# Chapter 2
# Water Requirements for Prevailing Cropping Pattern

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**Abstract** The objective of this chapter was to calculate water requirements for the prevailing cropping pattern in the five agroclimatic zones of Egypt. Weather data were collected for 2014/15 growing seasons to calculate water requirements for the studied cropping pattern for the five agroclimatic zones. BISm model was used to calculate ETo. The planting and harvest dates for 19 important crops that existed in the cropping pattern was determined. The date of each growth stage and the values of crop coefficients for each of the studied crops, as well as its water consumptive use were then calculated by the model. These calculations will help in the determination of water requirements for each of the studied crops in the level of each agroclimatic zone and on the national level.

**Keywords** Agroclimatic zones of Egypt · ETo · Crops coefficients · Crops water requirements

## Introduction

The actual water resources currently available for use in Egypt are 55.5 BCM/year from the Nile River, and 1.3 BCM/year effective rainfalls on the northern strip of the Nile Delta, 1.3 BCM/year of nonrenewable ground water in the western desert and Sinai, whereas water requirements for different sectors are in the order of 76.4 BCM/year. The gap between the needs and availability of water is about 20 BCM/year, which is overcome by recycling agricultural drainage water. Of this amount agriculture consumes 85% of the total water resources, namely 62.3 BCM/year (Ministry of Irrigation and Water Resources 2014).

Furthermore, on-farm irrigation systems are low efficient coupled with poor irrigation management and surface irrigation is the major system applied to 83% of the old cultivated lands in the Nile Delta and Valley (Abou Zeid 2002). Application efficiency of surface irrigation in Egypt on farm level is 60%, which endure large losses in the applied irrigation water to drainage canals. Thus, it is highly imperative to use it most judiciously to ensure sustainable agriculture development and



S.A.H Ouda et al., *Cropping Pattern Modification to Overcome Abiotic Stresses*, SpringerBriefs in Water Science and Technology,
https://doi.org/10.1007/978-3-319-69880-9_2

productivity. This, in turn requires knowledge of crop water requirements in various agroclimatic zones of Egypt. A superior water management program seeks to provide an optimal balance of water and air in the soil, which allows full expression of genetic potential in plants. The differences among poor, average, and record crop yields generally can be attributed to the amount and timing of the soil's water supplies (Cooke 2012).

Thus, the objective of this chapter was to calculate water requirements for the prevailing cropping pattern in the five agroclimatic zones of Egypt.

## Agroclimatic Zones of Egypt

The Basic Irrigation Scheduling (BIS) application was used to calculate water requirements for the cultivated crops. The model is written using MS Excel to help people plan irrigation management of crops. The BIS application calculates evapotranspiration (ETo) using the Penman–Monteith equation (Monteith 1965) as presented in the United Nations FAO Irrigation and Drainage Paper (FAO 56) by Allen et al. (1998) and using the Hargreaves–Samani equation (1985). If only temperature data are input, Hargreaves–Samani equation is used. For ETo calculations, the station latitude and elevation must also 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 requires sowing and harvest dates as input and irrigation frequency to calculate crop kc. The model also account for water depletion from root zone. Therefore, it requires to input total water holding capacity and available water. The model then determines the time when irrigation needs to be applied and the required amounts (Snyder et al. 2004).

ETo values for 30 years were calculated by BISm model (Snyder et al. 2004) in 17 governorates in the Nile Delta and Valley. ETo values was averaged over 10, 20, and 30 years from 1985 to 2014 and graphed together in Fig. 2.1 for comparison purpose. The figure showed that lowest value for ETo were found using 30-year average, followed by 20-year average then 10-year average in all studied sites, except Alexandria governorate. These results implied that weather elements are in continuous rising over the years.

