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**RESEARCH ARTICLE**

**WATER CONSUMPTION VARIABILITY FOR MAJOR CROPS IN EGYPT UNDER CLIMATE
 CHANGE CONDITIONS.**

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*Water Consumption, Climate Change,
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Abstract

Egypt appears to be particularly vulnerable to climate change especially with water scarcity problem. Climate change not only affects the spatial and temporal distribution of water resources, but also will increase the crop evapotranspiration. The aim of this paper is to assess the impact of climate change on water consumptive use for six main major crops in Egypt (rice, summer potato, summer tomato, wheat, winter potato, and winter tomato). The climate change data has been developed from downscaling of global climate model ECHAM6 of scenario RCP. 4.5 by a horizontal resolution 50 km during the period from 2010 up to 2090, and the water consumption has been assessing at the governorates that have largest areas of determined crops distributed in different geographic regions. The obtained results indicate that, climate change conditions expected to increase water consumption for all examined regions in Egypt, and the most effect will be in Upper Egypt and specific areas in Lower Egypt region. The results also indicated to extreme increment [decrement] will effect during 2070 and 2080 [2050 and 2060] decades in Dakahlia [Aswan and Minya] governorates. Also the study concluded that, the impact of climate change on water consumption is limited and acceptable up to 2040 for the studied crops among the determined governorates and it not exceeded 5% than its current, however, after this period the rate of increment transit to higher level, and sharp extreme effects appeared in some regions.

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Introduction:-

Climate change is expected to exacerbate this situation by increasing potential evapotranspiration, decreasing rainfall and increasing the frequency and intensity of droughts (Nianget *al.*, 2014; IPCC, 2014). Temperature raise as projected by many climatological studies will lead to highly increased evapotranspiration on the territory of Egypt especially because of the traditionally irrigated agriculture. Besides, the projected high temperature would increase the local water demands especially on the agricultural sector. Limited water resources and scarcity of water in Egypt is the main challenge for agricultural horizontal expanding under current and future climate. All crops are projected to have a decrease in yields and an increase in irrigation needs. Some crops only decrease a few percent while others have a reduction of more than one-fourth (UNDP 2013). Egypt as an arid country relying on the Nile River which

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provides 95% of its water resources is suffering water stress due to the limited supplies and growing population, and increased competition on water from the upper Nile basin countries. Water management in Egypt is further pressured by uncertain climate change impacts on the Nile flow (Nour El-Din 2013). According to UNESCO around 70% of total used freshwater is consumed by agriculture. This number is even higher for Egypt and increases up to 77% in order to afford food security (El-Shirbenyet *et al.*, 2014). As such, Egypt faces many challenges of current and future water scarcity. Egypt has reached a state where the quantity of water available is imposing limits on its national economic development. As indication of scarcity in absolute terms, often the threshold value of 1000 m³/capita/year is used. Egypt has passed that threshold already in nineties. As a threshold of absolute scarcity 500 m³/capita/year is used, this will be evident with population predictions for 2025 which will bring Egypt down to 500 m³/capita/year (MWRI, 2014). Globally, around 70 percent of all freshwater withdrawals are used for food production. Over the past four decades, irrigation has undoubtedly contributed to an increase in global crop yields, allowing global food production to keep pace with population growth (United Nations 2006). Previous research was done in Egypt on the effect of climate change on water requirements for crops. It revealed that it will increase by 16% for summer crops compared to their current requirements under current conditions. Furthermore, climate change conditions could decrease water demand for winter crops up to 2% in the year of 2050 (Eid and El-Mowelhi, 1998). According to (Oudaet *et al.*, 2011) under temperature increase by 2°C, the total required water for agriculture in the Arabic countries will be increased by a percentage between 9% and 36%. The large variation in the previous percentage is mainly due to population growth and increasing demand for water assigned for agriculture. Also according to Oudaet *et al.* (2011) developed a prediction equation to calculate total water requirements needed to support irrigation in Egypt in 2025 and concluded that an increase by 33% is expected to occur. Oudaet *et al.* (2015) indicated that annual PET values will increase by 8% and water requirements for wheat and maize will increase by 2 and 15%, respectively in 2040 at El-Behira governorate (North Egypt). The objective of the present study is to evaluate the water requirements of key crops in Egypt under climate change in Egypt

Material and Methods:-

Study area:-

The study was carried out on the governorate which have largest cultivated area distributed in different geographic regions (Lower, Middle, and Upper Egypt) of determined crops. Governorates have been selected based on the Bulletin of the Agricultural Statistics (BAS) 2013 and 2014.

