VARIATION OF EVAPOTRANSPIRATION DURING 2000 TO 2010 IN EGYPT DUE TO CONSEQUENCES OF CLIMATE CHANGE

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ABSTRACT

Egypt is challenging the possessions of global warming and potentially facing variation consequences in water scarcity, agriculture and food insufficiency, new pressures on national economy and energy production. To highlight and try to confront these adverse impacts, a study is conducted through a period of a decade during 2000 to 2010 to estimate evapotranspiration variation taking into consideration meteorological elements alteration as part of climate change. This paper provides a comparisons between emitted evapotranspiration related to planted areas allover Egypt through the period of one decade between 2000 and 2010 taking into consideration variation in meteorological parameters as average air temperature, maximum and minimum relative humidity, average radiation and mean wind speed to find total consumed water through this natural phenomena at various Egyptian governorates during the studied period. Results indicated that due to heterogeneous of meteorological parameters applied in the model reveal reference evapotranspiration (ETo) took quite parabolic shape with maximum difference of 0.6 mm/day during studied years, even though the increment in temperature and solar radiation which had the dominant factor to increase ETo the curve decrease was due to increase of maximum relative humidity and decrease in wind speed, and water consumption in agricultural sector has direct relation with ETo and cultivated areas considering crop patterns during the studied period.

Keywords: Environment, evapotranspiration, meteorological parameters

1 INTRODUCTION

Egypt's Climate is semi-desert, characterized by hot dry summers, moderate winters and very little rainfall, Fathy, M. (2013). The impact of human activities on the atmosphere and the accompanying risks of long-term global climate change are by now familiar topics to experts, globally about one-third of the total human-induced warming effect due to greenhouse gas (GHGs) emissions comes from agriculture and land-use change, Keith, P. and John, M. (2006).

A glance at average variation of average temperature obtained by data of meteorological stations during the studied period indicates a slight increase in temperature as shown in Fig. 1.

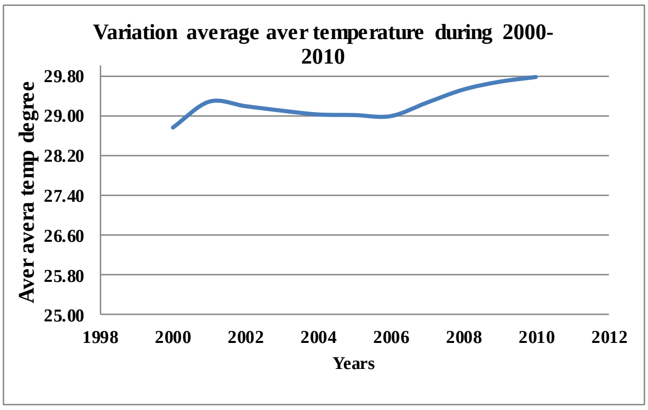


Figure 1. Average variation of average temperature during 2000-2010 all over Egypt

Vulnerability according to; IPCC, 2007a is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes, it is clear as indicated in Fig. 2 that negative effects increased in vulnerability by 0.40% at agriculture sector between years 2000-2010 due to increase of average temperature and socio economic reasons, the items with direct effect include the following:-

- Increase evapotranspiration (ET)
- Increase crop water requirements
- Affect planting date
- Reduce agriculture production
- Farmer abandon marginal land
- (Eid et al., 2001) reported that climate change could increase crop water demand for summer crops (up to +16%) & it could decrease the water demand for winter crops (up to 20 %) by the year 2050.

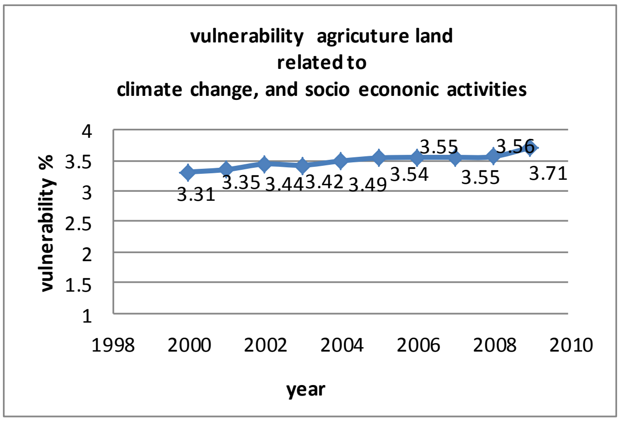


Figure 2. Vulnerability of agriculture sector considering climate change, and socio economic parameters, Climate Change Knowledge Portal

The present study is focusing on the effect of meteorological parameters variation through 10 years on reference evapotranspiration and relation with cultivated areas on water consumption which is the most dominant on present and future water deficiency in Egypt.