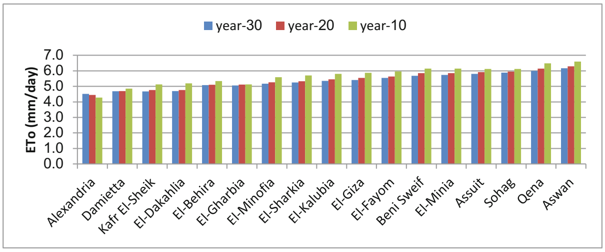


**Fig. 2.1** Comparison between values of ETo averaged over 10, 20, and 30 years

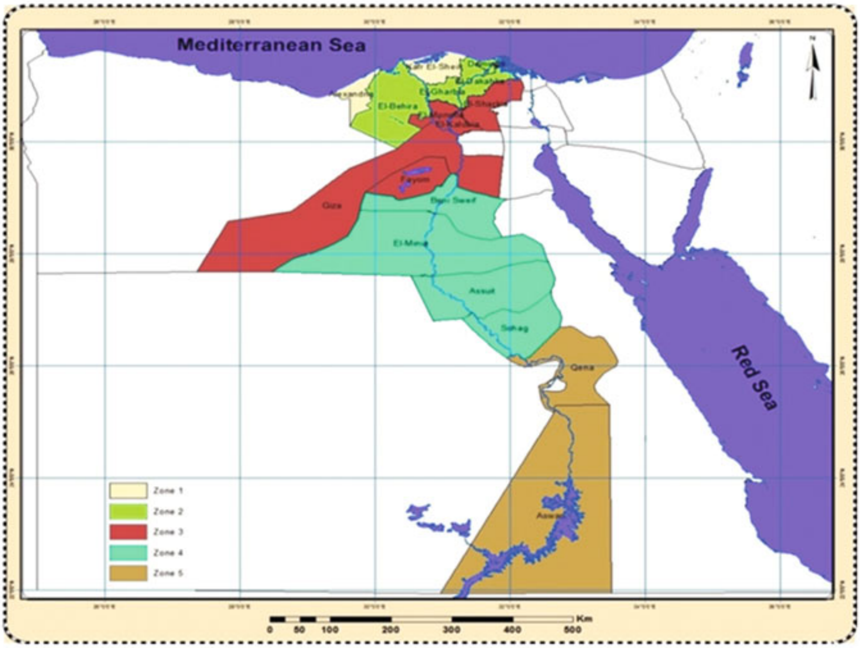


**Fig. 2.2** Map of agroclimatic zones of Egypt using 10-year of ETo values

Noreldin et al. (2016), Ouda and Noreldin (2017) used ETo values for these three time periods, namely 30, 20, and 10 year from 1985 to 2014 to develop agroclimatic zones for Egypt. In that methodology, monthly means of weather data for 10-year were calculated for each governorate. Analysis of variance was used and the means was separated and ranked using least significant difference test ($LSD_{0.05}$). Zoning using 10-year values of ETo resulted in five agroclimatic zones only and higher values of ETo in each zone, compared to 20-year and 30-year ETo values. Figure 2.2 showed the five agroclimatic zones developed by Ouda and Noreldin (2017).

## Water Requirements for the Prevailing Cropping Pattern

Hess (2005) stated that the ICID-CIID (2000) defined crop water requirements 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. Whereas, USDA, Soil Conservation Service (1993) defined it as the amount of water required to compensate the evapotranspiration loss from a cropped field.

Calculation of water requirements depends on ETo. ETo is the total amount lost from the field by both soil evaporation and plant transpiration (Gardner et al. 1985). Accurate estimation of ETo is important factor to attain prop water management. Earlier studies compared different ETo equations for their accuracy and revealed that Penman–Monteith equation is the most accurate because of its detailed theoretical base and its accommodation of small time periods (Valipour 2017). It was found that air temperature and solar radiation contributed most to the temporal variation of ETo in the upper reaches, as well as solar radiation and wind speed were the determining factors for the temporal variation of ETo in the middle-lower reaches (Zhao et al. 2015).

