

Chapter 2

Water Requirements for Major Crops

Samiha Ouda, Khaled Abd El-Latif and Fouad Khalil

Abstract The objective of this chapter was to calculate water requirements for four crops: wheat, maize, rice and sugarcane grown in 17 governorates in Egypt under current climate and under the A1B climate change scenario in 2040. The BISm model was used to calculate crop coefficient water depletion from root zone. Water requirements under A1B climate change were calculated using the model. The results indicated that water requirements for wheat will increase by 2–19% depending on governorate location. The effect of climate change was more pronounced on maize as a summer crop, where the applied irrigation amount is expected to increase in all governorates under climate change in 2040 by 10–19%. Regarding rice, water requirements were increased by 10–14%. With respect to sugarcane, which is a unique case because of its long growing season (365 days), its water requirements under climate change conditions increased by 11–19%.

Keywords Wheat • Maize • Rice • Sugarcane

The term crop water requirement is defined as the amount of water required to compensate the evapotranspiration loss from the cropped field (USDA Soil Conservation Service 1993). The ICID-CIID (2000) describes it as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. Although the values for crop evapotranspiration and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration (ET_c) refers to the amount of water that is lost through evapotranspiration (Allen et al. 1998). 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) accounts for the difference between ET_c and ET (Snyder et al. 2004). The k_c takes into account the

S. Ouda (✉) · K.A. El-Latif · F. Khalil

Water Requirements and Field Irrigation Research Department, Soils,
Water and Environment Research Institute, Agricultural Research Center, Giza, Egypt

relationship between atmosphere, crop physiology, and agricultural practices (Lascano 2000). Therefore, sowing date, which reflects the weather of a certain site, could affect growth pattern of a crop and consequently affects the period of growth stages, the value of k_c , and growth period. As a crop canopy develops, the ratio of transpiration (T) to ET increases until most of the ET comes from T and evapotranspiration (E) is a minor component. This occurs because light interception by the foliage increases until most light is intercepted before it reaches the soil (Snyder et al. 2004). Therefore, crop coefficients for field crops generally increase until the canopy ground cover reaches about 75 % and the light interception is near 80 %. The accurate calculation of crop k_c for each growth stage is an important component for accurate calculation of water requirements (Shideed et al. 1995).

Irrigation would help maintain optimal soil moisture during the growing period, thereby ensuring a more stable and higher agricultural production. Irrigation and its planning are demanding tasks, which involve a multidisciplinary approach to define and calculate all the relevant factors and parameters. The evidence of future warming is another reason for paying much attention to the efficiency of water use by plants (Katerji and Rana 2008).

The objective of this chapter was to calculate water requirements for four crops: wheat, maize, rice, and sugarcane grown in 17 governorates in Egypt under current climate and under A1B climate change scenario in 2040.

BISm Model

The required irrigation water need to be applied to the studied crops was estimated using BISm model (Snyder et al. 2004). The model requires planting and harvesting dates as input. The model calculates crop coefficient (k_c). The model also account for water depletion from root zone. Therefore, it requires to input total water holding capacity and available water in the soil. 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 2.1).

Planting and harvesting dates under current climate for the studied crops in each of the 17 governorates were obtained from bulletins published by Agricultural Research Center. Wheat and maize are cultivated in all governorates. The season length for wheat, as winter crop, is 155 days. Maize season length is 110 days. Planting and harvesting dates are included in Table 2.2.

Season length for rice is 140 days and cultivated in the all Nile Delta governorates, except El-Monofia governorate. It is cultivated on 15th of May and harvested on 30th of September. Sugarcane is an annual crop planted for sugar industry in 4 governorates, i.e., El-Minia, Suhag, Qena, and Aswan. Spring sugarcane is cultivated on 15th of February and harvested on 14th of February in the following year.

