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Investigation of the effect of climate change on reference evapotranspiration in Tekirdag, Turkiye

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Abstract

It is important to determine the impact of global climate change on water resources. In the effective use of water resources, the amount of water required for agricultural irrigation should be planned under these conditions. In this study, the trend analysis of the climate data required for the calculation of reference evapotranspiration (ET0) between 2011 and 2020 for the meteorology station of Tekirdag, Turkey was carried out. Analysis of change in the study was carried out according to the methods of Linear Regression Test, Mann-Kendall Test and Sen T Test. As a result of the change analysis, it was determined that the reference evapotranspiration (ET0) values had a decreasing trend in June and July and this decrease was statistically significant. As a result of the analysis of the changes in the climate parameters used in the calculation of reference evapotranspiration (ET0), it was determined that the values of maximum temperature, average relative humidity and average sunshine duration were in a decreasing trend, while minimum temperature and wind speed values were in an increasing trend. In the study, the change in monthly precipitation amounts during the measurement periods was also examined. As a result of the analysis of the changes, it was determined that the monthly precipitation amounts have a decreasing trend and the changes especially in April, September, October and December are statistically significant. It is thought that the results obtained will contribute to the future agricultural production planning in the regional conditions.

Keywords: *Trend analysis, Penman-Monteith method, monthly precipitation amounts, water resources.*

Resumen

Es importante determinar el impacto del cambio climático global sobre los recursos hídricos. En el uso efectivo de los recursos hídricos, la cantidad de agua requerida para el riego agrícola debe planificarse bajo estas condiciones. En este estudio se llevó a cabo el análisis de tendencia de los datos climáticos requeridos para el cálculo de la evapotranspiración de referencia (ET0) entre 2011 y 2020 para la estación meteorológica de Tekirdag, Turquía. El análisis de cambio en el estudio se llevó a cabo de acuerdo con los métodos de Prueba de Regresión Lineal, Prueba de Mann-Kendall y Prueba T de Sen. Como resultado del análisis de cambio, se determinó que los valores de evapotranspiración de referencia (ET0) tuvieron una tendencia decreciente en junio y julio y esta disminución fue estadísticamente significativa. Como resultado del análisis de los cambios en los parámetros climáticos utilizados en el cálculo de la evapotranspiración de referencia (ET0), se determinó que los valores de temperatura máxima, humedad relativa promedio y tiempo de insolación promedio presentaban una tendencia decreciente, mientras que la temperatura mínima y los valores de la velocidad del viento tenían una tendencia creciente. En el estudio, también se examinó el cambio en las cantidades de precipitación mensual durante los períodos de medición. Como resultado del análisis de los cambios se determinó que las cantidades de precipitación mensual tienen una tendencia decreciente y los cambios especialmente en abril, septiembre, octubre y diciembre son estadísticamente significativos. Se piensa que los resultados obtenidos contribuirán a la futura planificación de la producción agrícola en las condiciones regionales.

Palabras claves: *Análisis de tendencias, Método de Penman-Monteith, Cantidades de precipitación mensual, Recursos hídricos.*

1 Introduction

The decrease in water potential due to global warming due to climate change affects agricultural production negatively. On the other hand, global warming causes problems such as expansion in arid and semi-arid areas, increase in annual average temperature values, desertification in agricultural areas, salinization and erosion. Decreased areas covered by seasonal snow and snow cover, shortening of snow-covered periods, and changes in water volume resulting from snowmelt adversely affect water resources, agriculture, transportation and energy sectors. Additionally; It also causes effects such as global warming, melting of glaciers, rising sea level, shifting of climate zones. The warming of sea water changes the lives of many species living in the sea and oceans, especially fishing. Changes in the temperature regime cause changes in the amount of rain, snowfall and therefore the amount of underground and surface water. The increase in temperature will accelerate evaporation, which causes a decrease in the volume of irrigation water. Large wells and aquifers in Asia, Africa and the Americas are drying up, groundwater levels are falling, and wetlands and swamps are under threat of extinction. On the other hand, as a result of the increase in evaporation, a more important air will dominate the earth and accordingly an increase in precipitation is expected. Extreme precipitation conditions also pose the risk of flooding and flooding. In addition, the increase in evaporation due to excessive heat in regions where precipitation increases also causes drought (Türkes et al., 2000; Kanber et al., 2010).