2 METHODOLOGY

Data were collected from 21 meteorological stations in which tabulated at TtuTiempo.net global climate web site - Africa historical data, Egypt. , and climate change knowledge portal which is a central hub of information related to the World Bank group, data and reports about climate change around the world, beside 2 years historical data in climate lab using précis model . Points which represent stations were placed into a GIS layer map according to their latitude and longitude. This study focused on the time period year’s 2000 to 2010 variation of evapotranspiration calculated at total cultivated areas in Egypt using reference evapotranspiration (ETo) model and considering meteorological parameters.

Geostatistical Analyst’s Kriging feature was used to interpolate rasters of various strips of Egypt map for meteorological parameters studied including temperature, solar radiation and precipitation for various studied years. Spatial analysis is used to find each strip area according to number of pixels in histogram curves chosen within selecting grid units measurements, the total number of pixels indicate an area equal to 10^6 km^2. Applying ETo model [6], using Penman-Monteith equation to obtain average reference evapotranspiration through 2000 to 2010, then crop evapotranspiration (ETcrop) and, total water requirements during growing period was also found according to cultivated areas, finally the crop factor variation according to cultivation pattern and meteorological parameters in two years 2007, 2008 was found and compared.

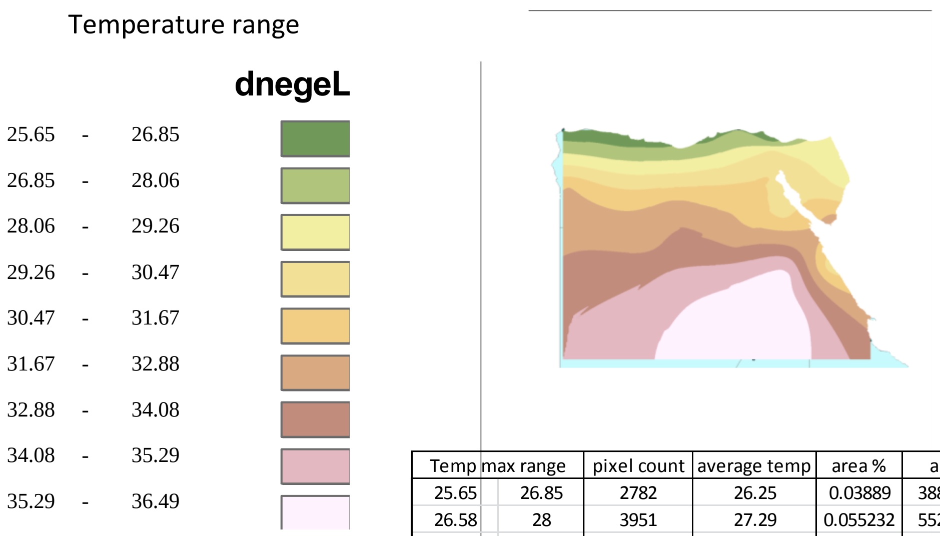
Table 1 introduces data obtained by meteorological stations for year 2010; these data were collected for each year studied for the period from 2000 to 2010.

Table 1. Recorded meteorological data year 2010 Average annual climate values, TuTiempo.com, Climate Change Knowledge Portal.

Latitude[N0]	Longitude[E]	Name	Year	Temp	T max	T min	Precepitat	Radiation w/m^2
25.13	31.56	Sallum	2010	20.4	25.9	15.7	8.63	77.20
31.1	31.55	Baltim	2010	22.2	26.9	18.7	50.04	91.16
27.21	31.33	Marsa matruh	2010	21.1	25.9	16.5	87.12	77.20
32.29	31.26	Port Said	2010	22.6	25.8	19.9	70*	76.30
29.95	31.2	Alexandria	2010	21.8	26.5	17.4	67.08	84.51
33.83	31.08	El Arish	2010	21.7	28.5	15.8	49.03	132.01
32.25	30.6	Ismailia	2010	22.9	30.1	16.9	5.32	195.64
31.4	30.13	Cairo	2010	24.2	29.8	18.8	59.44	181.98
33.73	29.91	Nekhel	2010	20.4	29.3	12.2	60.45	160.98
34.78	29.6	Taba	2010	21.2	28.4	14.3	50*	128.79
32.7	29.58	Ras sedr	2010	24.4	30.3	19	6.35	205.20
25.31	29.2	siwa	2010	23.9	31.8	16.3	4.82	288.22
28.9	28.33	Bahira	2010	24.5	32.6	16.8	15*	340.68
30.73	28.08	minya	2010	24.1	31.9	16.8	12*	294.46
34.38	27.96	sharm sheik	2010	27.6	32.2	23.4	30*	313.74
33.71	27.15	Hurguada	2010	26.7	31.9	21.3	76.45	294.46
31.01	27.05	Asyut	2010	24.7	32.5	17	8.89	333.81
32.75	26.2	south of vall	2010	27.3	34.8	19.8	3.56	514.33
34.3	26.13	kosseir	2010	26	29.4	22.1	13.21	165.00
32.7	25.66	Luxor	2010	27.6	35.7	19.5	51.06	597.78
34.58	25.55	Marsa Alm	2010	27.8	30.8	23.8	45*	230.65
29	25.48	Dakahla	2010	25.9	34.7	17.2	5*	505.50
30.53	25.45	Kharga	2010	27.2	35	18.8	2.03	532.25
32.78	23.96	Aswan	2010	29.1	36.4	21.7	8*	667.67
31.61	22.36	Abu Simpl	2010	28.6	36.3	20.5	5*	657.42

