

Water requirements for clover and cotton under climate change conditions.

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ABSTRACT

Water requirements for the clover and cotton crops under both current climate and climate change conditions in 2040 was calculated using Basic Irrigation Scheduling (BISm) model. Hargreaves-Samani equation is used to calculate ETo in case of only temperature data are input. ECHAM5 model (Roeckner *et al.* 2003) was used to develop A1B climate change scenario for each weather station in each governorate in 2040. The herein results indicated that climate change condition in 2040 is expected to increase ET values for all Egyptian Governorates and consequently crop water requirements will follow similar trend. Crop water requirements for the crops grown at Middle and Upper Egypt will be higher than those cultivated at Lower Egypt. Under climate change conditions, great competition on the limited water resources between economic sectors will be raised and agricultural activity is the most negatively affected sector.. The most important results could be as follows:-

- 1- Under climate change conditions the yearly ETo value is expected to increase by 8% in the Nile Delta for governorates that has a shore on Mediterranean Sea i.e. Alexandria, El-Behira, Kafr El-Sheik, El-Dakahlia and Demiatt. In the rest of Nile Delta Governorates, the percentage of increase was 9%. In Middle Egypt, the increase percentage reached to 11%. Furthermore, in Upper Egypt the increase percentage was between 11and 18%, where the highest increase percentage was 18% in Aswan.
- 2- The difference between ET under current climate and under climate change during clover growing season was low (4-5%). Starting from El-Gharbia governorate, the difference became higher (10%) and highest difference was found in Aswan which reached 15%.
- 3- The applied irrigation water for cotton under climate change conditions were higher than those under current climate conditions by 6 to 8% in the Nile Delta, 9% in Middle Egypt and 10-12% in Upper Egypt.

Based on the above results and to mitigate such problem, irrigation practices, in particular surface irrigation methods, must be change to be more effective to save irrigation water without significant reduction in output yields. The saved water could be oriented for establishing new agricultural societies in the newly reclaimed lands. In addition, it is very important to improve the production system via cultivated high – yielding crop varieties, proper sowing dates and applying suitable irrigation and fertilization management will be helpful in this respect.

Keywords: Climate change expected, Water requirements, Clover and cotton.

INTRODUCTION

The term crop water requirement is defined as the amount of water required to compensate the evapotranspiration loss from the cropped field (USDA, 1993). The ICID (2000) describes it as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or

irrigation so that it does not limit plant growth and crop yield. Furthermore, in estimating crop water requirements, efficiency of the irrigation system should be taken into account. ET_c accounts for variations in weather and offers a measure of the "evaporative demand" of the atmosphere. Whereas, crop coefficient (k_c) is a function of ET_c/ET (Snyder *et al.*, 2004). The k_c takes into account the relationship between atmosphere, crop physiology and agricultural practices (Lascano, 2000). Therefore, sowing date, which reflects the weather of a certain site and growing season could affect crop growth pattern and consequently affects the period of growth stages, value of k_c and growth period (Snyder *et al.*, 2004).

Worldwide cotton represents about 50% of the fiber used in textile industry. Water stress occurring during cotton growing season may reduce final lint yield and numerous studies have reported that the effect of water stress on cotton yield depends on the timing and severity of the drought. Water stress causes a decrease in fiber length and fiber immaturity (Ritchie *et al.*, 2004; McWilliams, 2004 and Mert, 2005). Furthermore, the strength and elongation factors in cotton were well correlated with soil water (Johnson *et al.*, 2002), where adequate soil water along with high ambient temperatures before and during boll development increased fiber maturity (Davidonis *et al.*, 2004).

Egyptian clover is the major winter forage crop cultivated in the Nile Valley and Delta. The crop occupies an area reached to 1.2 million feddans. The e.g. Egyptian clover is playing a vital role in the sustainability of Egyptian agriculture. where it is nourished the soils, suppressing weeds and providing a disease break in cereal-dominated crop rotations. In addition, it is a major forage crop for honey bees. It can be mowed several times for forage and then ploughed under as green manure, which helps to increase the organic matter content of the soil, thus improving soil physical, chemical and biological properties (El-Nahrawy, 2008).

