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Research Article

Calculation of rainwater harvest in greenhouses for semi-arid and continental climate zones

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ABSTRACT

In this study, it is aimed to determine the irrigation water required due to solar radiation in high technology greenhouses where soilless cultivation is carried out according to TS825 standards, and to determine the annual water consumption and storage capacity with the harvested rainwater. As a result of the calculations made for Turkey Mediterranean region, it has been determined that if 90% of the rainfall in the western Mediterranean region is harvested, 72% of the annual water consumption can be met, and 45% in the eastern Mediterranean region. In the inner regions where the terrestrial climate is dominant, 22%–32% of the annual water consumption can be met with 90% of the rain harvested depending on the amount of rainfall. The required storage volume in the western Mediterranean is 0.420 $m^3.m^{-2}$, while it is 0.096 $m^3.m^{-2}$ in the eastern Mediterranean and 0.044 $m^3.m^{-2}$ in Kırşehir, where the continental climate prevails.

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INTRODUCTION

The increasing need for food in parallel with the population growth in the world increases the demand for agricultural products as well. It is estimated that by the year 2026, the world population will have reached 8.3 billion, with an increase of 35% compared to 2000 [1]. In order to ensure the food security of the growing population in our country, it is necessary to increase agricultural production and productivity in agricultural production. It is not possible to say that our country has sufficient land and water resources, which are the two main elements of agricultural production. One of the most effective ways to increase production and efficiency is to increase the yield per unit area of land. This is possible by using new technologies in agriculture and increasing irrigated areas.

According to the State Hydraulic Works (DSI), average annual precipitation in Turkey is 574 mm. The average above ground and underground water potential of Turkey is 112 billion m^3 per year [2]. Turkey's current water consumption is 44 $km^3.year^{-1}$. 74% of this water is used in agriculture while 15% is consumed as domestic water and 11% is used in the industrial sector [3]. When water use

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in our country is analysed by sectors, it is seen that the agricultural sector has the highest share. The pressure on resources in order to meet the increasing requirements of Turkey shows an upward trend [4].

Irrigation is the agricultural activity that has the highest effect on the yield increase in crop production. Water use efficiency (WUE), which is the ratio of yield to irrigation water usage, is generally used as a measure of water use in irrigation systems. Due to diminishing water resources, increasing water use efficiency is of great importance. WUE values in tomato production using greenhouses vary between 20.47 kg.m^{-3} and 47.7 kg.m^{-3} [5–7]. A significant amount of water is consumed in vegetative production in greenhouses. The ratio of tomato production in Turkey's under cover vegetative production is 48%. Studies have shown that 193 litters of water are consumed for 1 kg of tomato production [8]. This reveals that water saving should be especially taken into consideration in the coming years in order to benefit more from the water resources that have diminished due to global warming.

Studies are being carried out to establish an optimum irrigation program for vegetables grown in greenhouses with medium technology on the Mediterranean coastline. In these studies, generally open water surface evaporation is used to determine the water requirement [9]. In their study on watering tomatoes in a glass greenhouse on the Mediterranean coastline, Tari and Sapmaz (2017) took advantage of the Class A-Pan evaporation vessel and determined the water consumption to be 1.8 mm.day^{-1} in January-April, 3.33 mm.day^{-1} in May and 5 mm.day^{-1} in June [10]. Using the FAO-Penman Monteith equality, Zabeltitz (2011) has determined the values as 0.86–3.5 mm.day^{-1} for January-April, 4.75 mm.day^{-1} for May and 5.9 mm.day^{-1} for June in his calculations of water consumption in Antalya, based on average daily temperatures [11].

Irrigation scheduling determines the amount of water applied to the plant (irrigation dose) and the application timing (irrigation frequency). Irrigation scheduling is made one in two different ways, depending water budget based on climatic data or soil and plant sensors [12].

In Turkey, irrigation for soilless agriculture production in high technology greenhouses established in recent years is scheduled according to the intensity of solar radiation. In soilless culture, normal planning for irrigation according to solar radiation intensity is one irrigation application per 80 J.cm^{-2}. In this method, plants can be directed towards the desired growth characteristics by decreasing or increasing irrigation intervals. Increasing the irrigation interval can increase salinity in the growing medium, which increases fruit sugar and generative growth as it increases plant stress [13].