*Estimated due to missing data

By studying the Spatial analysis distribution of contour lines for each strip locations in Egypt map for various average temperature in year 2010, it is noticed a widening in strip areas when going south and increase in average temperature according to GIS model results [2], the interpolation of data for average maximum temperature year 2010 distributed as contour lines is demonstrated in Fig. 3.



Temp max range		pixel count	average temp	area %	area km2
25.65	26.85	2782	26.25	0.03889	38890.05382
26.58	28	3951	27.29	0.055232	55231.70476
28	29.27	5832	28.635	0.081527	81526.52548
29.27	30.47	8444	29.87	0.11804	118040.1202
30.47	31.68	8453	31.075	0.118166	118165.9328
31.68	32.88	10455	32.28	0.146152	146152.2332
32.88	34.1	10101	33.49	0.141204	141203.6066
34.1	35.29	11494	34.695	0.160677	160676.5919
35.92	36.5	10023	36.21	0.140113	140113.2313
		71535		1	1000000

Figure 3. Distribution of contour lines and values for average maximum temperature for year 2010

3. EVAPOTRANSPIRATION CALCULATIONS

The agriculture water requirements are mainly the dominant consumer for Egypt water budget; the irrigation requirement for any crop is the amount of water that must be applied to meet the crop's evapotranspiration (ET) needs. The amount of (ET) is the combination for soil, water evaporation and crop transpiration, the quantity of water needed to build the plant tissues reaches only to around 5% of the consumptive use which can be considered equal to evapotranspiration. Both evaporation and transpiration occur in response to climate demand. Evapotranspiration is greatest on hot, sunny and dry days and lowest on cool, cloudy and humid days, H. E. Gad and S. M. El-Gayar (2010), [10].

according to difficulties of getting accurate direct field data measurements of quantities of evapotranspiration, the researches considered meteorological parameters as main factor to perform required calculation and comprised in the Food and Agriculture Organization (FAO) Penman-Monteith equation as the standard method for calculating the reference evapotranspiration (ETo) and hence the crops water requirements (ETcrop). By applying penman-monteith equation in (ETo) model calculator taking input obtained data, the quantity of total average evapotranspiration in the studied years where easy to calculate in Egypt. Equation (1) includes each parameter definition, with standard units.

$$ETo= 0.408\Delta (Rn-G) +\gamma *(900/ (T+273)) U2 (es-ea)/ (\Delta+\gamma (1+0.34U2)) \qquad (1)$$

ETo reference evapotranspiration [mm day^{-1}],
Rn net radiation at the crop surface [MJ m^{-2} day^{-1}],
G soil heat flux density [MJ m^{-2} day^{-1}],
T mean daily air temperature at 2 m height [°C],
u2 wind speed at 2 m height [m s^{-1}],
es saturation vapor pressure [kPa],
ea actual vapour pressure [kPa],

es-ea saturation vapor pressure deficit [kPa],
slope vapour pressure curve [kPa °C^{-1}],
psychrometric constant [kPa °C^{-1}].

Few data for year 2006 including average limits for relative humidity, wind speed and solar radiation for studied governorates are shown in table 2.

Table 2. Average limits for relative humidity, wind speed and radiation for studied governorates stations on year 2006 (day, night)

Name	T	Ave radiation w/m^2	Ave max RH	Ave min RH	Average wind speed (mph)
Baltim	21.1	155.017	84	44	7.3
Marsa matruh	20.4	150.992	85	40	17.7
Port Said	21.9	160.457	88	50	18.3
Alexandria	21	154.4	92	43	15.1
El Arish	20.7	192.6825	83	38	7.7
Ismailia	21.9	194.4225	83	38	12.8
Cairo	22.6	166.4	82	23	12.7
Ras sedr	23	168.6	84	31	11.1
siwa	22.9	168.035	84	30	6
Bahira	22.9	168.035	75	15	8.5
minya	22.1	194.7825	82	19	8.6
sharm sheik	26.1	206.1825	85	20	21.3
Hurguada	25.2	202.92	84	20	25.9
Farafra	26.3	206.9625	80	11	10.5
Asyut	22.5	195.5625	80	14	15.2
Luxor	25.3	242.4775	88	13	8.4
Dakahla	24.4	231.16			8.5
Kharga	25.3	242.4775	78	14	9.9
Aswan	26.7	259.2775	56	9	15.7

Taking the average for all governorates stations in each studied year for each climatic parameter the data needed to feed the model will be obtained and shown in table 3.

