth of 2-3%, and with the political instability in persistence for the several decades ago, exert more pressure on already limited available natural resources. Palestinians need to struggle to make sure that they can meet the demand under the possible future complicated circumstances. Should the political crises stayed unresolved and climate trend favour the increase in average temperature with a reduction in rainfall, then the region will be facing serious setbacks. A climate change adaptation strategies and actions should be prepared by the Palestinian authority taken into account all possible scenarios.

[1] Intergovernmental Panel on Climate Change

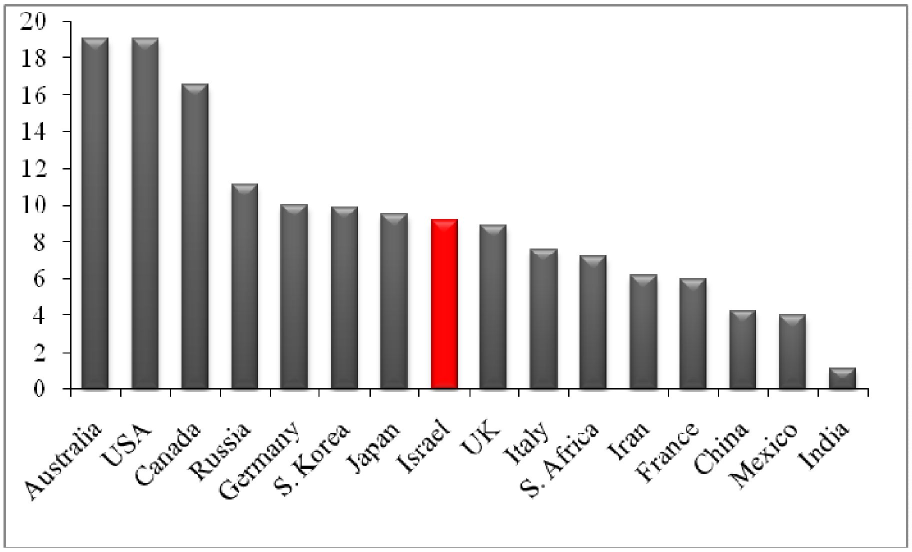

Figure 1 – CO_2 per capita emissions in major countries in millions of tons [4]

In a joint effort carried out with the German Potsdam Institute of Climate Impact Research (PIK) within the German GLOWA (Global Change of Hydrology Cycle) program, investigation of climate change for Palestine was carried out. The GLOWA-Jordan River project funded by the German Ministry for Education and Research (BMBF) facilitated the study of east Mediterranean basin climate in order to assess the hydrology cycle of the Jordan River basin that contains the major surface and underground water resources. In the business-as-usual scenario with the expected population growth, the future change in the climate may lead to a sharp decrease in precipitation with an increase in average air temperature resulting in possible adverse consequences on natural resources such as water, biodiversity, etc. In such scenario, Palestinians should be prepared to adapt to the possible change and to propose mitigation measures.

In this paper the climate change for Palestine is investigated using statistical modelling approach and considering the business-as-usual scenario. Results are discussed and further recommendations for mitigation measures are listed. Measures include opportunities for utilizing renewable energy sources, in particular solar and wind energies.

2. Methodology

In order to produce the climate change scenarios for Palestine until 2045, two approaches were implemented. The first approach entails the assessment of climate trend over the 20^{th} century for a regional geographic domain, containing Palestine, with relatively coarse grid resolution. This enables identifying the climate trends for Palestine as part of a larger region, which is greatly influenced by measoscale climate phenomena. This approach helps valuation of the development of underlying geographic climate zones based on the Köppen climate classification and thus having larger picture on possible climate change for Palestine and for the surrounding region.

The second approach focuses on a smaller geographic domain of Palestine using finer grid resolutions for assessing the climate variables development over a considerable time, based on historical climate observations for Palestine. Results should agree well with the results of the first approach. Further, climate historical observations and trend is used for modelling the climate change scenario that corresponds to the IPCC [5] recommendations.