Climate data:-

The climate change data has been developed from downscaling the global climate model (ECHAM6) of scenario RCP (Representative Concentration Pathways). 4.5 by a horizontal resolution 50 km using regional climate model (RegCM 4). The climate parameters of (temperature, relative humidity, solar radiation, wind speed, and precipitation) have been exported and processed from 2010 up to 2090 to calculate evapotranspiration and water consumption.

Water consumption:-

Assessing the water consumption ET_c for six strategic crops representing both summer and winter season (Rice, summer potato, summer tomato, wheat, winter potato, and winter tomato) under climate change in Egypt had been done according to equation (1). The averages of results for each 10 seasons were calculated to study the effect of climate change on the water consumption for selected crops.

$$ET_c = k_c \times ET_o \quad (1);$$

Where ET_o is the reference evapotranspiration and has been estimated using FAO Penman-Monteith method (Allen *et al.* 1998), and K_c is the crop coefficient and has been determined according to growth stages of each crop.

Estimation of evapotranspiration:-

The FAO Penman-Monteith method is recently recommended as the sole standard method when all data required are available (Allen *et al.*, 1998). It is a method with strong likelihood of correctly predicting ET_o in a wide range of locations and climates. The FAO Penman-Monteith method to estimate ET_o is expressed as:

$$ET_o = \frac{0.408\Delta (R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

Where E_{To} = reference evapotranspiration (mm day^{-1}); R_n = net radiation at the crop surface ($\text{MJ m}^{-2} \text{Day}^{-1}$); G = soil heat flux density ($\text{MJ m}^{-2} \text{day}^{-1}$); T = mean daily air temperature at 2 m height ($^{\circ}\text{C}$); U_2 = wind speed at 2 m height (m s^{-1}); e_s = saturation vapour pressure (KPa); e_a = actual vapour pressure (KPa); $e_s - e_a$ = saturation vapour pressure deficit (KPa); Δ = slope vapour pressure curve ($\text{KPa } ^{\circ}\text{C}^{-1}$); γ = psychrometric constant ($\text{KPa } ^{\circ}\text{C}^{-1}$);

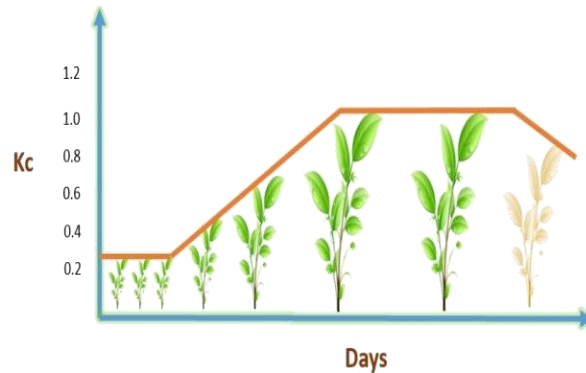


Figure (1): Crop coefficient K_c variation curve according to crop growth stages.

Crop coefficient (K_c) for different main crops:-

The project of K_c was introduced by Jensen (1968) and further developed by the other researchers (Doorenbos and Pruitt, 1975, 1977; Burman *et al.*, 1980a, Burman *et al.*, 1980b; Allen *et al.*, 1998). The crop coefficient is the ratio of the potential crop evapotranspiration (E_{Tc}) to reference crop evapotranspiration (E_{To}) and it integrates the effects of characteristics that distinguish field crops from grass, like ground cover, canopy properties and aerodynamic resistance.

The FAO and WMO (World Meteorological Organization) experts have summarized such evolution in the “crop coefficient curve” to identify the K_c value corresponding to the different crop development and growth stages (initial, middle and late, hence it has $K_{c\text{ in}}$, $K_{c\text{ mid}}$, $K_{c\text{ end}}$) (Tarantino and Spano, 2001). Values of K_c for most agricultural crops increase from a minimum value at planting until maximum K_c is reached at about full canopy cover.

The K_c tends to decline at a point after a full cover is reached in the crop season. The declination extent primarily depends on the particular crop growth characteristics (Jensen *et al.*, 1990) and the irrigation management during the late season (Allen *et al.*, 1998).

Results and Discussion:-

Evapotranspiration values:-

The results of this study divided into averages each ten years during the seasons from (2011-2090) at the studied governorates for the selected crops.

Evapotranspiration values ($\text{m}^3/\text{feddan}^1$) at the studied governorates for the selected crops are shown in table (1) and it has been indicated that, the evapotranspiration directed to increase in the future in all studied governorates taking in the consideration the geographic locations level (lowest values in Lower Egypt and highest values in Upper Egypt).

