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## Irrigation Water Management under Changing Climate

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## Irrigation Water Management under Changing Climate

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# Contents

# Introduction

Egypt is located in the eastern corner of Africa on the Mediterranean Sea. The agricultural area in Egypt is composed of two parts: Nile Delta and Valley, which is the main contributor to food production, trading activities and national economy. It is also the most densely populated area in Egypt. Climate variability and change have forced us to think about the future of water resources and its sustainability under the current situation of water scarcity. The limited share of the Nile water that Egypt receives is not expected to increase in the future. Taking into account the population growth and the expected negative effect of climate change on rain in Ethiopia, Egypt will face a problem to allocate water to agriculture to maintain food security. The major crops involve in food security in Egypt are: wheat, maize, rice and sugarcane. There is a gap between production and consumption of wheat, maize and sugarcane. Whereas, for rice, there is a need to reduce its cultivated area, as its water consumption is high and its production is enough for local consumption at the time being.

The actual water resources currently available for use in Egypt are 55.5 BCM/year, and 1.3 BCM/year effective rainfalls on the northern strip of the Nile Delta, non-renewable groundwater for western desert and Sinai, while water requirements for different sectors are of the order of 79.5 BCM/year. The gap between the needs and availability of water is about 20 BCM/year. This gap is overcome by recycling agricultural drainage water. 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 $m^3$/capita/year is used. Egypt has passed that threshold already. As a threshold of absolute scarcity 500 $m^3$/capita/year is used, this will be evident with population predictions for 2025, which will bring Egypt down to 500 $m^3$/capita/year (Ministry of Irrigation and Water Resources, 2014). Since 85 % of the total available water is consumed in agriculture and most of the on-farm irrigation systems are low efficient coupled with poor irrigation management, water scarcity will negatively affect food security. Furthermore, surface irrigation is the major system in Egypt applied to 83 % of the old cultivated land (Nile Delta and Valley). Application efficiency of surface irrigation in Egypt is 60 %, which endures large losses in the applied irrigation water to drainage canals.

Previous research on the effect of using improved agricultural management practices on cultivated crops revealed that cultivation on raised beds could reduce the applied irrigation water by 20 %, which result in yield increase by 15 % (Abouelenein et al. 2009). Furthermore, changing application efficiency from 60 % under surface irrigation to 80 % under sprinkler system or 95 % under drip irrigation could save large amounts of irrigation water. Under this practice, yield is expected to increase by 15 and 18 % under sprinkler and drip system, respectively (Taha 2012). Thus, existing agricultural water management technologies are available to help meet the challenge of water scarcity. Furthermore, the saved amounts of irrigation water can be used to cultivate new land and increase national production of these crops.

The uncertain climate change impacts on the Nile flow could add another challenge for water management in Egypt. Studies on the effect of climate change on the Nile flow clearly show that the assessment is strongly dependent on the choice of the climate scenario and the underlying GCM model. For temperature, although the magnitude of the change varies, the direction of change is clear; all models expect temperatures to rise. For rainfall, however, not only the magnitude varies substantially across the models, but even the signal of the change varies. The choice of the emission scenario also leads to different estimates (Sayed 2004). There are large uncertainties attached at all the steps of scenario construction that need to be quantified in the analysis of future impacts. In addition, the reviewed studies show that the Nile flow is extremely sensitive to climate, and especially rainfall changes due to the highly nonlinear relationship between precipitation and runoff (Sayed 2004). Thus, water gap in Egypt could increase in the future and under expected climate change (Sanchez et al. 2005).

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. While 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.

Our objectives were to quantify the effect of climate change on production of wheat, maize, rice and sugarcane cultivated in the governorates of Nile Delta and Valley. Furthermore, quantification of the effect of strategies could be used as adaptation to reduce the risk of climate change on these crops. These quantifications are very important for policy makers to be included in their future plans.

The studied area is composed of 17 governorates in the Nile Delta and Valley. These governorates are: Alexandria (latitude 31.70°, longitude 29.00° and elevation

7.00 m), Demiatte (latitude 31.25º, longitude 31.49º and elevation 5.00 m), Kafr El-Sheik (latitude 31.07º, longitude 30.57º and elevation 20.00 m), El-Dakahlia (Latitude 31.03º, longitude 31.23º and elevation 7.00 m), El-Behira (latitude 31.02º, longitude 30.28º and elevation 6.70 m), El-Gharbia (latitude 30.47º, longitude 32.14º and elevation 14.80 m), El-Monofia (latitude 30.36º, longitude 31.01º and elevation 17.90 m), El-Sharkia (latitude 30.35º, longitude 31.30º and elevation 13.00 m), El-Kalubia (latitude 30.28º, longitude 31.11º and elevation 14.00 m), El-Giza (latitude 30.02º, longitude 31.13º and elevation 22.50 m), El-Fayoum (latitude 29.18º, longitude 30.51º and elevation 30.00 m), Beni Swief (latitude 29.04º, longitude 31.06º and elevation 30.40 m), El-Minia (latitude 28.05º, longitude 30.44º and elevation 40.00 m), Assuit (latitude 27.11º, longitude 31.06º and elevation 71.00 m) Suhag (latitude 26.36º, longitude 31.38º and elevation 68.70 m), Qena (latitude 26.10º, longitude 32.43º and elevation 72.60 m) and Aswan (latitude 24.02º, longitude 32.53º and elevation 108.30 m).

