Effect of climate change on evapotranspiration in Egypt

Khalil A.A.

Central Laboratory for Agricultural Climate (CLAC)- Agricultural Research Center (ARC)- Ministry of Agriculture and Land Reclamation- Dokki, Giza, Egypt.
alaa_armka@yahoo.com

Abstract: Estimating Evapotranspiration (ET_o) is one of the first important step for calculating crop water requirements that has a special economic importance in rationalization of water consumption in the agricultural field under current and future climate conditions. The present work is mainly directed to discuss the spatial variation in evapotranspiration under climate change in Egypt. In this study the agrometeorological data were collected from 20 stations in the Nile valley and Nile Delta to determine the variation of evapotranspiration under current and future climate conditions. Moreover the Penman Monteith equation was used to calculate reference evapotranspiration (ET_o) according to the agrometeorological data. Their responses to future climate scenarios of 21st century projected by the GCM (HadCM3) with Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (IPCC SRES) A1, A2, B1 and B2 emissions are investigated. The results show that under current climate Aswan region gave the highest (ET_o) in comparison with other regions and Damietta gave the lowest (ET_o).
In general the average of the 20 stations, the evapotranspiration increased under climate change in comparison with control one. A2 scenario at 2100 gave the highest ET_o and B1 scenario at 2040 gave the lowest ET_o in comparison with other scenarios. This work reveals that water requirements will be increased under climate change conditions du to increase ET_o
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1. Introduction

More than half of the solar energy absorbed by land surfaces is currently used to evaporate water **(Trenberth *et al.,* 2009).** Climate change is expected to intensify the hydrological cycle and to alter evapotranspiration **(Huntington, 2006),** with implications for ecosystem services and feedback to regional and global climate. Evapotranspiration changes may already be under way, but direct observational constraints are lacking at the global scale. Until such evidence is available, changes in the water cycle on land a key diagnostic criterion of the effects of climate change and variability remain uncertain. Land evapotranspiration (ET_o) is a central process in the climate system and a nexus of the water, energy and carbon cycles. Global land ET returns about 60% of annual land precipitation to the atmosphere **(Oki *et al.,* 2006)**. Terrestrial ET can affect precipitation **(Koster *et al.,* 2004),** and the associated latent heat flux helps to control surface temperatures, with important implications for regional climate characteristics such as the intensity and duration of heat waves **(Seneviratne 2006 and Vautard *et al.,* 2007).** Acceleration or intensification of the hydrological cycle with global warming is a long-standing paradigm in climate research **(Huntington, 2006),** but direct observational evidence of a positive trend in global ET is still lacking. A global network (FLUXNET) of continuous in situ measurements of land–atmosphere exchanges, including of water vapor, has been established over the last decade. There is a wide scientific conviction that global climate is changing as a result of the combined anthropogenic forcing due to greenhouse gases, aerosols, and land surface changes. The recent climatologically studies found that the global surface air temperature increased by 0.76 °C from year 1850 to year 2005. Moreover, the linear warming trend over the last 50 years is recorded by 0.13 °C per decade **(IPCC, 2007b)**. Furthermore, there has been an increase in extreme events frequency and intensity in many parts of the world. Regarding the global trends, the recent studies found that the Arab region experienced an uneven increase in surface air temperature ranged from 0.2 to 2 °C occurred from 1970 to 2004 **(IPCC, 2007a)**. The historical climate record for Africa shows warming of approximately 0.7°C over most of the continent during the twentieth century **(Desanker, 2002)**. Moreover, all of Africa is very likely to warm during this century, and the warming is very likely to be larger than the global **(IPCC, 2007a)**. To obtain water sustainability, the planners must envisage how climate interacts with various aspects of the water cycle. This means understanding the link between climate and evapotranspiration. Climatic conditions, which determine both the scale and the temporal distribution of watershed hydrology, may attenuate or accentuate evapotranspiration. a good estimate of evapotranspiration is required if water sustainability is to be achieved. Measurements of evapotranspiration are rarely available and are unlikely to be sufficient to describe the influence on the evapotranspiration regime. In the absence of measurements, an alternative approach is to use mathematical models to predict the variations in evapotranspiration, using meteorological data to describe variations in the temperature. The aims of this study is employs the Penman-Monteith potential model to estimate evapotranspiration under current and future climate over Egypt by using agrometeorological data from 20 weather stations and discuss the spatial variation in evapotranspiration during this stations.