Also it has been observed an extreme increment in E_{to} values at Dakahlia during 2070 and 2080 decades even it exceeded upper Egypt values, and at Gharbia during 2060 decade, and an extreme decrement at Minya during 2060 decade and at Aswan during 2050 decade.

¹ 1 feddan = 42000 m^2

Table 1:- Average evapotranspiration values (m³/feddan) each 10 years for the years from 2011 up to 2090.

	2011 - 2020	2021 - 2030	2031 - 2040	2041 - 2050	2051 - 2060	2061 - 2070	2071 - 2080	2081 - 2090
Alexandria	6.3	6.5	6.4	6.5	6.6	6.7	6.6	6.8
Behera	6.3	6.4	6.4	6.4	6.5	6.6	6.6	6.7
Kafr El-sheikh	6.3	6.4	6.4	6.5	6.5	6.6	6.6	6.7
Ismailia	6.5	6.6	6.7	6.7	6.8	6.9	6.9	7.0
Dakahlia	6.5	6.6	6.7	6.7	6.8	7.2	10.0	9.6
Monufia	6.7	6.8	6.8	6.9	7.0	7.1	7.1	7.2
Gharbia	6.8	6.9	6.9	7.0	7.1	7.7	7.2	7.3
Sharqia	6.9	7.0	7.0	7.1	7.1	7.3	7.3	7.4
Faiyum	7.1	7.2	7.2	7.3	7.4	7.5	7.5	7.6
Beni Suef	7.2	7.3	7.3	7.4	7.5	7.6	7.6	7.7
Giza	7.3	7.4	7.4	7.5	7.6	7.7	7.7	7.8
Minya	7.6	7.6	7.7	7.7	7.7	6.8	8.0	8.1
Asyut	7.7	7.7	7.9	7.9	8.0	8.1	8.2	8.2
Sohag	8.6	8.6	8.7	8.7	8.9	9.0	9.0	9.1
Qena	8.5	8.5	8.7	8.6	8.8	9.0	9.0	9.0
Aswan	9.4	9.5	9.6	9.4	8.1	9.9	9.9	9.9

Red cells are the extreme increment, and blue cells are the extreme decrement.

Water consumption for selected summer crops:-

Rice:-

Rice crop has been studied in five governorates which are Dakahlia, Kafr El-sheikh, Sharqia, Behera, and Gharbia according to Ministry of Supply and Ministry of Water Resources and irrigation in collaborate with Ministry of Agriculture determination in 2016 (**Parlmany**²⁰¹⁶²). Table (2) shows the water consumption of rice during the seasons from (2011-2090) divided into averages each ten years of study period and it has been observed that, Sharqia governorate is the highest water consumption in current and future condition up to 2070 season and after this time Dakahlia governorate jumped to highest results among the studied governorates during the study period, while Kafr El-sheikh kept its position the lowest rice water consumption in current and under future condition. Also it has been found that, water consumption is increasing with time and the period of (2011-2020) has the lowest values in all governorates among the studied periods while the highest one was (2061-2070) in all governorates except in Dakahlia which shows its highest water consumption during the (2071-2080) period. The changing rate has been calculated in relative to (2011-2020) period and the result has been shown in figure (2) which indicated that, all periods of studied governorate will increase than (2011-2020) period, however, (2061-2070) is a milestone period than its pervious where the increment rate has been ranged from 2 up to 7% greater than the base period during the seasons from 2021 up to 2060 while has been ranged from 7 up to 23% after this period and continued in this range up to 2090. Also it has been observed an extreme increment in Dakahlia governorate after 2070 season and its rate was above 50% than base period from 2071 up to 2090.

²<http://www.parlmany.com/News/10/80754/%D8%AA%D8%B9%D8%B1%D9%81-%D8%B9%D9%84%D9%89-%D8%A7%D9%84%D9%85%D8%AD%D8%A7%D9%81%D8%B8%D8%A7%D8%AA-%D8%A7%D9%84%D9%85%D8%B3%D9%85%D9%88%D8%AD-%D9%84%D9%87%D8%A7-%D8%A8%D8%B2%D8%B1%D8%A7%D8%B9%D8%A9-%D8%A7%D9%84%D8%A3%D8%B1%D8%B2-%D9%88%D9%85%D8%A7-%D9%87%D9%89-%D8%A7%D9%84%D8%B9%D9%82%D9%88%D8%A8%D8%A9>

Table 2:-Average water consumption amount (m³/feddan) for rice crop in the periods form (2011-2020) up to (2081-2090)³.

