Impacts of Climate Change on a Spatially Distributed Water Balance in the Gaza Strip, Palestine

Salem S. Gharbia[1*] Adnan Aish[2] Francesco Pilla[1]
1.Department of Civil, Structural and Environmental Engineering, Trinity College, Dublin, Ireland.
2.Institute of Water and Environment, Al-Azhar University- Gaza, Palestine
E-mail address: GharbiaS@TCD.ie

Abstract
As Mediterranean coastal area, the Gaza Strip is likely to be at high risk for water scarcity due to climate change, thus hydrological studies are necessary. This study aims to investigate the impacts of climate change on water balance elements of the Gaza Strip and generate future projections. The Water Balance computer model (WetSPASS) integrated with the GIS was used for simulating the hydrological cycle for the Gaza Strip coastal aquifer in this study. The mean annual simulated evapotranspiration were 157.34 mm/year, 156.46 mm/year, 151.85 mm/year and 131.44 mm/year for baseline, year 2020, year 2050 and year 2080 respectively. While 34.88 mm /year, 32.35 mm /year, 26.73 mm /year and 18.71 mm /year were the mean annual simulated surface runoff for baseline, year 2020, year 2050 and year 2080 respectively. The mean annual simulated groundwater recharge were 125.33 mm/year, 105.07 mm/year, 64.44 mm/year and 20.14 mm/year for baseline, year 2020, year 2050 and year 2080 respectively. The mean simulated interception values were 8.31 mm/year, 7.71 mm/year, 6.41 mm/year and 4.56 mm/year for baseline, 2020, 2050 and 2080 respectively. The main conclusion from projected water balance elements is that Gaza Strip will be in a condition of severe water scarcity risk.
Keywords: water balance, climate change, WetSPASS, Gaza Strip

1. Introduction

The Gaza Strip is a part of the Palestinian coastal plain located in an arid to semi-arid region. It is bordered by Egypt from the south, the green line from the North, Nagev desert from the East and the Mediterranean Sea from the West, so The Gaza Strip is located on the south-eastern coast of the Mediterranean Sea, between longitudes 34° 2" and 34° 25" east, and latitudes 31° 16" and 31° 45" north Figure (1). The total surface area of the Gaza Strip is 360 km (Naciri, 2001), where about 1,443,737 Palestinian people live and work (PCBS, 2004) . This figure classifies the Gaza Strip as one of the most densely populated area in the world. The Gaza Strip is divided geographically into five Governorates: Northern, Gaza, Mid Zone, Khan Younis and Rafah. The annual average rainfall varies from 400 mm in the north to about 200 mm in the south of the strip. Most of the rainfall occurs in the period from October to March, the rest of the year being dry (PHG, 2002).

According to current climate projections, Mediterranean Countries are at high risk for an even pronounced susceptibility to changes in the hydrological budget and extremes. While there is scientific consensus that climate induced changes on the hydrology of Mediterranean regions are presently occurring and are projected to amplify in the future, very little knowledge is available about the quantification of these changes, which is hampered by a lack of suitable and cost effective hydrological monitoring and modeling systems (Gampe et al. 2013). In the Gaza Strip no permanent surface water exists in form of streams and natural lakes. Only the Wadi Gaza could provide surface water during the winter months. The source of freshwater in the area is the Coastal Aquifer. The Coastal Aquifer, hereafter referred as Gaza Aquifer, covers a large area of about 2.000km², from the Carmel Mountains in the north, to the Sinai Desert in the south with a width of 15 - 30km. The aquifer provides freshwater for the entire Gaza Strip, and parts of Israel, including the metropolis of Tel Aviv - Jaffa in the north (Baalousha, 2008).

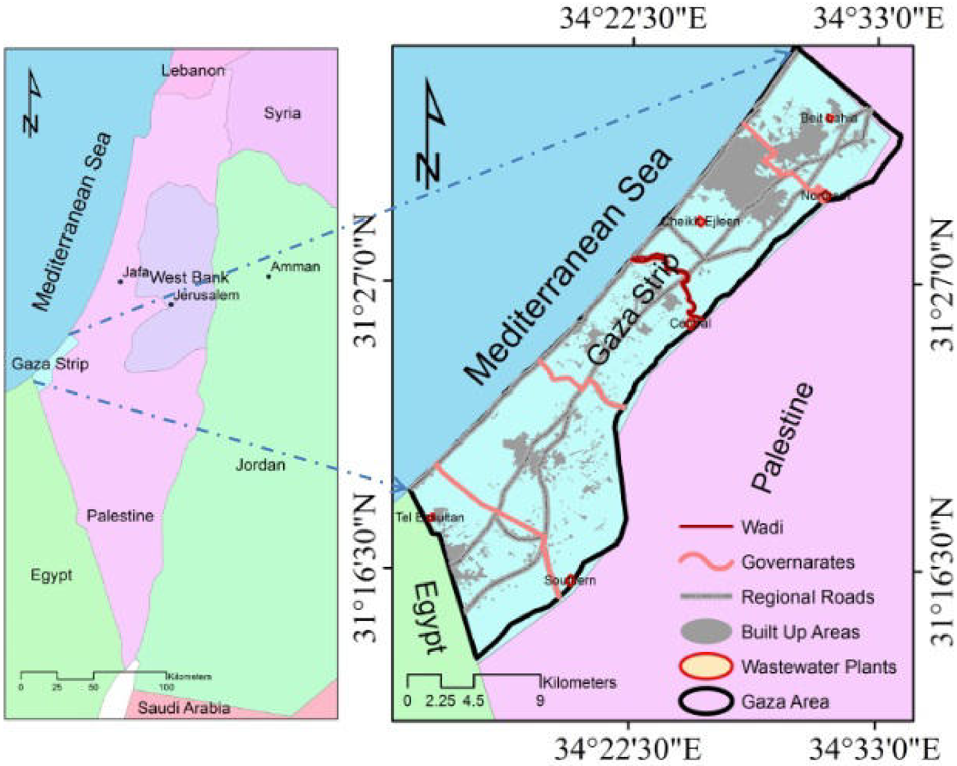

Figure 1: Location map of the Gaza strip.

This paper aims to investigate the impacts of future climate change on water balance over the Gaza strip based on Projection of future climate by multi-model median approach under Geographic Information System GIS environment.

2. Materials and Methods

2.1 Climate change scenarios

Gharbia et al, 2015 presented a spatially distributed climate change projected maps for temperature and precipitation over Gaza Strip according to A1F1 with high sensitive case were developed based on baseline period maps for three time intervals (2020, 2050 and 2080) and used as input in this modeling work in order to investigate the impacts of climate change on water balance elements of the Gaza coastal area. The baseline period maps were prepared for temperature and precipitation for mean values from 1972 to 2002 as shown in Figure (2) & Figure (6). Fossil energy intensive (A1F1) with high sensitivity is the emission scenario that was used for the prediction process by SimCLIM climate model. The median assembly approach was used to get the representative results from multi General Circulation Model (GCM) outputs. As shown in Figures (3-5) the predicted mean annual temperatures for years 2020, 2050 and 2080 were 20.66 ^{o}C, 22.48 ^{o}C and 25.08 ^{o}C respectively, While 0.85 ^{o}C, 2.67 ^{o}C and 5.28 ^{o}C were the mean annual changes from baseline period for years 2020, 2050 and 2080 respectively. Figures (7-9) illustrate the predicted mean annual precipitation for years 2020, 2050 and 2080 were 294.68 mm/year, 243.70 mm/year and 170.82 mm/year respectively. Hence -7.48, -23.98 and -46.37 mm/year were the predicted mean annual precipitation changes from baseline period for years 2020, 2050 and 2080 respectively (Gharbia et al, 2015).

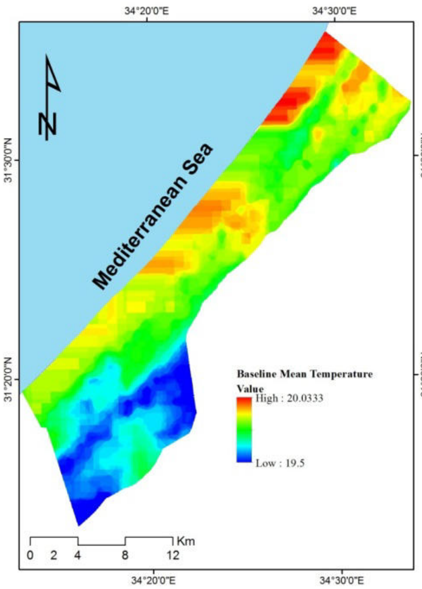

Figure 2: Mean annual temperature (1972 – 2002), (Gharbia et al, 2015).