Rainwater harvesting is the collection and accumulation of the portion of the rainwater that passes to the surface flow and the provision of water necessary for plant and animal production as well as domestic consumption [14]. The biggest problem that global climate change will create in terms of sustainable agriculture in the future will be water scarcity. In the future, in areas where water resources are not sufficient, it will be of great importance to collect rainwater and use it for greenhouse irrigation. However, under these conditions, the gutters collecting rainwater and their storage volumes water should be calculated based on the amount of rainfall and daily water consumption [11].

In storing rainwater, the factors to be taken into consideration when determining the storage capacity are the area of the greenhouse area and the size of the storage area, the distribution of rainfall, the total amount of rainfall, the water requirement of the plant grown, and whether the storage tanks to be planned will be used only for storing rainwater or for a mixture made with waste or salt water [11]. In large greenhouse enterprises with high technology, storage structures are constructed by taking into account the daily maximum water consumption during the production period.

This study aims to determine storage capacity for different harvest rates and determine the rates of meeting water consumption requirements with harvested rainwater by taking into account the monthly rainfall and daily water consumption for tomato production in high technology greenhouses in three different climate zones in Turkey, established in compliance with TS 825 standards.

MATERIALS AND METHODS

In this study, the calculations are based on high technology greenhouses in Turkey in different provinces set in compliance with TS 825, where greenhouse cultivation is common and the daily solar radiation in these provinces: Antalya, Mersin and Adana in Region I, Denizli, Yalova and Şanlıurfa in Region II, Kırşehir and Kütahya in Region III where there are geothermal resources.

Determining Plant Water Consumption

Daily water consumption in greenhouses where soilless agriculture is carried out has been determined according to the intensity of solar radiation. In Table 1, monthly average solar radiation values for the 2004–2018 (kWh.m^{-2}day^{-1}) provided by the General Directorate of Meteorology for provinces located in different climatic regions are given. In the calculation of daily water consumption depending on the months, based on the values given in Table 1, 3 mL.m^{-2} irrigation water was calculated for 1 J.cm^{-2} radiation energy.

Determining Storage Pool Capacity

In determining the accurate rainwater storage capacity, daily repetitions of rainfall are used. However, since these values are not known for many areas, in this study monthly

Table 1. Average daily radiation values of different provinces based on months (kWh.m^{-2}.day^{-1})

Region	Province	January	February	March	April	May	June	July	August	September	October	November	December
Region I	Adana	1.98	2.42	4.12	4.98	6.07	6.68	6.46	5.91	4.90	3.78	2.33	1.81
	Antalya	2.12	2.57	4.37	5.47	6.36	6.93	6.65	6.14	5.16	3.93	2.51	1.92
	Mersin	2.11	2.65	4.27	5.24	6.28	6.86	6.66	6.08	5.04	3.84	2.47	1.91
Region II	Denizli	2.01	2.45	4.11	5.26	6.22	6.73	6.62	6.00	4.99	3.75	2.39	1.79
	Şanlıurfa	1.94	2.48	4.09	5.08	6.18	6.83	6.58	5.94	5.02	3.79	2.42	1.80
	Yalova	1.40	2.23	3.24	4.44	5.63	6.05	5.82	5.30	4.20	2.90	1.70	1.22
Region III	Kırşehir	1.78	2.38	3.89	4.83	6.09	6.47	6.42	5.85	4.84	3.43	2.08	1.58
	Kütahya	1.77	2.36	3.75	4.93	6.08	6.48	6.38	5.72	4.69	3.28	2.04	1.51

Table 2. Daily water consumption based on solar radiation in greenhouses in different climatic regions established according to TS 825 standards (L.m^{-2} day^{-1})

Region	Province	January	February	March	April	May	June	July	August	September	October	November	December
Region I	Adana	2.1	2.6	4.4	5.4	6.6	7.2	7.0	6.4	5.3	4.1	2.5	2.0
	Antalya	2.3	2.8	4.7	5.9	6.9	7.5	7.2	6.6	5.6	4.2	2.7	2.1
	Mersin	2.3	2.9	4.6	5.7	6.8	7.4	7.2	6.6	5.4	4.1	2.7	2.1
Region II	Denizli	2.2	2.6	4.4	5.7	6.7	7.3	7.1	6.5	5.4	4.1	2.6	1.9
	Şanlıurfa	2.1	2.7	4.4	5.5	6.7	7.4	7.1	6.4	5.4	4.1	2.6	1.9
	Yalova	1.5	2.4	3.5	4.8	6.1	6.5	6.3	5.7	4.5	3.1	1.8	1.3
Region III	Kırşehir	1.9	2.6	4.2	5.2	6.6	7.0	6.9	6.3	5.2	3.7	2.2	1.7
	Kütahya	1.9	2.5	4.1	5.3	6.6	7.0	6.9	6.2	5.1	3.5	2.2	1.6

