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ESTIMATE OF IRRIGATION REQUIREMENTS UNDER CLIMATE CHANGE SCENARIOS (A1 AND B1) FOR OLIVE TREES IN EGYPT

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By
A. A. Farag and A. A. El-Taweel *

*Central Laboratory for Agricultural Climate - * Olive and Fruits of Semi arid-zone Department Horticultural Research Institute, Agricultural Research Center, Giza, Egypt*

ABSTRACT

The impacts of climate changes on irrigation requirements of olive trees under different climatic zones were studied using actual previous data of 2000 to 2007 for all studied regions. These data were used to generate the climatic data under climate change conditions by using magicc\scengen. The major governorates cultivating olive trees located in five agricultural climatic regions were selected; Ismailia Governorate in the Nile Delta, Fayoum Governorate in middle Egypt and Assuit Governorate represented the in Upper Egypt. Matruh and North Sinai have large cultivation area in outside the Nile valley. Furthermore, the irrigation requirements for olive trees in all the studied regions were calculated. The target of this step was comparing the irrigation requirements of different climatic regions under current and future climate conditions. The FAO equation was used to calculating the irrigation requirements for olive trees under current and future conditions. The future climatic values (2050 and 2100) were entered to the model individually. Two climate change scenarios (A1 and B1) were used to assess the consequences of climate change on irrigation requirements for olive in two time slices (2050, and 2100). The results indicated that the highest evapotranspiration and irrigation requirement for olive trees were obtained in Assuit 11.36 mm/day in July and irrigation requirement (4174 m^3/feddan/year), respectively, followed by Fayoum 10.85 mm/day in July, (3997 m^3/feddan/year) under A1 scenario. While, the lowest ETo value was obtained in Fayoum 2.02 mm/day in January and the irrigation requirement was found to be (2942 m^3/feddan/ year) in Ismailia. Furthermore, A1 scenario has higher ETo and irrigation need value than B1 scenario . The ETo and irrigation requirements under 2050s were lower than those under 2100s under both tested scenarios. The highest water use efficiency (WUE) was obtained by Fayoum Governorate followed by Assuit Governorate under current climate conditions. Under climate change scenarios the highest WUE was obtained under Fayoum condition and the lowest WUE under North Sinai.

Key words: *climate change scenarios, irrigation , olive trees, wue.*

1. INTRODUCTION

Olive (*Olea europaea* L.) is the most adapted tree in the semiarid Mediterranean regions.The tolerance of the tree to drought, and its capacity to grow in shallow, poor quality soils, make it among the most species interesting for cultivation in arid and semiarid areas (Fernandez and Moreno 1999).

Olive oil production has historical importance throughout the Mediterranean basin where there is an evidence of human cultivation and consumption from as far back as 5,000–6,000 years ago (Vossen 2007). Traditionally, olive trees are not irrigated, but recently water application has been recognized as constructive in order to (a) increase yields in regions with traditional rain-fed olive production (Moriana *et al.,* 2003), (b) allow high-density olive orchards and (c) expand olive production into regions where there is not enough rainfall as supplementary irrigation (Connor 2005).

Regions classified as semi-arid or arid constitute roughly one third of the total global land cover. Within these regions, water scarcity is one of the main factors limiting agricultural development. The impact of such water scarcity is amplified by inefficient irrigation practices, especially since the irrigation consumes more than 85% of the available water in these regions (Chehbouni *et al.,* 2008).

Agriculture productivity is affected by a number of factors of climate change including rainfall pattern, temperature hike, changes in sowing and harvesting dates, water availability, evapotranspiration and land suitability. All these factors can change yield and agricultural productivity (Kaiser *et al.*, 1993).

The general trend of the climate change impacts was an increase in ETo values from North to south. This increase will be uneven between regions and seasons. The future climatic changes will increase the potential irrigation-demands by range of 6-16%, due to the increase in ETo only by 2100s. (Hassanein *et al.*, 2012)

Climate is the major driving force of crop production and water use (Harmsen *et al.*, 2009). The increased air temperature and changed precipitation pattern will significantly affect crop yield and water use efficiency (Kattge and Knorr 2007).

Very little experiments were conducted in olive to evaluate the WUE under different irrigation regimes (Magliulo *et al.*, 2003; Iniesta *et al.*, 2009). This information is essential to evaluate the balance between benefit and costs associated with production, since water used for irrigation in most cases is expensive. Thus, the knowledge of WUE is crucial in supporting the decision to the more appropriate irrigation management when water available is scarce.

Climate change has been recognized globally as the most impending and pressing critical issue affecting mankind survival in the 21st century. The last assessment report from the Intergovernmental Panel on Climate Change predicted an increment in mean temperature from 1.1 – 6.4 °C by 2100 (IPCC 2007).

The aim of this study was to estimate water requirement for olive trees under climate change scenarios (A1 and B1) for 2050s and 2100s in five different Egyptian climatic regions.