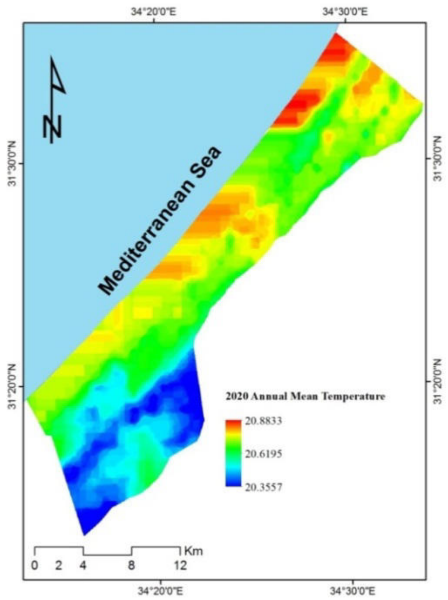

Figure 3: Mean annual projection temperature for 2020, (Gharbia et al, 2015).

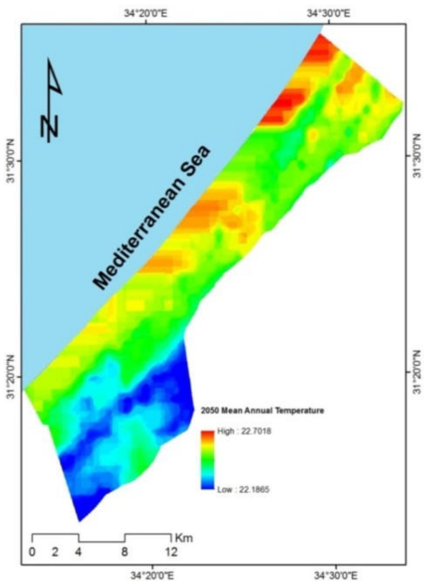

Figure 4: Mean annual projection temperature for 2050, (Gharbia et al, 2015).

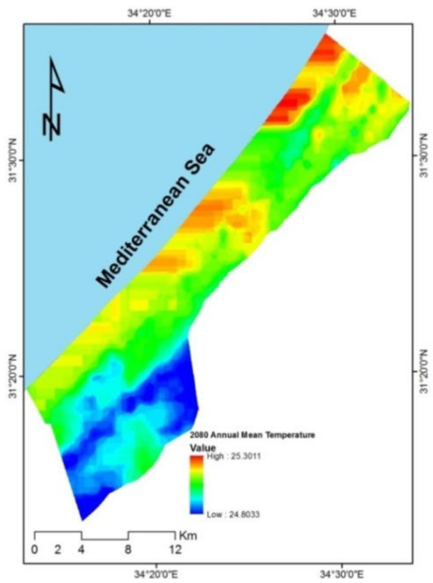

Figure 5: mean annual projection temperature for 2080, (Gharbia et al, 2015).

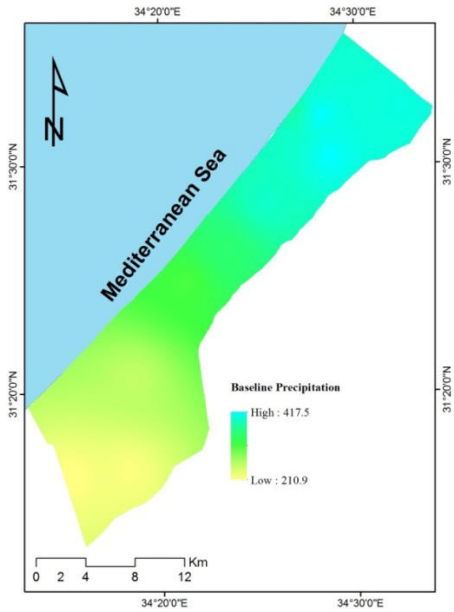

Figure 6: Mean annual precipitation (mm) (1972 – 2002) , (Gharbia et al, 2015).

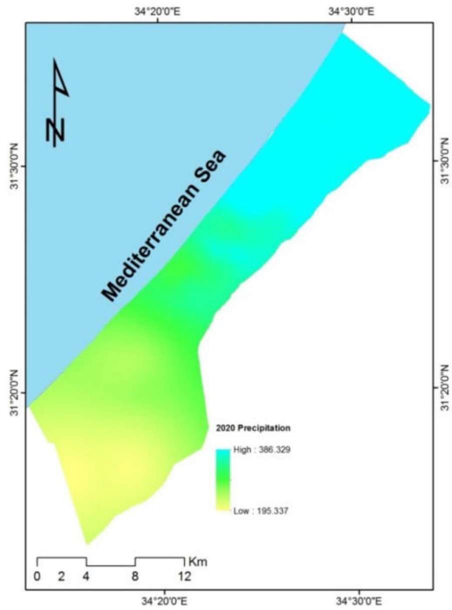

Figure 7: Annual projection precipitation for 2020, (Gharbia et al, 2015).

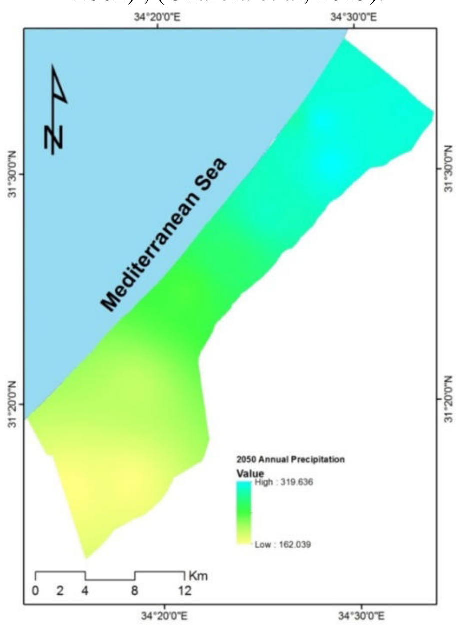

Figure 8: Annual projection precipitation for 2050, (Gharbia et al, 2015).

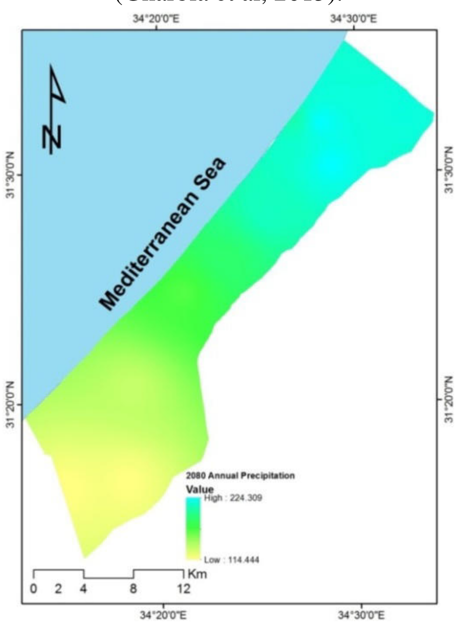

Figure 9: Annual projection precipitation for 2080, (Gharbia et al, 2015).

2.2 WetSPASS model

WetSPASS (an acronym for Water and Energy Transfer in Soil, Plants and Atmosphere under quasi Steady State) is a numerical model to simulate long-term average spatial distributions of hydrological parameters and processes on basin scale (Batelaan and De Smedt, 2001, 2007). The model makes use of grid GIS technology and digital data to partition the precipitation into surface runoff, evapotranspiration and groundwater recharge (Gebreyohannes et all, 2013).

The model is based on the long-term average seasonal water balance equation (Gebreyohannes et all, 2013):

$$P = S + ET + R, \quad (1)$$

Where P is precipitation [L], S is surface runoff [L], ET is evapotranspiration [L], and R is groundwater recharge [L]. Surface runoff is determined as:

$$S = f_1\,(LLV, ST, SA) \times Pn, \quad (2)$$

Where f_1 (.) is a runoff factor depending upon land-use and vegetation characteristics (LV), soil texture (ST) and slope angle (SA), and Pn is the net precipitation [L], i.e. precipitation minus interception, the latter being also a function of LV. Evapotranspiration ET is determined from soil evaporation and transpiration by the vegetation, as:

$$ET = f_2\ (LV, ST)\ x\ Ep, \quad (3)$$

Where $f_2(.)$ is an evapotranspiration factor depending upon land-use and vegetation characteristics (LV) and soil texture (ST), and Ep is the potential evaporation of open water [L]. The groundwater recharge is determined as the closing term in Eq. (1). In the equations above, all variables and parameters are digital maps and the calculations and derivations are obtained by means of GIS tools. To operate the model the user has to provide spatial digital data of terrain properties and of seasonal climatic variables. Because, the model was originally developed for conditions in temperate regions in general and Belgium in particular, the user can interfere in the calculations and predictions by modifying default parameters and procedures (Gebreyohannes et all, 2013).