Table 3. Daily and monthly water consumption based on solar radiation in greenhouses under climatic conditions of Antalya

Consumption	January	February	March	April	May	June	July	August	September	October	November	December
L.m^{-2}.day^{-1}	2.3	2.8	4.7	5.9	6.9	7.5	7.2	6.6	5.6	4.2	2.7	2.1
L.m^{-2}.mon^{-1}	71.3	78.4	145.7	177.0	213.9	225.0			168.0	130.2	81.0	65.1

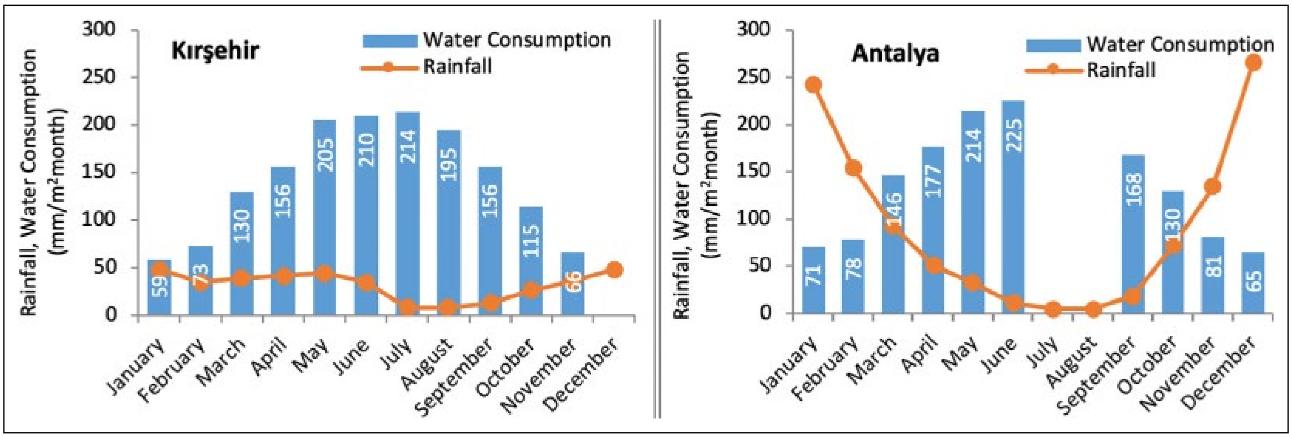

Figure 1. Amounts of water consumption based on monthly rainfall and intensity of solar radiation in Antalya, where greenhouse cultivation is intensively carried out, and in Kırşehir, where geothermal greenhouse cultivation has become a practice.

rainfall amounts were used in order to determine the storage capacity. The monthly amount of rainwater that can be stored was calculated with Equation 1 [11].

$CV_m = Pre * R_C$ ($L.m^{-2}month^{-1}$) (Equation 1.)

In the equation;

CV_m: Amount of water harvested ($L.m^{-2}month^{-1}$), R_C: Water harvest rate (%), Pre: Monthly precipitation ($mm.month^{-1}$). In the calculations made, the R_C value was taken as 40–90%.

Storable monthly rainfall was calculated with the help of Equation 2:

$STP_m = CV_m - CWR_m - EV_{pond}$ ($L.m^{-2}month^{-1}$) (Equation 2.)

In the equation:

STP_m: Monthly stored rainfall ($l.m^{-2}month^{-1}$), CWR_m: Monthly plant water consumption ($l.m^{-2}month^{-1}$), EV_{pond}: Evaporation losses in the storage pool ($L.m^{-2}month^{-1}$)

In the calculations made, evaporation losses from the storage pool were taken as 0, assuming that the pool surface is covered with PE plastic. As a result of the calculations, when the monthly storable precipitation amount (STP_m) is positive, the pool is filled, and when STP_m is negative, the water in the pool decreases.