Table 3. Available nesessary meteorological data input in ETo model through period 2000-2010

year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
average temperature	28.76	29.28	29.19	29.10	29.02	29.01	28.99	29.26	29.52	29.68	29.78
max rh %	81.8	81.79	81.9	80.99	81.70	82.25	82.88	83	82.5	83.9	83.88
min rh %	26.3	26.11	26	26.8	26.40	27.3	27.5	27.6	27.4	28.4	28.5
aver ws m/s	2.85	2.90	2.84	2.83	2.80	2.72	2.67	2.66	2.64	2.64	2.68
solar radiation w/m2	191.93	192.89	190.98	193.28	195.48	200.99	202.40	200.59	202.30	205.63	207.62

Before running the ETo model few steps are taken in the following sequence:

The model starts by defining each station characteristic including time range, its location description if interior or shore and number of stations, Fig.4 shows station description for Cairo station, the data limits for each meteorological parameter is defined with optional units. This equation contains many terms that depend on climatic parameters such as mean solar radiation, air temperature, relative humidity and wind speed.

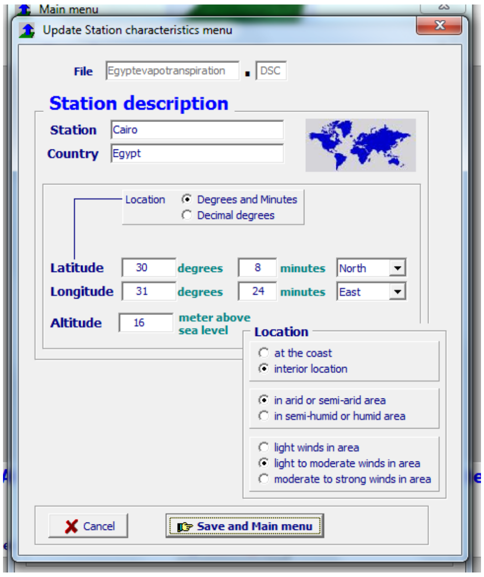


Figure 4. Station Characteristic for Cairo station

By running the model the total average evapotranspiration for Egyptian valley and delta was also obtained in million cubic meters of water which in irrigation field is the dominant consumer of water budget in Egypt. Comparing the evapotranspiration variation quantities due to meteorological parameters and cultivated areas is made. It is found that a relationship exists between evapotranspiration and both cultivated areas and meteorological parameters. The available meteorological parameters to be input in the model for each station are defined according to the following menu of the ETo calculator program as shown in Fig. 5.

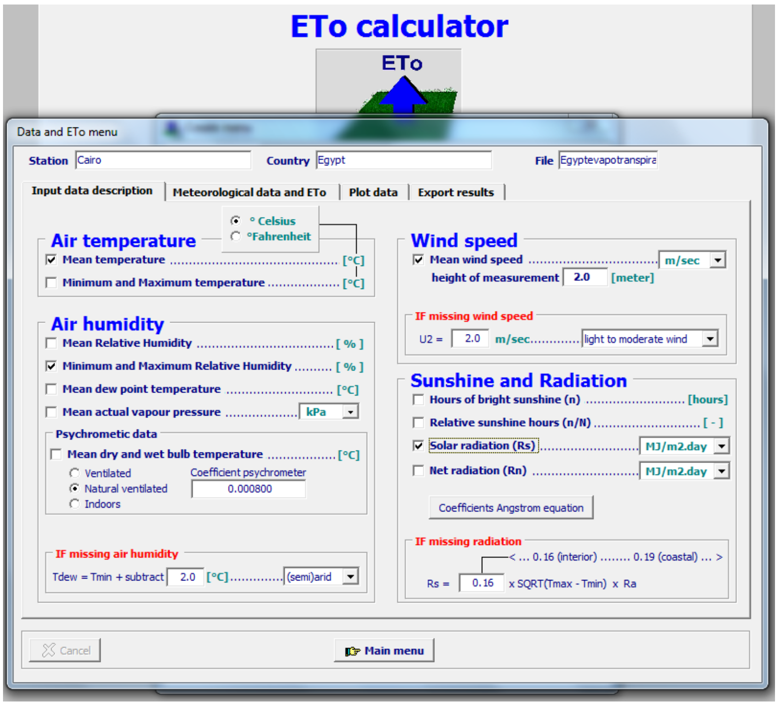
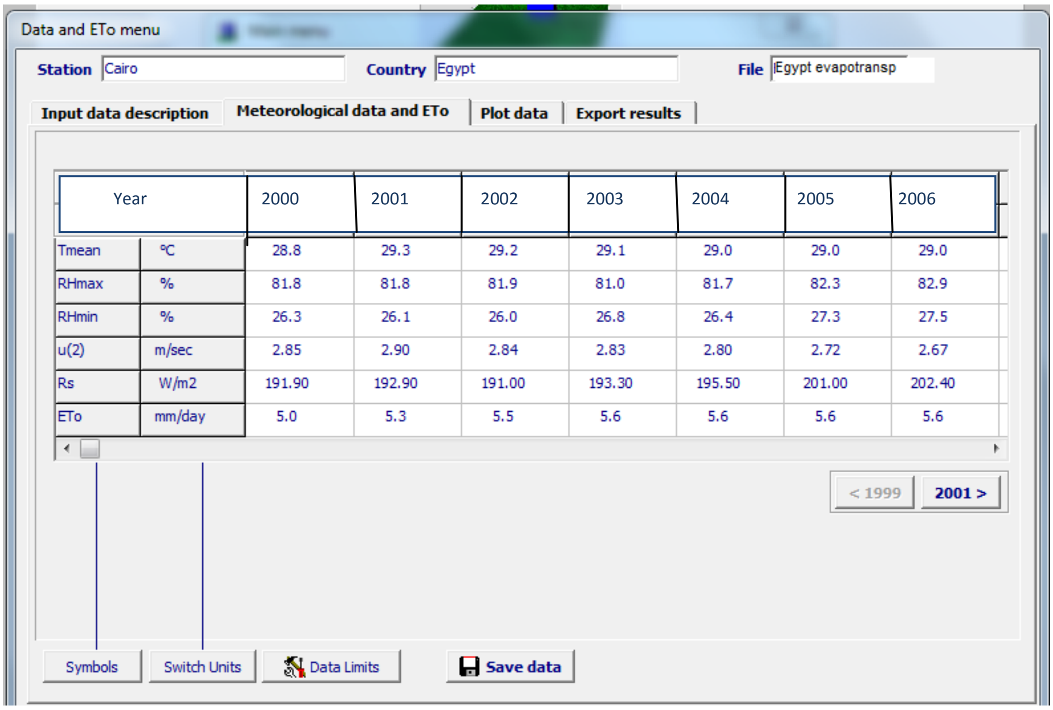