2. Materials and Methods

Daily historical data of minimum, maximum air temperature, relative humidity, wend speed and solar radiation of 20 weather satiations of the Central Laboratory for Agriculture Climate (CLAC) were obtained from 2000 to 2009, the data were calculated and analyzed in order to measure the changes in ET_o trends under current and future climate in Egypt by using the equation of estimating ET_o in arid zones especially Egypt (Gafar, 2009). Locations of those stations are in Table (1). The current ET_o (average data of 2000-2009) was assessed at different levels of analysis of monthly, seasonal and annual averages. Average ET_o of 2000-2009 was assumed as a normal and compared to the ET_o under climate change during 2040, 2060, 2080 and 2100. The weather stations were distributed in to four regions (Delta, Middle Egypt, Upper Egypt and outside valley) to determine the occurred changes in ET_o trends by regions under current climate in Egypt

Climate change scenarios for locations were assessed according to future conditions derived from MAGICC/SCENGEN software of the university of East angle (UK). In this the study one GCM model (HadCM3) and four scenarios of climate data were used A1, A2, B1 and B2. The principal of MAGICC/SCENGEN is allowing the user to explore the consequences of a medium range of future emissions scenarios **(Wigley *et al.*, 2000)**. Such data generated from MAGICC/SCENGEN are represented in one scenario A1 these scenarios are described by IPCC 2001 as follows: The A1 scenario describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies.

Table (1): The coordinates of the basic weather stations.

	station	Latitude [°N]	Longitude [°E]	Altitude [m]
1	Alexandria	31.1	29.0	7.0
2	Behira	31.0	30.5	6.7
3	Elgharbya	30.8	31.0	14.8
4	Dakahlia	31.0	30.5	7.0
5	kfrelshikh	31.1	30.9	20.0
6	Damietta	31.4	31.8	5.0
7	Sharkia	30.6	31.5	13.0
8	Ismailia	30.6	32.2	10.0
9	Monofeya	30.6	31.1	17.9
10	Qulybiya	30.5	31.2	14.1
11	Giza	30.0	31.2	22.5
12	Benisuef	29.1	31.1	30.4
13	Fayoum	29.3	30.9	30.0
14	Minia	28.5	30.4	40.0
15	Assiut	27.5	31.1	71.0
16	Sohag	26.6	31.6	68.7
17	Qena	26.1	32.7	72.6
18	Aswan	24.0	32.9	108.3
19	Newvalley	25.4	30.6	72.0
20	Arish	31.1	33.7	17.1

Results and discussion

1- Under Current Climate

a- Monthly Evapotranspiration (ET_o)

Understanding average monthly ET_o trend of the studied period (2000-2009) for the 20 locations was the first step in carrying out this study. Fig. (1) shows the average monthly ET_o, at the 20 studied weather stations. Aswan and Qena stations had the highest monthly ET_o trends compared to the other stations. Alexandria and Damietta stations gave the lowest value of ET_o. Regarding the average of the 20 stations, the highest values of ET_o of 7.8 mm/day, were observed in July. In addition, the lowest values ET_o of 2.1 mm/day, were observed in January. When the monthly average ET_o were compared to the stations, the highest ET_o of 9.9 mm were observed in July at Aswan station. In December, Damietta station recorded the lowest ET_o of 1.6 mm/day.

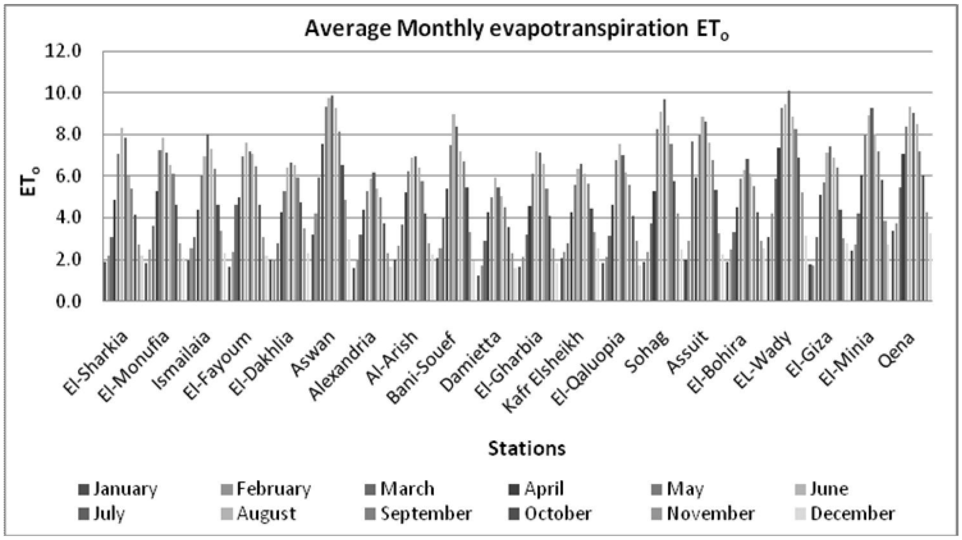

Fig. (1): Average monthly evapotranspiration (ETo, mm month) at the 20 studied weather stations.

