Issue:5 2022
International Journal of Water Management and Diplomacy
e-ISSN:2717-8277

Research Article

Assessment of crop water requirements by using cropwat for sustainable water resources management in agriculture (Akhisar-Manisa, Turkey)

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Abstract
This study was planned to assess the optimum water requirements of chosen crops and contribute to sustainable water management in Manisa-Akhisar Beyoba Region, which makes agricultural production with groundwater. A severe regional hydrological and agricultural drought for the past two years in this region has led to more use of groundwater. This resulted in a rapid decrease in groundwater levels. This study created a guide on the optimum water requirement of the crops to be grown for the sustainable use of groundwater in the region.

Keywords: optimum water requirement, sustainable water use, CROPWAT, CLIMWAT, FAO, climate change, agriculture

1. Introduction

Groundwater is the primary source of freshwater in terms of volume. It is the source of the majority of our potable water (Schwarz and Zhang, 2003). It is also utilised for irrigation in several places (Siebert et al., 2010).

Being invisible causes groundwater to be used more uncontrolled. 67% of the groundwater withdrawn in Turkey is allocated for agricultural irrigation (Gunes et al., 2016). However, illegal withdrawals are made from many unauthorised wells (Aydin et al., 2020). This situation complicates the sustainable management of groundwater in terms of quality and quantity (Göçmez and İşçioğlu, 2004). So, it is essential to consider the optimum water demand of the crop, especially in agricultural lands under the threat of limited groundwater and climate change (Bhattarai and Shakya, 2020).

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International Journal of Water Management and Diplomacy
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Therefore, groundwater is an important resource for agricultural irrigation and drinking water, especially in dry periods. Without groundwater, surface waters would dry up and experience a decline in water quality and ecological health (Schwarz and Zhang, 2003).

In order to prevent this unsustainable water use, irrigation systems must be modernised and well-managed by properly evaluating water system requirements. To meet the irrigation demand, it is essential to understand crop water requirements (CWRs) and irrigation schedules (Ewaid et al., 2019).

To identify crop evapotranspiration, crop water requirement (CWR), and irrigation scheduling, researchers rely heavily on software modelling with packages such as CROPWAT 8.0. This software was created by the Food and Agriculture Organization (FAO) (Smith, 1996) to aid watering experts and farmers in doing the standard computations for water irrigation and in the design and management of irrigation systems (Clarke et al., 2001). This study creates a guideline for the irrigation water requirements of some agricultural products (wheat, maize, grape, cotton and barley) in Beyoba village (Akhisar–Manisa Province) of Turkey were analysed employing the CROPWAT model.

1.1. Study area

The study area was taken as Beyoba village in the Akhisar district of Manisa province in the west of Turkey (Figure 1).

Figure 1. The study area (generated by using ArcGIS pro v2.18) The photos of the study area (right below) were obtained from the Beyoba Irrigation Cooperative (see acknowledgements).

Agricultural irrigation in the study area is carried out by using groundwater under the management of Beyoba Irrigation Cooperative. The irrigation area of Beyoba irrigation cooperative is 7500 decares, and maize, cotton and table grapes are grown in Figure 2. Approximately 5.5 million m³ of groundwater is drawn annually from 23 wells for agricultural irrigation.

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e-ISSN:2717-8277

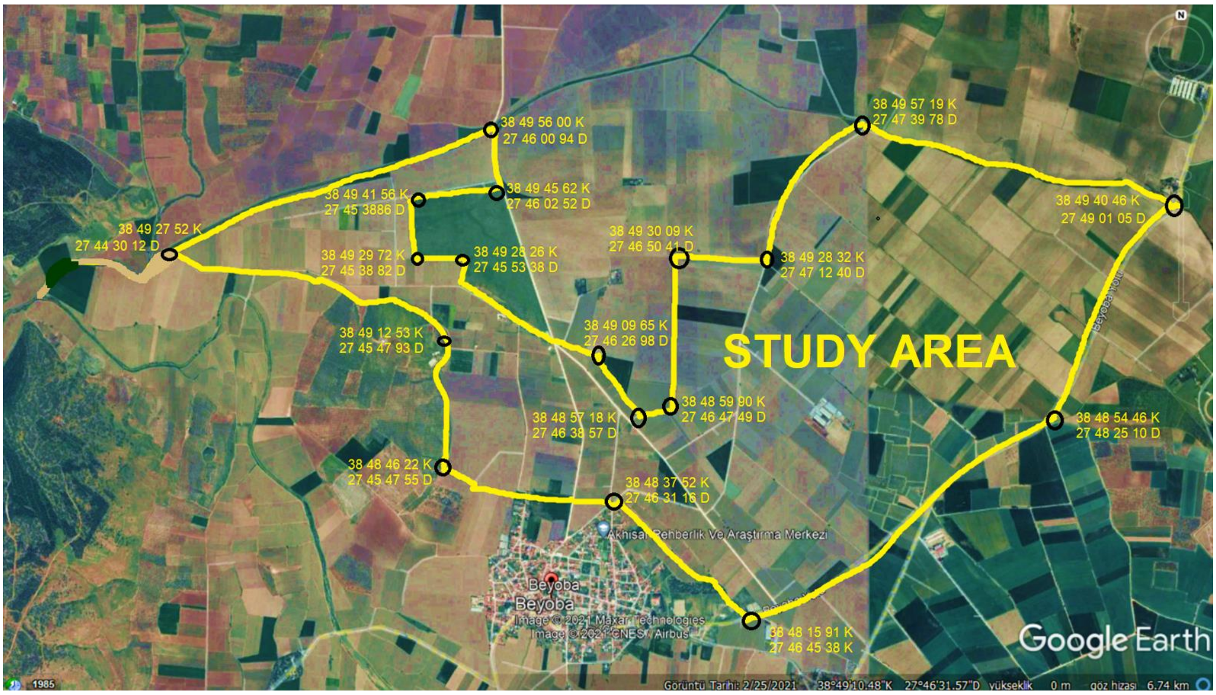

Figure 2. The irrigation area of Beyoba irrigation cooperative.