Figure 5. Choice for available meteorological parameters

Figures 6 and 7 represent results for reference evapotranspiration after applying ETo model using Penman-Monteith equation through 2000 to 2010



Year		2000	2001	2002	2003	2004	2005	2006
Tmean	°C	28.8	29.3	29.2	29.1	29.0	29.0	29.0
RHmax	%	81.8	81.8	81.9	81.0	81.7	82.3	82.9
RHmin	%	26.3	26.1	26.0	26.8	26.4	27.3	27.5
u(2)	m/sec	2.85	2.90	2.84	2.83	2.80	2.72	2.67
Rs	W/m2	191.90	192.90	191.00	193.30	195.50	201.00	202.40
ETo	mm/day	5.0	5.3	5.5	5.6	5.6	5.6	5.6

Figure 6. Values for evapotranspiration obtained from ETo calculator model for each studied years

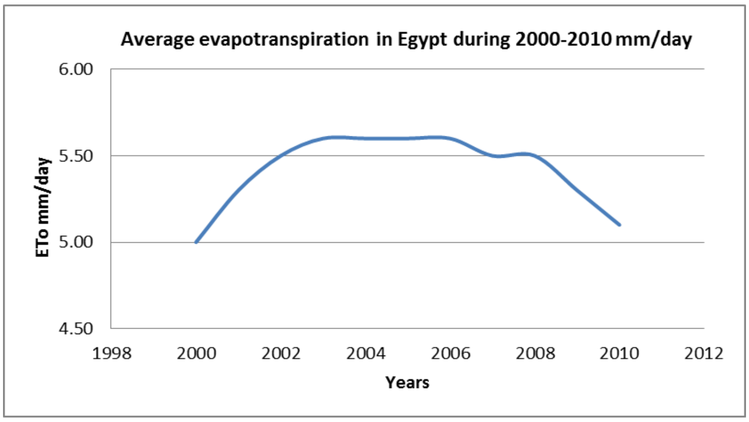


Figure 7. Final results for average reference evapotranspiration in mm/day during studied period

The computer curve fitting is used to derive the mathematical equation for each climatic parameter, trying to find few possible trend relations for parameters in the previous curves using excel regression methods the following can be concluded, and considering data quality control as a necessary step before analyzing their trends. According to obtained data Average wind speed m/s follow the polynomial equation $y=-12.97x^2+71.18x-92$, $R^2 = 0.14$, Solar radiation data is essential for estimating the ETo value, the polynomial trend line option in 10 years average of solar radiation in Egypt was $y = -0.006x^2+2.39x-232.11$, $R^2 = 0.50$.