Water consumptive use can be calculated by multiplying ETo with crop coefficient (kc). Water consumptive use accounts for variations in weather and offers a measure of the "evaporative demand" of the atmosphere. Whereas, crop coefficient (kc) account for the difference between ETc and ET (Snyder et al. 2004). The kc takes into account the relationship between atmosphere, crop physiology, and agricultural practices (Lascano 2000). Water consumptive use is affected by planting date, which reflects the weather of a certain site. Planting date also could affect growth pattern of a crop and consequently affects the period of growth stages, the value of kc and growth period (Gardner et al. 1985). As a crop canopy develops, the ratio of transpiration to ETo increases until most of the ETo comes from transpiration and evapotranspiration 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% (Snyder et al. 2004). The accurate calculation of crop kc for each growth stage is an important component for accurate calculation of water requirements (Shideed et al. 1995).

To calculate water requirements for the studied cropping pattern, weather data were collected for 2014/15 growing seasons for the five agroclimatic zones. BISm model was used to calculate ETo. The kc for each of the studied crops and its water consumptive use were then calculated. Table 2.1 showed planting and harvest dates for the selected crops. It worth noting that there is a range of time a crop can be cultivated in. However, for calculation purpose, a certain date was assigned for planting.

In the first agroclimatic zone, the dates of each growth stage are presented in Table 2.2. All the strategic crops are cultivated in the first agroclimatic zone, except sugarcane, where it is only cultivated in south Egypt.

Table 2.3 presented the value of each crop coefficients and water consumptive use for the studied crops in the first agroclimatic zone.

The most important cultivated crops in the second agroclimatic zone are presented in Table 2.4, as well as the date of each growth stage.

Values of crop coefficient for the studied crops and its water requirements in the second agro climatic zone are presented in Table 2.5. Several studies were done to calculate water consumptive use for crops grown in this zone. The measured values of water consumptive use for wheat in 2009/10 and 2010/11 were 355–384 mm

**Table 2.1** Planting and harvest dates of selected crops in the prevailing cropping pattern

| Crop | Planting date | Harvest date |
|---|---|---|
| Wheat | 15 Nov | 18 Apr |
| Faba bean | 25 Oct | 25 Mar |
| Clover | 15 Oct | 1 Apr |
| Onion | 15 Nov | 15 May |
| Tomato | 1 Oct | 1 Mar |
| Potato | 1 Nov | 1 Feb |
| Sugar beet | 15 Oct | 12 Apr |
| Cotton | 15 Mar | 1 Sep |
| Rice | 15 May | 16 Sep |
| Maize | 15 May | 1 Sep |
| Soybean | 15 May | 25 Aug |
| Sunflower | 15 May | 15 Aug |
| Tomato | 1 May | 1 Sep |
| Citrus* | 15 Feb | 14 Feb |
| Olive* | 15 Feb | 14 Feb |
| Grape* | 15 Feb | 14 Feb |

*End of the agricultural year

**Table 2.2** The dates of each growth stage for the studied crops in the first agroclimatic zone in 2015

| Crop | *A–B* | *C* | *D* | *E* |
|---|---|---|---|---|
| Wheat | 15 Nov–16 Dec | 23 Jan | 11 Mar | 18 Apr |
| Faba bean | 25 Oct–30 Nov | 24 Dec | 12 Mar | 25 Mar |
| Clover | 15 Oct–26 Oct | 4 Dec | 15 Mar | 1 Apr |
| Onion | 15 Nov–3 Dec | 1 Jan | 31 Mar | 15 May |
| Tomato | 1 Oct–8 Nov | 16 Dec | 30 Jan | 1 Mar |
| Potato | 1 Nov–19 Nov | 12 Dec | 12 Jan | 1 Feb |
| Sugar beet | 15 Oct–11 Nov | 4 Jan | 8 Mar | 12 Apr |
| Cotton | 15 Mar–9 Apr | 26 Apr | 7 Aug | 1 Sep |
| Rice | 15 May–14 Jun | 30 Jun | 30 Aug | 16 Sep |
| Maize | 15 May–6 Jun | 30 Jun | 5 Aug | 1 Sep |
| Soybean | 15 May–4 Jun | 30 Jun | 5 Aug | 25 Aug |
| Sunflower | 15 May–2 Jun | 25 Jun | 28 Jul | 15 Aug |
| Tomato | 1 May–1 Jun | 2 Jul | 8 Aug | 1 Sep |
| Citrus | 15 Feb | 15 Jun | 17 Oct | 14 Feb |
| Olive | 15 Feb | 15 Jun | 17 Oct | 14 Feb |
| Grape | 15 Feb | 28 Apr | 20 Sep | 14 Feb |