2. Data and Method

2.1. ETo, ETc and Kc values by using CROPWAT

FAO created the CROPWAT computer tool for irrigation management and planning (FAO, 1992). Its fundamental duties include calculating reference evapotranspiration, agricultural water needs, and irrigation planning. (Allen et al., 1998; Rajput and Patel, 2006). By CROPWAT, the crops' coefficient (Kc), reference crop evapotranspiration (ETo) and finally crop evapotranspiration (Etc) can be considered for selected crop and irrigation requirements can be calculated under effective rainfall (or without considering effective rainfall) (CROPWAT, 2022).

ETc relates to crop evapotranspiration from disease-free, well-fertilized crops produced in wide areas, under optimal soil water requirements, and attaining cultivation under specified climatic conditions (Allen et al., 1998; Vu et al., 2005). ETc is analyzed by multiplying the ETo by Kc as given:

$$\mathbf{ETc = Kc * ETo} \tag{1}$$

where Etc is mm/d; Kc is coefficient, and ETo is mm/d. ETo was analysed based on the FAO Penman-Monteith method (Allen et al., 1998; Vu et al., 2005). ETo is the amount of evapotranspiration from a proposed reference crop with a supposed crop height of 12 cm, a fixed canopy resistance of 70 sm-1, and an albedo of 0.23, which closely resembles the ET from a comprehensive surface of grass cover that is of suitable height, growing, totally shading the field, and receiving acceptable water (Allen et al., 1998; Vu et al., 2005). The FAO Penman-Monteith method needs solar radiation, maximum, minimum and means air temperatures, air humidity and wind speed data (Smith et al., 2002).

The Kc of plants is determined by climatic conditions and crop development phases. Changes occur in the plant cover, crop height, and leaf area as the crop matures. Due to changes in evapotranspiration during different growth stages, the Kc for a given crop alters over the

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growing period. The growing period can be separated into four different growing periods: initial, crop development, mid-season and late-season (Vu et al., 2005, Yarami et al., 2011).
In this study, the climate data (average for the 1970–2000 period (Ewaid et al., 2019): temperature, humidity, wind speed, sun hours and rainfall) were attained by CLIMWAT software attached to the CROPWAT software for Akhisar station (Manisa-Turkey) (Figure 3). According to temperature, humidity, wind speed, sun hours data, Monthly Radiation and Monthly ETo Penman-Monteith (Smith et al., 2002; Ewaid et al., 2019) values were calculated (Table 1). The effective rainfall values were also calculated based on the USDA soil conservation service (USDA, 1970; Tigkas et al., 2016; CROPWAT Software, 2022) (Table 2). According to Bokke and Shoro (2020) USDA soil conservation method is good for water-scarce areas.

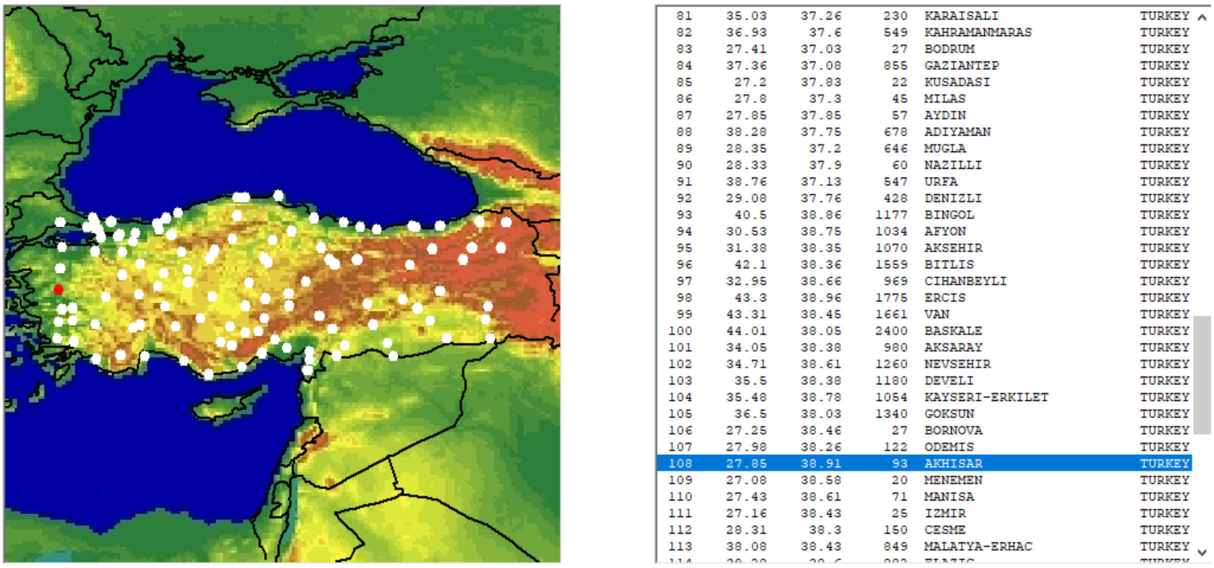

Figure 3. Akhisar Manisa Station from CLIMWAT software.