Table 2.1 Soil water holding capacity and available water prevailed in each governorate

Governorate	Water holding capacity (m/m)	Available water (m/m)
<i>Nile Delta</i>		
Alexandria	0.373	0.206
Demiatte	0.376	0.222
Kafr El-Sheik	0.405	0.170
El-Dakahlia	0.395	0.196
El-Behira	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
<i>Middle Egypt</i>		
Giza	0.363	0.209
Fayoum	0.426	0.194
Beni Swief	0.429	0.245
El-Minia	0.435	0.239
<i>Upper Egypt</i>		
Assuit	0.438	0.235
Suhag	0.446	0.244
Qena	0.454	0.293
Aswan	0.447	0.257

Table 2.2 Planting and harvesting dates for wheat and maize under current climate conditions

Governorate	Wheat		Maize	
	Planting date	Harvest date	Planting date	Harvest date
Nile Delta and Middle Egypt	15-Nov	18-Apr	15-May	01-Sep
Upper Egypt	01-Nov	01-Apr	01-May	18-Aug

A1B climate change scenario was developed using ECHAM5 climate model (Roeckner et al. 2003) in 2040 for each 17 governorates in the Nile Delta and Valley. ECHAM5 model is an Atmospheric Oceanic General Circulation model with low resolution, i.e., $1.9 \times 1.9^\circ$. Water requirements under climate change were calculated using BISm model (Snyder et al. 2004). The same planting date was assumed under climate change, and harvesting date was assumed to be one week earlier for all crops, except sugarcane. Previous research on the effect of climate change on season length indicated that it could be reduced by 7–12 days (Khalil et al. 2009; Ouda et al. 2009). Water requirements for selected crops were calculated under surface irrigation, where application efficiency is 60 % (Abou Zeid 2002). The calculations were done under current climate and under climate change scenario A1B in 2040.

Water Requirements for Wheat

Table 2.3 presents the applied amount of irrigation water for wheat in 2012/13 growing season and the value of water requirements in 2040. The lowest percentage of increase between applied and required water (PI %) was found in the governorates that have seashore on the Mediterranean Sea. In these governorates, the difference between ET under current climate and under climate change during wheat growing season was low. Starting from El-Gharbia governorate, the difference between ET under current climate and under climate change became higher. Furthermore, the ET value for March in El-Gharbia governorate and the rest of governorates was relatively higher, compared to the value of February. Going south of Egypt, PI % became high, i.e., 17–19 %.

Ouda et al. (2010) and Ibrahim et al. (2012) calculated water requirements for wheat grown in El-Behira governorate under climate change in 2030. They both concluded that it would increase by an average of 3–4 % under A2 and B2 climate change scenarios developed by Hadley model. In Demiatte governorate, the water requirement for wheat is expected to increase under climate change condition by

Table 2.3 Applied irrigation water for wheat under current climate, water requirements under A1B in 2040, and percentage of increase (PI %)

Governorate	Applied irrigation under current climate (mm)	Water requirements under climate change (mm)	PI(%)
<i>Nile Delta</i>			
Alexandria	462	478	3
Demiatte	495	505	2
Kafr El-Sheik	510	521	2
El-Dakahlia	519	528	2
El-Behira	501	513	2
El-Gharbia	497	585	18
El-Monofia	521	618	19
El-Sharkia	560	658	18
El-Kalubia	580	689	19
<i>Middle Egypt</i>			
Giza	556	664	19
Fayoum	516	594	15
Beni Swief	544	644	18
El-Minia	531	631	19
<i>Upper Egypt</i>			
Assuit	625	728	16
Suhag	546	645	18
Qena	654	776	19
Aswan	803	953	19

3 % (Noreldin et al. 2013). Similar results were obtained by Khalil et al. (2009), where water requirements for wheat grown in Giza were increased by 10 % under climate change conditions in 2030.