Temperature characteristic is also analyzed which is used to compute the prevailing average distribution within the period of study. The polynomial trend equation obtained equal to y= -1.65x^2+96.4x-1404, R^2=0. 57, the relative humidity (RH %) expresses the degree of saturation of air, approximately the fit equation can be obtained for the plot of curve average relative humidity data in various years related to ETo with polynomial formula obtained y=-0.215x^2+23.57x-640 with R^2=0.38. The correlation coefficient, R^2 to measure the strength of the relationship between weather parameters and (ETo) mostly indicated values between 0.3 and 0.6 which mean moderate positive relationship via a fuzzy-firm linear rule, this also indicate the random existence in measured data, Fig. 8 represent correlation.

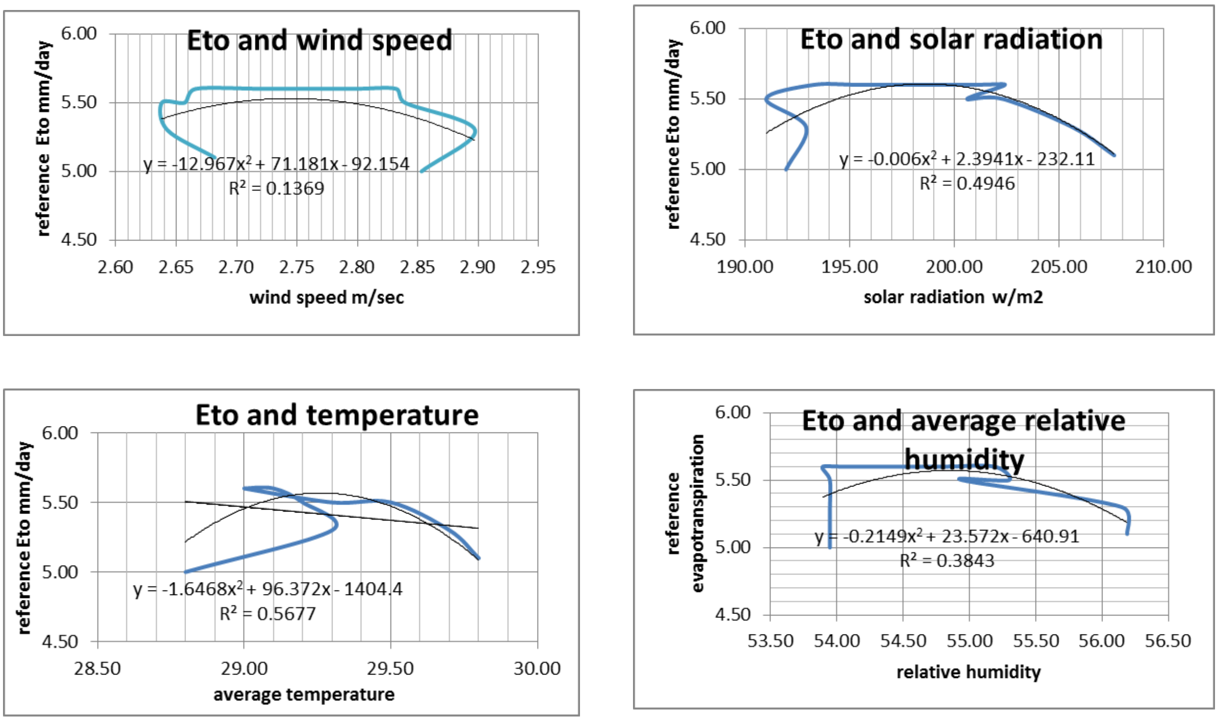


Figure 8. Trend relationship between weather parameters and (ETo)

A study by Fouad, K. and Samiha, O. 2011 through the period of 1997 to 2006, A CROPWAT model was used to calculate reference evapotranspiration (ETo), the minimum difference of evapotranspiration was equal to 4%, at year 2000, maximum difference was 15% as obvious in year 2004, there was 5 different stations locations, other reason to variation is the random results of few measured data, the stations data and obtained results for (ETo) are shown in tables 4, 5.

Table 4. Average values of weather parameters over the studied period for the 20 agricultural governorates