Storable annual precipitation depending on the stored rainfall per month was determined with Equation 3:

$STP_y = \Sigma(+)STP_m$ ($L.m^{-2}month^{-1}$) (Equation 3.)

The annual deficit due to plant water consumption was calculated with Equation 4:

$Def_y = \Sigma(-)STP_m$ ($L.m^{-2}month^{-1}$) (Equation 4.)

The stored annual precipitation amount was calculated with Equation 5:

$STB_y = STP_y - Def_y$ ($L.m^{-2}month^{-1}$) (Equation 5.)

While determining the storage capacity, the following conditions were taken into account [15].

1- When $STB_y > 0$ or $STP_y > Def_y$ the amount of stored water will meet the water needs of the plants during the production period. In this case, the storage capacity should be taken as VST=Defy ($l.m^{-2}$).

When the precipitation changes over the months are large, the storage volume should be increased. In this case, the storage volume should be taken as $VST = Def_y (1+V_C)$($L.m^{-2}$).

2- If $STB_y < 0$ or $STP_y < Def_y$ then stored rainfall is not sufficient for irrigation. In this case, two conditions must be considered:

(a) If the amount of stored rainfall is greater than the monthly maximum rainfall collected ($STP_y > CV_{mmax}$) then the storage volume should be $VST = STP_y$, and when the precipitation variation due to months is large, it should be determined as$VST = STP_y (1+V_C)$.

(b) If the amount of stored rainfall is less than the monthly maximum rainfall collected ($STP_y < CV_{mmax}$) then the storage volume should be VST=CV_mmax, and when the precipitation variation due to months is large, it should be determined as $VST = CV_{mmax} (1+V_C)$.

FINDINGS

The plant water requirements calculated based on solar radiation in soilless agriculture practices in high technology greenhouses established in provinces located in different climatic regions according to TS 825 are given in Table 2. As can be seen from the Table 2, the highest daily water requirement in all three climatic regions is in July.

The plant production period in greenhouses varies depending on the climate of the region. The production in high technology greenhouses in the provinces within Region I starts in the last week of August and continues until the end of June. The water consumption amounts during the production period depending on the daily total radiation intensities of the Antalya province located in Region I are given in Table 3.

Table 4. The monthly rates of meeting water requirement and the required storage capacities in Antalya climate conditions when 90% of rainwater is harvested

Month	Pre mm/m²mon.	CV_m mm/m²mon.	d_m	CWR_d L/m²day	CWR_m L/m²mon	STP_m L/m²mon.	STP_m L/m²mon.	IW_m L/m²
January	242.1	217.9	31	2.3	71.3	146.6	359.5	0.0
February	154.4	139.0	28	2.8	78.4	60.6	420.0	0.0
March	97.2	87.5	31	4.7	145.7	-58.2	361.8	0.0
April	50.4	45.4	30	5.9	177.0	-131.6	230.2	0.0
May	32.1	28.9	31	6.9	213.9	-185.0	45.2	0.0
June	10.9	9.8	30	7.5	225.0	-215.2	-170.0	170.0
July	4.5	4.1	0	7.2	0.0	4.1	4.1	0.0
August	4.6	4.1	0	6.6	0.0	4.1	8.2	0.0
September	18.1	16.3	30	5.6	168.0	-151.7	-143.5	143.5
October	72.1	64.9	31	4.2	130.2	-65.3	-208.8	65.3
November	133.6	120.2	30	2.7	81.0	39.2	39.2	0.0
December	265.3	238.8	31	2.1	65.1	173.7	212.9	0.0
Total	**1085.3**	**976.8**			**1355.6**			**378.8**
Rate of meeting irrigation water		0.72						

If it is assumed that there is no vegetative production in the greenhouse due to the high temperature during July and August in Antalya climatic conditions, the amount of water consumed during the production period is 1.356 $m^3.m^{-2}a^{-1}$. According to different resources, the average water requirement in greenhouses for summer months can be taken as 5 $L.m^{-2}$ plant area per day or 0.15 $m^3.m^{-2}month^{-1}$. The annual requirement is 0.8–2.0 $m^3.m^{-2}$. Annual water requirement in irrigation with fogging method can be 3 m^3/m^2 or more [15].

The fact that Turkey has different climate zones leads to different temperatures and different quantities of rainfall. In Figure 1, monthly water consumption amounts in the greenhouse based on monthly rainfall and intensity of solar radiation have been given. The values are given for Antalya, where greenhouse cultivation is a common practice and for Kırşehir, where geothermal greenhouse cultivation has become widespread in recent years.