Table 1. Akhisar station (LAT:38.91°N, LON:27.85°E; Altitude: 93 m.) climate data (average for 1970–2000 period), calculated monthly radiation and ETo Penman-Monteith (CROPWAT, 2022).

Month	**Minimum Temperature**	**Maximum Temperature**	**Humidity**	**Wind**	**Sun**	**Radiation**	**ETo**
	°C	**°C**	**%**	**km/day**	**hours**	**MJ/m²/day**	**mm/day**
January	2	10.8	79	112	4	7.3	0.85
February	2.8	12.3	74	121	5.1	10.3	1.27
March	4.2	15.9	66	138	5.9	14	2.13
April	7.7	21.4	61	112	7.3	18.5	3.14
May	11.8	26.8	59	104	8.6	22.1	4.2
June	15.6	31.7	51	130	11.4	26.6	5.77

Table 1. Akhisar station (LAT:38.91°N, LON:27.85°E; Altitude: 93 m.) climate data (average for 1970–2000 period), calculated monthly radiation and ETo Penman-Monteith (CROPWAT, 2022).

Month	**Minimum Temperature**	**Maximum Temperature**	**Humidity**	**Wind**	**Sun**	**Radiation**	**ETo**
	°C	**°C**	**%**	**km/day**	**hours**	**MJ/m²/day**	**mm/day**
July	18.5	34.1	48	164	13.2	28.7	6.8
August	18.4	34.2	48	156	12.4	26	6.26
September	14.5	30.8	51	121	10.6	20.7	4.51
October	10	24.4	62	95	7.7	13.7	2.53
November	5.7	18.1	77	61	5.5	9	1.18
December	3.6	12.7	80	78	4.2	6.8	0.77
Average	9.6	22.8	63	116	8	17	3.28

Table 2. Akhisar station rainfall data (average for 1970–2000 period) and calculated effective rainfall values based on USDA soil conservation service (USDA, 1970).

Month	**Rain (mm)**	**Eff rain (mm)**
Jan	96	81.3
Feb	81	70.5
Mar	63	56.6
Apr	53	48.5
May	29	27.7
Jun	15	14.6
Jul	5	5
Aug	7	6.9
Sept	14	13.7
Oct	35	33
Nov	72	63.7
Dec	124	99.4
Total	594	520.9

Here, five basic crops were selected to reveal the irrigation requirements in the study region. The selected crops are (1) wheat, (2) maize, (3) grape, (4) cotton, and (5) barley (table). For the determination of the Crop Water Requirements (CWR), each crop information is essential for further calculations, therefore the planting and harvesting dates of the selected crops were found for Turkey from USDA Foreign Agricultural Service (USDA IPAD, 2022) and Turkey Seed Union (TSU) (TSU, 2022) (in Table 3). After the integration of the harvesting dates of each crop, the CROPWAT have calculated the harvesting date (CROPWAT, 2022) according to the

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e-ISSN:2717-8277

crop's distinct growing stages (in Table 4). All the crop information was given for the selected crops between Figure 4 to Figure 8 in this paper.

Table 3. The crops calendar for Turkey according to USDA Foreign Agricultural Service (USDA IPAD, 2022); for grapes, TSU was used to reference (TSU, 2022).

Turkey Crop Calendar	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wheat (spring)												
Maize												
Grape												
Cotton												
Barley												
	Plant											
	Mid-season											
	Harvest											

Table 4. FAO's CROPWAT based planting and harvesting dates of the selected crops (Table 3 was considered for these dates).

	Planting Date	Harvesting Date
Wheat	01/03	08/07
Maize	01/02	28/10
Grape	01/02	31/01
Cotton	15/03	14/11
Barley	01/10	27/07