Alexandria is the wettest city in Egypt. Demiatte and Kafr El-Sheik are governorates with the least temperature fluctuation between day and night. Minia, Assuit, Qena and Suhag are governorates with the most temperature fluctuation between day and night. Aswan is the hottest in summer days. Figure 1 shows the map of Nile Delta and Valley governorates.

To accomplish the quantification of the effect of climate change on production of the selected crops, ET, crop factor and water requirements for the selected crops should be calculated under present time. Furthermore, a similar procedure should be

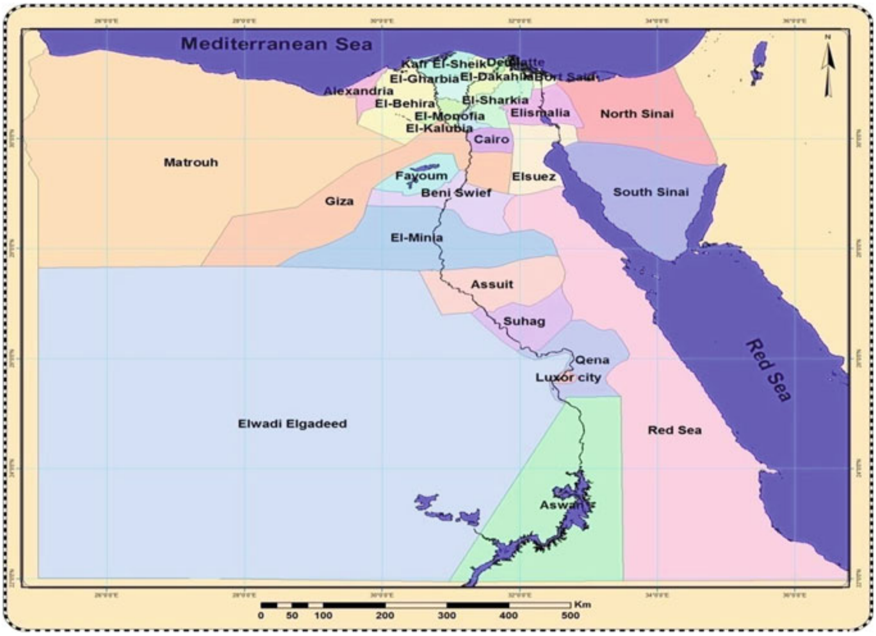

**Fig. 1** Map of Nile Delta and Valley of Egypt

carried out under the future climate change scenario developed by an Atmospheric Oceanic General Circulation model to determine the percentage of increase in water requirements for each of the selected crops. The effect of improved water management practices, such as cultivation on raised beds or increasing water application efficiency on the selected crops will be investigated under both present time and climate change, where it can be used as adaptations to climate change.

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# Chapter 1
# Evapotranspiration Under Changing Climate

**Samiha Ouda, Tahany Noreldin and Mohamed Hosney**

**Abstract** This chapter described methodology to calculate evapotranspiration (ET) values similar to the values calculated with Penman–Monteith equation (P–M), using ET values calculated by Hargreaves–Samani equation (H–S) under current and climate change. The BISm model was used to calculate monthly values of ET using P–M and H–S equations using weather data averaged over 10 years, from 2004 to 2013 for each of the 17 studied governorates and the values were compared. The comparison showed that there were deviations between monthly ET values calculated for each equation in each governorate. Thus, a linear regression equation was established with ET values resulted from P–M plotted as the dependent variable and ET values from H–S equation plotted as the independent variable. The quality of the fit between the two methodologies was presented in terms of the coefficient of determination ($R^2$) and root mean square error per observation (RMSE/obs). ECHAM5 climate change model was used to develop A1B climate change scenario for each governorate for the years 2020, 2030 and 2040, where ET values were calculated. The results indicated that $R^2$ was between close to one and RMSE/obs values were close to zero. The results also indicated that the calibration coefficients were capable to account for the effect of relative humidity, wind speed and potential sunshine hours, which were not included in the H–S equation. Furthermore, under A1B climate change scenario, the values of ET were increased. The above methodology could solve a large problem that faces researchers and extension workers in irrigation scheduling in Egypt and in other developing countries under current climate and in calculation of water requirements under climate change.

**Keywords** Penman–Monteith and Hargreaves–Samani equations · BISm model · ECHAM5 model · A1B climate change scenario

Climate plays an important role in crop production. Crops growth periods, crops water requirements, and scheduling irrigation for crops are dependent on weather conditions. The calculation of the evapotranspiration (ET) includes all the weather

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