The geographic model domain of the first approach is a large area of the east Mediterranean basin that extends from 30^o E to 43^o E longitude and from 27^o N to 38^o N latitude with a spatial grid resolution size of 0.5^o x 0.5^o on both longitude and latitude extensions. The climate data for the chosen domain were originally stored at the Climate Research Unit (CRU) of the University of East Anglia [6]. The data include the monthly values of mean surface air temperature and sums of precipitation from rain gauge measurements (land only) available for the same domain's 0.5° x 0.5° grids. The CRU climate data were further homogenized over the domain with the help of statistical method at PIK [7]. Data cover the 21st century and extend in time over the period from 1901 to 2003. Evaluation of the domain's climate development is based on the trends and changes of the surface air temperature and precipitation for the 103 years, and the century seasonal changes of both climate values. In order to assess any possible changes on the underlying land, the domain climate was classified into 13 climate types based on quantifying the approximate relationship between the climate of a regional extension and the qualitative features if the lands vegetation. This method is based on the known Köppen climate classification which was further enhanced by Trewartha [8] and Rudolf [9]. A multivariate statistical clustering technique developed at the PIK [10] was used. By such method grid points of similar climate behaviour and whose spatial distribution can be presented were grouped together for the 103 years on successive climate period of 15 years, which is the minimum time required to describe a climate. Thus, from 1901, the spatial distributions of the climate types were calculated and grouped for each 15years; i.e. first period represents the underlying climate over 1901-1915, the next for the period 1902-1916 and so forth until the last period of 1989-2003. Any changes in the climate types are thus given in spatial land areas (zone).

The model domain of the second approach is Palestine extending from 29° N-34° N and from 34° E-36° E, latitude and longitude respectively. A fine grid resolution of 8 km x 8 km is used. Meteorlogical obervations for the domain are those daily climatic values for the period 1958 – 1996 including:

- Daily maximum air temperature
- Daily minimum air temperature
- Daily average air temperature
- Daily precipitation

The climate observation over the said time slice were used to build the trend of the control run of the statistical downscaling model STAR of PIK. The model used runs simulation based on ECHAM4.0 model General Circulation Model (GCM) [11] run based on the SRES A1B-Scenario [12] to produce the climate simulation results for the time slice of 2000 – 2045.

3. Results

Analysis of the climate development over the 20th century showed a substantial increase in the average annual and seasonal temperatures in the range 1.0 – 2.0 °C over most of the east Mediterranean Basin. Over Palestine a century increase of around 1.0 °C is noticed. This agrees well with the IPPC-Third Assessment Report (TAR) findings. Precipitation trends showed also decreases over most of the domain's area. In addition, a seasonal shift in winter towards March months was clearly shown over the 20th century (see Figure 2).

The assessment of the temperature and precipitation revealed a cyclical climate where rainy years follows several drought years and that in rainy years rain tends to fall heavily over short time. Such conditions favour runoff over replenishment of the main underground water aquifers thus making the deficit gab between the pumping of aquifer water to the aquifer recharge widen.

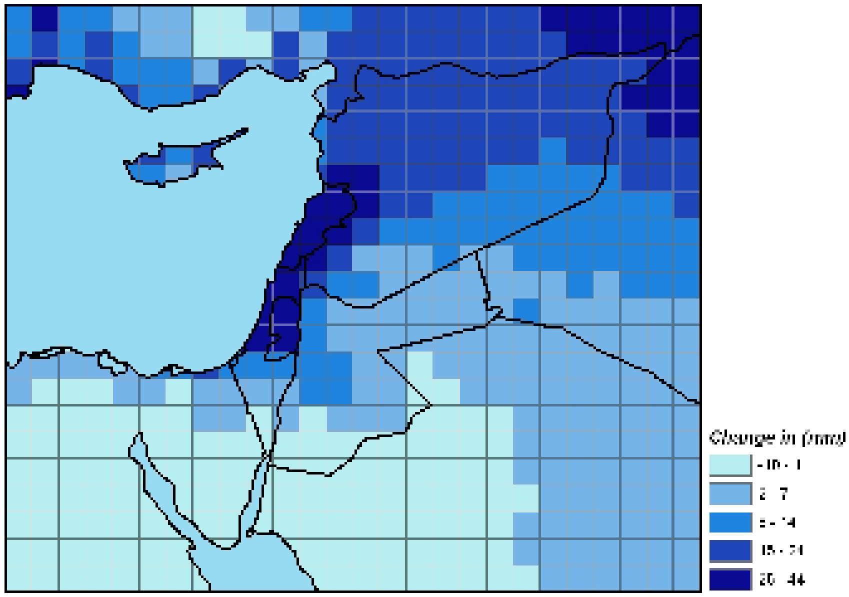

Figure 2 – The 20th century rainfall seasonal shift towards March

The consequence of the century decrease in precipitations and the increase in average seasonal temperature may strongly contribute to the increase in the aridity of the region, especially in the southern parts. The results of analyzing the climate classifications supports such hypothesis, as it was shown that dry climate type zones have increase over other climate type zones , in particular in mid and southern parts of the domain; i.e. from 32° N towards south of the domain. Most parts of the domain have experienced two or three time's climate change in the last century (Figure 3).