Rice Crop					
Date	Dakahlia	Kafr El-sheikh	Sharqia	Behera	Gharbia
2011 - 2020	3638	3410	3828	3476	3767
2021 - 2030	3713	3488	3898	3550	3840
2031 - 2040	3730	3505	3924	3557	3868
2041 - 2050	3744	3518	3927	3575	3868
2051 - 2060	3837	3605	4028	3668	4020
2061 - 2070	4112	3680	4100	3739	4628
2071 - 2080	5737	3652	4077	3711	4020
2081 - 2090	5470	3669	4080	3722	4016

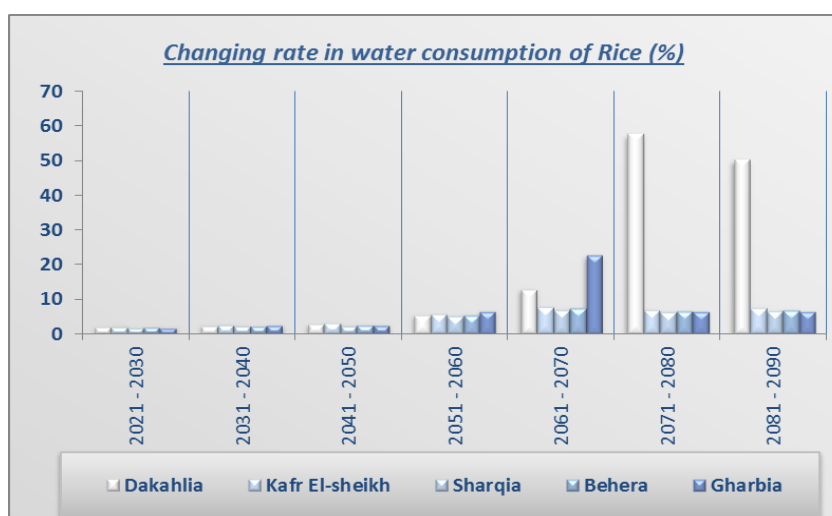


Figure 2:-Changing rate percentage than (2011-2020) in water consumption of rice at selected governorates.

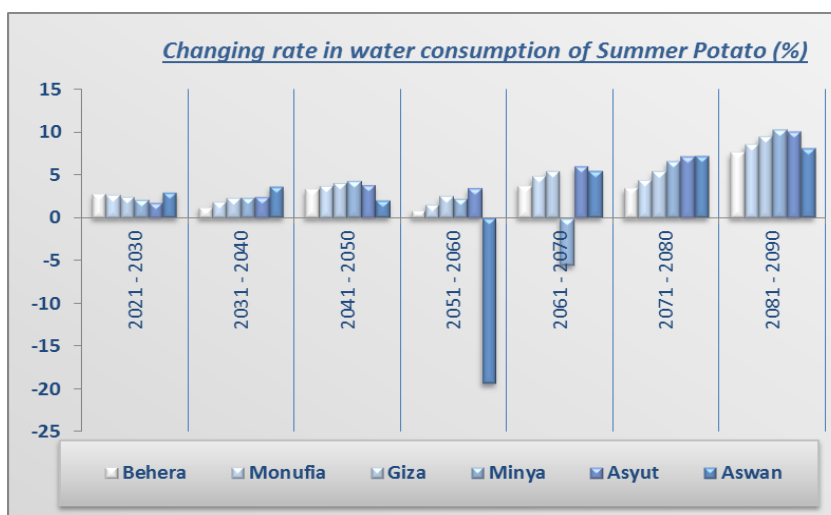
Summer Potato:-

Potato of summer season has been studied in the governorates of Behera&Monufia in Lower Egypt, Giza &Minya in Middle Egypt, and Asyut &Aswan in Upper Egypt which are the highest agricultural area in each region according to (BAS, 2013) Table (3) shows the water consumption of summer potato during the seasons from (2011-2090) divided into averages each ten years of study period and it has been observed that, water consumption is increasing with time and the (2011-2020) period has the lowest values in all governorates except in Minya and Aswan where their lowest values has been observed in (2061-2070) and (2051-2060) periods respectively, while the highest water consumption was found in the period of (2081-2090) at all studied governorates. The changing rate has been also calculated in relative to (2011-2020) period and the result has been shown in figure (3) which indicated that, all periods of studied governorate will increase than (2011-2020) period except Aswan which will decrease its water consumption about 20% in 2050 decade and Minya which will decrease also by 6 % than base period. The highest increment rate than base period found in 2080 decade and it was ranged between 8 to 10%, while the lowest rate found in 2020 decade by values ranged from 2 to 3%. The lowest governorate affected by climate change condition in water consumption of summer potato was Behera while the highest one was Asyut governorate.