2.3 Data gathering

The WetSPASS model calculates water balances per seasons, which are by default the 6-months winter and summer season of a humid climate, to enable transfer of accumulated soil moisture storage from the wet winter season to the dry summer season. For application in the Gaza Strip, this was changed according to the hydrological cycle of the Gaza Strip. The WetSPASS model requires two types of input data, i.e. GIS grid maps and parameter tables (Batelaan and De Smedt, 2001). The data was obtained from the hydrogeological data bank department in the Palestinian Water Authority (PWA). The grid maps consist of slope angle, land-use, soil texture, groundwater depth, and seasonal meteorological maps of precipitation and temperature which were projected by SimCLIM for three time interval. Also, potential evapotranspiration, and wind speed is required for the simulation. The WetSPASS model was applied using GIS grid maps with a cell size of 30 X 30 m2. The Gaza digital elevation model (DEM) of the basin Figure (10) topography is characterized by elongated ridges and depressions, dry streambeds and shifting sand dunes. The ridges and depressions generally extend in a NNE-SSW direction, parallel to the coastline. They are narrow and consist primarily of sandstone (Kurkar). In the south, these features tend to be covered by sand dunes. Land surface elevations range from mean sea level to about 110 m above mean sea level as shown in Figure 10. The ridges and depressions show considerable vertical relief, in some places up to 60 m. Surface elevations of individual ridges range between 20 m and 90 m above mean sea level (Aish, 2004). A slope angle map was produced from this DEM using ArcMap GIS tools. The soil Figure (11) in the Gaza Strip is composed mainly of three types, sands, clay, and loess. The sandy soil is found along the coastline extending from south to outside the northern border of the Strip, at the form of sand dunes. The thickness of sand fluctuates from two meters to about 50 meters due to the hilly shape of the dunes. The general land use of the Gaza Strip is divided to agricultural areas, built-up areas, and governmental areas as seen in Figure (12). Maps of groundwater depth are needed in the WetSPASS model for delineation of wetlands, where water balance calculations have to include seepage fluxes. Seasonal meteorological parameters were the baseline Figures (2-9). During the winter, most of the wind blow from the Southwest and the mean wind speed is 4.2 m/s. In summer, strong winds blow regularly at certain hours, and the daily mean wind speed is 3.9 m/s and come from the Northwest direction. Storms have been observed in winter with maximum hourly wind speed of 18 m/s (EMCC, 2012). In the Gaza Strip, reference evapotranspiration value varies from 2 to 3.03 mm/d in winter, and reaches its maximum value in summer at about 5.11 mm/d (Ajour, 2012).

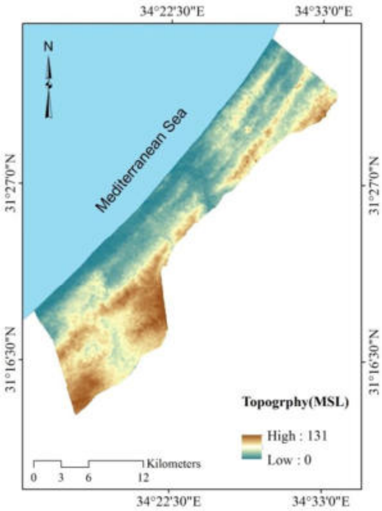

Figure 10: Topography of Gaza Strip (Data Source: PWA, 2012).

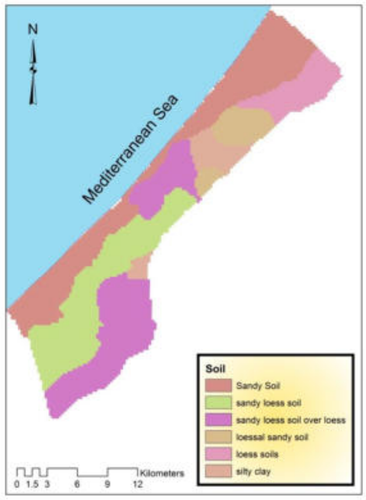

Figure 11: Soil map of the Gaza Strip (Data source: PWA, 2012)

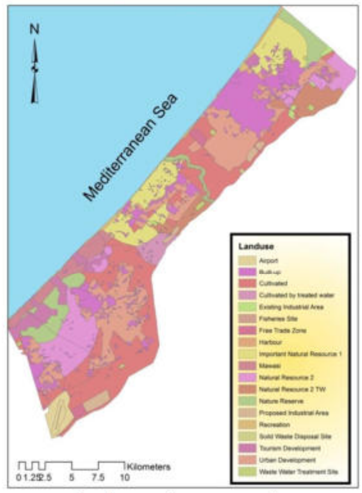

Figure 12: land use in the Gaza strip (Data Source: PWA, 2012)

3. Results and Discussions

The WetSPASS model results comprise several annual and seasonal predictions. The most important ones to follow climate change impacts are the digital maps of annual hydrologic outputs. Due to the research purposes and the lack of monthly data for land use, wind speed and groundwater depth, same maps were used as input for the three time intervals simulation process in the WetSPASS. This of course makes assumption to the fact that these parameters stay the same during all of the simulation times and years. All of the input grids and tables were set for summer and winter seasons, and for all simulation climate period of baseline and projected climate periods of 2020, 2050, and 2080. Therefore, the WetSPASS simulation develops a projected water balance for the Gaza strip. The model was run for these four periods, and the model output grids include projected results for runoff, evapotranspiration, interception transpiration soil evaporation recharge and the error percentage in water balance.

Evapotranspiration is a key factor in water balance computations. The surface of vegetation provides a temporary storage for rainfall water, as an interception. It is then lifted back to the air in the form of evaporation. Plants also lose water through transpiration at the leave surface. WetSPASS calculates the total actual Evapotranspiration as the sum of the evaporation of intercepted water by vegetation, transpiration and evaporation from bare soil in between the vegetation cover. The evapotranspiration values were simulated to baseline period and projected years 2020, 2050, and 2080. As shown in Figures (13-16) respectively, and the values for baseline period were ranges from 59.85 to 221.63 mm/yr with a mean of 157.34 mm/yr and standard deviation of 40.23 mm, the values were slightly decrease in 2020 projected period to range from 66.3 to 221.78 mm/yr with a mean of 156.46 mm/yr and standard deviation of 38.91 mm, the slightly decrease were continue for 2050 projected period to range from 74.76 to 221.48 mm/yr with a mean of 151.85 mm/yr and standard deviation of 35.74 mm. For the 2080 projected period the values ranged from 59.63 to 205.77 mm/yr with a mean of 131.44 mm/yr and standard deviation of 30.65 mm. The result for Evapotranspiration shows a fluctuation in evapotranspiration that correlates with vegetation cover and annual rainfall. In the Gaza city, which is mostly urban area with minimum vegetation, ET values are generally below 100mm/yr. The western line of the Gaza strip has the maximum ET in general due to the vegetation work in this area.

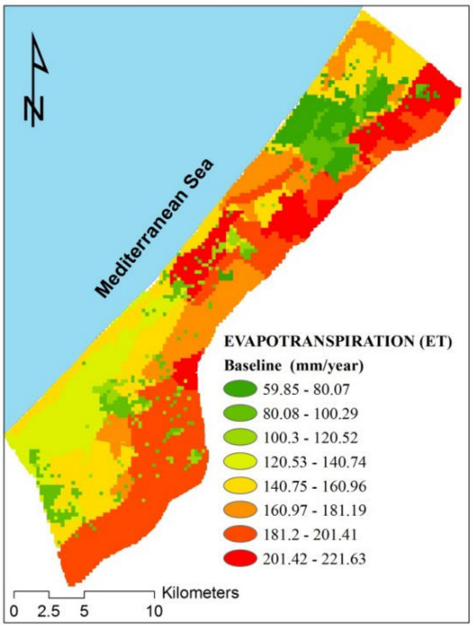

Figure 13: Baseline period simulated mean annual evapotranspiration.