2. MATERIAL AND METHOD

2.1. Cultivation area

Table (1) shows that the total area of olive cultivation in Egypt was 202743 feddan. The cultivation area in Lower Egypt was 45465 feddan, the highest Governorate was Ismailia 19571 feddan. The Middle Egypt area was 23708 feddan where the highest Governorate was Fayoum 14890 feddan. Assuit was the highest Governorate in Upper Egypt and the cultivation area was 2976 feddan and the total area 4013 feddan in Upper Egypt. Matruh and North Sinai have large cultivation area in Outside the Nile valley about 28960 and 43468 feddan, respectively.

Table (1): Area and Yield of the olive Fruits in Egypt in 2012.

Governorates	Area (feddan)	Yield (ton/ feddan)
Ismailia	19571	6.606
Lower Egypt	45465	4.667
%	43%	
Fayoum	14891	4.617
Middle Egypt	23708	5.221
%	63%	
Assuit	2976	5.300
Upper Egypt	4013	5.200
%	74%	
Matruh	28960	2.574
Outside the valley	129557	3.518
%	22%	
North Sinai	43468	2.286
Outside the valley	129557	3.518
%	34%	
Total Egypt	202743	4.109

Source : Agriculture Directorates of Governorates, Publisher : Economic Affairs Sector 2012

2.2. Evapotranspiration

The Penman – Monteith (PM) evapotranspiration (ET) equation predicts the rate of total evaporation and transpiration from the earth's surface using commonly measured weather data (solar radiation, air temperature, vapor content, and wind speed). The PM equation follows a single-layer or 'big leaf' approach, where single-surface resistance and single aerodynamic resistance terms represent the transport properties of the cropped surface.

The ET_o (Potential evapotranspiration) for olive was calculated depending on historical climatic data from 5 climate stations (Ismailia, Fayoum, Assuit, Matruh and North Sinai). The historical data cover the period from 2000^{th} to 2009^{th} (about 10 years). Calculation of potential evapotranspiration was made according to the Penman–Monteith (PM) for the following formula **(**ASCE ,2002**)**:

$$ET = \frac{\Delta(R_n - G) + \rho_a c_p (e_s - e_a)/r_a}{\left(\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)\right)\lambda \rho_w}$$

where:

Δ is the slope of the saturation vapor pressure vs. temperature curve.
R_n is the net radiation flux at the surface.
G is the sensible heat exchange from the surface to the soil (positive if the soil is warming)
P_a is air density.
C_p is specific heat of the dry air.
e_s is the saturation vapor pressure of the air at some height above the surface
e_a is the actual vapor pressure of the air.
r_a is aerodynamic resistance to turbulent heat and/or vapor transfer from the surface to some height z above the surface.
ƛ is the psychometric constant (defined later)
r_s is a bulk surface resistance that describes the resistance to the flow of water vapor from inside the leaf, vegetation canopy, or soil to outside the surface.
ƛ is the latent heat of vaporization, defined as the energy required to convert a mass of liquid water into vapor (having typical units of joules per kilogram)
P_w is density of liquid water.

2.3. Estimation of Irrigation requirements for olive tree

Most of the effects of the various weather conditions are incorporated into the ETo estimate. Therefore, as ETo represents an index of climatic demand, Kc varies predominately with the specific crop characteristics and only to a limited extent with climate. This enables the transfer of standard values for Kc between locations and between climates. This has been a primary reason for the global acceptance and usefulness of the crop coefficient approach and the Kc factors developed in past studies. ETo is determined by the crop coefficient approach whereby the effect of the various weather conditions are incorporated into ETo and the crop characteristics into the Kc coefficient. In the crop coefficient approach the crop evapotranspiration, ETc, is calculated by multiplying the reference crop evapotranspiration, ETo, by a crop coefficient, Kc according to FAO (1979) paper No. 33, the same methodology was adopted by many studies (Allen *et al.*, 1998, Gafar, 2009).

$IR = K_c * ET_o * LF * IE * R* Area (Feddan)/1000$

Where:
IR = Irrigation requirement (m^3/feddan).
K_c = Crop coefficient [0.65-0.75] according to (Allen *et al.,* 1998 and Goldhamer *et al.,* 1994) .
ET_o = Reference crop evapotranspiration [mm/day].
LF = Leaching fraction (assumed 20% of irrigation water).
IE = Irrigation efficiency of the irrigation system in the field, (assumed 90% of the total applied).
R = Reduction factor (60-70 % cover in this study)
Area = the irrigated area (one fedan = 4200 m^2).
1000 = To convert from liter to cubic meter.

2.4.Climate change scenarios

The climate change data were conducted by MAGICC/SCENGEN tool to extract the projection changes in air temperature (Δ air temp) under the two IPCC's SRES scenarios (A1 and B1) that are described in Table (2). HadCM3 climate model was the base model under the two scenarios. Each experiment extracted monthly Δ air-temp, for one of the two scenarios, for the coming years 2050s and 2100s. The resulted data from MAGICC/SCENGEN were in 5°X 5° coordination grid. The future Δ air temp data were downscaled by simple statistical approach, according to the Egyptian coordinates.

Table (2): Description of IPCC Special Report on Emissions Scenarios(SRES).