³Colored cells indicate to Highest (orange cell) and lowest (blue cells) water consumption each 10 seasons for the selected crops

Table 3:-Average water consumption amount (m³/feddan) for summer potato in the periods form (2011-2020) up to (2081-2090).

Summer Potato						
Date	Behera	Monufia	Giza	Minya	Asyut	Aswan
2011 - 2020	1954	2088	2250	2303	2337	3084
2021 - 2030	2009	2145	2305	2352	2379	3174
2031 - 2040	1979	2128	2302	2358	2395	3197
2041 - 2050	2020	2166	2341	2403	2425	3146
2051 - 2060	1971	2121	2307	2354	2418	2486
2061 - 2070	2028	2189	2374	2175	2477	3252
2071 - 2080	2023	2180	2373	2455	2504	3307
2081 - 2090	2103	2266	2463	2540	2573	3333

**Figure 3:-**Changing rate percentage than (2011-2020) in water consumption of summer potato at selected governorates.**Summer Tomato:-**

Tomato of summer season has been studied in the governorates of Alexandria & Behera in Lower Egypt, Giza & Minya in Middle Egypt, and Asyut & Sohag in Upper Egypt which are the highest agricultural area in each region according to (BAS, 2013)

Table (4) shows the water consumption of summer tomato during the seasons from (2011-2090) divided into averages each ten years of study period and it has been observed that, the highest water consumption was found in (2061-2070) period at all studied governorates except in Minya where its highest value was found in (2081-2090) period, while the lowest values has not been observed in specific period where it was in (2031-2040) period at Alexandria and Giza governorates, in (2011-2020) at Behera governorate, in (2061-2070) at Minya governorate, in (2021-2030) at Asyut and Sohag governorates.

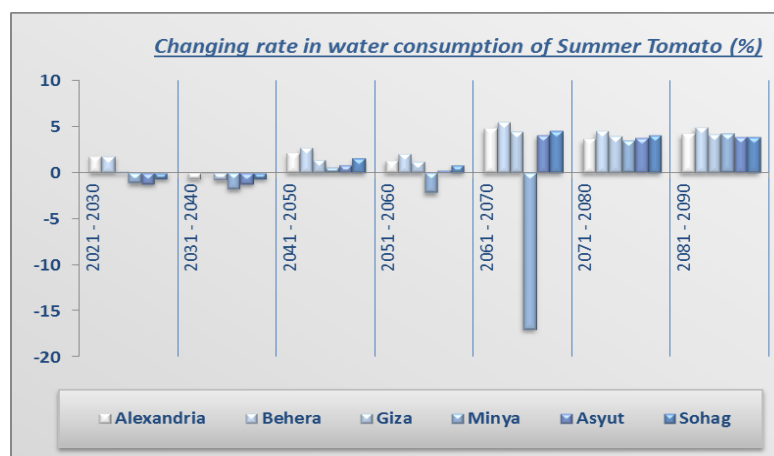
Table 4:-Average water consumption amount (m³/feddan) for summer tomato crop in the periods form (2011-2020) up to (2081-2090).

Summer Tomato						
Date	Alexandria	Behera	Giza	Minya	Asyut	Sohag
2011 - 2020	2596	2571	3037	3181	3224	3514
2021 - 2030	2642	2617	3044	3145	3184	3491
2031 - 2040	2579	2573	3012	3125	3184	3491
2041 - 2050	2651	2640	3079	3198	3252	3569
2051 - 2060	2631	2623	3074	3110	3233	3542
2061 - 2070	2721	2711	3171	2640	3355	3671
2071 - 2080	2690	2687	3157	3291	3344	3657
2081 - 2090	2705	2697	3164	3317	3348	3650

The changing rate has been also calculated in relative to (2011-2020) period and the result has been shown in figure (4) which indicated that, the water consumption of decades 2040, 2070, and 2080 will increase than base period at all studied governorates and the rate of increment was the highest in 2080 decade where it ranged between 4-5 %, while it was the lowest in 2040 decade and ranged between 1-3 %.

Also it has been observed that water consumption of summer tomato will decrease than base period at all studied governorates by values ranged between 1-2% in 2030 decade, in addition the results indicated to extreme decrement projected in Minya governorate in 2060 decade and it was about more than 15% lower than base period.

The highest governorate affected by climate change condition in water consumption of summer tomato was Behera while the lowest one was Minya governorate, and it's worth to mentioning that water consumption of summer tomato in Upper Egypt governorates will decrease in 2020 and 2030 period and starting its effect by increase after 2030.