**Table 2.3** Values of crop coefficients for the cultivated crops in the first agroclimatic zone and its water consumptive use

| Crop | Crop coefficient (kc) | | | | Water consumptive use (mm) |
|---|---|---|---|---|---|
| | *A–B* | *C* | *D* | *E* | |
| Wheat | 0.34 | 1.09 | 1.09 | 0.21 | 363 |
| Faba bean | 0.31 | 0.96 | 0.92 | 0.22 | 338 |
| Clover | 0.29 | 1.15 | 1.15 | 1.15 | 526 |
| Onion | 0.33 | 1.20 | 1.20 | 0.54 | 615 |
| Tomato | 0.28 | 1.10 | 1.10 | 0.64 | 313 |
| Potato | 0.31 | 1.09 | 1.09 | 0.68 | 199 |
| Sugar beet | 0.29 | 1.15 | 1.15 | 0.95 | 508 |
| Cotton | 0.31 | 0.95 | 0.95 | 0.49 | 725 |
| Rice | 0.40 | 1.02 | 1.02 | 0.78 | 667 |
| Maize | 0.26 | 1.04 | 1.04 | 0.58 | 535 |
| Soybean | 0.27 | 1.10 | 1.10 | 0.40 | 530 |
| Sunflower | 0.27 | 1.09 | 1.09 | 0.38 | 474 |
| Potato | 0.25 | 1.10 | 1.10 | 0.69 | 422 |
| Tomato | 0.27 | 1.10 | 1.10 | 0.65 | 611 |
| Citrus | 0.30 | 1.0 | 1.0 | 1.0 | 1412 |
| Olive | 0.30 | 0.8 | 0.8 | 0.8 | 1155 |
| Grape | 0.37 | 0.8 | 0.8 | 0.35 | 874 |

**Table 2.4** The dates of each growth stage for the studied crops in the second agroclimatic zone

| Crop | *A–B* | *C* | *D* | *E* |
|---|---|---|---|---|
| Wheat | 15 Nov–16 Dec | 23 Jan | 11 Mar | 18 Apr |
| Faba bean | 25 Oct–30 Nov | 24 Dec | 12 Mar | 25 Mar |
| Clover | 15 Oct–26 Oct | 4 Dec | 15 Mar | 1 Apr |
| Onion | 15 Nov–3 Dec | 1 Jan | 31 Mar | 15 May |
| Tomato | 1 Oct–8 Nov | 16 Dec | 30 Jan | 1 Mar |
| Potato | 1 Nov–19 Nov | 12 Dec | 12 Jan | 1 Feb |
| Sugar beet | 15 Oct–11 Nov | 4 Jan | 8 Mar | 12 Apr |
| Cotton | 15 Mar–9 Apr | 26 Apr | 7 Aug | 1 Sep |
| Rice | 15 May–14 Jun | 30 Jun | 30 Aug | 16 Sep |
| Maize | 15 May–6 Jun | 30 Jun | 5 Aug | 1 Sep |
| Soybean | 15 May–4 Jun | 30 Jun | 5 Aug | 25 Aug |
| Sunflower | 15 May–2 Jun | 25 Jun | 28 Jul | 15 Aug |
| Potato | 1 Aug–25 Aug | 24 Sep | 2 Nov | 28 Nov |
| Tomato | 1 May–1 Jun | 2 Jul | 8 Aug | 1 Sep |
| Citrus | 15 Feb | 15 Jun | 17 Oct | 14 Feb |
| Olive | 15 Feb | 15 Jun | 17 Oct | 14 Feb |
| Grape | 15 Feb | 28 Apr | 20 Sep | 14 Feb |