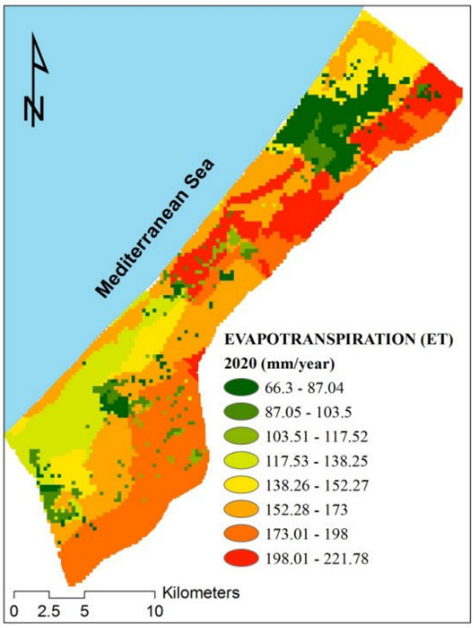

Figure 14: Simulated mean annual evapotranspiration for year 2020.

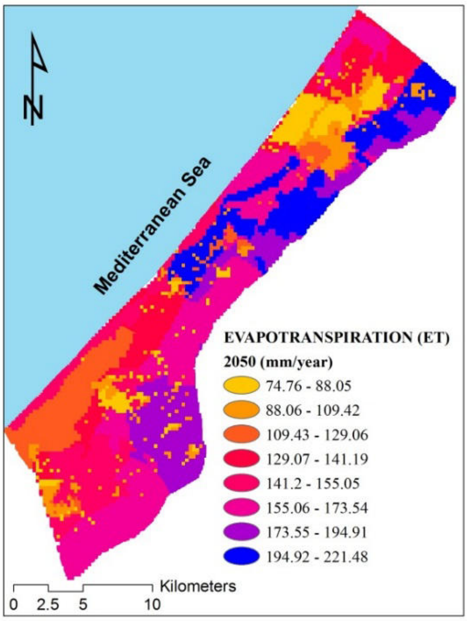

Figure 15: Simulated mean annual evapotranspiration for year 2050.

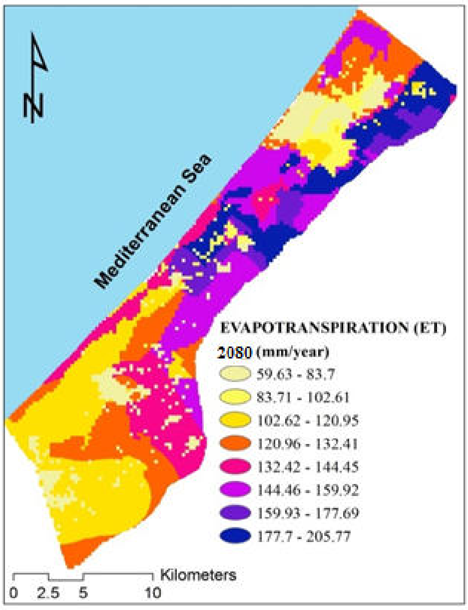

Figure 16: Simulated mean annual evapotranspiration for year 2080.

WetSPASS estimates surface runoff by using runoff coefficients. These coefficients are based on vegetation type, soil texture class and slope value. The Runoff values was simulated to baseline period and projected years 2020, 2050 and 2080. As shown in Figures (17-20) respectively and the values were as for baseline period: ranges from 0.93 to 216.08 mm/yr with a mean of 34.88 mm/yr and standard deviation of 59.88 mm. Because of the decrease in rainfall amount the surface runoff values continually decreased for all the projected periods. The values for 2020 projected period ranged from 0.87 to 199.83 mm/yr with a mean of 32.35 mm/yr and standard deviation of 55.38 mm. For projected period 2050 the values ranged from 0.72 to 165.08 mm/yr with a mean of 26.73 mm/yr and standard deviation of 45.74 mm. About 2080 projected period the values ranged from 0.51 to 115.4 mm/yr with a mean of 18.71 mm/yr and standard deviation of 31.96 mm. Most of Gaza strip area has very little or no surface runoff. Values here are generally less than 100mm/yr except for the urban area such as Gaza city, which has the maximum runoff value, and the other Gaza strip cities.

Recharge is a naturally occurring process whereby permeable soil or rock allows water to seep readily into the aquifer. This takes place intermittently during and immediately following periods of rain. This depends on the rate and duration of rainfall, the conditions at the upper land surface boundary, soil moisture conditions, the water table depth and the soil type. Monitoring of groundwater recharge is very important because it allows the estimation of its temporal variability and areal distribution. The groundwater recharge values were simulated by WetSPASS to baseline period and projected years 2020, 2050 and 2080. As shown in Figures (21-24) respectively and the values were been for baseline period in ranges from 14.58 to 265.71 mm/yr with a mean of 125.33 mm/yr and standard deviation of 61.21 mm, so the total recharge volume 44.23 MCm, for 2020 projected period ranges were from 11.51 to 237.5 mm/yr with a mean of 105.07 mm/yr and standard deviation of 56.88 mm, so the total recharge volume 38.35 MCm, about 2050 projected period the ranges were from 4.93 to 177.71 mm/yr with a mean of 64.44 mm/yr and standard deviation of 45.19 mm, so the total recharge volume 23.52 MCm and for 2080 projected period the ranged from -19.72 to 94.08 mm/yr with a mean of 20.14 mm/yr and standard deviation of 23.89 mm, so the total recharge volume 8.719 MCm. The variability of groundwater recharge is influenced by precipitation and runoff. The northern region appears to be a high groundwater recharge area. In the south-west areas, most of the little short annual rainfall cannot infiltrate to the vadose zone. Higher values are simulated for regions with low topography and permeable soils such northern coastal zones.

The vegetation cover significantly affects interception. Much of the total annual rainfall received by the vegetation area never reaches the ground. Instead, it is intercepted retained on vegetation for a short duration, absorbed by plants, or evaporated from the canopy. Therefore, vegetation serves as a bridge between the gap of rainfall and infiltration into the soil. Interception is very much associated with vegetation and varies with the vegetation type as shown by the result of this analysis. The interception values were simulated by WetSPASS to baseline period and projected years 2020, 2050 and 2080 as shown in Figure (25-28) respectively and the values ranged for baseline period: ranges from 0.98 to 20.88 mm/yr with a mean of 8.31 mm/yr and standard deviation of 6.75 mm, for 2020 projected period it ranged from 0.93 to 19.32 mm/yr with a mean of 7.71 mm/yr and standard deviation of 6.23 mm, for 2050 projected period the values ranged from 0.8 to 15.98 mm/yr with a mean of 6.41 mm/yr and standard deviation of 5.13 mm and for 2080 projected period it ranged from 0.62 to 11.22 mm/yr with a mean of 4.56 mm/yr and standard deviation of 3.56 mm. Gaza strip as a Simi-arid area and the lack of vegetation cover lead to the small values of interception.

The soil evaporation values was simulated by WetSPASS to baseline period and projected years 2020, 2050 and 2080 As shown in Figures (29-32) respectively and the values ranged for baseline period from 0.00 to 132.71 mm/yr with a mean of 92.08 mm/yr and standard deviation of 42.97 mm. For the 2020 projected period the values ranged from 0.00 to 132.47 mm/yr with a mean of 91.41 mm/yr and standard deviation of 42.80 mm, for 2050 projected period it ranged from 0.00 to 131.88 mm/yr with a mean of 89.66 mm/yr and standard deviation of 42.37 mm and for 2080 projected period: ranges from 0.00 to 131.27 mm/yr with a mean of 85.49 mm/yr and standard deviation of 40.95 mm. The trend shows higher values of about 100mm per year for semi-arid regions of the Gaza strip. This trend is not surprising because these areas are characterized by very high daily and seasonal temperature variations, high evaporation intensity and intense solar radiation.

Transpiration is the vaporization of liquid water contained in plant tissues. Transpiration, like direct evaporation, depends on factors such as radiation, air temperature, air humidity, and wind speed. In addition, the soil water content and the ability of the soil to conduct water upwards play a role. The vegetation type is equally important in assessing transpiration. The Mean annual transpiration values was simulated by WetSPASS to baseline period and projected years 2020, 2050 and 2080 As shown in Figure (33-36) respectively and the values were for baseline period: ranges from 27.31 to 112.04 mm/yr with a mean of 57.72 mm/yr and standard deviation of 20.03 mm, it ranged from 26.92 to 112.58 mm/yr with a mean of 57.52 mm/yr and standard deviation of 19.98 mm for 2020 projected period, for 2050 projected period the values ranged from 24.01 to 113.69 mm/yr with a mean of 54.78 mm/yr and standard deviation of 20.75 mm and according to 2080 projected period the values ranged from 3.32 to 99.38 mm/yr with a mean of 40.34 mm/yr and standard deviation of 23.72 mm. The maximum values of transpiration between about80 to 130 mm are located in the agricultural area around the north and middle governorates.