b- Seasonal Evapotranspiration (ET_o)

Fig. (2) Shows the average seasonal ET_o, at the 20 studied weather stations. Aswan station had the highest seasonal ET_o trends compared to the other stations. Damietta station gave the lowest value of ET_o. Regarding the average of the 20 stations, the highest values of ET_o was 7.5 mm/day, were observed in summer. In addition, the lowest values ET_o of 2.3 mm, were observed in winter. When the seasonal ET_o were compared to the stations, the highest ET_o of 9.6 mm/day were observed in summer season (JJA) at Aswan station. In winter season (DJF), Damietta station showed the lowest ET_o of 1.5 mm/day.

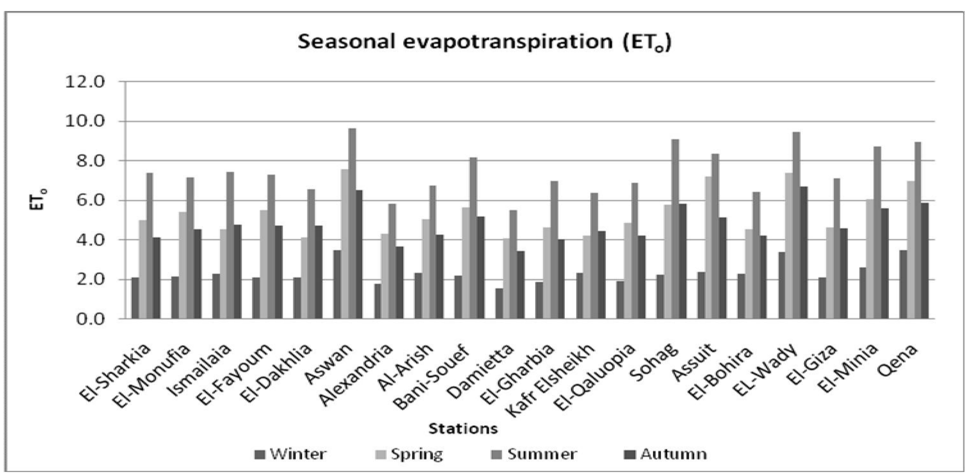

Fig. (2): Average seasonal evapotranspiration (ETo, mm) at the 20 studied weather stations.

c- Annual Evapotranspiration (ET_o)

Fig. (3) shows the average annual ET_o, of the 20 studied weather stations. Aswan station had the highest annual ET_o (6.8mm) trends compared to the other stations. Damietta station gave the lower value of annual ET_o (3.6mm). Regarding the average of the 20 stations, the values of ET_o of 5 mm.

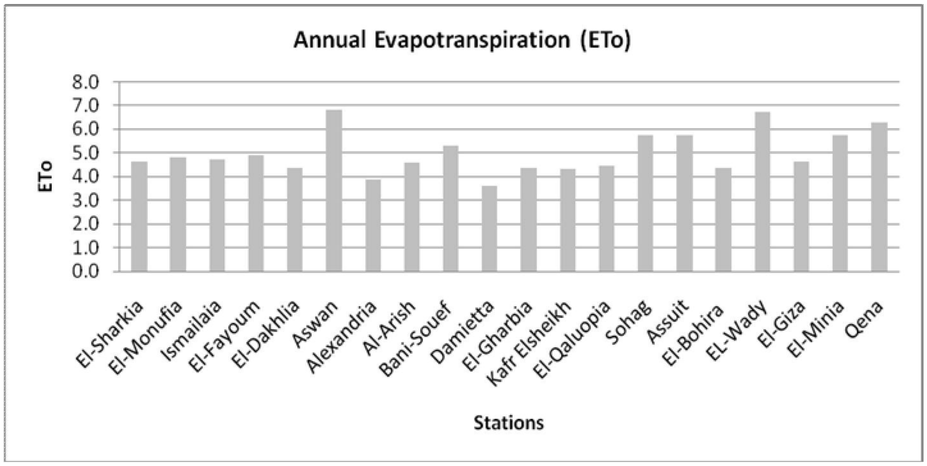

Fig. (3): Average annual evapotranspiration (ET_o, mm) at the 20 studied weather stations