As reported by Eid (2001), a temperature rise by 1°C may increase evapotranspiration (ET) rate by about 4-5%, while a rise of 3°C may increase ET rate by about 15%. Furthermore, Attaher *et al.*, (2006) and Khalil (2013) concluded that the future climate change will increase potential irrigation demands, due to the increase in evapotranspiration (ET) in 2100. In connection, Ouda *et al.*, (2011) developed prediction equations to calculate total water requirements needed to support irrigation in Egypt in 2025 and they found that an increase by 33% in water required for irrigation is expected to occur as a result of temperature increase by 2°C and population growth. Thus, crop production in Egypt will be highly vulnerable to climate change due to increase in its water requirements that will reduce cultivated area and consequently reduce total production.

The objective of this trial is to calculate water requirements for clover and cotton grown in 17 governorates in Egypt under current climate and under A1B climate change scenario in 2040 to find out the undesired prospective impacts upon the agricultural activities to develop the proper solution mitigating such problems.

MATERIALS AND METHODS

The studied area:

The studied area is composed of 17 governorates in the Nile Delta and Valley. Data of latitude, longitude and elevation above sea level for those Governorates are shown in Table 1. Clover is cultivated in all these governorates, whereas cotton is cultivated in the same governorates except Giza, Qena and Aswan.

The selected crops:

Planting and harvest dates under current climate for the studied crops in each of the 17 governorates were obtained from bulletins published by Agricultural Research Center. Clover is cultivated on 1st of October and harvested on 13th of April in all governorates, where its growing season is 195 days. Cotton is cultivated in 15th of March in Nile Delta and Middle Egypt and in 1st of March in Upper Egypt. Its season length is 200 days. The same planting date was assumed under climate change and harvest date was assumed to be one week earlier for both crops. Khalil *et al.* 2009 and Ouda *et al.* 2009 stated that growing season could be reduced by 7-12 days under climate change conditions.

Table 1: Latitude, longitude and elevation above sea level for Nile Delta and Valley Governorates.

Governorate	Latitude	Longitude	Elevation above sea level (m)
Alexandria	31.70°	29.00°	7.00
Damietta	31.25°	31.49°	5.00
Kafr El-Sheik	31.07°	30.57°	20.0
El-Dakahlia	31.03°	31.23°	7.00
El-Behira	31.02°	30.28°	6.70
El-Gharbia	30.47°	32.14°	14.80
El-Monofia	30.36°	31.01°	17.90
El-Sharkia	30.35°	31.30°	13.00
El- Kalubia	30.28°	31.11°	14.00
El-Giza	30.02°	31.13°	22.50
El-Fayoum	29.18°	30.51°	30.00
Beni Sweif	29.04°	31.06°	30.40
El-Minia	28.05°	30.44°	40.00
Assuit	27.11°	31.06°	71.00
Sohag	26.36°	31.38°	68.70
Qena	26.10°	32.43°	72.60
Aswan	24.02°	32.53°	108.30

Water requirements calculation:

The irrigation water need to be applied to the studied crops was estimated using BISM model (Snyder *et al.*, 2004). The BISM model calculates ET, crop kc, water depletion from root zone and schedules irrigation. Moreover, ET values can be directly input in the model. The BISM application calculates ET using the Penman-Monteith (P-M) equation (Monteith, 1965) as presented in FAO Irrigation and Drainage Paper (FAO 56) by Allen *et al.* (1998). If only