Scenario	Storylines
A1	Rapid economic growth, low population growth, rapid adoption of new technologies, convergence of regions, capacity building, increased social interaction, reduced region differences in per capita income. Temperature increased 1.4 - 6.4 °C
B1	Convergent world with low population growth, transition to service and info economy, resource productivity improvements, clean technology towards global solutions Temperature increased 1.1 - 2.9 °C

2.5.Water use efficiency (WUE)

The water use efficiency (WUE) was calculated according to FAO (1982) as follows: The ratio of crop yield (y) to the total amount of irrigation water use in the field for the growth season (IR).

WUE (Kg/m3) = Y(kg) / IR (m^3)

2.6. Statistical analysis

Statistical analysis was determined by computer, using SAS program for statistical analysis. The t – test was used to establish whether there exist any significant differences in the Actual ETo and irrigation requrement at 2000-2007 and ETo and irrigation requrement at 2050 and 2100 under significant level 0.05 (SAS, 2000).

3. RESULT AND DISUSSION

3.1. Air temperature under current and future climate conditions

Fig. (1) indicates the mean monthly temperature on Ismailia weather station in 2000-2009 year and 2050, 2100 years under A1and B1 climate change Scenarios HadCM3 climate model. The mean temperature was 19.7 ^{o}C, 22.1 ^{o}C , 23.7 ^{o}C , 21.6 ^{o}C and 22.7 ^{o}C in 2000-2009, 2050A1,2100A1, 2050B1 and 2100B1, respectively. The mean monthly temperature in 2050 and 2100 A1 increased from 1.2 ^{o}C to 3.6 ^{o}C and 2.4 to 5.8 than 2000-2009 years. In addition, mean monthly temperature in 2050 and 2100B1 increased from 1.0 ^{o}C to 3.5 ^{o}C and 1.9 to 4.7 than 2000-2009 year.

Figs (2&3) show the mean monthly temperature on Assuit and Fayoum weather station in 2000-2009 year and 2050,2100 years under A1 and B1 Scenarios. The mean annual temperature increased under 2050 and 2100 A1 Scenario 2.9 ^{o}C , 5.2 ^{o}C on Assuit and 2.6 ^{o}C , 5.0 ^{o}C on Fayoum than 2000-2009 year. In other site B1 Scenario increased temperature in 2050 and 2100 about 2.4 ^{o}C , 3.8 ^{o}C on Assuit and 2.2 ^{o}C , 3.7 ^{o}C on Fayoum than 2000-2009 year.

Figs (4&5) illustrate the mean monthly temperature on North Sinai and Matrouh weather station in 2000-2009 years and 2050, 2100 years under A1 and B1 Scenarios. The percentage of increase in annual mean temperature in 2050 , 2100 was 11.9 , 22 and 10.5,16.9% under A1 and B1, respectively, on North Sinai and 12.1,21.3 and 9.9, 15.3% under A1 and B1, respectively, on Matrouh than 2000-2009 year.

These results are in line with the report of IPCC (2007) which mentioned that the temperature will increase by uneven values in different climatic regions under climate change conditions. Moreover, climate change may have important impacts on agriculture. Based on the simulation of GCMS, future changes of global average temperature are expected to be between 2.8°C and 4.5°C in this century (IPCC, 2001), and some regional areas would be even warmer than the global average (Giorgi and Bi, 2005). So, both for policymakers and scientists, impacts of global warming on agriculture and water resources are referred to as an important issue (Gregory and Ingram, 2000; Fuhrer, 2003).

3.2. ETo under current and future climate conditions

Tables (3, 4 & 5) present the monthly ETo at 2000 - 2009 and two climate change Scenarios A1,B1 at 2050 and 2100 under five different climate region (Ismailia, Assuit, Fayoum, North Sinai and Matrouh).

The trend of ETo was almost the same under different climatic regions; the ETo values started low at the beginning of the year during January and February, then increased gradually and reached the highest ETo at mid of the year (June and July) and declined again at the end of the year during November and December.

Under current climate conditions (2000-2009) Assuit has the highest annual ETo (Table 1); while Ismailia has the lowest annual ETo (Table 3). The highest average monthly ETo value 8.4 mm was recorded at Assuit Governorate in July month (Table 1). On the other hand Fayoum recorded the lowest ETo value 2.02 mm in January month (Table 2).

The ETo increased significantly under climate change scenarios A1 and B1 at 2050 and 2100 compared to 2000-2009 in all climate regions.

The highest ETo value 11.4 mm was found at 2100 under A1 scenario during July at Assuit ; while the lowest ETo value 2.04 mm was found at Fayoum during January under B1 scenario in 2050.

From the previous results it can be concluded that the average ETo increased from 0.6 to 1.0 mm/ day for Ismailia Governorate; in Assuit ETo increased from 0.8 to 1.4 mm/ day; in Fayoum ETo increased from 0.7 to 1.3 mm/ day; in North Sinai ETo increased from 0.6 to 1.1 mm/ day, while in Matrouh ETo increased from 0.5 to 1.1 under A1 scenario in comparison with the current annual ETo. The B1 scenario increased ETo under different climate region as the following, Ismailia Governorate from 0.5 to 0.8 mm; Assuit Governorate from 0.7 to 1.1 mm; Fayoum from 0.6 to 1.0 mm ; North Sinai from 0.5 to 0.9 mm and Matrouh Governorate from 0.4 to 0.7 mm.