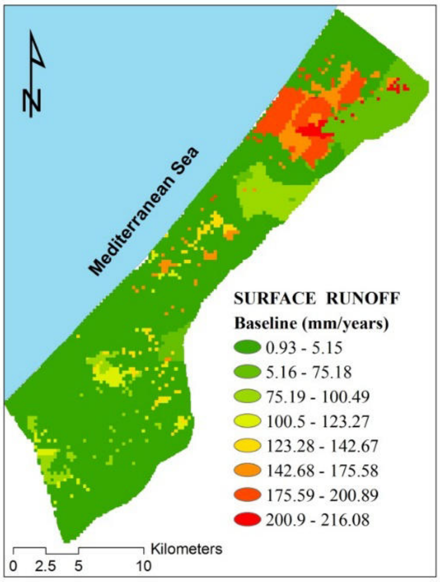

Figure 17: Baseline period simulated mean annual runoff.

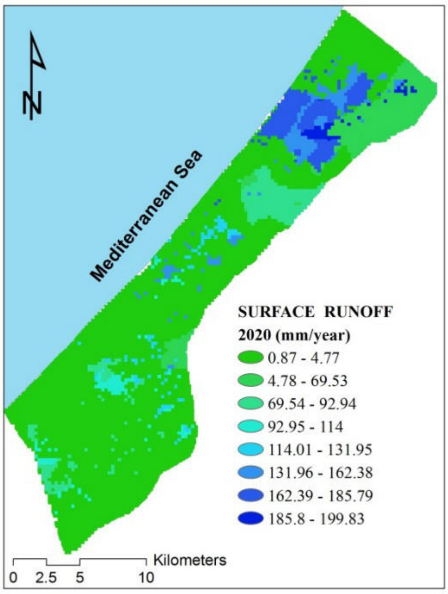

Figure 18: Simulated mean annual runoff for year 2020.

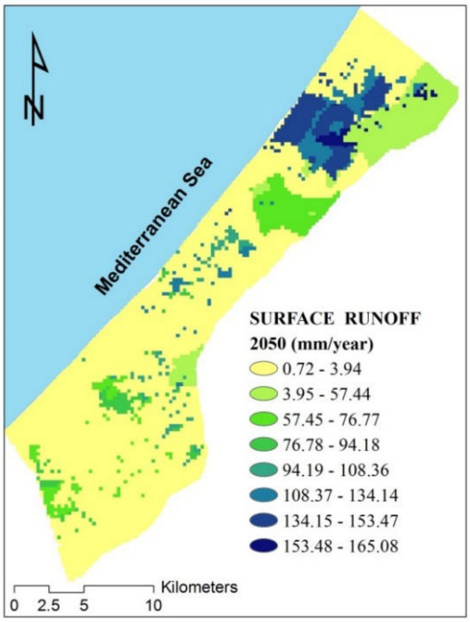

Figure 19: Simulated mean annual runoff for year 2050.

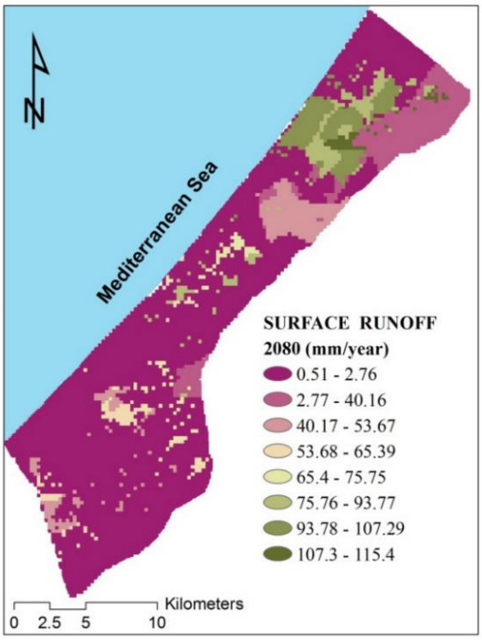

Figure 20: Simulated mean annual runoff for year 2080.

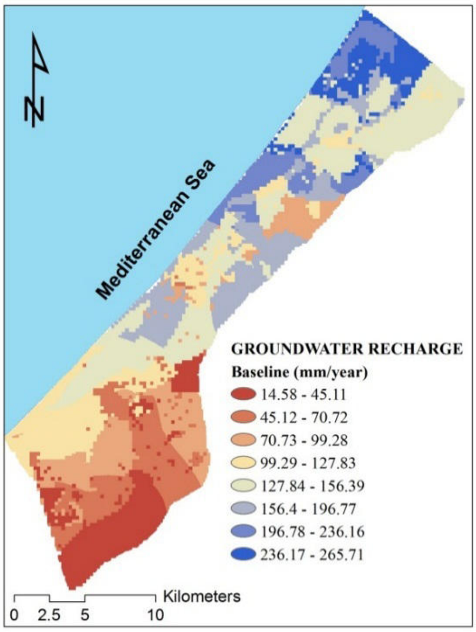

Figure 21: Baseline period simulated mean annual groundwater recharge.

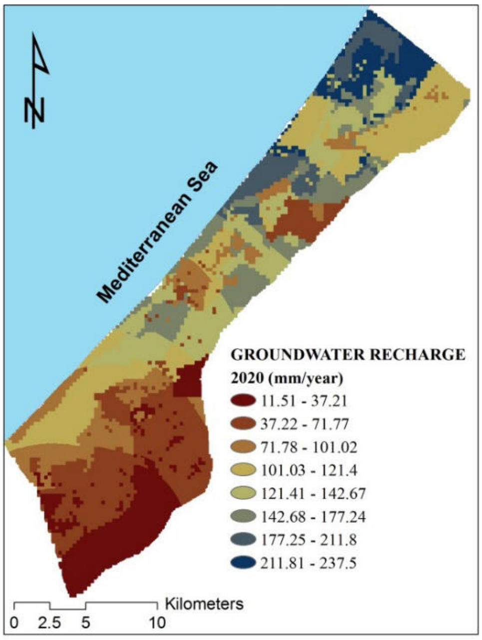

Figure 22: Simulated mean annual groundwater recharge for year 2020.

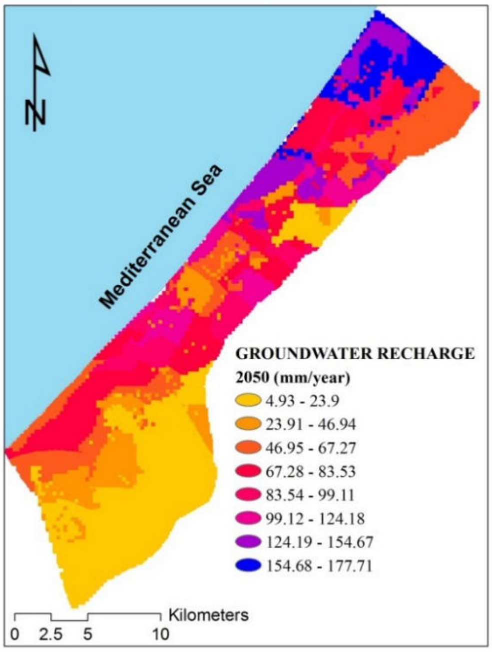

Figure 23: Simulated mean annual groundwater recharge for year 2050.

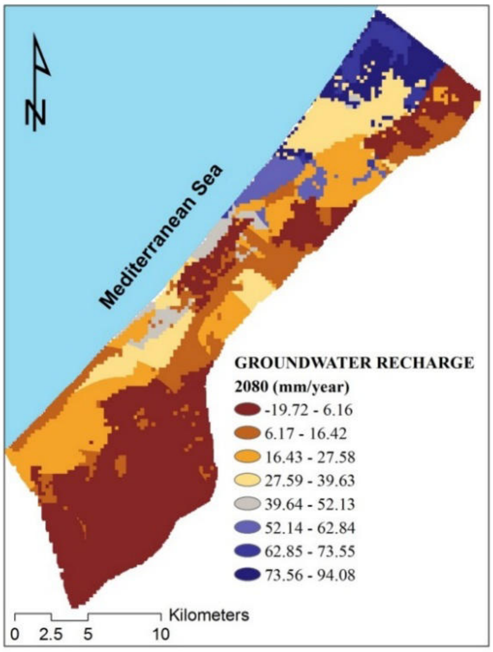

Figure 24: Simulated mean annual groundwater recharge for year 2080.