temperature data are input, Hargreaves-Samani equation is used to calculate ETo (Hargreaves and Samani, 1985). For ET calculations, the station latitude and elevation must be input. After calculating daily means per month, a cubic spline curve fitting subroutine is used to estimate daily ETo rates for the entire year. The model inputs are sowing and harvest dates (to calculate crop kc), irrigation frequency (to determine initial kc) and total water holding capacity and available water (to calculate water depletion from root zone). These values were obtained from previous research done in The Water Requirements and Field irrigation Research Department, Soils, Water and Environment Research Institute, Agricultural Research Center, Egypt (Table 2). The model then determines when irrigation needs to be applied and the required water amounts. The calculated amount of applied water by BISm model and the date of application are mainly depended on the water depletion from the crop root zone. It is worthy to mention that the model was used to calculate water requirements for the studied crops under current climate using averages weather data from 2003-2013, supplied by Water Requirements and Field irrigation Research Department, Soils, Water and Environment Research Institute, Agricultural Research Center, Egypt. Moreover, BISm model was used to calculate water requirements for the selected crops under climate change in 2040 under surface irrigation, where application efficiency is 60% (Abou Zeid, 2002).

Table 2: Soil water holding capacity and available water prevailed in each Governorate.

Governorate	Water holding capacity (m m ⁻¹)	Available water (m m ⁻¹)
Nile Delta		
Alexandria	0.373	0.206
Demiatte	0.376	0.222
Kafr El-Sheik	0.405	0.170
El-Dakahlia	0.395	0.196
El-Beheira	0.408	0.230
El-Gharbia	0.380	0.220
El-Monofia	0.418	0.232
El-Sharkia	0.420	0.210
El-Kalubia	0.400	0.218
Middle Egypt		
Giza	0.363	0.209
Fayoum	0.426	0.194
Beni Sweif	0.429	0.245
El-Minia	0.435	0.239
Upper Egypt		
Assuit	0.438	0.235
Sohag	0.446	0.244
Qena	0.454	0.293
Aswan	0.447	0.257

Climate change scenario:

ECHAM5 model (Roeckner *et al.*, 2003) was used to develop A1B climate change scenario for each weather station in each governorate in 2040.

The model is atmospheric oceanic general circulation model. The resolution of the model is 1.9 X 1.9 degrees.

RESULTS AND DISCUSSION

Evapotranspiration values:

The annual ET values under current climate and under A1b climate change scenario in 2040 are presented in Table 3. The results reveal that under climate change conditions the yearly ETo value is expected to increase by 8% in the Nile Delta for governorates that has a shore on Mediterranean Sea, i.e. Alexandria, El-Behira, Kafr El-Sheik, El-Dakahlia and Demiatte. In the rest of Nile Delta governorates, the percentage of increase and reached to 9%. In Middle Egypt, the increase percentage reached 11%. Furthermore, in Upper Egypt, the increase percentage was increased to be between 11-18%, where the highest increase percentage reached to 18% in Aswan, which was previously reported by Khalil (2013) who found that highest value of percentage of increase under climate change will occur in Aswan government.

Table 3. Annual value of ETo (mm day⁻¹) under current climate, under A1b climate change scenario and percentage of increase (PI).

Governorate	ET _o under current climate	ET _o under A1b	PI (%)
Nile Delta			
Alexandria	4.32	4.67	8
Demiatte	4.25	4.67	8
Kafr El-Sheik	4.28	4.74	8
El-Dakahlia	4.59	4.96	8
El-Behira	4.79	5.17	8
El-Gharbia	4.71	5.26	9
El-Monofia	4.83	5.33	9
El-Sharkia	4.38	4.77	9
El-Kalubia	5.01	5.44	9
Middle Egypt			
Giza	4.91	5.46	11
Fayoum	5.01	5.58	11
Beni Swief	4.94	5.49	11
El-Minia	4.66	5.17	11
Upper Egypt			
Assuit	5.76	6.40	11
Suhag	5.04	5.63	12
Qena	5.87	6.50	11
Aswan	7.01	8.29	18

Water requirement for clover:

Data in Table 4 indicated the both applied amount of irrigation water for clover under current climate and the value of water requirements and percentage of increase in 2040. The lowest percentage of increase (PI %) in WR for clover climate change condition was found in the governorates that has seashore on the Mediterranean Sea. In these governorates, the difference

between ET under current climate and under climate change during clover growing season was low and reached from 4 to 5%. Starting from El-Gharbia governorate, the difference between ET under current climate and under climate change became higher and comprised 10%. Whereas the highest value of PI % was found in Aswan, i.e. 15% (Table 4).