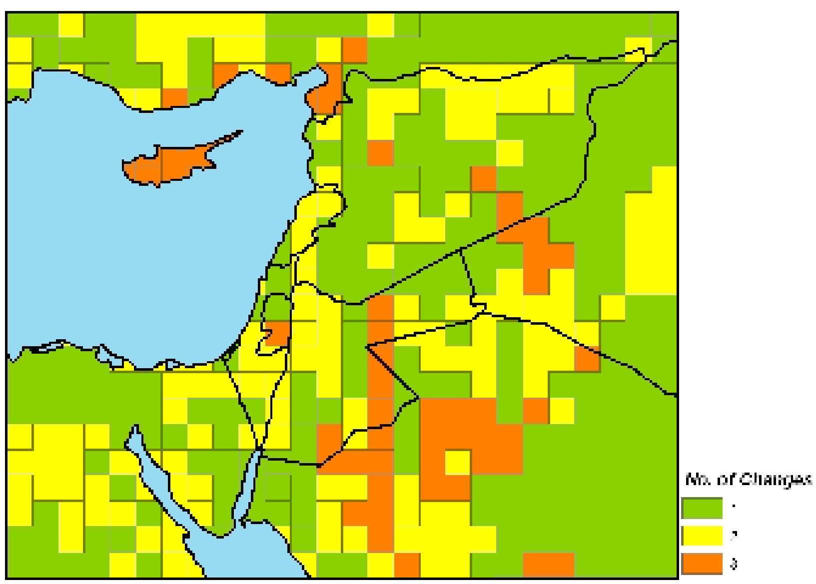

Figure 3 – Number of climate changes over the period 1901 - 2003

The statistical downscaling using scenario SRES A1B brought similar results for the smaller domain when using the observation time slice 1958-1996. The scenario simulation output suggests an increase in the average seasonal temperature over the time slice 2000-2045 in the range 0.5-1.0 °C. Simulated precipitation trend over Palestine showed a decrease in rainfall over 2000-2045 by an average of 10% - 20% (see Figure 4).

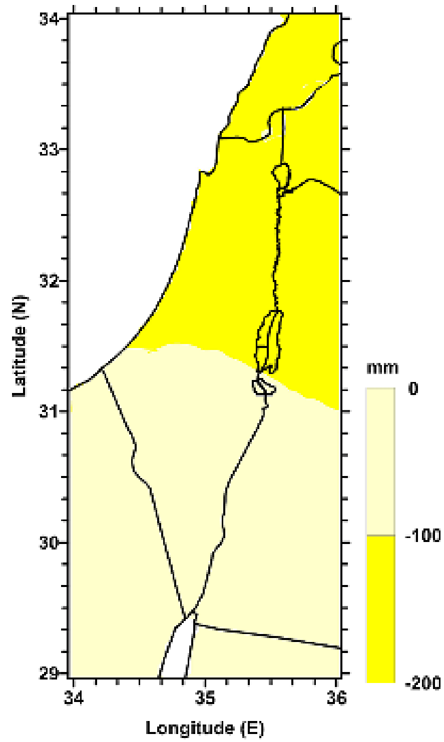

Figure 4 – Simulated precipitation change for the time slice 2000-2045

3.1. Possible Impacts

The simulation results of the scenario A1B suggest a considerable reduction in precipitation coupled with an increase in average air temperature. In addition there are suggestions that favour the cyclic increase in the extreme climate events (droughts, heavy rains over short time, heat waves, etc.). The expected consequences could adversely impact all sectors including:

- **The water sector:** reduction of at least 20% in water availability due to the suggested reduction in rainfall and due to the increase in cyclic droughts and other climate extreme events.
- **The public health sector**: The increase in average temperature may lead to the increase in Mosquito population and their distribution, increasing the associated health risks. In marginalized areas, such as the refugee camps, public health may be a risk of Malaria due to the shortage of water and the bad hygienic conditions.
- **The agriculture**: The suggested decrease in water availability due to the reduction in rainfall of around 20% may fail to meet the continuous increase on water demand. This may lead to adverse impacts on crops and agriculture in general.
- **The biodiversity sector**: The increase in dry climate zone could disrupt the unique biodiversity and the flora and fauna habitats.
- **Socio-economic sector**: It is clear that the poor people are those who are most vulnerable to the effects of climate change, in particular in the developing countries. The average household size in Palestinian West Bank and Gaza Strip areas is about 5.8 [13] and the average annual per capita income is less than US$2,000. Considering that the Palestinian economy is very much linked to the Israeli economy, which is very similar to those developed countries' economy, most Palestinians will be vulnerable to any climate change. Palestinians living in rural areas, who depend more on agriculture, could compromise agriculture activities in order to maintain their basic living conditions. The possible future shortage in water resources would lead to an increase in water tariffs exposing people to more economical pressures. The indirect impact would risk the food security of the society and would increase the unemployment rates as well as the poverty among the people.