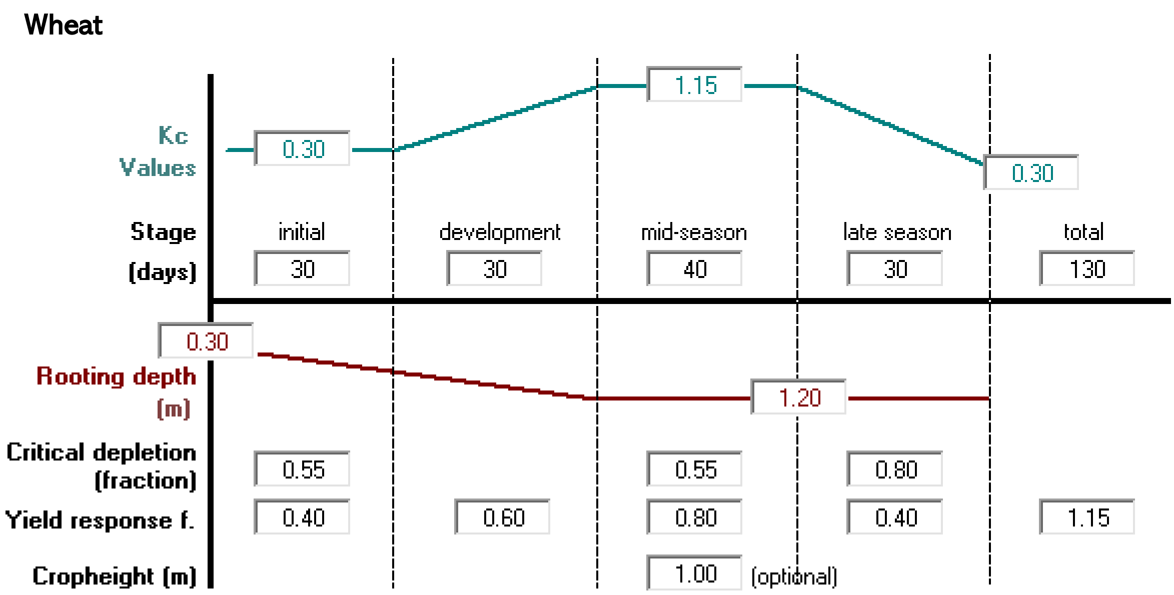

Figure 4. The crop properties of **wheat** from FAO CROPWAT.

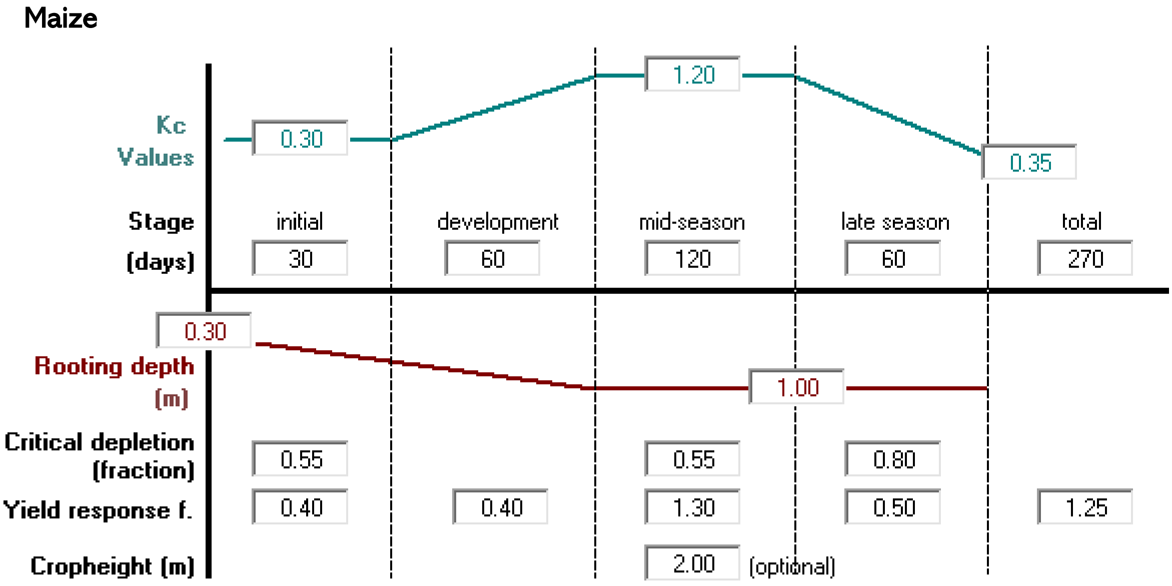

Figure 5. The crop properties of **maize** from FAO CROPWAT.

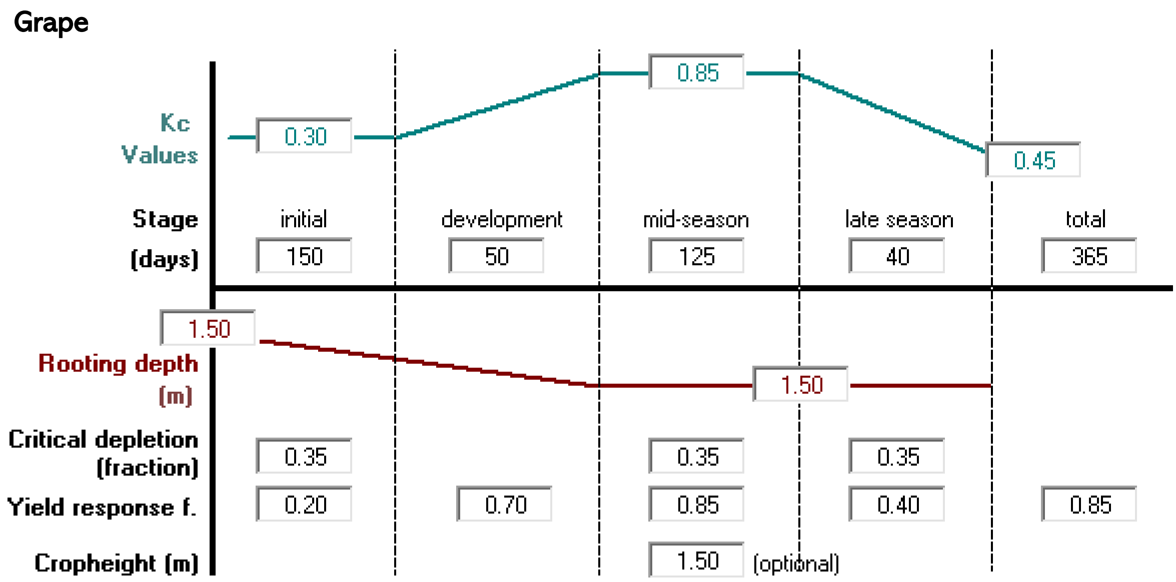

Figure 6. The crop properties of **grape** from FAO CROPWAT.