Table 4. Applied irrigation water for clover under current climate, under A1B climate change scenario and percentage of increase (PI%).

Governorate	Applied irrigation under current climate (mm)	Applied irrigation under estimated climate change (mm)	PI (%)
Nile Delta			
Alexandria	839	881	5
Demiatte	804	836	4
Kafr El-Sheik	816	857	5
El-Dakahlia	826	870	5
El-Behira	821	859	5
El-Gharbia	815	899	10
El-Monofia	853	935	10
El-Sharkia	872	958	10
El-Kalubia	891	976	10
Middle Egypt			
Giza	899	1002	11
Fayoum	885	980	11
Beni Sweif	879	985	12
El-Minia	861	959	11
Upper Egypt			
Assuit	959	1079	13
Sohag	937	1053	12
Qena	1008	1134	13
Aswan	1201	1376	15

Water requirements for cotton:

Cotton crop having long growing season, i.e. 200 days extended from March to September, which reflected on higher applied irrigation water under current climate and under climate change conditions. This long growing season will affect the percentage of increased between applied irrigation water under current climate and that under climate change conditions. The value of PI% was between 6 -8% in the Nile Delta and increased to be 9% in Middle Egypt. Moreover, it was between 10-12% in Upper Egypt (Table 5).

Table 5. Applied irrigation water for cotton under current climate, under A1B climate change scenario and percentage of increase (PI%).

Governorate	Applied irrigation under current climate (mm)	Applied irrigation under estimated climate change (mm)	PI (%)
Nile Delta			
Alexandria	1458	1547	6
Demiatte	1442	1550	7
Kafr El-Sheik	1433	1515	6
El-Dakahlia	1592	1697	7
El-Behira	1629	1732	6
El-Gharbia	1552	1653	7
El-Monofia	1647	1743	6
El-Sharkia	1677	1818	8
El-Kalubia	1640	1774	8
Middle Egypt			
Fayoum	1778	1938	9
Beni Sweif	1729	1884	9
El-Minia	1669	1702	9
Upper Egypt			
Assuit	1685	1860	10
Sohag	1572	1764	12

CONCOLUSION

The attained results indicated that climate change condition in 2040 is expected to increase ET values for all governorates in Egypt. As a consequence, water requirements are also increased. The lowest increase in water requirements were at the Nile Delta, compared to Middle Egypt and Upper Egypt.

Due to the Egyptian circumstance as located in semiarid region, more pressure will be put on water resources distribution between economic sectors under climate change, especially agriculture. Reduction in the amount of allocated irrigation water, increase in water requirements for crops and yield reduction under climate change conditions will worsen food security situation in Egypt. So, it is must to improve the performance of surface irrigation scheme as the prevailing method in conveying the water to the cultivated fields. Implementing such option will save appreciable amount of applied irrigation water, which can be oriented to irrigate new lands under climate change conditions. In addition, it is very important to revise and fix the production system for cultivated crops, in terms of the using high –yielding cultivars and applying the proper fertilizer and irrigation management could mitigate such problem.