These results agreed with Allen *et al.* (1998) who reported that other variables are related to temperatures which affect crop growth and yield,

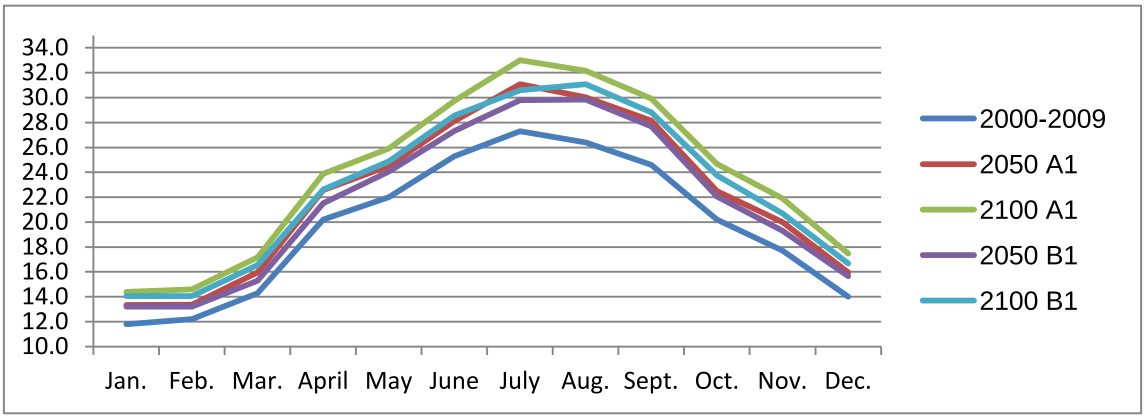

Fig. (1): Mean temperature on Ismailia weather station in 2000-2009 year and 2050, 2100 years under A1 and B1 Scenarios.

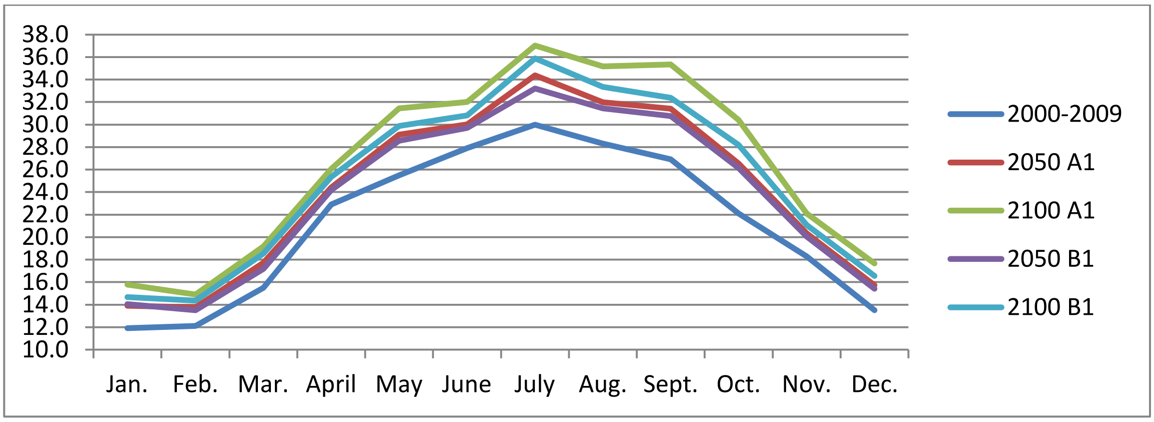

Fig. (2): Mean temperature on Assuit weather station in 2000-2009 year and 2050, 2100 years under A1 and B1 Scenarios.

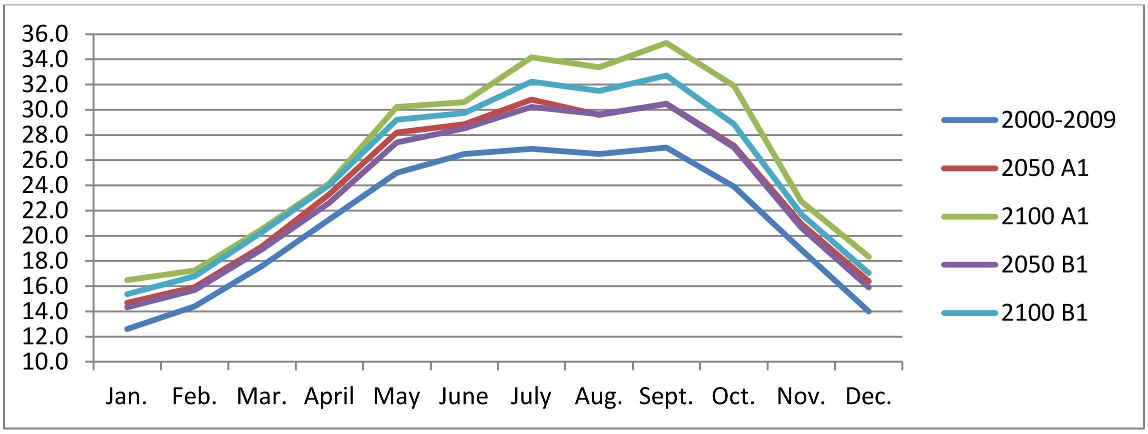

Fig. (3): Mean temperature on Fayoum weather station in 2000-2009 year and 2050, 2100 years under A1 and B1 Scenarios.