Cotton

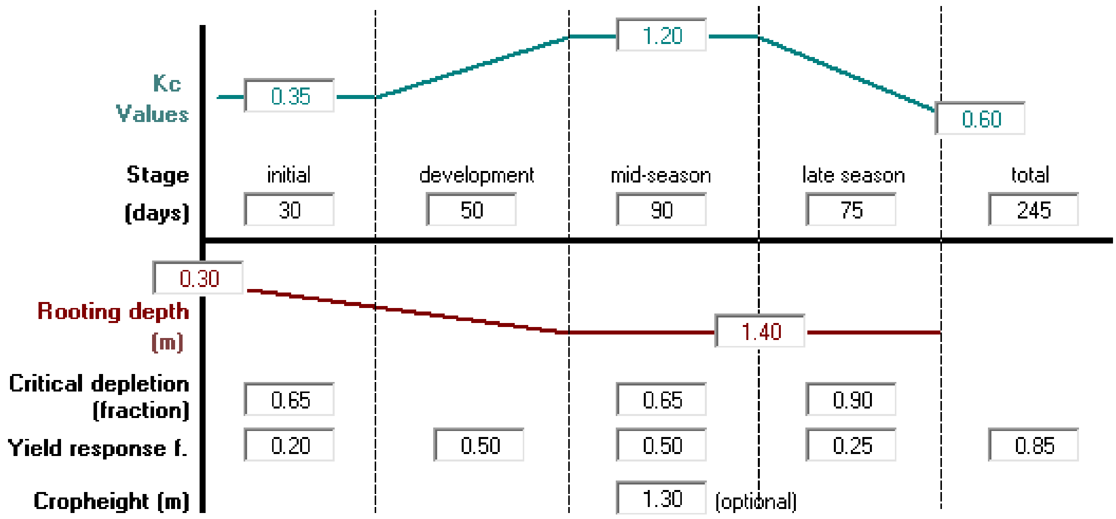

Figure 7. The crop properties of **cotton** from FAO CROPWAT.

Barley

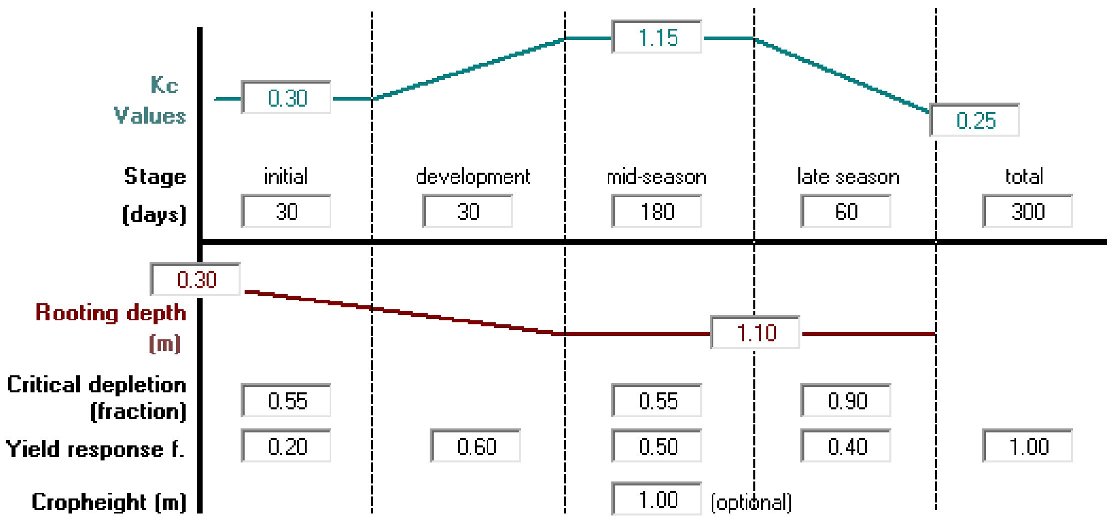

Figure 8. The crop properties of **barley** from FAO CROPWAT.

Included within the input provided in the CROPWAT and CLIMWAT programs were the Manisa Akhisar station data, the crop properties, the cultivation date, and the soil type. (Table 5). After all of the data were submitted to the software, it computed the crop's climatic characteristics, ETo, effective rainfall, and total irrigation needs.

Table 5. Optimal soil texture for wheat (NASA, 2022), maize (Eco Farming Daily, 2022), grape (Sommelier Choice Award, 2022), cotton (Wikifarmer, 2022) and barley (Valenzuela and Smith, 2022). The soil texture in this table is based on FAO soil texture classification (CROPWAT, 2022).