REFERENCES

- Abou Zeid, K. 2002. Egypt and the World Water Goals, Egypt's statement in Johannesburg and beyond: The 2002 World Summit on Sustainable Development and the Rise of Partnership.
- Allen, R.G; M.E. Jensen; J.L. Wright and R.D. Burman 1998. Operational estimate of reference evapotranspiration. *Agron. J.* 81, 650-662.
- Attaher S.M; M.A. Medany; A.A. Abdel Aziz and A. El-Gindy 2006. Irrigation-water demands under current and future climate conditions in Egypt. *Misr. J. Ag. Eng.*, 23(4) : 1077-1089.
- Davidonis, G.H; A.S. Johnson,; J.A. Landivar and C.J. Fernandez 2004. Cotton fiber quality is related to boll location and planting date. *Agron. J.* 96, 42–47.
- Eid, H. M (2001). "Climate change studies on Egyptian Agriculture" Soils, Water and Environment research institute (SWERI) ARC, Ministry of Agriculture, Giza, Egypt.
- El-Nahrawy, M.A. 2008. Vital role of berseem in Egyptian agriculture. Ninth International Conference on Dry Land Development, Alexandria, Egypt.
- Hargreaves, G. L. and Z. A. Samani, 1985. Reference crop evapotranspiration from temperature. *Basin. Journal of the Irrigation and Drainage Division-ASCE*, New York, v. 111, n. 1, p. 113-124. [http://dx.doi.org/10.1061/\(ASCE\)0733-9437\(1985\)111:2\(113\)](http://dx.doi.org/10.1061/(ASCE)0733-9437(1985)111:2(113)).
- ICID-CIID 2000. Multilingual Technical Dictionary on Irrigation and Drainage. - CD Version September 2000, International Commission on Irrigation and Drainage, New Dehli.
- Johnson, R.M; R.G. Downer; J.M. Bradow; P.J. Bauer and E.J. Sadler 2002. Variability in cotton fiber yield, fiber quality, and soil properties in a southeastern coastal plain. *Agron. J.* 94, 1305–1316.
- Khalil, A. A. 2013. Effect of climate change on evapotranspiration in Egypt. *Researcher*, 5(1): 7-12.
- Khalil, F.A.; H. Farag; G. El Afandi and S.A. Ouda 2009. Vulnerability and adaptation of wheat to climate change in Middle Egypt. 13th Conference on Water Technology, 12-15 March, Hurghada, Egypt, pp: 71-88.
- Lascano, R.J. 2000. A general system to measure and calculate daily crop water use, *Agronomy Journal*, 92, 821–832.
- McWilliams, D. 2004. Drought Strategies for Cotton. Cooperative Extension Service Circular 582 College of Agriculture and Home Economics (available on-line at: <http://www.cahe.nmsu.edu/pubs/circulars>. Verified on 15 October 2007).
- Mert, M. 2005. Irrigation of cotton cultivars improves seed cotton yield, yield components and fiber properties in the Hatay region, Turkey. *Acta Agric. Scand. B* 55, 44–50.
- Monteith, J. L. 1965. Evaporation and environment. In: G. E. Fogg (Ed.), *Symposium of the Society for Experimental Biology: The State and Movement of Water in Living Organisms*, 19: 205–234. Academic Press, Inc., NY.

- Ouda, S.; F. Khalil; G. El Afendi and S. Abd El-Hafez 2011. Prediction of total water requirements for agriculture in the Arab World under climate change. 15th International Water Technology Conference. 1150-1163.
- Ouda, S; F. Khalil and H. Yousef 2009. Using adaptation strategies to increase water use efficiency for maize under climate change conditions. 13th Int Conf on Water Technology. Hurghada, Egypt. 12-15 March.
- Ritchie, G.L; C.W. Bednarz; P.H. Jost and SM. Brown 2004. Cotton growth and development.Cooperative Extension Service and The University of Georgia, College of Agricultural and Environmental Sciences Bulletin 1252.
- Roeckner, E.; G. B"aumli; L. Bonaventura; R. Brokopf; M. Esch; M. Giorgetta; S. Hagemann; I. Kirchner; L. Kornblueh; E. Manzini; A. Rhodin; U. Schulzweida and A. Tompkins 2003. The atmospheric general circulation model ECHAM5, part I: Model description, Report 349, Max Planck Institute for Meteorology, Hamburg.
- Snyder, R. L; M. Orang; K. Bali and S. Eching 2004. Basic Irrigation Scheduling (BIS).
http://www.waterplan.water.ca.gov/landwateruse/wateruse/Ag/CUP/California/Climate_Data_010804.xls.
- USDA, Soil Conservation Service 1993. Irrigation Water Requirements. National Engineering Handbook (NEH), Part 623, Chapter 2, National Technical Information Service.