**Table 2.5** Values of crop coefficients for the cultivated crops in the second agroclimatic zone and water consumptive use

| Crop | Crop coefficients (kc) | | | | Water consumptive use (mm) |
|---|---|---|---|---|---|
| | *A*–B | *C* | *D* | *E* | |
| Wheat | 0.33 | 1.09 | 1.09 | 0.20 | 385 |
| Faba bean | 0.30 | 0.96 | 0.96 | 0.21 | 355 |
| Clover | 0.28 | 1.15 | 1.15 | 1.15 | 558 |
| Onion | 0.32 | 1.20 | 1.20 | 0.54 | 663 |
| Tomato | 0.27 | 1.10 | 1.10 | 0.64 | 343 |
| Potato | 0.30 | 1.09 | 1.09 | 0.68 | 206 |
| Sugar beet | 0.28 | 1.15 | 1.15 | 0.95 | 541 |
| Cotton | 0.30 | 0.95 | 0.95 | 0.49 | 792 |
| Rice | 0.38 | 1.02 | 1.02 | 0.78 | 722 |
| Maize | 0.25 | 1.04 | 1.04 | 0.58 | 579 |
| Soybean | 0.25 | 1.10 | 1.10 | 0.40 | 572 |
| Sunflower | 0.25 | 1.09 | 1.09 | 0.37 | 509 |
| Potato | 0.23 | 1.10 | 1.10 | 0.69 | 451 |
| Tomato | 0.26 | 1.10 | 1.10 | 0.65 | 661 |
| Citrus | 0.30 | 1.00 | 1.00 | 1.00 | 1532 |
| Olive | 0.30 | 0.80 | 0.80 | 0.80 | 1253 |
| Grape | 0.37 | 0.80 | 0.80 | 0.35 | 955 |

(Taha 2012). In another experiment in the same zone, the measured values of water consumptive use for wheat grown in five growing seasons from 2001/02 season until 2005/06 season was around 334–349 mm (Ouda et al. 2008). Regarding maize, its water consumptive use was 478–507 mm in 2009 and 2010 growing seasons (Taha 2012). Table 2.5 showed that water consumptive use in was 385 mm for wheat and 579 mm for maize, which imply the increasing trend in weather data through the past decades.

Table 2.6 showed the date of growth stages in the most important cultivated crops in the third agroclimatic zone in Egypt.

Table 2.7 indicated that the value of kc for the selected crops was slightly different in the third agroclimatic zone, compared with the first agroclimatic zone. The table also showed that water consumptive use values in 2014/15 growing season were 409, 577, 597, and 530 mm, for wheat, sugar beet, maize, and sunflower, respectively. Khalil et al. (2007) stated that water consumptive use for wheat was 381–401 mm in 2005/06 and 2006/07 growing seasons. Measured values of water consumptive use for sugar beet was between 534 and 565 mm in 2010/11 growing season (personal communication). With respect to maize, Khalil and Mohamed (2006) indicated that maize water consumptive use was 541–546 mm, whereas sunflower water consumptive use was 531–536 mm (Khalil 2007). The differences in water consumptive value can be attributed to the effect of climate change on increasing these values in the third agroclimatic zone.