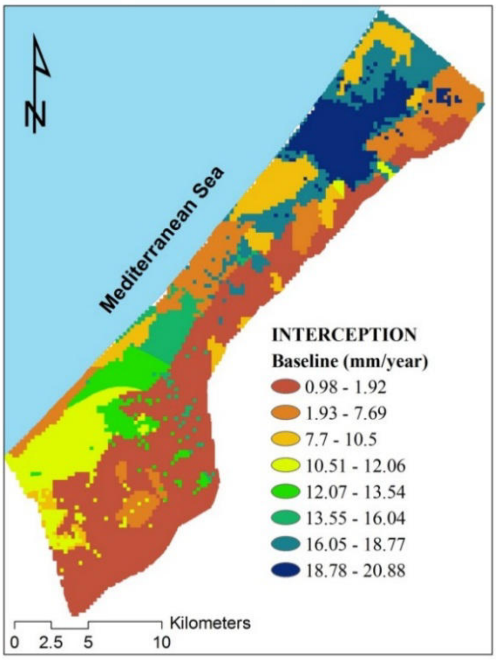

Figure 25: Baseline period simulated mean interception.

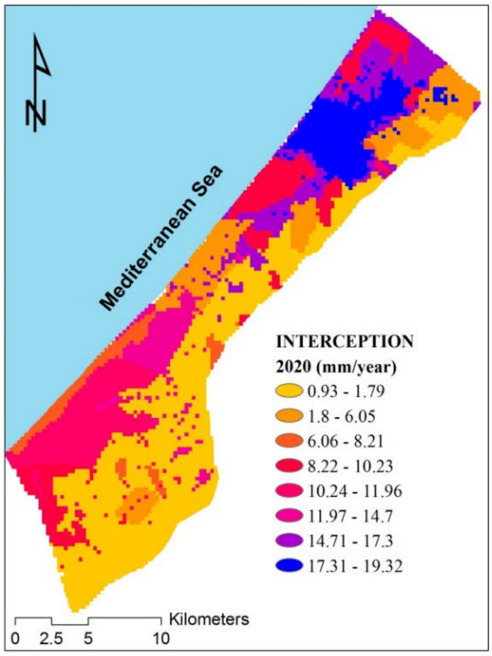

Figure 26: Simulated mean annual interception for year 2020.

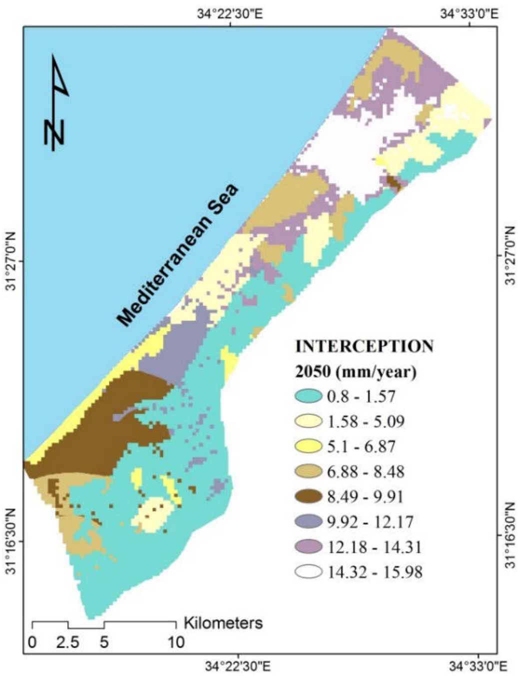

Figure 27: Simulated mean annual interception for year 2050.

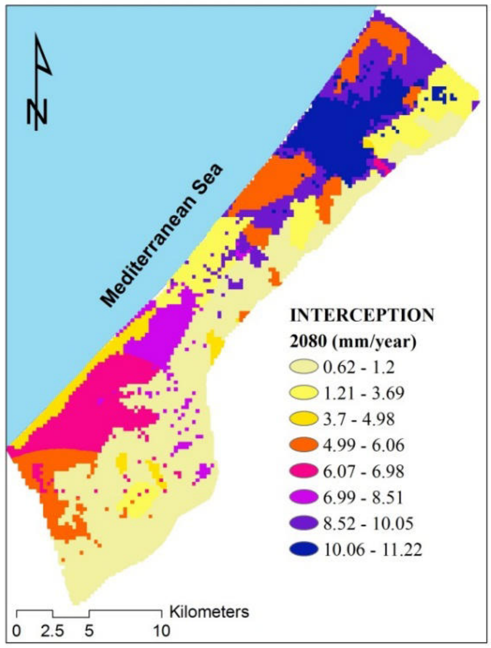

Figure 28: Simulated mean annual interception for year 2080.

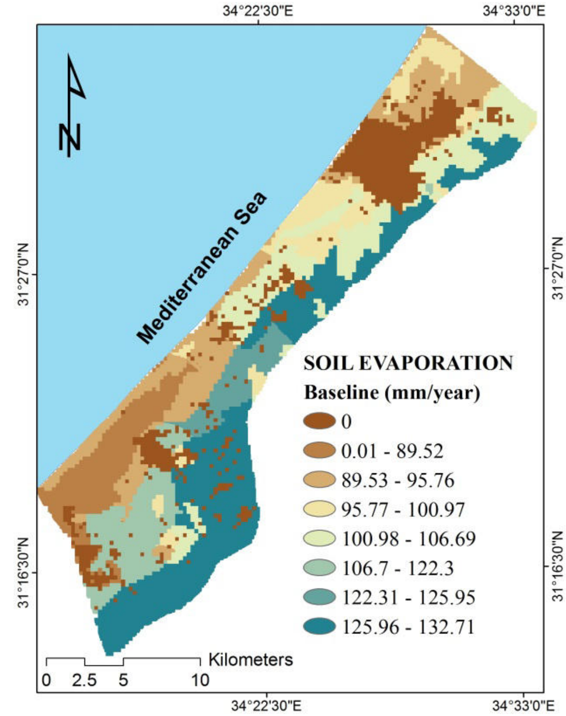

Figure 29: Baseline period simulated mean soil evaporation.

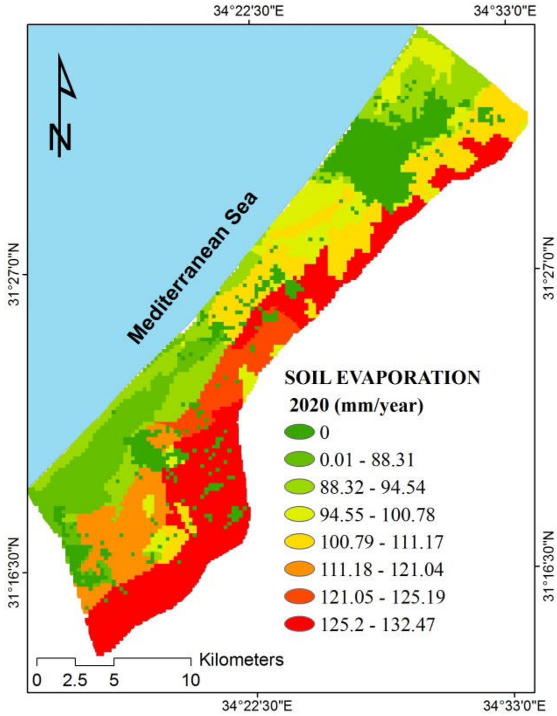

Figure 30: Simulated mean annual soil evaporation for year 2020.

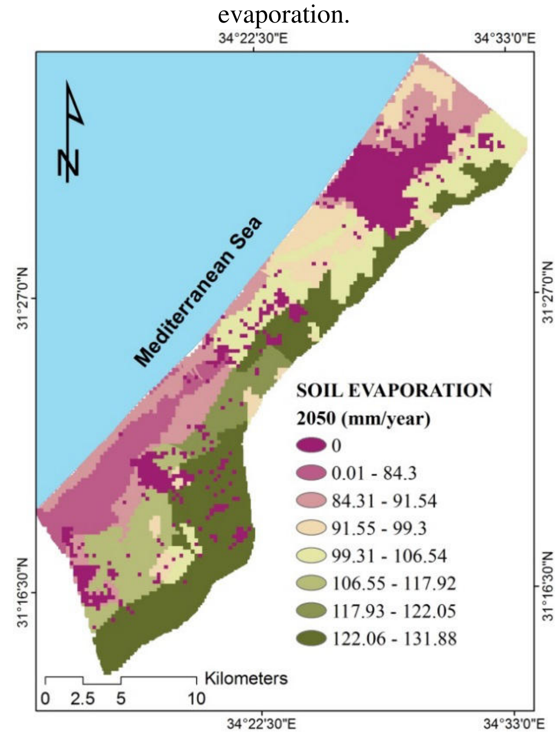

Figure 31: Simulated mean annual soil evaporation for year 2050.