In Antalya, where greenhouse cultivation is a common practice, the amounts of rainfall in November-February period exceed the water required for the plant production in the greenhouse (Fig. 1). In the case of harvesting and storing rainfall during this period, a significant part of the plant water required in the following months will be met.

Inner parts of Anatolia are insufficient in terms of rainfall. When the rainfall and water consumption are examined in Kırşehir, which is located in Central Anatolia and where geothermal greenhouse cultivation has gained momentum in recent years, it is seen that in the case of storing monthly rainfall, a very small part of the monthly water consumption can be met, yet this amount is not for storage (Fig. 1). In Kırşehir, while rainfall cannot fully meet the water consumption of the greenhouse in any month, it does not provide any possibility for storage.

The required storage capacities and the rate of meeting irrigation water with rainfall according to the water consumption quantities calculated depending on the monthly amount of precipitation and intensity of solar radiation in Antalya are given in Table 4. The highest precipitation in Antalya climate conditions falls is observed in December and the total annual precipitation is 1085.3 $mm.m^{-2}$. Considering that 90% of the rainfall on the greenhouse cover surface is harvested, the amount of rainfall that can be stored is 976.8 $mm.m^{-2}year^{-1}$.

Under the climatic conditions of Antalya, when it is considered that greenhouse cultivation starts in the last week of August and ends at the end of June, 8.2 $L.m^{-2}$ water can be stored by collecting the rainfall in the months of July and August. Assuming that 90% of the rainfall in September is collected (16.3 $L.m^{-2}month^{-1}$) and that 8.2 $l.m^{-2}$ water kept in the tanks is used, only 14.6% of the 168 $l.m^{-2}month^{-1}$ water requirement in September will be met by precipitation. The remaining amount of the irrigation water required in September (143.5 $L.m^{-2}month^{-1}$) must be met from different sources. While the amount of required irrigation based on solar radiation decreases in October, with the increasing amount of rainfall, the amount of irrigation water needed from external sources is 65.3 $L.m^{-2}month^{-1}$.

In Antalya climate conditions, the collection of rainwater starts in November. As can be seen from Table 4, the

Table 5. The monthly rates of meeting water requirement and the required storage capacities in Kırşehir climate conditions when 90% of rainwater is harvested

Month	Pre mm/m²mon.	CV_m mm/m²mon.	d_m	CWR_d L/m²day	CWR_m L/m²mon	STP_m L/m²mon.	STP_m L/m²mon.	IW_m L/m²
January	48.4	43.6	31	1.9	58.9	-15.3	28.4	0
February	35.2	31.7	28	2.6	72.8	-41.1	-12.8	12.8
March	39.3	35.4	31	4.2	130.2	-94.8	-107.6	94.8
April	41.5	37.4	30	5.2	156	-118.7	-226.2	118.7
May	44.8	40.3	31	6.6	204.6	-164.3	-390.5	164.3
June	34.6	31.1	30	7	210	-178.9	-569.4	178.9
July	8.3	7.5	31	6.9	213.9	-206.4	-775.8	206.4
August	7.9	7.1	31	6.3	195.3	-188.2	-964.0	188.2
September	12.9	11.6	30	5.2	156	-144.4	-1108.4	144.4
October	26.7	24.0	31	3.7	114.7	-90.7	-1199.1	90.7
November	36.4	32.8	30	2.2	66	-33.2	-1232.3	33.2
December	48.5	43.7	0	1.7	0	43.7	43.7	0
Total	**384.5**	**346.05**			**1578.4**			**1232.4**
Rate of meeting irrigation water		0.22						

amount of irrigation water required due to the decreasing solar radiation in November is 81 L.m^{-2}month^{-1} and the amount of rainwater collected is 120.2 L.m^{-2}month^{-1}. Under these conditions, the remaining 39.2 L.m^{-2}month^{-1} of the collected rainfall can be stored. In the case of collecting 90% of the rainfall after November in Antalya, it is possible to meet the irrigation water in the greenhouse without the need for water supply from external sources until the end of May.