2- Under Climate Change

a- Monthly Evapotranspiration (ET_o)

The average monthly evapotranspiration ET_o trends of the studied time serious (2000-2009) for the 20 stations were compare the change occurred in ET_o under current and future climate scenarios (A1, A2, B1and B2) during (2040, 2060, 2080, 2100). Fig.(4) shows comparison between the average monthly evapotranspiration under current and future climate. Regarding the average of the 20 stations, the evapotranspiration increased under climate change in comparison with normal. When the monthly average ET_o for the 20 stations under normal were compared to the future climate, the highest ET_o of 8.04 mm were observed in July at 2100 for A2 scenario. In addition, normal gave the lowest ET_o of 2.03 mm, was observed in January and B1 scenario gave the lowest ET_o of 2.11 was observed in January during 2040 in comparison with other scenario.

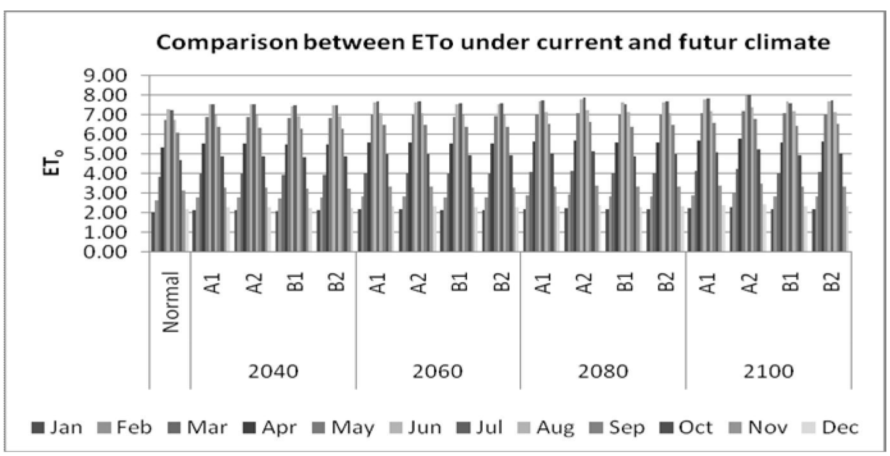

Fig. (4): Average monthly evapotranspiration (ETo, mm month) at the 20 studied weather stations under future climate.

b- Seasonal Evapotranspiration (ET_o)

Fig. (5) shows comparison between the average seasonal evapotranspiration under current and future climate. Regarding the average of the 20 stations, the evapotranspiration for all seasons increased under climate change in comparison with normal. The highest ET_o of 7.78 mm were observed in Summer at 2100 for A2 scenario. In addition, normal gave the lowest ET_o of 2.28 mm, was observed in winter and B1 scenario gave the lowest ET_o of 2.37 was observed in winter during 2040 in comparison with other scenarios.

c- Annual Evapotranspiration (ET_o)

Fig.(6) shows comparison between the average annual evapotranspiration under current and future climate. A2 scenario had the highest annual ET_o (5.31mm) in comparison with other scenario. In addition, normal gave the lowest ET_o of 4.28 mm, was observed under normal and B1 scenario gave the lowest ET_o of 4.69 was observed in 2040 compared to other scenarios.

In general, 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. Atmospheric temperature is probably the most widely used indicator of climatic changes both on global and regional scales. Global temperature has increased by 0.3–0.6 ◦C since the late 19th century and by 0.2–0.3 ◦C over last 40 years. In last 140 years, the 1990s was the warmest period **(Jones and Briffa, 1992)**. In Indian context, **Hingane *et al.* (1985)** reported an increase in mean annual temperature by 0.4 ◦C/100 years during the 20th century. As a consequence of climatic changes, a significant impact on hydrological parameters, viz. runoff, evapotranspiration, soil moisture, ground water etc. is expected **(Nemec and Schaake, 1982; Gleick, 1986; Bultot *et al.*, 1988).** Evapotranspiration (ET) is the major component of hydrological cycle after precipitation and determines the crop water requirement. The principal factors that influence the crop water requirement (or ET) depend upon several climatic parameters, viz. rainfall, temperature, humidity, sunshine hours etc. Any change in climatic parameters due to global warming will also affect evapotranspiration or crop water requirement. Eventual global warming would increase dry conditions in the world's arid regions by increasing potential evapotranspiration, aggravating the processes of desertification in conjunction with the ever-growing impact of man and domestic animals on fragile and unstable ecosystems **(Houerou and Le Houerou, 1993)**. **Mahmood (1997)** reported a 5% increase and a 4% decrease in total seasonal evapotranspiration, which occurs under each 1 ◦C warmer and cooler air temperature conditions, respectively.