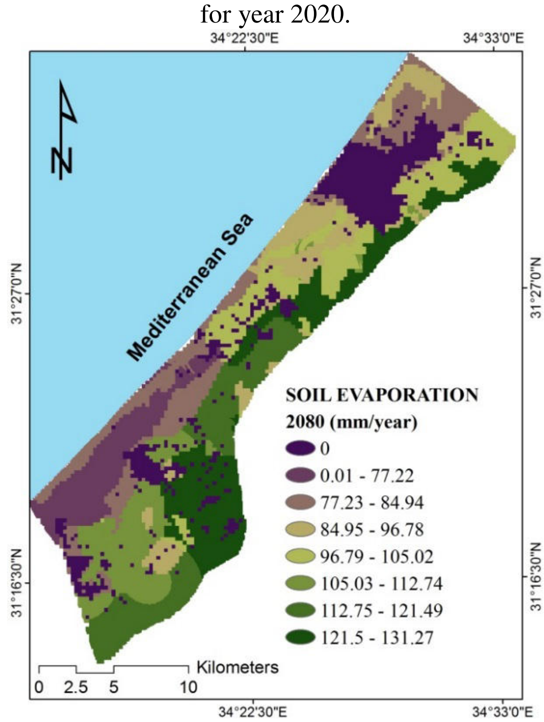

Figure 32: Simulated mean annual soil evaporation for year 2080.

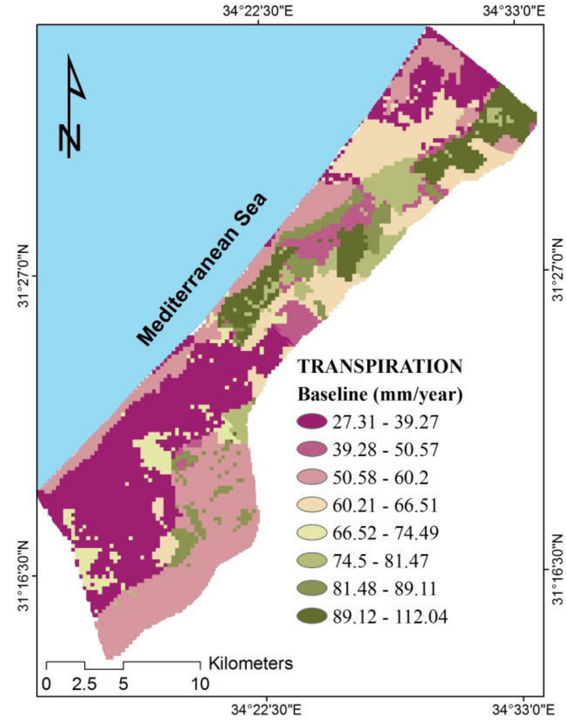

Figure 33: Baseline period simulated mean transpiration.

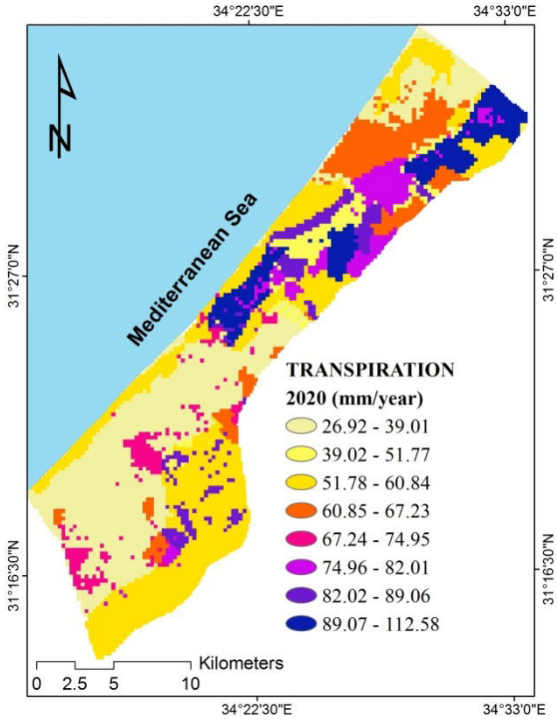

Figure 34: Simulated mean annual transpiration for year 2020.

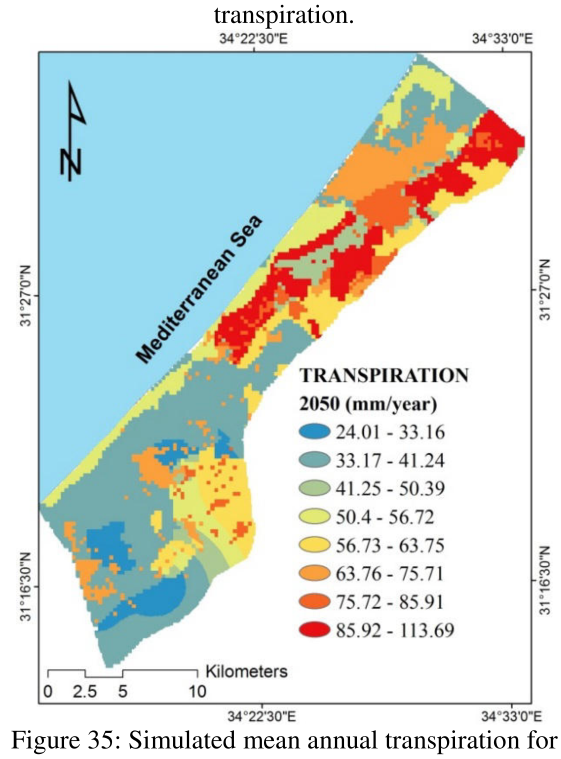

Figure 35: Simulated mean annual transpiration for year 2050.

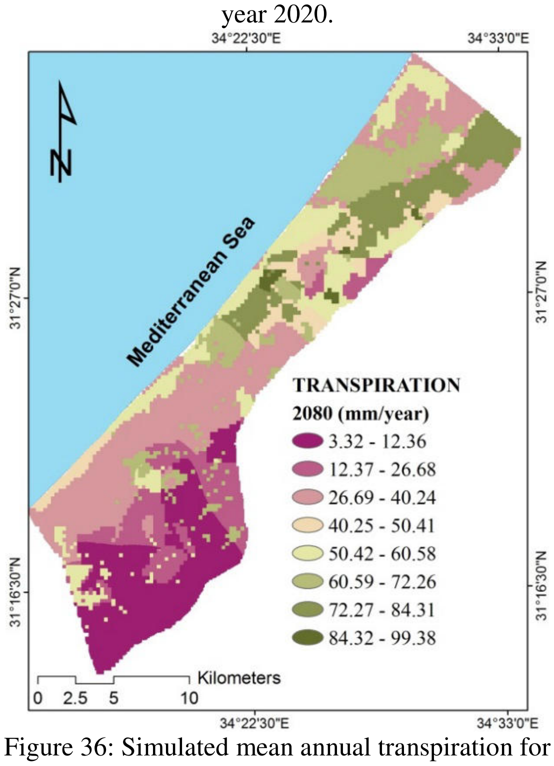

Figure 36: Simulated mean annual transpiration for year 2080.

Water balance computation is essentially a representation of the net result of the inflow and outflow of water. Precipitation is the most significant inflow component. The most important outflow components of water balance are surface runoff, evapotranspiration, and groundwater recharge. An area of the world would have water surplus if it receives more rainfall than the amount that it loses mainly through the process of evapotranspiration. Similarly, regions with water deficit would get fewer rains than the amount that they lost through evapotranspiration. While, those which neither get surpluses nor deficits will experience some sort of a balance. A summary of the numerical contribution to this net balance of the various components was discussed earlier for baseline period, 2020, 2050, and 2080 is presented below in the Figure (37) and water balance table 5.17.