Governorate	**Latitude**	**Longitude**	**Elevation**	**MTemp**	**RH (%**	**WS (km/da**	**PSSH**
Lower							
Egypt North	31.07	33.45	17.10	20.6	79	252.4	9.3
Sinia	31.70	29.00	7.00	21.0	77	255.6	9.4
Alexandria	31.25	31.49	5.00	19.5	65	221.0	9.2
Demiatte	31.07	30.57	20.00	19.9	65	117.2	9.3
Kafr El-Sheik	31.03	31.23	7.00	21.7	66	126.2	9.1
El-	31.02	30.28	6.70	21.2	57	350.6	9.4
Dakahlia	30.47	32.14	14.80	21.9	63	72.1	9.3
El-Beheira	30.36	32.14	10.00	22.0	57	138.3	9.3
El-Gharbia	30.36	31.01	17.90	21.2	62	186.5	9.3
Ismailia	30.35	31.30	13.00	23.6	61	144.7	9.3
El-	30.28	31.11	14.00	21.9	58	187.2	9.3
Middle Egypt							
Giza	30.02	31.13	22.50	22.8	53	195.1	9.5
Fayoum	29.18	30.51	30.00	23.2	58	231.2	9.8
Beni	29.04	31.06	30.40	22.9	55	122.4	9.9
Swief El-	28.05	30.44	30.00	21.3	55	145.4	10.3
Upper Egypt							
Assuite	27.11	31.06	71.00	22.5	50	207.4	10.5
Souhg	26.36	31.38	68.70	22.4	53	159.1	10.5
Quena	26.10	32.43	72.60	24.2	39	126.2	10.7
Aswan	24.02	32.53	108.30	25.7	38	145.4	10.7
El-Wadi El-Gadid	25.26	30.34	72.70	25.7	42	103.7	10.5
Mean	--	--	--	22.3	58	174.4	9.7
Range	--	--	--	6.2	41	278.5	1.6

Table 5. Annual ETo values (mm/day) for the 20 agricultural governorates in Egypt

Gov	199	199	199	200	200	200	200	200	200	200	Avera
LE											
1	-	-	4.00	3.88	3.99	3.94	3.98	3.90	4.00	3.94	3.95
2	-	-	4.29	4.26	4.30	4.21	4.30	4.15	4.13	4.14	4.22
3	-	-	4.58	4.14	3.94	4.27	4.47	3.95	4.17	4.14	4.22
4	-	-	3.72	3.61	3.80	3.79	3.81	3.90	3.95	3.94	3.77
5	3.9	4.6	4.17	4.16	4.07	4.11	4.13	3.94	4.00	3.96	4.06
6	3	0	5.88	5.84	6.16	6.04	5.33	5.36	5.26	5.37	5.61
7	3.7	3.9	3.75	3.73	3.83	3.88	3.86	3.82	3.69	3.75	3.76
8	4	4	4.24	4.58	4.45	4.21	4.58	4.44	4.49	4.42	4.45
9	3.9	4.1	4.48	4.51	4.66	4.79	4.85	4.52	4.65	4.78	4.62
ME											
12	4.89	5.29	5.55	5.66	5.42	5.14	5.19	5.17	5.13	5.04	5.25
13	5.43	5.68	5.60	5.56	5.75	5.80	5.63	5.69	5.59	5.58	5.63
14	4.19	4.49	4.71	4.73	4.90	4.81	4.65	4.74	4.67	4.71	4.66
15	4.46	4.82	4.77	4.76	4.77	4.69	4.78	4.76	4.81	4.85	4.75
UE											
16	5.7	5.7	5.80	5.78	5.95	5.85	5.83	5.85	5.87	6.17	5.86
17	3	7	5.00	5.37	5.12	5.29	5.35	5.29	5.18	5.17	5.20
18	5.1	5.0	5.21	5.11	5.18	4.97	5.56	5.22	5.12	5.16	5.31
19	5	5	5.91	5.78	5.90	6.01	5.84	5.96	6.00	5.90	5.92
Average				4.81	4.85	4.81	4.82	4.75	4.75	4.77	

Gov= governorate; LE= Lower Egypt; 1= North Sinia; 2= Alexandria; 3= Demiatte; 4= Kafr El-Sheik; 5= El-Dakahlia; 6= El-Beheira; 7= El-Gharbia; 8= Ismailia; 9= El-Monofia; 10= El-Sharkia; 11= El-Kalubia; ME= Middle Egypt; 12= Giza; 13= Fayoum; 14= Beni Swief; 15= El-Minia; UE= Upper Egypt; 16= Assuite; 17= Souhag; 18= Quena; 19= Aswan; 20=El-Wadi El-Gedid

the Agricultural production area in general have been identified, obtained through the period of studied years from 2000 to 2010 by ministry of agricultural records and land reclamation, department of agriculture economy, [16]. To calculate the evabotranspiration as a water consumption in cubic meter in each year the referance evapotranspiration is multiblied by total cultivated area, results are represented in table 6. Data for major sustained crops as alfalfa, maize, rice, cotton and wheat including crop water needs, cultivated area, and average growing period for two years 2007, 2008 are shown in table 7. Egypt total evapotranspiration is the summation of ET over land including cultivated, ET over open water, and ET over wetlands; “Water Balance in the Nile Basin, (FAO)” [11], the reference evapotranspiration “ETo” is a large uniform grass field completely covers the soil, considered worldwide as a reference surface, which kept short, well watered and is actively growing under optimal agronomic conditions, but due to variation of crop patterns considering irrigation systems in 2 or 3 field rotations per year, the necessary to find routes to transport farmer equipment on field, the adaptation of crops to the conditions of the region 's agricultural cycles, these factors reflect that planted crops actually don’t cover all agriculture area as the large uniform grass and it is necessary to consider a crop evapotranspiration (ETcrop), and crop factor (Kc) in the calculations to have an accurate results for the total water volume needed in agriculture sector yearly, the relation equation Kc=ETc/ETo according to natural resources management and environment department, FAO, corporate 1986.this relation has been applied to find the crop factor for two years 2007, 2008 as obvious in table 8.