**Table 2.6** The dates of each growth stage for the studied crops in the third agroclimatic zone

| Crop | *A–B* | *C* | *D* | *E* |
|---|---|---|---|---|
| Wheat | 15 Nov–16 Dec | 23 Jan | 11 Mar | 18 Apr |
| Faba bean | 25 Oct–30 Nov | 24 Dec | 12 Mar | 25 Mar |
| Clover | 15 Oct–26 Oct | 4 Dec | 15 Mar | 1 Apr |
| Onion | 15 Nov–3 Dec | 1 Jan | 31 Mar | 15 May |
| Tomato | 1 Oct–8 Nov | 16 Dec | 30 Jan | 1 Mar |
| Potato | 1 Nov–19 Nov | 12 Dec | 12 Jan | 1 Feb |
| Sugar beet | 15 Oct–11 Nov | 4 Jan | 8 Mar | 12 Apr |
| Cotton | 15 Mar–9 Apr | 26 Apr | 7 Aug | 1 Sep |
| Rice | 15 May–14 Jun | 30 Jun | 30 Aug | 16 Sep |
| Maize | 15 May–6 Jun | 30 Jun | 5 Aug | 1 Sep |
| Soybean | 15 May–4 Jun | 30 Jun | 5 Aug | 25 Aug |
| Sunflower | 15 May–2 Jun | 25 Jun | 28 Jul | 15 Aug |
| Potato | 1 Aug–25 Aug | 24 Sep | 2 Nov | 28 Nov |
| Tomato | 1 May–1 Jun | 2 Jul | 8 Aug | 1 Sep |
| Citrus | 15 Feb | 15 Jun | 17 Oct | 14 Feb |
| Olive | 15 Feb | 15 Jun | 17 Oct | 14 Feb |
| Grape | 15 Feb | 17 May | 15 Nov | 14 Feb |

**Table 2.7** Value of crop coefficients for the cultivated crops in the third agroclimatic zone and water consumptive use

| Crop | Crop coefficient (kc) | | | | Water consumptive use (mm) |
|---|---|---|---|---|---|
| | *A–B* | *C* | *D* | *E* | |
| Wheat | 0.31 | 1.08 | 1.08 | 0.19 | 409 |
| Faba bean | 0.28 | 0.96 | 0.96 | 0.20 | 375 |
| Clover | 0.27 | 1.15 | 1.15 | 1.15 | 598 |
| Onion | 0.30 | 1.20 | 1.20 | 0.54 | 707 |
| Tomato | 0.26 | 1.10 | 1.10 | 0.64 | 364 |
| Potato | 0.28 | 1.09 | 1.09 | 0.68 | 216 |
| Sugar beet | 0.27 | 1.15 | 1.15 | 0.95 | 577 |
| Cotton | 0.28 | 0.95 | 0.95 | 0.49 | 830 |
| Rice | 0.36 | 1.02 | 1.02 | 0.78 | 740 |
| Maize | 0.24 | 1.04 | 1.04 | 0.58 | 597 |
| Soybean | 0.24 | 1.10 | 1.10 | 0.40 | 592 |
| Sunflower | 0.24 | 1.09 | 1.09 | 0.37 | 530 |
| Potato | 0.23 | 1.10 | 1.10 | 0.69 | 473 |
| Tomato | 0.24 | 1.10 | 1.10 | 0.65 | 679 |
| Citrus | 0.29 | 0.8 | 0.8 | 0.8 | 1607 |
| Olive | 0.35 | 0.8 | 0.8 | 0.35 | 1314 |
| Grape | 0.29 | 0.95 | 0.95 | 0.95 | 996 |

**Table 2.8** The dates of each growth stage for the studied crops in the fourth agroclimatic zone

| Crop | *A–B* | *C* | *D* | *E* |
|---|---|---|---|---|
| Wheat | 15 Nov–16 Dec | 23 Jan | 11 Mar | 18 Apr |
| Faba bean | 25 Oct–30 Nov | 24 Dec | 12 Mar | 25 Mar |
| Clover | 15 Oct–26 Oct | 4 Dec | 15 Mar | 1 Apr |
| Onion | 15 Nov–3 Dec | 1 Jan | 31 Mar | 15 May |
| Tomato | 1 Oct–8 Nov | 16 Dec | 30 Jan | 1 Mar |
| Potato | 1 Nov–19 Nov | 12 Dec | 12 Jan | 1 Feb |
| Sugar beet | 15 Oct–11 Nov | 4 Jan | 8 Mar | 12 Apr |
| Cotton | 15 Mar–9 Apr | 26 Apr | 7 Aug | 1 Sep |
| Maize | 15 May–6 Jun | 30 Jun | 5 Aug | 1 Sep |
| Soybean | 15 May–4 Jun | 30 Jun | 5 Aug | 25 Aug |
| Sunflower | 15 May–2 Jun | 25 Jun | 28 Jul | 15 Aug |
| Potato | 1 Aug–25 Aug | 24 Sep | 2 Nov | 28 Nov |
| Tomato | 1 May–1 Jun | 2 Jul | 8 Aug | 1 Sep |
| Sugarcane | 15 Mar | 22 Jun | 3 Sep | 1 Mar |
| Citrus | 15 Feb | 15 Jun | 17 Oct | 14 Feb |
| Olive | 15 Feb | 15 Jun | 17 Oct | 14 Feb |
| Grape | 15 Feb | 17 May | 15 Nov | 14 Feb |