The water requirement and storage capacity calculated based on monthly amounts of rainfall and water consumption in Kırşehir, a province in Central Anatolia, are given in Table 5. As can be seen from the Table 5, in the case of greenhouse cultivation all year under Kırşehir climate conditions, planting in the greenhouse starts in the last week of December and continues until the first week of December of the following year. Under these conditions, the storage of the rainfall in December takes place, and the storage capacity of 43.7 L/m² is sufficient as the rainfall in the following months meets only a small part of the monthly water requirement. When 90% of the precipitation is harvested in Kırşehir climate conditions, only 22% of the annual water consumption can be met.

The rates of meeting irrigation water requirement with rainwater depending on different rainwater harvest rates in provinces located in different climatic zones according to TS 825 standards are given in Table 6. By harvesting 90% of rainwater in Antalya climate conditions, 72% of the annual water requirement can be met. In the event that harvest rate drops to 70%, this rate drops to 56%.

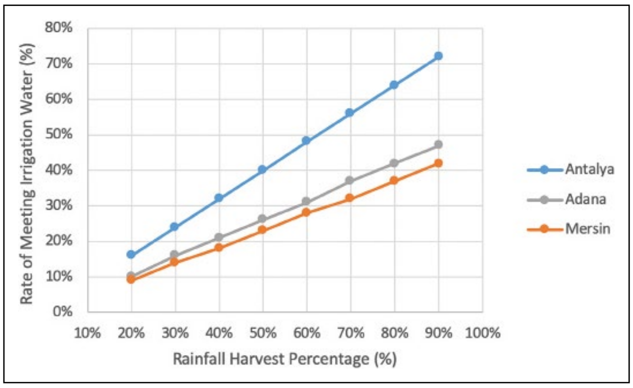

Figure 2. Rates of meeting irrigation water requirement in different provinces according to TS 825 based on rainfall harvest rates.

As can be seen from Table 6, the rates of meeting irrigation water with harvested rainwater show significant differences in the provinces located in Region I. If the rainwater harvest rate is 90% in Antalya, the irrigation water is met 72%, while this rate is 47% in Adana and 42% in Mersin. This shows that the rate of meeting irrigation water requirement is influenced by the amount of precipitation rather than the temperatures in different regions.

In Figure 2, the rates of meeting the irrigation water with rainwater for different rainfall harvest rates are given for the provinces of Antalya, Adana and Mersin, which are located in Region I according to TS 825 standards and where greenhouse cultivation is intensely carried out. As can be seen from the figure, depending on the increase

Table 6. Rates of meeting irrigation water requirement with rainfall in different climatic regions according to ts 825 based on rainfall collection rates

TS825 region	Region I			Region II			Region III	
Provinces	Antalya	Adana	Mersin	Yalova	Denizli	Şanlıurfa	Kütahya	Kırşehir
Rainfall (mm/m²)	1085	671	616	757	572	464	562	385
Harvest rate (%)								
90	72	47	42	54	40	32	32	0.22
80	64	42	37	48	35	29	29	19
70	56	37	32	42	31	25	25	17
60	48	31	28	36	26	21	22	15
50	40	26	23	30	22	18	18	12
40	32	21	18	24	18	14	14	10

Table 7. Storage volumes based on rainwater harvest rates in different climatic regions according to TS 825 ($L.m^{-2}$)

TS825 region	Region I			Region II			Region III	
Provinces	Antalya	Adana	Mersin	Yalova	Denizli	Şanlıurfa	Kütahya	Kırşehir
Rainfall (mm/m²)	1085	671	616	757	572	464	562	385
Harvest rate (%)								
90	420.0	95.9	95.9	117.7	36.9	28.3	76.4	43.7
80	340.5	64.0	70.1	89.1	20.8	11.5	62.5	38.8
70	261.0	40.1	44.3	60.3	18.2	3.8	54.7	34.0
60	182.3	16.3	18.7	37.2	15.6	3.2	46.9	29.1
50	117.4	10.0	9.3	17.1	13.0	2.7	39.1	24.3
40	66.5	8.0	7.4	12.7	10.4	2.2	31.2	19.4
30	15.8	6.0	5.6	9.5		1.6	23.4	

in rainwater harvest rate, irrigation water coverage rate increases linearly. Among the provinces located in Region I, the highest rainfall occurs in Antalya, while the amount of rain decreases from the western Mediterranean to the eastern Mediterranean. When 90% of the rainfall is collected in Adana climate conditions, 47% of the irrigation water need can be met, while this value is 42% in Mersin.