		Soil Texture (FAO)
		Medium (loam)
Tot. avail. soil moist.	**mm/meter**	290
Max. rain infiltrat. rate	**mm/day**	40
Max. rooting depth	**cm**	900

Table 5. Optimal soil texture for wheat (NASA, 2022), maize (Eco Farming Daily, 2022), grape (Sommelier Choice Award, 2022), cotton (Wikifarmer, 2022) and barley (Valenzuela and Smith, 2022). The soil texture in this table is based on FAO soil texture classification (CROPWAT, 2022).

		Soil Texture (FAO)
Initial soil moist. deplet. (as % TAM)	%	0
Initial. avail. soil moist.	**mm/meter**	290
Crops		Wheat, Maize, Grape, Cotton, Barley

3. Results

3.1. Crop Water Requirements (CWR) of all crops

The crop's water requirement is the quantity (or depth) of water equal to the ET water loss. Crops have varying water needs according to location, climate, soil type, cultivation technique, effective rainfall, etc., and the full amount of water essential for crop development is not evenly distributed across its entire average lifespan (Azevedo et al., 2007; Ewaid et al., 2019). Tables 6–10 demonstrate the effective rain and the IR of wheat, maize, grape, cotton and barley computed by CROPWAT. Also, the irrigation requirements, which do not consider effective rainfall, were given in the same tables for selected crops. In tables, (Init, initial; Dev, development; Eff. Rain, effective rain; Irr. Req., irrigation requirements).

Table 6. CWR for spring **wheat** for (1) eff. rain. considered based on USDA soil conservation service and (2) no eff. rain. considered.

Month	**Decade**	**Stage**	**Kc**	**ETc**	**ETc**	**Eff rain**	**Irr. Req.**	**Eff rain**	**Irr. Req.**
			coeff	**mm/day**	**mm/dec**	**mm/dec**	**mm/dec**	**mm/dec**	**mm/dec**
Mar	1	Init	0.3	0.55	5.5	20.3	0	0	5.5
Mar	2	Init	0.3	0.64	6.4	18.6	0	0	6.4
Mar	3	Deve	0.3	0.75	8.2	17.8	0	0	8.2
Apr	1	Deve	0.48	1.36	13.6	17.4	0	0	13.6
Apr	2	Deve	0.77	2.4	24	16.7	7.3	0	24
Apr	3	Mid	1.04	3.65	36.5	14.2	22.3	0	36.5
May	1	Mid	1.15	4.41	44.1	11.3	32.8	0	44.1
May	2	Mid	1.15	4.82	48.2	8.9	39.3	0	48.2
May	3	Mid	1.15	5.41	59.5	7.5	52	0	59.5
Jun	1	Late	1.14	5.97	59.7	6.3	53.4	0	59.7
Jun	2	Late	0.93	5.39	53.9	4.8	49.1	0	53.9
Jun	3	Late	0.65	3.99	39.9	3.7	36.1	0	39.9
Jul	1	Late	0.4	2.6	20.8	1.9	18.4	0	20.8

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Table 6. CWR for spring **wheat** for (1) eff. rain. considered based on USDA soil conservation service and (2) no eff. rain. considered.

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec
				Total	420.2	149.5	**310.7**	0	**420.2**

Table 7. CWR for spring **maize** for (1) eff. rain. considered based on USDA soil conservation service and (2) no eff. rain. considered.

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec
Feb	1	Init	0.3	0.34	3.4	24.8	0	0	3.4
Feb	2	Init	0.3	0.38	3.8	23.6	0	0	3.8
Feb	3	Init	0.3	0.47	3.7	22	0	0	3.7
Mar	1	Deve	0.35	0.65	6.5	20.3	0	0	6.5
Mar	2	Deve	0.5	1.07	10.7	18.6	0	0	10.7
Mar	3	Deve	0.66	1.64	18	17.8	0.2	0	18
Apr	1	Deve	0.82	2.3	23	17.4	5.6	0	23
Apr	2	Deve	0.97	3.05	30.5	16.7	13.8	0	30.5
Apr	3	Deve	1.12	3.93	39.3	14.2	25	0	39.3
May	1	Mid	1.21	4.64	46.4	11.3	35.1	0	46.4
May	2	Mid	1.21	5.07	50.7	8.9	41.8	0	50.7
May	3	Mid	1.21	5.7	62.7	7.5	55.2	0	62.7
Jun	1	Mid	1.21	6.33	63.3	6.3	57	0	63.3
Jun	2	Mid	1.21	6.96	69.6	4.8	64.8	0	69.6
Jun	3	Mid	1.21	7.37	73.7	3.7	70	0	73.7
Jul	1	Mid	1.21	7.87	78.7	2.4	76.3	0	78.7
Jul	2	Mid	1.21	8.32	83.2	1.2	82.1	0	83.2
Jul	3	Mid	1.21	8.07	88.7	1.5	87.2	0	88.7
Aug	1	Mid	1.21	7.85	78.5	2	76.6	0	78.5
Aug	2	Mid	1.21	7.68	76.8	2.1	74.7	0	76.8

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e-ISSN:2717-8277
International Journal of Water Management and Diplomacy

Table 7. CWR for spring **maize** for (1) eff. rain. considered based on USDA soil conservation service and (2) no eff. rain. considered.