For the fourth agroclimatic zone, the date of crops growth stages for the studied crops is presented in Table 2.8. In this zone, rice is not planted, as it is prohibited by law. Furthermore, sugarcane is cultivated in this zone.

The effect of weather of the agroclimatic zone is shown in this zone resulted in differences in the values of kc for the studied crops, compared to the other mentioned zones (Table 2.9). Furthermore, Ouda et al. (2010a) stated that the value of faba bean water consumptive use was 355–366 mm in 2000/01 growing season (Ouda et al. 2010b), whereas it was 392 mm in 2014/15 season. The value of cotton water consumptive use was 876–899 mm in 2000 and 2001 growing seasons. El-Sayed (2016) indicated that water consumptive use for cotton in the fourth agroclimatic zone was 1005–1056 mm in 2012 and 2013 respectively, whereas it was 905 mm in 2014/15 season (Table 2.9).

The date of growth stages in the fifth agroclimatic zones is presented in Table 2.10, where rice is prohibited for cultivation there. Furthermore, the weather of this zone is not suitable for cotton and sugar beet.

Table 2.11 showed the values of crop coefficients and water consumptive use of the studied crops in the fifth agroclimatic zone.

Water requirements for selected crops at each zone can be calculated under surface irrigation in the old lands of the Nile Delta and Valley using 60% application. In the new lands, water requirements for selected crops at each zone can be calculated under irrigation systems, namely sprinkler with 75% application efficiency and drip systems with 85% application efficiency.

**Table 2.9** Values of crop coefficients for the cultivated crops in the fourth agroclimatic zone and water consumptive use

| Crop | Crop coefficient (kc) | | | | Water consumptive use (mm) |
|---|---|---|---|---|---|
| | *A–B* | *C* | *D* | *E* | |
| Wheat | 0.31 | 1.08 | 1.08 | 0.18 | 431 |
| Faba bean | 0.28 | 0.96 | 0.96 | 0.20 | 392 |
| Clover | 0.25 | 1.15 | 1.15 | 1.15 | 623 |
| Onion | 0.30 | 1.20 | 1.20 | 0.54 | 750 |
| Tomato | 0.24 | 1.10 | 1.10 | 0.64 | 378 |
| Potato | 0.28 | 1.09 | 1.09 | 0.68 | 222 |
| Sugar beet | 0.25 | 1.15 | 1.15 | 0.95 | 604 |
| Cotton | 0.28 | 0.95 | 0.95 | 0.49 | 905 |
| Maize | 0.23 | 1.04 | 1.04 | 0.58 | 643 |
| Soybean | 0.23 | 1.10 | 1.10 | 0.40 | 638 |
| Sunflower | 0.23 | 1.09 | 1.09 | 0.37 | 574 |
| Potato | 0.22 | 1.10 | 1.10 | 0.69 | 524 |
| Tomato | 0.23 | 1.10 | 1.10 | 0.65 | 735 |
| Sugarcane | 0.21 | 1.2 | 1.2 | 0.62 | 1971 |
| Citrus | 0.27 | 0.8 | 0.8 | 0.8 | 1735 |
| Olive | 0.34 | 0.8 | 0.8 | 0.35 | 1416 |
| Grape | 0.27 | 0.95 | 0.95 | 0.95 | 1082 |