**Figure 4:-**Changing rate percentage than (2011-2020) in water consumption of summer tomato at selected governorates.

Water consumption for selected winter crops:-

Wheat:-

Wheat crop has been studied in the governorates of Sharqia&Behera in Lower Egypt, Faiyum&Minya in Middle Egypt, and Asyut &Sohag in Upper Egypt which are the highest agricultural area in each region according to (BAS, 2013) Table (5) shows the water consumption of wheat during the seasons from (2011-2090) divided into averages each ten years of study period and it has been observed that, water consumption of wheat crop is increasing with

time and (2011-2020) period has the lowest values in all studied governorates except Minya which observed its lowest vale in (2061-2070) period, while the highest wheat water consumption has been observed in (2081-2090) period in all studied governorates. Also it has been found that Behera and Sohag governorate were the lowest and highest wheat water consumption in current and future condition respectively.

Table 5:-Average water consumption amount (m³/feddan) for wheat crop in the periods form (2011-2020) up to (2081-2090).

Wheat						
Date	Sharqia	Behera	Faiyum	Minya	Asyut	Sohag
2011 - 2020	1877	1703	1885	2017	2042	2291
2021 - 2030	1919	1750	1921	2048	2074	2337
2031 - 2040	1910	1718	1923	2047	2085	2353
2041 - 2050	1924	1744	1929	2057	2091	2359
2051 - 2060	1897	1705	1922	2013	2074	2343
2061 - 2070	1958	1757	1991	1822	2163	2427
2071 - 2080	1978	1777	2007	2137	2180	2464
2081 - 2090	2023	1820	2064	2212	2238	2507

The rate of change in wheat water consumption in relative to (2011-2020) period has been calculated and the result has been shown in figure (5) which indicated that, the water consumption of wheat crop will increase than base period in all studied governorates during study period except in Minya of 2060 decade which decrease its water consumption about 10% than base period. The rate of increment was lowest in 2050 decade where it has been ranged between 0 - 2%, while it was the highest in 2080 decade and has been ranged between 7 - 10% among the studied governorates.

The lowest governorate affected by climate change condition in water consumption of wheat crop was Behera while the highest effect has been observed in Sohag governorates.

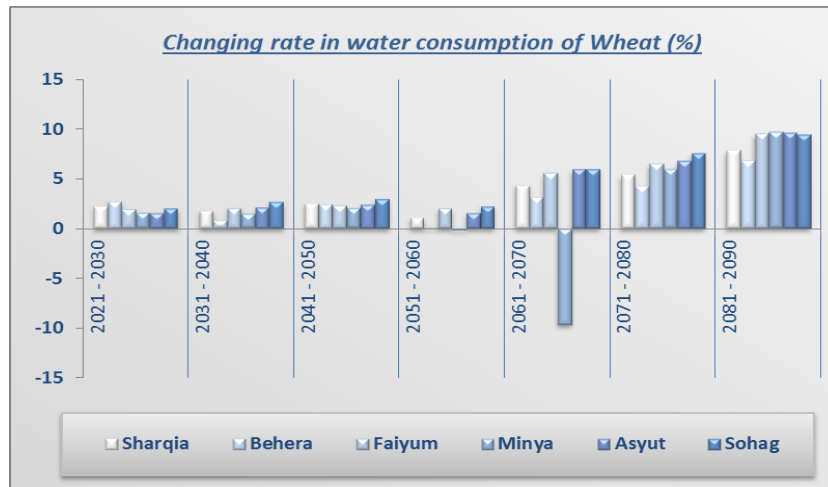


Figure 5:-Changing rate percentage than (2011-2020) in water consumption of wheat crop at selected governorates.

Winter Potato:-

Potato crop of winter season has been studied in the governorates of Dakahlia&Behera in Lower Egypt, BeniSuef& Giza in Middle Egypt, and Sohag& Aswan in Upper Egypt which are the highest agricultural area in each region according to (BAS, 2013) Table (6) shows the water consumption of winter potato during the seasons from (2011-2090) divided into averages each ten years of study period and it has been observed that, the lowest water consumption of winter potato has been observed during (2011-2020) period in Dakahlia and Middle Egypt

governorates, and not determined to specific period in the upper Egypt governorates, while the highest water consumption has been observed during (2081-2090) period in all governorates. Also it has been found that Behera and Aswan governorate were the lowest and highest winter potato water consumption in current and future condition respectively.

Table 6:-Average water consumption amount (m³/feddan) for winter potato crop in the periods form (2011-2020) up to (2081-2090).