Water Requirements for Maize

The effect of climate change was more pronounced on maize as a summer crop. The applied irrigation amount for maize is expected to increase in all governorates under climate change in 2040. The highest percentage of increase in the applied irrigation water in the Nile Delta existed in El-Behira, El-Monofia, and El-Kalubia, i.e., 15 %. Similar results were obtained by Ouda et al. (2012) and Abdrabbo et al. (2013) under El-Behira governorate. A value of 16 % increase in the water requirements under climate change conditions existed in all Middle Egypt and Upper Egypt governorates, except for Aswan, where the PI % value was 19 % (Table 2.4). This could be attributed to the difference between ET under current climate and under climate change conditions which was high in all months of the year at Aswan. Furthermore, Aswan is characterized by having hottest summer days in Egypt.

Table 2.4 Applied irrigation water for maize under current climate, water requirements under AIB in 2040, and percentage of increase (PI %)

Governorate	Applied irrigation under current climate (mm)	Water requirements under climate change (mm)	PI (%)
<i>Nile Delta</i>			
Alexandria	772	859	11
Demiatte	735	812	10
Kafr El-Sheik	780	865	11
El-Dakahlia	703	797	13
El-Behira	728	838	15
El-Gharbia	710	809	14
El-Monofia	734	846	15
El-Sharkia	764	869	14
El-Kalubia	802	925	15
<i>Middle Egypt</i>			
Giza	871	1013	16
Fayoum	879	1018	16
Beni Swief	881	1021	16
El-Minia	896	1040	16
<i>Upper Egypt</i>			
Assuit	895	1039	16
Suhag	884	1023	16
Qena	890	1035	16
Aswan	1090	1295	19

Water Requirements for Rice

The value of PI (%) between applied irrigation water for rice under current climate and water requirements under climate change was high (Table 2.5). The value was between 10 and 14 %, with the lowest value in Alexandria and Demiatte, i.e., 10 % and the highest value existed in El-Kalubia governorate.

Water Requirements for Sugarcane

Sugarcane is a unique case because its growing season is 365 days and it is cultivated in four governorates only in south Egypt. The value of PI (%) between applied water under current climate and water requirements under climate change conditions was between 11 and 19 %. The highest value was in Aswan, i.e., 19 % (Table 2.6).

Table 2.5 Applied irrigation water for rice under current climate, water requirements under A1B in 2040, and percentage of increase (PI %)

Governorate	Applied irrigation under current climate (mm)	Applied irrigation under climate change (mm)	PI (%)
Alexandria	1045	1146	10
Demiatte	1018	1124	10
Kafr El-Sheik	1031	1141	11
El-Dakahlia	1116	1234	11
El-Behira	1162	1290	11
El-Gharbia	1104	1236	12
El-Sharkia	1145	1279	12
El-Kalubia	1113	1267	14

Table 2.6 Applied irrigation water for sugarcane under current climate, under A1B climate change scenario, and percentage of increase (PI)

Governorate	Applied irrigation under current climate (mm)	Applied irrigation under climate change (mm)	PI (%)
El-Minia	3140	3488	11
Suhag	3333	3758	13
Qena	3824	4246	11
Aswan	4680	5553	19

Conclusion

Our results indicated that climate change condition in 2040 is expected to increase ET values for all governorates in Egypt. Consequently, water requirements will also increase. The lowest increase in water requirements was at the Nile Delta, compared to Middle Egypt and Upper Egypt.

In semiarid regions, where Egypt is located, more pressure will be put on water resources distribution between economic sectors under climate change, especially agriculture. Reduction in the amount of allocated water for irrigation, increase in water requirements for crops, and yield reduction under climate change conditions will worsen food security situation in Egypt. Since surface irrigation is prevailing in Egypt with low application efficiency, it is important to test options to increase it. 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. Thus, it is very important to revise and fix the production system for cultivated crops, in terms of the used cultivars, fertilizer, and irrigation application.

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Major Crops and Water Scarcity in Egypt
Irrigation Water Management under Changing Climate
Ouda, S.
2016, XII, 126 p. 81 illus., 44 illus. in color., Softcover
ISBN: 978-3-319-21770-3