**Table 2.10** The dates of each growth stage for the studied crops in the fifth agroclimatic zone

| Crop | *A–B* | *C* | *D* | *E* |
|---|---|---|---|---|
| Wheat | 15 Nov–16 Dec | 23 Jan | 11 Mar | 18 Apr |
| Faba bean | 25 Oct–30 Nov | 24 Dec | 12 Mar | 25 Mar |
| Clover | 15 Oct–26 Oct | 4 Dec | 15 Mar | 1 Apr |
| Onion | 15 Nov–3 Dec | 1 Jan | 31 Mar | 15 May |
| Tomato | 1 Oct–8 Nov | 16 Dec | 30 Jan | 1 Mar |
| Potato | 1 Nov–19 Nov | 12 Dec | 12 Jan | 1 Feb |
| Maize | 15 May–6 Jun | 30 Jun | 5 Aug | 1 Sep |
| Soybean | 15 May–4 Jun | 30 Jun | 5 Aug | 25 Aug |
| Sunflower | 15 May–2 Jun | 25 Jun | 28 Jul | 15 Aug |
| Potato | 1 Aug–25 Aug | 24 Sep | 2 Nov | 28 Nov |
| Tomato | 1 May–1 Jun | 2 Jul | 8 Aug | 1 Sep |
| Sugarcane | 15 Feb | 18 Apr | 21 Oct | 14 Feb |
| Citrus | 15 Feb | 15 Jun | 17 Oct | 14 Feb |
| Olive | 15 Feb | 15 Jun | 17 Oct | 14 Feb |
| Grape | 15 Feb | 17 May | 15 Nov | 14 Feb |

**Table 2.11** Values of crop coefficients for the cultivated crops in the fifth agroclimatic zone and water consumptive use

| Crop | Crop coefficient (kc) | | | | Water consumptive use (mm) |
|---|---|---|---|---|---|
| | *A–B* | *C* | *D* | *E* | |
| Wheat | 0.30 | 1.08 | 1.08 | 0.18 | 451 |
| Faba bean | 0.27 | 0.96 | 0.96 | 0.19 | 413 |
| Clover | 0.25 | 1.15 | 1.15 | 1.15 | 659 |
| Onion | 0.29 | 1.20 | 1.20 | 0.54 | 787 |
| Tomato | 0.24 | 1.10 | 1.10 | 0.64 | 400 |
| Potato | 0.27 | 1.09 | 1.09 | 0.68 | 239 |
| Maize | 0.21 | 1.03 | 1.03 | 0.58 | 645 |
| Soybean | 0.22 | 1.10 | 1.10 | 0.40 | 643 |
| Sunflower | 0.22 | 1.09 | 1.09 | 0.37 | 577 |
| Potato | 0.22 | 1.10 | 1.10 | 0.69 | 538 |
| Tomato | 0.23 | 1.10 | 1.10 | 0.65 | 743 |
| Sugarcane | 0.21 | 1.20 | 1.20 | 0.62 | 2028 |
| Citrus | 0.27 | 0.80 | 0.80 | 0.80 | 1792 |
| Olive | 0.33 | 0.80 | 0.80 | 0.35 | 1463 |
| Grape | 0.27 | 0.95 | 0.95 | 0.95 | 1097 |

## Conclusion

Climate variability in the past 30 years in Egypt increased ETo values, which affected water requirements for the growing crops in the prevailing cropping pattern. To improve irrigation water management in Egypt, agroclimatic zones was developed using the latest 10-year values of ETo and five agroclimatic zones. BISm model was used to calculate crops kc values, the date of each stage for the selected crops and water consumptive use in each of the five agroclimatic zones. These calculations will help in the determination of water requirements for the cultivated crops on the level of each agroclimatic zone and on the national level.

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Cropping Pattern Modification to Overcome Abiotic Stresses
Water, Salinity and Climate

Ouda, S.; Zohry, A.E.-H.; Morsy, M.

2018, VII, 111 p. 11 illus. in color., Softcover
ISBN: 978-3-319-69879-3