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec
Aug	3	Late	1.2	6.91	76	2.9	73.1	0	76
Sep	1	Late	1.1	5.6	56	3.4	52.6	0	56
Sep	2	Late	0.96	4.32	43.2	4	39.2	0	43.2
Sep	3	Late	0.81	3.14	31.4	6.3	25	0	31.4
Oct	1	Late	0.67	2.14	21.4	8.5	12.9	0	21.4
Oct	2	Late	0.53	1.34	13.4	10.5	2.9	0	13.4
Oct	3	Late	0.4	0.83	6.6	10.2	0	0	6.6
				Total	1159.5	273.1	**971**	0	**1159.5**

Table 8. CWR for **grape** for (1) eff. rain. considered based on USDA soil conservation service and (2) no eff. rain. considered.

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec
Feb	1	Init	0.3	0.34	3.4	24.8	0	0	3.4
Feb	2	Init	0.3	0.38	3.8	23.6	0	0	3.8
Feb	3	Init	0.3	0.47	3.7	22	0	0	3.7
Mar	1	Init	0.3	0.55	5.5	20.3	0	0	5.5
Mar	2	Init	0.3	0.64	6.4	18.6	0	0	6.4
Mar	3	Init	0.3	0.74	8.1	17.8	0	0	8.1
Apr	1	Init	0.3	0.84	8.4	17.4	0	0	8.4
Apr	2	Init	0.3	0.94	9.4	16.7	0	0	9.4
Apr	3	Init	0.3	1.05	10.5	14.2	0	0	10.5
May	1	Init	0.3	1.15	11.5	11.3	0.2	0	11.5
May	2	Init	0.3	1.26	12.6	8.9	3.7	0	12.6
May	3	Init	0.3	1.42	15.6	7.5	8.1	0	15.6
Jun	1	Init	0.3	1.57	15.7	6.3	9.5	0	15.7

Table 8. CWR for **grape** for (1) eff. rain. considered based on USDA soil conservation service and (2) no eff. rain. considered.

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec
Jun	2	Init	0.3	1.73	17.3	4.8	12.5	0	17.3
Jun	3	Init	0.3	1.83	18.3	3.7	14.6	0	18.3
Jul	1	Deve	0.36	2.33	23.3	2.4	21	0	23.3
Jul	2	Deve	0.46	3.2	32	1.2	30.8	0	32
Jul	3	Deve	0.57	3.84	42.3	1.5	40.7	0	42.3
Aug	1	Deve	0.69	4.46	44.6	2	42.7	0	44.6
Aug	2	Mid	0.79	5.03	50.3	2.1	48.2	0	50.3
Aug	3	Mid	0.83	4.76	52.4	2.9	49.4	0	52.4
Sep	1	Mid	0.83	4.22	42.2	3.4	38.8	0	42.2
Sep	2	Mid	0.83	3.74	37.4	4	33.4	0	37.4
Sep	3	Mid	0.83	3.19	31.9	6.3	25.6	0	31.9
Oct	1	Mid	0.83	2.64	26.4	8.5	17.9	0	26.4
Oct	2	Mid	0.83	2.09	20.9	10.5	10.4	0	20.9
Oct	3	Mid	0.83	1.72	18.9	14.1	4.8	0	18.9
Nov	1	Mid	0.83	1.29	12.9	17.7	0	0	12.9
Nov	2	Mid	0.83	0.89	8.9	21	0	0	8.9
Nov	3	Mid	0.83	0.81	8.1	25.1	0	0	8.1
Dec	1	Mid	0.83	0.75	7.5	30.8	0	0	7.5
Dec	2	Mid	0.83	0.64	6.4	35.6	0	0	6.4
Dec	3	Late	0.78	0.62	6.9	32.8	0	0	6.9
Jan	1	Late	0.67	0.55	5.5	28.9	0	0	5.5
Jan	2	Late	0.56	0.48	4.8	26.8	0	0	4.8
Jan	3	Late	0.45	0.44	4.9	25.7	0	0	4.9
				Total	638.9	521.4	**412.3**	0	**638.9**

Table 9. CWR for **cotton** for (1) eff. rain. considered based on USDA soil conservation service and (2) no eff. rain. considered.

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec
Mar	2	Init	0.35	0.75	4.5	11.2	0	0	4.5
Mar	3	Init	0.35	0.86	9.5	17.8	0	0	9.5
Apr	1	Init	0.35	0.98	9.8	17.4	0	0	9.8
Apr	2	Deve	0.4	1.25	12.5	16.7	0	0	12.5
Apr	3	Deve	0.57	1.97	19.7	14.2	5.5	0	19.7
May	1	Deve	0.74	2.84	28.4	11.3	17.1	0	28.4
May	2	Deve	0.91	3.82	38.2	8.9	29.3	0	38.2
May	3	Deve	1.09	5.15	56.6	7.5	49.1	0	56.6
Jun	1	Mid	1.21	6.34	63.4	6.3	57.1	0	63.4
Jun	2	Mid	1.21	6.98	69.8	4.8	65	0	69.8
Jun	3	Mid	1.21	7.39	73.9	3.7	70.2	0	73.9
Jul	1	Mid	1.21	7.89	78.9	2.4	76.5	0	78.9
Jul	2	Mid	1.21	8.35	83.5	1.2	82.3	0	83.5
Jul	3	Mid	1.21	8.09	89	1.5	87.5	0	89
Aug	1	Mid	1.21	7.88	78.8	2	76.8	0	78.8
Aug	2	Mid	1.21	7.7	77	2.1	74.9	0	77
Aug	3	Mid	1.21	6.96	76.5	2.9	73.6	0	76.5
Sep	1	Late	1.16	5.94	59.4	3.4	55.9	0	59.4
Sep	2	Late	1.08	4.88	48.8	4	44.8	0	48.8
Sep	3	Late	1	3.85	38.5	6.3	32.1	0	38.5
Oct	1	Late	0.92	2.92	29.2	8.5	20.7	0	29.2
Oct	2	Late	0.83	2.11	21.1	10.5	10.6	0	21.1
Oct	3	Late	0.75	1.55	17.1	14.1	3	0	17.1
Nov	1	Late	0.66	1.03	10.3	17.7	0	0	10.3
Nov	2	Late	0.6	0.65	2.6	8.4	0	0	2.6
				Total	1097.1	205	**932.2**	0	**1097.1**