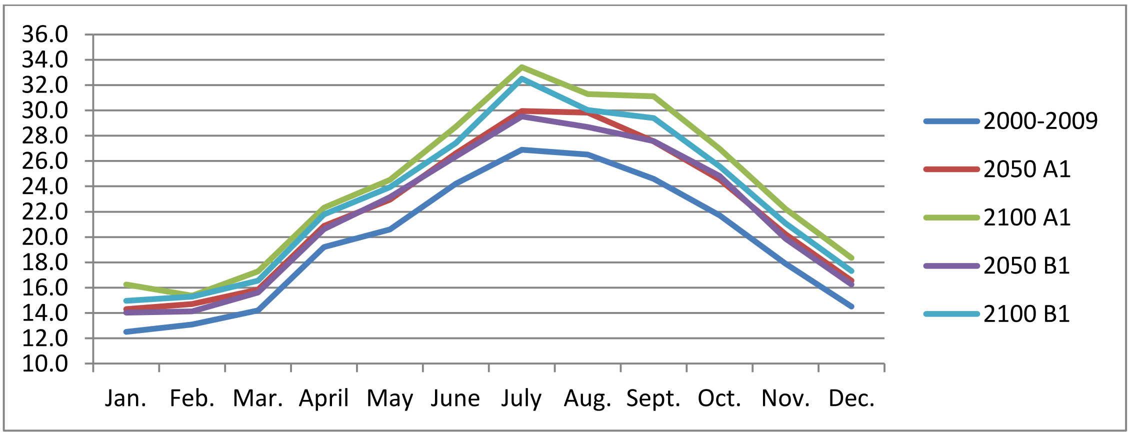

Fig. (4): Mean temperature on North Sinai weather station in 2000-2009 year and 2050, 2100 years under A1 and B1 Scenarios.

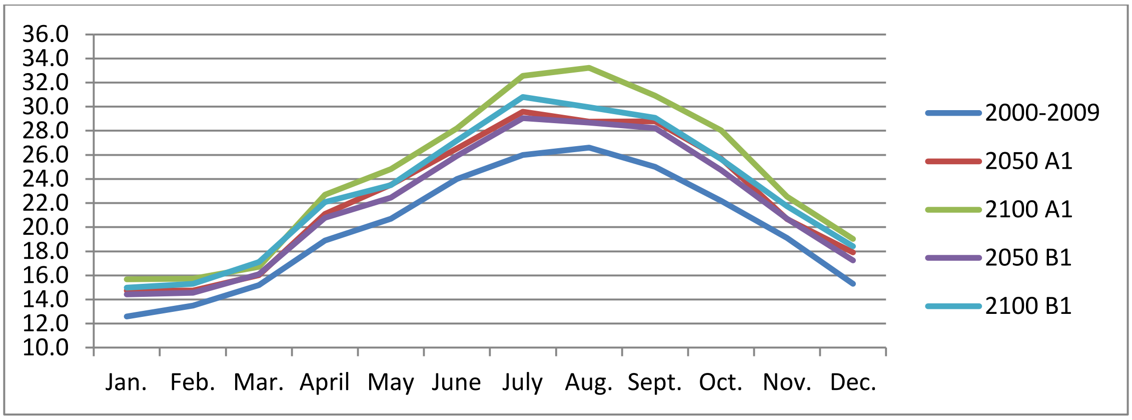

Fig. (5): Mean temperature on Matrouh weather station in 2000-2009 year and 2050, 2100 years under A1 and B1 Scenarios.

Table (3): Average monthly ETo under current and future climate conditions at Ismailia and Assuit Governorates.

Month	ETo mm/day									
	Ismailia					Assuit				
	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1
Jan.	2.19	2.36	2.48	2.35	2.44	2.06	2.26	2.46	2.28	2.34
Feb.	2.50	2.65	2.81	2.63	2.74	3.32	3.60	3.79	3.56	3.70
Mar.	3.61	3.92	4.13	3.79	4.02	3.94	4.38	4.67	4.27	4.54
April	4.82	5.39	5.71	5.14	5.40	5.57	5.99	6.45	5.92	6.25
May	5.39	6.08	6.45	5.95	6.17	6.56	7.74	8.51	7.57	7.99
June	7.17	8.18	8.76	7.90	8.34	7.96	8.81	9.60	8.68	9.12
July	7.64	9.08	9.81	8.59	8.89	8.41	10.25	11.36	9.76	10.88
Aug.	6.64	7.84	8.54	7.78	8.19	7.20	8.53	9.67	8.33	9.02
Sept.	5.96	7.02	7.55	6.88	7.22	6.13	7.52	8.71	7.31	7.81
Oct.	4.40	4.91	5.39	4.81	5.19	4.85	5.93	6.87	5.84	6.33
Nov.	3.30	3.68	4.00	3.57	3.80	3.10	3.41	3.69	3.37	3.53
Dec.	2.49	2.73	2.92	2.69	2.82	2.45	2.73	2.97	2.69	2.83
P- value		*	*	*	*		*	*	*	*
Average	**4.7**	**5.3**	**5.7**	**5.2**	**5.4**	**5.1**	**5.9**	**6.6**	**5.8**	**6.2**