- **The energy sector**: The suggested increase in average air temperature and the increase in heat waves will increase demand on energy for air conditioning and cooling. As Palestinian produces very minimal electrical energy, their economy would suffer much by depending on the electrical energy imported from Israel.

3.1. Mitigating climate change impacts

The economic cost of climate change could be very high if the country fails to take the necessary actions to adapt to possible climate change and if no mitigation measures are considered and taken when necessary. There is a strong need to have a national climate change adaptation strategy with inputs from all relevant stakeholders. Strategies should include a main section that advocates public awareness and participation with definite programs and actions. Very recently, the Palestinian cabinet has approved the convening of the national climate change advisory committee, which should meet to put an agenda and a time-frame of actions. In the context of the simulation results, and those of the IPCC's, the following mitigation actions should be considered:

- Water sector is the most vulnerable sector to climate change. This sector is controlled by the Israeli occupation and yet the simulation suggests future trends where water availability will decrease by around 20% while demand is expected to increase by no less than 20%. Mitigation water scarcity needs public awareness and intervention by retrofitting houses with water-saving devices such as flow regulators in faucets and shower heads and two-volume flush toilets. Authority should promote actions for saving water in public buildings, using drip irrigation in agricultural lands, promoting the use of treated effluents that meet the stringent standards to irrigate agricultural lands. The authority should provide funds for establishing wastewater treatment plants. In Gaza strip, authority should promote the use of medium and small size desalination units that may utilize the available solar.
- In order to minimize the use of conventional energy sources, decision makers should encourage the use of renewable energy sources such as solar and wind energy sources. The potential of utilizing solar energy in Palestine is great as Palestine is fortunate with average daily solar radiation intensity in the range 5-7 kWh/m^2 (Figure 5).

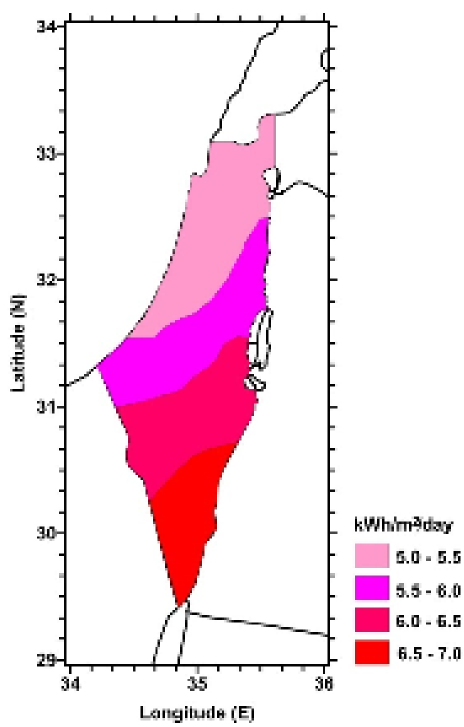

Figure 5 – Spatial distribution of solar radiation intensity over Palestine

The utilization of solar energy in Palestine began more than three decades ago, mainly by using solar energy for heating water for domestic use. The recent statics showed that more than 70% of the Palestinian households use the solar domestic hot water systems (SDHW) for their daily household use [13]. Solar energy thermal conversion projects, such as solar power towers could be established in Jericho where land is available with a minimum of 6 kWh/m^2/day solar intensity. Direct conversion of solar radiation is considered a potential option, especially for roads and public buildings lightings. In remote areas solar energy could be used for marginalized communities to provide basic energy for lightings and refrigeration. The Global Environmental Facility (GEF) has funded small projects in Palestinian rural areas where solar energy was utilized for providing electricity for remotely located communities and for providing proper local technology for drying crops [14].

Wind energy is another potential energy source in Palestine. The mesoscale phenomena which favour the presence of dominant winds resulted from the natural circulations, such as land/sea breezes, katabatic/anabatic and channelling winds with average wind speed in the range 5-10 m/s is considered potential that should be investigated.

Further actions for mitigating possible future climate change could be realized, however, actions should be regulated by the authority by encouraging other sectors to actively interfere and cooperate.

4. Conclusions

On the basis of the analysis carried out for the climate development in the past 20th century, distinct climate changes could be observed for east Mediterranean region and for Palestine. The SRES A1B scenario simulation results for the period 2000-2045 suggests continuous increase in air temperature, decrease in precipitation, and increase in the occurrence of climate extreme events. Such possible scenario requires Palestinian decision makers to prepare national adaptation strategies and actions for mitigating possible future climate change impacts focusing also on worst possible Political scenario. Measures should take into account the utilization of the potential non-monopolized renewable energy sources, such as solar and wind. Adaptation strategies should propose actions for reaching out and mobilize the public by special awareness programs. Water sector could be the most vulnerable sector that requires regulatory-public cooperation in mitigating the possible future adverse impacts.

5. Acknowledgement

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