The rate of meeting irrigation water requirement from rainwater is the lowest in Kırşehir, which is located in Region III. Table 6 shows the percentages of meeting irrigation water requirements at different rainfall collection rates in provinces located in different climatic zones.

It is necessary to know the volumes calculated according to the monthly rainfall and water consumption in order to resize the tanks to be established for storing rainwater. In Table 4, the storage volumes calculated depending on the monthly rainfall and plant water requirement in Antalya climatic conditions are given. As can be seen from the calculations made, if 90% of the rainwater is harvested, the highest storage volume is in February with 420 $L.m^{-2}month^{-1}$.

When the rainfall harvested in the regions with low amount of rainfall covers some of the water consumption, storage cannot be made. As can be seen from the calculations in Table 5 made for Kırşehir, where rainfall amounts are low, rainfall is not stored as the monthly rainfall amounts meet only a small part of the water consumption. Since irrigation water is not needed only in December, when planting is carried out, it is possible to store rainfall in this month.

Storage volume varies depending on harvested rainfall and water requirement. In Table 7, the maximum storage volumes calculated based on different rainwater harvest rates in provinces in different climatic zones according to TS 825 standards are given. As can be seen from the Table, depending on the amount of rainfall, the highest storage volume occurs in Antalya, while the lowest storage volume is calculated for Kırşehir, where geothermal greenhouse cultivation is practiced.

CONCLUSION AND EVALUATION

74% of Turkey's current water consumption is in agriculture while domestic use and industrial use are 15% and 11%

respectively. Turkey's growing need for water has increased the pressure on resources. Global climate change and the gradual reduction of water resources may put the sustainability of agricultural production, which has important contributions to human nutrition, at risk in the coming years.

Reducing water consumption in agriculture will be possible by increasing water use efficiency (WUE). In Turkey, which follows Spain in Europe in terms of greenhouse area, increasing water use efficiency will be possible by collecting the rainwater that reaches greenhouse surface and using it for irrigation rather than implementing water constraints.

For harvesting and storing the rain water reaching the greenhouse cover surface, it is necessary to resize the water gutters in the greenhouse structures and to accurately determine the storage volumes to be installed. When determining an accurate storage volume, daily rainfall and daily water consumption quantities should be known. However, it is not possible to obtain the daily amount of rainfall for every location. For the stated reason, monthly total precipitation is taken as a basis in determining the storage volume.

Along the Mediterranean coastline, where greenhouse cultivation is a common practice, rainfall shows significant differences. While the annual precipitation amount in Antalya is 1085 mm.year^{-1}, it is 671 mm.year^{-1} in Adana and 616 mm.year^{-1} in Mersin. In the case of harvesting 90% of rainwater in the production under cover in Antalya, 72% of the annual water consumption can be met, while in Adana and Mersin the rates are 47% and 42%. In the case of harvesting 90% of rainwater, the required storage volume in Antalya is 420 L.m^{-2}, while it is 96 L.m^{-2} in Adana and Mersin.

In areas where terrestrial climate is dominant and geothermal greenhouse cultivation is carried out, the amount of rainfall is considerably low. Total annual precipitation in Kütahya is 562 mm.year^{-1}, and in Kırşehir it is 385 mm.year^{-1}. In the study conducted, it has been shown that in the case of harvesting 90% of the rainwater in Kütahya climatic conditions, 32% of the annual water consumption can be met, while only 22% of it can be met in Kırşehir.

In order for the irrigation water in the greenhouses to rest and not to risk the product in the greenhouse, the water tanks installed should be of a sufficient size to meet the irrigation water need for at least two days. Considering that the effective size of greenhouses established as large enterprises is 20160 m^2, the maximum water requirement in June in the Mediterranean region and in July where the continental climate prevails is 150 m^3.day^{-1}. In this case, the capacity of the water tank to be installed should be at least 300 m^3. Whenever possible, the tanks to be established for storing rainwater should be built in a closed area within a greenhouse tunnel. Under these conditions, evaporation of water is prevented during hot periods, and frostbite can be prevented during cold periods. The diameter of the pipes that will carry the water to the collection tanks varies depending on the greenhouse floor area. The diameter of the collecting pipe should be 125 mm if the area where the rainwater will be harvested is 400–700 m^2 and 150 mm when the collection area is 700–1200 m^2 [11].

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DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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