Table 10. CWR for **barley** for (1) eff. rain. considered based on USDA soil conservation service and (2) no eff. rain. considered.

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec	mm/dec	mm/dec
Oct	1	Init	0.3	0.96	9.6	8.5	1	0	9.6
Oct	2	Init	0.3	0.76	7.6	10.5	0	0	7.6
Oct	3	Deve	0.3	0.63	6.9	14.1	0	0	6.9
Nov	1	Deve	0.48	0.75	7.5	17.7	0	0	7.5
Nov	2	Deve	0.75	0.81	8.1	21	0	0	8.1
Nov	3	Mid	1.02	1	10	25.1	0	0	10
Dec	1	Mid	1.12	1.01	10.1	30.8	0	0	10.1
Dec	2	Mid	1.12	0.86	8.6	35.6	0	0	8.6
Dec	3	Mid	1.12	0.89	9.8	32.8	0	0	9.8
Jan	1	Mid	1.12	0.92	9.2	28.9	0	0	9.2
Jan	2	Mid	1.12	0.95	9.5	26.8	0	0	9.5
Jan	3	Mid	1.12	1.11	12.2	25.7	0	0	12.2
Feb	1	Mid	1.12	1.27	12.7	24.8	0	0	12.7
Feb	2	Mid	1.12	1.43	14.3	23.6	0	0	14.3
Feb	3	Mid	1.12	1.75	14	22	0	0	14
Mar	1	Mid	1.12	2.07	20.7	20.3	0.4	0	20.7
Mar	2	Mid	1.12	2.39	23.9	18.6	5.3	0	23.9
Mar	3	Mid	1.12	2.77	30.4	17.8	12.6	0	30.4
Apr	1	Mid	1.12	3.14	31.4	17.4	14	0	31.4
Apr	2	Mid	1.12	3.52	35.2	16.7	18.5	0	35.2
Apr	3	Mid	1.12	3.92	39.2	14.2	25	0	39.2
May	1	Mid	1.12	4.31	43.1	11.3	31.8	0	43.1
May	2	Mid	1.12	4.71	47.1	8.9	38.2	0	47.1
May	3	Late	1.11	5.26	57.8	7.5	50.3	0	57.8
Jun	1	Late	1	5.23	52.3	6.3	46.1	0	52.3
Jun	2	Late	0.85	4.92	49.2	4.8	44.4	0	49.2
Jun	3	Late	0.71	4.32	43.2	3.7	39.5	0	43.2
Jul	1	Late	0.56	3.66	36.6	2.4	34.2	0	36.6
Jul	2	Late	0.42	2.87	28.7	1.2	27.6	0	28.7
Jul	3	Late	0.29	1.96	13.7	1	12.2	0	13.7
				Total	702.8	500	**401.1**	0	**702.8**

Clearly, the cultivation of these five crops in the district represents a small-scale fraction of the national crop pattern; consequently, there is an immediate necessity to modify agriculture and irrigation infrastructure in order to increase output. As stated in Ewaid et al (2019), modernization of the watering system incorporates the latest techniques such as sprinkler and drip watering, with a focus on valuable products, water availability, and soil quality. It is crucial to educate farmers on the demand to conserve water and employ contemporary techniques.

4. Conclusions

The application of the FAO CROPWAT 8.0 technique produced an intriguing outcome. Due to the seasonal and ecological characteristics of the district, it is evident that crop watering needs were peculiar to the local research region. In this instance, maize had greater evapotranspiration and water demands than the other four crops in this order: Cotton > Grape > Barley > Wheat.

The findings of this study increase our knowledge of the water demand of a number of important crops in Manisa, Turkey; thus, strategies based on these results will assist in enhancing the management of water and crop yield.

Using scientific technologies such as CROPWAT and CLIMWAT, it is possible to evaluate CWRs with a reasonable level of precision and recommend crop patterns and crop rotations that growers are willing to acknowledge. The outputs of this study can be utilized by water resource administrators for planning activities, so aiding in the conservation of water in achieving CWRs, and by producers for determining the quantity of irrigation for the products under consideration.

A thorough approach should be developed to determine the CWRs for all districts without such research. Such a plan might serve as the foundation for agricultural operations. Moreover, testing must be conducted to validate the use of these software programs.

Acknowledgement
We would like to thank the General Director of Central Union of Turkey's Irrigation Cooperatives A. Halis Uysal and the Managers of Beyoba Village Irrigation Cooperative for their patient help and for providing data for this study effort.

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Received: 21 May 2022

Accepted: 18 June 2022