*** significant at P < 0.05**

Table (4): Average monthly ETo under current and future climate conditions at Fayoum and North Sinai Governorates.

Month	ETo mm/day									
	Fayoum					North Sinai				
	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1
Jan.	2.02	2.07	2.24	2.04	2.13	2.29	2.58	2.93	2.55	2.66
Feb.	2.39	2.57	2.73	2.54	2.67	2.37	2.48	2.55	2.41	2.54
Mar.	3.93	4.23	4.50	4.19	4.46	4.14	4.48	4.77	4.43	4.62
April	5.21	5.73	5.96	5.55	5.93	5.97	6.47	6.90	6.40	6.74
May	7.44	8.62	9.38	8.33	9.00	7.12	7.96	8.52	8.03	8.31
June	8.24	9.22	9.94	9.07	9.57	7.94	8.90	9.73	8.79	9.22
July	7.96	9.51	10.85	9.28	10.08	7.50	8.65	9.94	8.48	9.59
Aug.	6.55	7.55	8.79	7.57	8.18	6.97	8.13	8.64	7.73	8.20
Sept.	5.83	6.85	8.25	6.84	7.49	5.60	6.43	7.42	6.43	6.94
Oct.	4.39	5.11	6.15	5.07	5.48	4.12	4.71	5.21	4.77	4.92
Nov.	3.19	3.52	3.80	3.47	3.64	2.94	3.28	3.57	3.23	3.40
Dec.	1.74	1.94	2.11	1.90	2.00	2.12	2.34	2.53	2.31	2.42
P- value		*	*	*	*		*	*	*	*
Average	**4.9**	**5.6**	**6.2**	**5.5**	**5.9**	**4.9**	**5.5**	**6.1**	**5.5**	**5.8**

*** significant at P < 0.05**

Table (5): Average monthly ETo under current and future climate conditions at Matrouh Governorate .

Month	ETo mm/day				
	Matrouh				
	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1
Jan.	2.70	2.99	3.12	2.95	3.02
Feb.	3.00	3.19	3.34	3.16	3.27
Mar.	3.80	3.95	4.09	3.97	4.16
April	5.77	6.41	6.87	6.31	6.69
May	6.62	7.55	7.98	7.20	7.54
June	6.40	7.54	8.49	7.37	7.94
July	7.14	8.04	8.64	7.83	8.28
Aug.	6.17	6.84	8.22	6.81	7.20
Sept.	5.20	6.19	6.74	6.04	6.26
Oct.	4.50	5.29	5.81	5.07	5.28
Nov.	3.10	3.34	3.63	3.35	3.51
Dec.	2.80	3.16	3.32	3.07	3.24
P- value		*	*	*	*
Average	**4.8**	**5.4**	**5.9**	**5.3**	**5.5**

*** significant at P < 0.05**

such as evaporation, transpiration, and vapor pressure deficit. Even solar radiation has been shown to be related to the diurnal air temperature difference. The increasing of air temperature will lead to increase evapotranspiration that make soils need more water and increase the need for irrigation water.

3.3. Irrigation requirements for olive under current and future conditions

Data in Tables (6, 7 and 8) indicated the irrigation requirements for mature olive trees at five climate regions under A1 and B1 climate change scenarios.

Monthly average irrigation need for mature olive trees resulted from multiplying the average monthly ETo for each climatic region by crop coefficient of mature olive trees. According to the current situation (2000-2009) one feddan of olive needs about 2942, 3232 , 3114, 3116 and 2943 m^3 / year of irrigation for Ismailia, Assuit, Fayoum, North Sinai and Matrouh, respectively. The highest irrigation requirement was recorded in Assuit Governorate followed by North Sinai but the lowest irrigation requirements were recorded in Ismailia and Matrouh.

The irrigation requirements under climate change increased significantly in both scenarios A1, B1 at 2050 and 2100 compared to the current situation (2000-2009). Furthermore, the B1 scenario was lower than A1 scenario in irrigation need under 2050 and 2100 years. While 2050s was lower than 2100s under both tested scenarios.