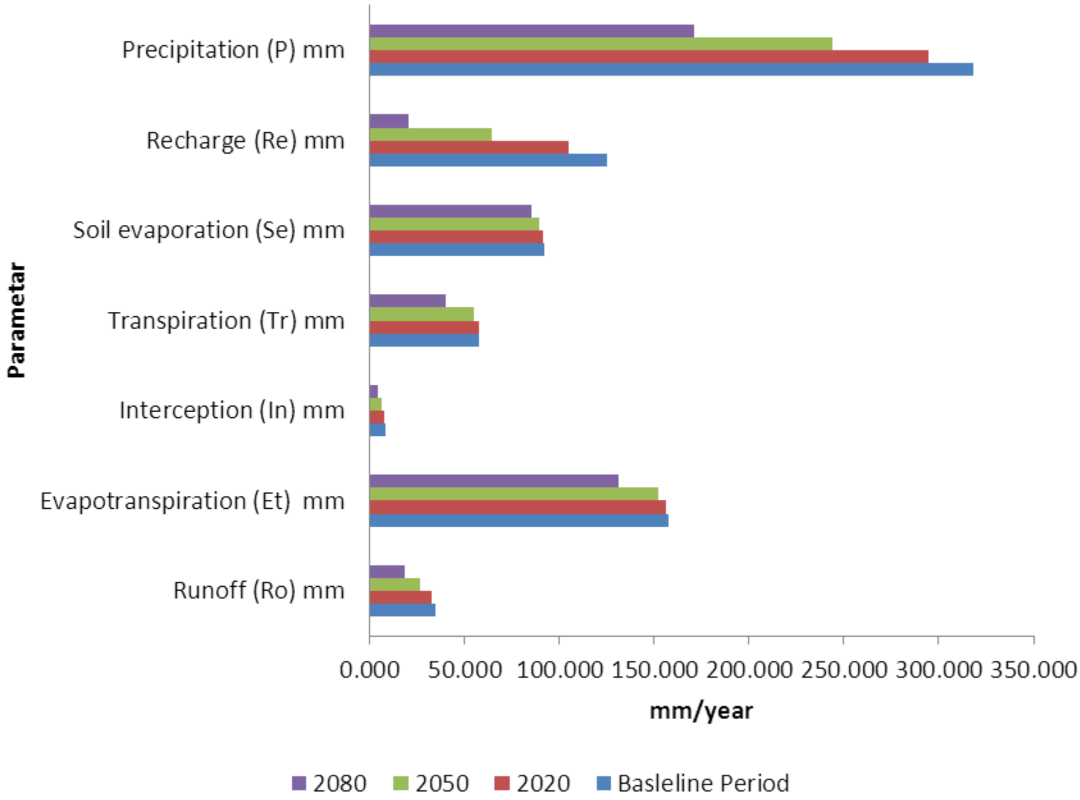

Figure 37: Summary of computed water balance components for Gaza strip.

Table 1: Summary of computed water balance components for Gaza strip.

Year	Component	Min	Max	Mean	Std. Dev.
Baseline Period (1972-2002)	Runoff (Ro) mm	0.930	216.080	34.880	59.880
	Evapotranspiration (Et) mm	59.850	221.630	157.340	40.230
	Interception (In) mm	0.980	20.880	8.310	6.750
	Transpiration (Tr) mm	27.310	112.040	57.720	20.030
	Soil evaporation (Se) mm	0.000	132.710	92.080	42.970
	Recharge (Re) mm	14.580	265.710	125.330	61.210
	Precipitation (P) mm	210.899	417.500	318.520	69.745
	Water balance (WB) = P-Ro-Et-Re ; mm	-	-	0.970	-
	Error in water balance (WB/ P; %)	-	-	0.305	-
2020	Runoff (Ro) mm	0.870	199.830	32.350	55.380
	Evapotranspiration (Et) mm	66.300	221.780	156.460	38.910
	Interception (In) mm	0.930	19.320	7.710	6.230
	Transpiration (Tr) mm	26.920	112.580	57.520	19.980
	Soil evaporation (Se) mm	0.000	132.470	91.410	42.800
	Recharge (Re) mm	11.510	237.500	105.070	56.880
	Precipitation (P) mm	195.336	385.570	294.680	64.520
	Water balance (WB) = P-Ro-Et-Re ; mm	-	-	0.800	-
	Error in water balance (WB/ P; %)	-	-	0.271	-
2050	Runoff (Ro) mm	0.720	165.080	26.730	45.740
	Evapotranspiration (Et) mm	74.760	221.480	151.850	35.740
	Interception (In) mm	0.800	15.980	6.410	5.130
	Transpiration (Tr) mm	24.010	113.690	54.780	20.750
	Soil evaporation (Se) mm	0.000	131.880	89.660	42.370
	Recharge (Re) mm	4.930	177.710	64.440	45.190
	Precipitation (P) mm	162.038	319.640	243.700	53.362
	Water balance (WB) = P-Ro-Et-Re ; mm	-	-	0.680	-
	Error in water balance (WB/ P; %)	-	-	0.279	-
2080	Runoff (Ro) mm	0.510	115.400	18.710	31.960
	Evapotranspiration (Et) mm	59.630	205.770	131.440	30.650
	Interception (In) mm	0.620	11.220	4.560	3.560
	Transpiration (Tr) mm	3.320	99.380	40.340	23.720
	Soil evaporation (Se) mm	0.000	131.270	85.490	40.950
	Recharge (Re) mm	-19.720	94.080	20.140	23.890
	Precipitation (P) mm	114.440	224.310	170.819	37.406
	Water balance (WB) = P-Ro-Et-Re ; mm	-	-	0.529	-
	Error in water balance (WB/ P; %)	-	-	0.310	-

4. Conclusions

Climate model outputs have been used to assess changes in hydrological cycle water balance. The WetSPASS model was applied to calculate the water balance of the Gaza Strip area in Palestine which is a very populated coastal area in Mediterranean Sea. Specific input data were prepared in the form of digital maps using various GIS tools, Food and Agriculture Organization of the United Nations (FAO) and Palestinian Water Authority (PWA) databases, field reconnaissance and meteorological observations and projected future climate change maps for three time intervals 2020, 2050 and 2080. From this long period simulation, it was clear that Gaza Strip will face a huge water scarcity in the future as response to climate change. This study also demonstrated that regional assessment of water resources for management purposes is feasible with only limited local data by using modeling tools that are readily available in contemporary practice. Hence, this approach can have large applicability in other basins, especially in developing regions because of the limited amount of required data and the possibility to use remote sensing techniques to get the missing data.

Acknowledgment

I would like to express my sincere gratitude to Palestinian Water Authority (PWA) and CLIM systems Ltd. for the great support; I really want to thank Dr. Yinpeng Li for his help, Dr. Peter Urich for his continuous advice and Dr. Peter Kouwenhoven for his support.

References

Aish, A., and De Smedt, November 2004. Hydrogeological Study and Artificial Recharge Modeling of the Gaza Coastal Aquifer Using GIS and MODFLOW, *PhD thesis,* Gaza.

Ajjour, S., 2012 .Effects of Climate Change on Groundwater Resources (Northern Gaza Strip Case Study*), Civil Engineering Dep., Islamic University of Gaza.*

Baalousha, H. (2008). Analysis of nitrate occurrence and distribution in groundwater in the Gaza Strip using major ion chemistry. *Global NEST, 10 (3):337–349.*

Batelaan, O., De Smedt, F., 2007. GIS-based recharge estimation by coupling surface subsurface water balances. *J. Hydrol. 337 (3–4), 337–355.*

EMCC *(Engineering and management consulting center),* 2012. Environmental and Social Impact Assessment (ESIA) & Environmental and Social Management Plan (ESMP) Gaza Water Supply and Sewage Systems Improvement, Gaza, Palestine.

Gampe D., Ralf Ludwig, Samir Afifi, 2013, "Assessing the impacts of climate change in Mediterranean catchments under conditions of data scarcity The Gaza Case Study", *IEEE.*

Gebreyohannes T., Florimond De Smedt, Kristine Walraevens, Solomon Gebresilassie, Abdelwasie Hussien, Miruts Hagos, Kasa Amare, Jozef Deckers, Kindeya Gebrehiwot, 2013, "Application of a spatially distributed water balance model for assessing surface water and groundwater resources in the Geba basin, Tigray, Ethiopia", *Journal of Hydrology 499 (2013) 110–123*

Gharbia S. Salem, Adnan Aish, Francesco Pilla, Abdalkarim S. Gharbia. "Projection of Future Climate by Multi-Model Median Approach under GIS Environment along the Gaza Strip, Palestine." *Journal of Environment and Earth Science* (2015).

Naciri A, Ttlich G. Policy guidelines for wastewater management in the Gaza Strip. Potential of wastewater reuse in the Gaza Strip, 2001, p. 1–2.

Palestinian Water Authority (PWA), 2012. *Hydrogeological data bank department*, Gaza Strip.

PCBS (2004).Palestinian Central Bureau of Statistics. Palestine in figures 2003, May 2004.

PHG (2002).*Palestinian Hydrology Group for Water and Environmental Resources Development*. Quality use of home reverse osmosis filters of some areas in Gaza Strip, 2002.