Winter Potato						
Date	Dakahlia	Behera	Beni Suef	Giza	Sohag	Aswan
2011 - 2020	1281	1231	1340	1401	1645	1904
2021 - 2030	1305	1248	1367	1426	1632	1952
2031 - 2040	1304	1247	1388	1442	1683	1975
2041 - 2050	1337	1285	1447	1497	1709	1956
2051 - 2060	1291	1236	1403	1443	1728	1549
2061 - 2070	1334	1273	1418	1471	1717	2001
2071 - 2080	1854	1224	1398	1442	1715	2010
2081 - 2090	1910	1297	1473	1524	1768	2028

The rate of change in water consumption of winter potato in relative to (2011-2020) period has been calculated and the result has been shown in figure (6) which indicated that, Dakahlia governorate is most affected by climate change condition in 2070 and 2080 decades where the water consumption during them has been increased by about 45 and 50 % than the base period, also it has been found that the decrement rate that observed in Aswan during 2050 decade has been reached to about 20% lower than the base period and it's worth to mention that the increment rate of Lower Egypt governorate during this decade also is negligible. The lowest governorate affected by climate change condition in terms of water consumption was Behera while the highest effect, if we ignore the Dakahlia extreme, will be in Aswan governorate.

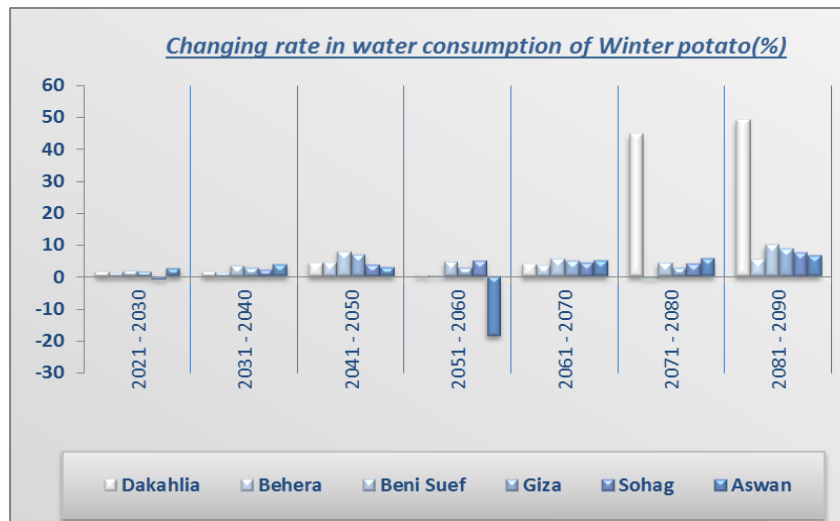


Figure 6:-Changing rate percentage than (2011-2020) in water consumption of winter potato crop at selected governorates.

Winter Tomato:-

Tomato crop of winter season has been studied in the governorates of Sharqia& Ismailia in Lower Egypt, Faiyum& Giza in Middle Egypt, and Qena&Sohag in Upper Egypt which are the highest agricultural area in each region according to (BAS, 2013) Table (6) shows the water consumption of winter tomato during the seasons from (2011-2090) divided into averages each ten years of study period and it has been observed that, water consumption of winter tomato is increasing with time and (2011-2020) period has the lowest values, while the highest water

consumption has been observed in (2081-2090) period in all studied governorates. Also it has been found that Ismailia and Sohag governorate were the lowest and highest winter tomato water consumption in current and future condition respectively.

Table 6:-Average water consumption amount (m^3 /feddan) for winter tomato in the periods form (2011-2020) up to (2081-2090).

Winter Tomato						
Date	Sharqia	Ismailia	Faiyum	Giza	Qena	Sohag
2011 - 2020	1658	1550	1628	1706	1960	1992
2021 - 2030	1689	1604	1669	1745	1972	2002
2031 - 2040	1713	1620	1699	1775	2039	2069
2041 - 2050	1736	1626	1736	1807	2021	2068
2051 - 2060	1704	1599	1708	1782	2088	2111
2061 - 2070	1720	1607	1724	1799	2076	2102
2071 - 2080	1702	1591	1712	1777	2086	2123
2081 - 2090	1782	1697	1789	1860	2140	2161

The rate of change in water consumption of winter tomato in relative to (2011-2020) period has been calculated and the result has been shown in figure (7) which indicated that, the water consumption of tomato crop will increase than base period in all studied governorates during study period. The rate of increment was lowest in 2020 decade where it has been ranged between 1 - 3%, while it was the highest in 2080 decade and has been ranged between 7 - 10% among the studied governorates.