الاحتياجات المائية لمحصولي البرسيم و القطن في مصر تحت ظروف تغير المناخ سميحة ابو الفتوح عودة ، محمد محمود عويس و محمود ابراهيم بدوي قسم بحوث المقننات المائية والري الحقلية - معهد بحوث الأراضي والمياه والبيئة

الغرض من هذا البحث تقدير مدى تأثير الاحتياجات المائية لمحصولي البرسيم والقطن تحت ظروف تغير المناخ في مصر عام ٢٠٤٠. تم حساب الاحتياجات المائية للمحصولين تحت الظروف المناخية الحالية وكذلك تحت ظروف التغير المناخي بالمحافظات المصرية بدلتنا ووادي نهر النيل باستخدام موديل (Roeckner *et al.*, 2003) ECHAM5 والاحتياجات المائية تحت ظروف كل محافظة علي حدة. يمكن تلخيص أهم النتائج فيما يلي:-

١- من المتوقع في عام ٢٠٤٠ زيادة قيم البخر- نتح السنوي ب ٨% عما هو عليه الآن بمحافظات دلتا النيل(اسكندرية، البحيرة، كفر الشيخ، الدقهلية ودمياط) وباقي محافظات الدلتا تصل الزيادة الي ٩% في محافظات مصر الوسطي (الجيزة، الفيوم، بني سويف والمنيا) تصل الزيادة في قيم البخر- نتح السنوي الي ١١% بينما تزيد الي ١١-١٨% بمحافظات مصر العليا (أسيوط، سوهاج، قنا وأسوان).

٢- الفرق في قيم البخر- نتح للبرسيم تحت الظروف المناخية الحالية والمتوقعة في ٢٠٤٠ تصل الي ٥-٤% بمحافظات الدلتا (اسكندرية، البحيرة، كفر الشيخ، الدقهلية ودمياط) ويزداد الفرق الي ١٠% في محافظات (الغربية ، المنوفية ، الشرقية والقليوبية). يصل الفرق في قيم البخر - نتح للبرسيم الي ١١% بمحافظات (الجيزة ، الفيوم ، بني سويف والمنيا) بينما يصل الي ١٢-١٥% بمحافظات (أسيوط، سوهاج ، قنا وأسوان).

٣- الفرق في كمية مياه الري المضافة للقطن تحت الظروف المناخية الحالية والمتوقعة في ٢٠٤٠ يصل الي ٦-٨% بمحافظات الدلتا والي ٩% بمحافظات مصر الوسطي والي ١٠-١٢% بمحافظات مصر العليا.

من النتائج السابقة يتضح وجود مشكلة بعدم كفاية الموارد المائية المتاحة للزراعة المصرية المستقبلية، لذا من الضروري عمل اللازم لتوفير المياه الكافية لري المساحات الحالية والمتوقعة مستقبلا من الرقعة الزراعية. تحسين أداء الري السطحي (شائع الاستخدام بمصر) بتطبيق طرق الري المنقوص التي تؤدي إلي توفير في مياه الري مع التقليل إلي أقصى درجة في ناتج المحصول. زراعة الأصناف عالية الإنتاج والزراعة في الميعاد المناسب وكذا الإدارة الجيدة في الأسمدة ربما تخفف من هذه المشكلة.