The highest increasing percentage of the estimated irrigation need was found in Assuit Governorate 29.1% followed by Fayoum Governorate 28.4% at 2100s under A1 scenario; while the lowest increasing percentage of the irrigation need was found in Maturoh 10.8% followed by Ismailia Governorate 11.3% at 2050s under B1 scenario. In spite of the highest irrigation requirements for mature olive trees (cubic meter /fed.year) under current and future (2050s and 2100s) was recorded in Assuit but the lower rate of the irrigation requirements was recorded in Maturoh governorate at 2050, 2100s under A1, B1 scenarios. Similar results were reported by many authors such as Eid (1993), Eid *et al*. (2001) and Medany, (2001). Furthermore, projected future temperature rise is likely to increase irrigation requirements, thereby directly decreasing crop water use efficiency and increase irrigation demands of the agriculture sector. Irrigation requirements of the important strategic crops in Egypt are expected to increase by a range of 6 to 16% by 2100. The high vulnerability of on-farm irrigation systems in Egypt is attributed to low efficacy of irrigation management patterns (EEAA, 2010).

Table (6): Average monthly irrigation requirements for mature olive trees under current and future conditions at Ismailia and Assuit Governorates.

Month	m^3/feddan									
	Ismailia					Assuit				
	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1
Jan.	69	74	77	73	76	64	71	77	71	73
Feb.	71	75	79	74	77	94	101	107	100	104
Mar.	169	184	194	178	189	185	205	219	200	213
April	237	265	281	253	265	274	294	317	291	307
May	295	332	353	325	337	359	423	466	414	437
June	406	464	496	448	473	452	499	544	492	517
July	507	603	652	570	590	558	680	755	648	723
Aug.	441	520	567	517	544	478	566	642	553	599
Sept.	338	398	428	390	409	348	426	494	414	443
Oct.	206	230	253	226	243	227	278	322	274	297
Nov.	125	139	151	135	143	117	129	139	127	133
Dec.	78	85	91	84	88	77	85	93	84	88
P- value		*	*	*	*		*	*	*	*
Total	**2942**	**3369**	**3622**	**3273**	**3436**	**3232**	**3760**	**4174**	**3670**	**3935**
%		**14.5**	**23.1**	**11.3**	**16.8**		**16.3**	**29.1**	**13.5**	**21.7**

*** significant at $P < 0.05$**

Table (7): Average monthly irrigation requirements for mature olive trees under current and future conditions at Fayoum and North Sinai Governorates.

Month	m³/feddan									
	Fayoum					North Sinai				
	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1
Jan.	59	65	70	64	67	72	81	92	80	83
Feb.	67	73	77	72	75	67	70	72	68	72
Mar.	184	198	211	196	209	194	210	224	208	217
April	256	282	293	273	291	293	318	339	314	331
May	407	471	513	456	492	389	435	466	439	454
June	467	523	563	514	543	450	505	552	499	523
July	528	631	720	616	669	498	574	660	563	637
Aug.	435	502	584	503	543	463	540	574	514	544
Sept.	331	388	468	388	425	318	364	421	365	393
Oct.	206	239	288	238	257	193	221	244	223	231
Nov.	121	133	144	131	138	111	124	135	122	129
Dec.	54	61	66	59	63	68	73	79	72	76
P- value		*	*	*	*		*	*	*	*
Total	**3114**	**3566**	**3997**	**3509**	**3772**	**3116**	**3514**	**3857**	**3466**	**3690**
%		**14.5**	**28.4**	**12.7**	**21.1**		**12.8**	**23.8**	**11.3**	**18.4**

*** significant at P < 0.05**

Table (8): Average monthly irrigation requirements for mature olive trees under current and future conditions at Matrouh Governorate.

Month	m³/feddan				
	Matrouh				
	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1
Jan.	84	93	97	92	94
Feb.	85	90	94	89	92
Mar.	178	185	192	186	195
April	284	315	338	310	329
May	362	413	436	394	413
June	405	456	490	444	470
July	425	501	564	490	527
Aug.	410	454	546	452	478
Sept.	295	351	382	342	355
Oct.	211	248	272	238	247
Nov.	117	126	137	126	133
Dec.	87	99	104	96	101
P- value		*	*	*	*
Total	**2943**	**3331**	**3652**	**3260**	**3434**
%		**13.2**	**24.1**	**10.8**	**16.7**

*** significant at P < 0.05**

3.4. Water use efficiency (water productivity)

Data in Table (9) showed that increasing irrigation quantity under different climate change scenarios led to a decrease water use efficiency for all governorates. The highest WUE obtained in Fayoum Governorate followed by Assuit Governorate under current climate condition. The lowest WUE was obtained in North Sinai Governorate. On the other hand, under climate change scenarios the highest WUE was obtained in Fayoum Governorate followed by Ismailia governorate. The lowest WUE was obtained in North Sinai Governorate. The high evapotranspiration under climate change makes WUE of olive in Egypt becoming the lowest compared with WUE under current condition. There were a different in productivity of olive between Governorates. The water productivity (WP) increases as ET decreases and, therefore, one can find an economic optimum, in terms of ET and therefore of irrigation amount (Moriana *et al.*, 2003)

Table (9): Water use efficiency WUE (Water productivity) kilogram olive per cubic meters water at Ismailia, Fayoum, Assuit, Matrouh and North Sinai Governorates.