Table 6. Planted areas allover Egypt and corresponding reference evapotranspiration in million m^3 during studied years

YEAR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
ETo mm/d	5	5.3	5.5	5.6	5.6	5.6	5.6	5.5	5.5	5.3	5.1
planted A 1000 fed	7833	7946	8148	8113	8279	8385	8411	8423	8432	8783	8272
ETo Mm^3/y	60040	64560	68700	69648	71074	71984	72207	71019	71094	71361	64673

Table 7. Major crops cultivated area and water needs in two years 2007, 2008

		Cultivated area mill m^2							
Crop	Crop water need	2007	2008	crop water need million m^3			Average total growing period DAYS		
(mm/total growing period)									
Alfalfa	100-1000	16800	16800	9240	9240			230	
Barley/Oats/Wheat	450-650	11340	12180	6237	6699			135	
Bean	300-500	798	966	319.2	386.4			90	
Cotton	700-1300	1302	2394	1302	2394			187	
Maize	500-800	7560	8400	4914	5460			120	
Rice (paddy)	1000-1600	6720	7140	8736	9282			120	
Sorghum/Millet	450-650	1050	1050	577.5	577.5			115	
Sugarcane	1500-2500	1386	1386	2772	2772			300	
vegetable	600	8820	8400	5292	5040			120	
fruit	1000	5880	5880	5880	5880			140	
	sum	61656	64596	45269.7	47730.9			1557	

Table 8. Irrigated water depth and crop factor in two years 2007-2008

year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
area 1000 fed	7833	7946	8148	8113	8279	8385	8411	8423	8432	8783
area mm2	32898.6	33373.2	34221.6	34074.6	34771.8	35217	35326.2	35376.6	35414.4	36888.6
water mm3	48651	49352	50607	50390	51421	52079	52240	52315	53474	55700
Eto mm/day								5.5	5.5	5.3
irrigated w m								1.48	1.51	1.51
Et crop mm/d								4.052	4.137	4.137
Kc factor aver								0.737	0.752	0.781

Irrigated water depth meter/year = (Irrigated water million m^3/year)/ cultivated area million m^2
ETcrop mm/d= irrigated water depth m *1000/365

Crop factor average = ETcrop/ reference ETo.

Area mm^2: Cultivated area million m^2
Water mm^3: Irrigated water million m^3
Eto mm/day: Reference evapotranspiration millimeter per day
Irrigated w m: Irrigated water depth m
Kc factor aver: Average crop factor

4 CONCLUSIONS

- The FAO Penman-Monteith equation contains many terms that depend on climate parameters such as solar radiation, air temperature, relative humidity, psychrometric constant, vapor pressure, slope of saturated air vapor pressure curve and wind speed. To obtain better accurate results of (ETo) and suitable for the Nile Delta central zone of Egypt, these terms and parameters should be accurate.

- The daily data of meteorological terms in ETo model has been compensated by yearly average data within studied years.
- The comparison between evapotranspiration during the years (2000-2010) at the 20 studied weather stations revealed a general increase in evapotranspiration till years 2005, 2006 then slight decrease till 2010 by 0.09 **due to increase of maximum relative humidity and decrease in wind speed, temperature and solar radiation had dominant for values of ETo.**

- Evapotranspiration has direct proportion with temperature, solar radiation, and wind speed, also has reverse proportion with maximum relative humidity.

- Increasing average temperature and solar radiation to maximum recorded values would increase evapotranspiration by 0.02 during studied period
- Estimating Evapotranspiration (ETo) is one of the first important steps 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.
- Evapotranspiration in the southern part of Egypt at Aswan and Qena stations had the highest reference ETo this was evident due to increase in solar radiation and average temperature, lack of humidity, and the evapotranspiration in the northern part of Egypt at Alexandria and Damietta stations gave the lowest value of ETo.
- Crop factor is mainly affected by reference evapotranspiration and crop evapotranspiration

5 RECOMMENDATIONS

To ease the water crisis which is getting more worth in Egypt Nile delta, especially after increasing the agricultural and industrial development projects in the area, the available water resources have to be utilized in such a manner to protect and conserve the available water for irrigated agriculture; this is obtained through the effective management of water consumption. Therefore, the irrigation systems must apply water in the most efficient way possible to prevent unnecessary losses and water wastage. Accurate calculations of water requirements for different crops have also critical influence.

Water consumption under climate change in Egypt should be developed to mitigate the negative effects of climate change on evapotranspiration. Selection of better cultivation and the suitable developed irrigation system and crop pattern depending on protected agriculture are the most important factors for maximizing yield production.

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