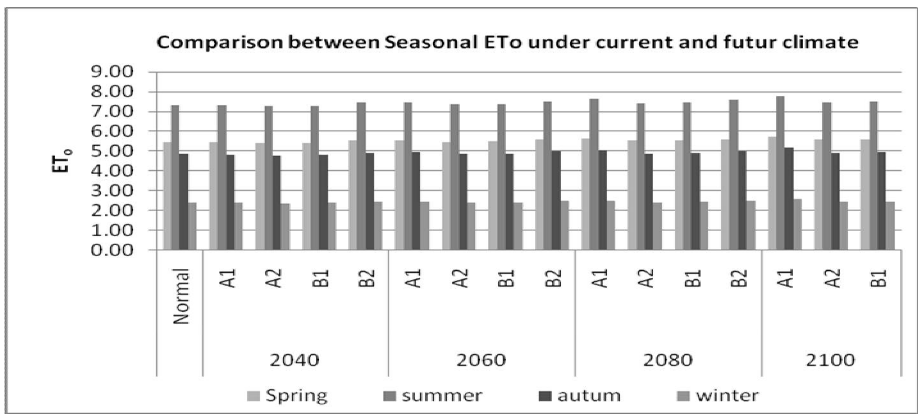

Fig. (5): Average Seasonal evapotranspiration (ETo, mm month) at the 20 studied weather stations under future climate.

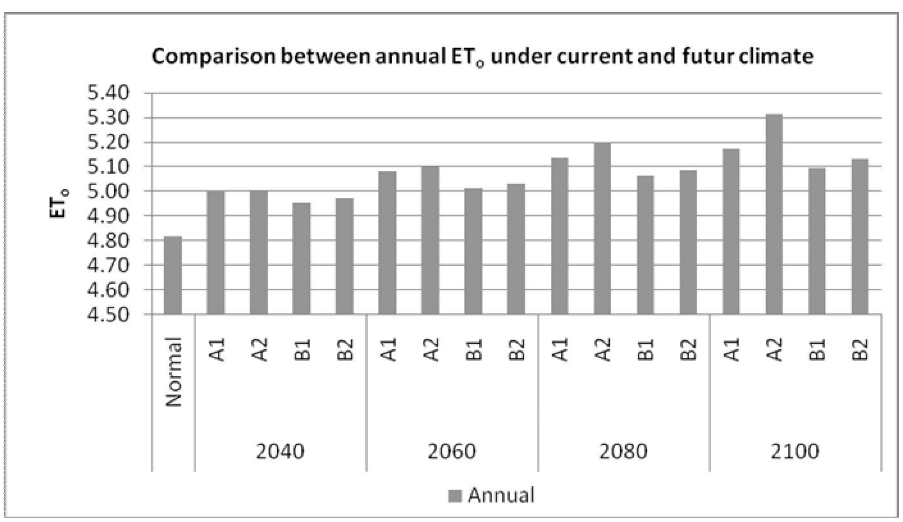

Fig. (6): Average annual evapotranspiration (ETo, mm month) at the 20 studied weather stations under future climate

Conclusion

Evapotranspiration in the south part of Egypt at Aswan and Qena stations had the highest monthly ET_o and the evapotranspiration in the north part of Egypt at Alexandria and Damietta stations gave the lowest value of ET_o. The highest and lowest values of ET_o were observed in July and January months, respectively. Regarding the seasonal Evapotranspiration, the highest ET_o were observed in summer season (JJA) and the lowest ET_o were observed in winter season (DJF). The results from general circulation model of HadCM3 data for four scenarios A1, A2, B1 and B2 shows that mean temperature has increased and the maximum increase will happen in 2100. The comparison between evapotranspiration during the years (2000-2009) and future climate during the years (2040, 2060, 2080 and 2100) at the 20 studied weather stations revealed a general increase in evapotranspiration under future climate for scenarios (A1, A2, and B1and B2). Water consumption under climate change in Egypt should be developed to mitigate the negative effects of climate change on evapotranspiration. Selection of better cultivar and the suitable irrigation level are most the important factors for maximizing yield production.

Corresponding author
Khalil A.A.
Central Laboratory for Agricultural Climate (CLAC)-
Agricultural Research Center (ARC)-
Ministry of Agriculture and Land Reclamation-
Dokki, Giza, Egypt.
alaa_armka@yahoo.com

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