Year	2000-2009	2050 A1	2100 A1	2050 B1	2100 B1
Ismailia					
Irrigation m^3	2942	3369	3622	3273	3436
WUE (Kg/m^3)	1.59	1.39	1.29	1.43	1.36
Fayoum					
Irrigation m^3	3114	3566	3997	3509	3772
WUE (Kg/m^3)	1.68	1.46	1.31	1.49	1.38
Assuit					
Irrigation m^3	3232	3760	4174	3670	3935
WUE (Kg/m^3)	1.61	1.38	1.25	1.42	1.32
Matrouh					
Irrigation m^3	2943	3331	3652	3260	3434
WUE (Kg/m^3)	1.20	1.06	0.96	1.08	1.02
North Sinai					
Irrigation m^3	3116	3514	3857	3466	3690
WUE (Kg/m^3)	1.13	1.00	0.91	1.02	0.95

In conclusion

From the obtained results it can be concluded that irrigation needs to increase depending on regions and climate change scenarios. The total amount of irrigation increase per fedden per year ranged from 331 to 680m^3 at Ismailia Governorate, 438 to 942m^3 at Assuit Governorate ; from 395 to 883m^3 at Fayoum Governorate; from 351 to 741m^3 at North Sinai Governorate and from 317 to 709 m^3 at Matrouh Governorate. Water use efficiency decreased under climate change scenarios in all regions at 2050s and 2100s. More studies are needed on the impacts of climate change on olive yield and olive oil production under Egyptian conditions.

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الاحتياجات الاروائية للزيتون تحت ظروف سيناريوهات تغير المناخ (A1 , B1) في مصر

احمد عوني احمد فرج - عبد العزيز احمد الطويل *

المعمل المركزي للمناخ الزراعي – *قسم بحوث الزيتون وفاكهة المناطق شبه الجافة
معهد بحوث البساتين – مركز البحوث الزراعية - الجيزة - مصر

ملخص

تم دراسة تأثير التغيرات المناخية على الاحتياجات الاروائية للزيتون تحت ظروف التغيرات المناخية باستخدام بيانات مناخية، خلال الفترة من ٢٠٠٠ الى ٢٠٠٧، بجميع مناطق الدراسة. حيث تم استخدام تلك البيانات لاستحداث بيانات المناخ تحت ظروف التغيرات المناخية من خلال استخدام نموذج scengen\magicc تم اختيار المحافظات التي بها اكبر مساحات للزيتون بالاقاليم المناخية الزراعية في الدلتا ومصر الوسطى ومصر العليا: اديترت الاسماعيلية لتمثل منطقة الدلتا ومحافظة الفيوم لتمثل مصر الوسطى ومحافظة اسيوط لتمثل مصر العليا ومحافظة مطروح وشمال سيناء. تم علاوة على ذلك، حساب الاحتياجات الاروائية للزيتون بالاقاليم المناخية المختلفة حيث تهدف هذه الخطوة لمقارنه الاحتياجات الاروائية بالمناطق المناخية المختلفة تحت الظروف الحالية وتحت ظروف التغيرات المناخية. استخدمت طريقة الفاو ٥٦ لحساب الاحتياجات الاروائية لمحصول الزيتون تحت الظروف الحالية وتحت ظروف التغيرات المناخية، تم ادخال البيانات المناخية المستقبلية (٢٠٥٠ و ٢١٠٠) طريقة الفاو ٥٦ منفردا لسنة ٢٠٥٠ وسنة ٢١٠٠. قدرت الاحتياجات الاروائية المستقبلية للزيتون تحت ظروف ٢ سيناريو من سيناريوهات التغيرات المناخية (**A1** و **B1**) وذلك على مرحلتين رئيسيتين ٢٠٥٠ و ٢١٠٠. ويتضح من النتائج ان البخر نتح المرجعي قد ازداد في كلا من عامي ٢٠٥٠ و٢١٠٠ مقارنتا بسنة الاساس ولقد وجد ان اعلى زيادة في قيم البخر نتح بمحافظة اسيوط ١١,٣٦ مم /يوم فى شهر يوليو بجمالى (٤١٧٤ م^{٣} / سنة). بينما كانت الفيوم اقل بخر نتح 2.02 مم / يوم فى شهر يناير واقل اجمالى (٢٩٤٢ م^{٣} / سنة) فى محافظة الاسماعيلية. كما وجد ان اعلى زيادة في قيم البخر نتح وجدت بسنة ٢١٠٠ مقارنتا بسنة ٢٠٥٠. اخيرا، وجد ان الزيادة في الاحتياجات الاروائية تحت سيناريو **A1** أعلى من الزيادة تحت سيناريو B١ في كلا من عامي ٢٠٥٠ و ٢١٠٠.قد تم الحصول على اعلى كفائة استخدام المياة فى محافظة الفيوم فى الظروف الحالية وتحت ظروف تعير المناخ يليها محافظة اسيوط تحت الظروف الحالية. وكانت محافظة شمال سيناء اقل كفاءة فى استخدام المياة تحت ظروف تغير المناخ.

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