The lowest governorate affected by climate change condition in water consumption of tomato crop was Sharqia while the highest effect has been observed in Faiyum governorates.

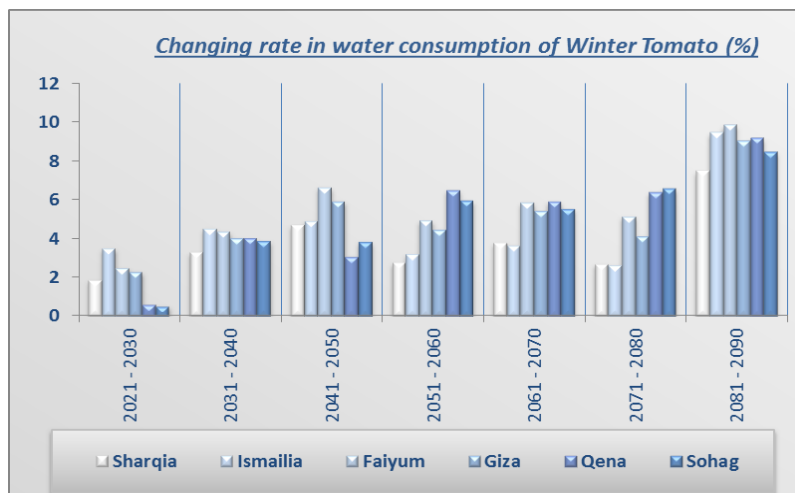


Figure 7:- Changing rate percentage than (2011-2020) in water consumption of winter tomato crop at selected governorates.

In general, these results are in accordance with (Khalil A.A.,2013) which recorded that, the evapotranspiration increased under climate change in Egypt. Water consumption under climate change in Egypt should be developed to mitigate the negative effects of climate change on evapotranspiration. (Gamal El Afandi and Mohamed Abdrabbo, 2015) evaluated the reference evapotranspiration equations under current climate conditions of Egypt and found that Egypt had divided into three agro-climatic regions (Nile Delta in the north, middle and Upper Egypt) according to the mean annual temperature (1971-2000) and the reference evapotranspiration measurements (1998-2007). Also similar results obtained by (Abdrabbo M. A. A. et al. 2013) who reported that under climate change

conditions, achieving greater water productivity is the primary challenge for scientists in agriculture. Therefore, changing irrigation schedule could provide a cheap and easy to implement irrigation management techniques to relief the harm effect of climate change, with no additional economic costs.

Similar predictions was reported by (Abdrabbo M. A. A., *et al.* 2016) who mentioned that the irrigation requirements increased depending on climatic region and climate change scenarios and the expected climate changes in Egypt according to the RCPs scenarios will cause an increase in annual ETo depending on the climate region. In the same line (Frag A.A. *et al.* 2015) study the impact of climate change on irrigation water Demand for rice crop in Kafr el-sheikh Governorate, and they found that the total amount of irrigation water demands increased per feddan per year ranging from 348 to 1370 m³ in Kafr El-Sheikh Governorate under different climate change RCP scenarios and water budget under climate change scenarios in the same Governorate will increase, ranging from 92 to 354 million cubic meters.

More adaptation options need to be studied under Egyptian condition. Climate change not only affects the spatial and temporal distribution of water resources, but also will increase the crop evapotranspiration, heightening the instability and imbalance of the supply and demand of agriculture water resources (Oki and Kanae 2006; Piao *et al.* 2010). These options, if implemented, will save on the applied irrigation water, which can be used to irrigate new lands under climate change conditions, which will contribute in maintaining the current production (Ouda *et al.* 2016).

Conclusion:-

Finally, it is undoubtedly that irrigation water use pressure will further aggravate under future climate change and since surface irrigation is prevailing in Egypt with low application efficiency, it is important to test options to increase it. The results indicated that, climate change conditions expected to increase ET values for all governorates in Egypt, consequently, a water requirement which is most affected in Upper Egypt area and specific regions in Lower Egypt area. Also the extreme decrement will effect during 2050 and 2060 decades in Aswan and Minya governorates which may be good sign in terms of water requirement but should be study it in other terms where it may be negative condition for it, such as, pests and plant disease, Moreover, extreme increment will effect during 2070 and 2080 decades in Dakahlia governorate and so on all crops in it. Also the study conclude that, the impact of climate change is systematic and acceptable up to 2040 for the studied crops among the determined governorates and it does not exceeded 5% than its current condition, however, after this period the rate of increment transit to higher stage, sharp extreme effects appeared in some regions

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