Evapotranspiration (ET), which is one of the most important parameters of the hydrological cycle, is important in terms of plant water consumption, designing irrigation systems, preparing irrigation programs and using it in hydrological studies. Therefore, the correct determination of ET should be considered for environmental protection, water balance, design of irrigation systems and management of water resources. Insufficient and excessive amount of irrigation water applied in plant production can adversely affect the soil, the morphological and anatomical development of the plant, thus its yield, and production inputs such as fertilizer. For these reasons, it is necessary to create the most appropriate irrigation program, taking into account the evapotranspiration, in order to obtain high quality and high yield products (Bircan and Kızıl, 2021). Evapotranspiration is defined as the total water vapor released into the atmosphere as a result of transpiration by the plant and evaporation from the soil surface. It can be determined directly by lysimeters as well as estimated by various empirical methods using climatic data. Lysimeters are the most accurate and reliable methods for estimating ET, but it is a difficult and expensive method to apply (Karaca, et al., 2017). Therefore, the idea of standardizing the equations used in the ET calculation by using the evapotranspiration (ET_0) values of plant was put forward (Jensen and Wright, 1971).

The temperature parameter affected by climate change increases significantly and other meteorological parameters tend to change globally or regionally. This situation has far-reaching effects on the development of natural ecosystems and agricultural production. Reference crop water consumption (ET_0) is a parameter based on meteorological data, which forms the basis for irrigation research studies. It is of guiding importance for examining the reference evapotranspiration spatial distribution characteristics of regions under climate change, estimating evapotranspiration, investigating the water cycle, evaluating water resources, irrigation planning and management (Zhang et al., 2018, Arabi, 2021). In the study carried out, the monthly and annual changes of ET_0 values were analysed by using the necessary climate data for the reference plant water consumption (ET_0) calculation for the meteorology station of Tekirdag, Turkey, between the years 2011-2020.

2 Methodology

In the research, the climate data obtained from the meteorological station of Tekirdag, Turkey which is 4 m above sea level and located at 40o57'30.6" N and 27o29'47.4" E, was used. According to the long-term averages of Tekirdag, where the research was conducted, the annual average temperature is 14.1°C. In terms of monthly average temperatures, the coldest month is January with 5.0°C, and the hottest month is July and August with 24.0°C. The majority of the average precipitation, which is 580.8 mm per year, occurs in the period between October and April. The annual average relative humidity is 76.9%. Average value of annual wind speed at 2 m height is 2.90 m s-1. The long-term temperature-precipitation relationship in Tekirdag province is given in figure 1.

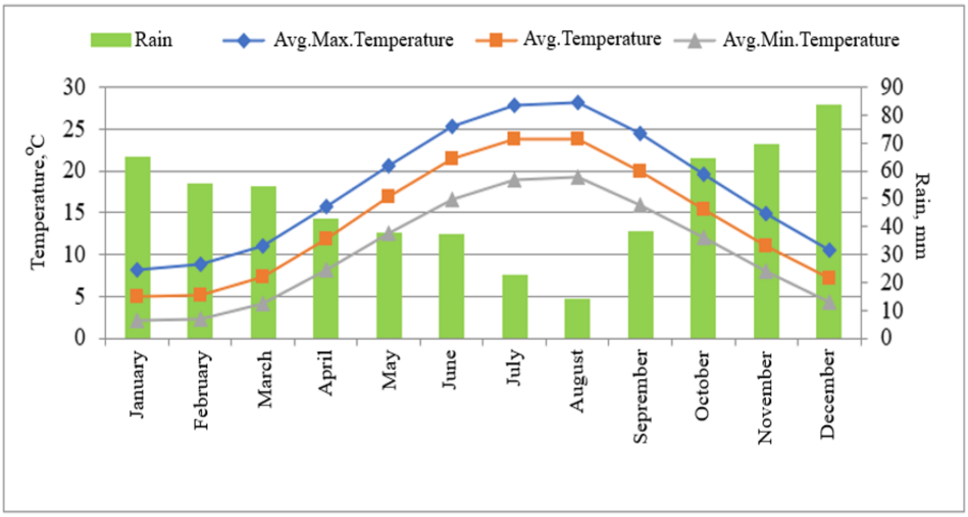

Figure 1: The long-term temperature-precipitation relationship in Tekirdag.

In the research, minimum temperature (Tmin), maximum temperature (Tmax), average relative humidity (RH mean), average wind speed (u) measured at 10 m altitude, daily sunshine duration (n) and average monthly precipitation (P) obtained from the Meteorology station between 2011 and 2020 years was evaluated. In general, it was determined that the maximum temperature and minimum temperature values were obtained in January, February and December as the lowest, and the highest in the months between June and September. While it was determined that the average relative humidity values were high especially in the winter months, it was observed that the average sunshine duration values were maximum in the summer months. On the other hand, it is seen that the wind speed values measured at a height of 10 m are close to the values throughout the year on average. It has been determined that monthly precipitation amounts differ on the basis of months and years. In estimating the reference evapotranspiration (ETo) by using the climate data, the method defined as FAO56-PM, which was obtained by the revision of the Penman-Monteith method by Allen et al., (1998), was used. Linear Regression Test, Mann-Kendall Test and Sen Trend Slope Test were used to determine the change analysis of the reference evapotranspiration (ETo).

Multiple Linear Regression Model: It shows the cause-effect relationship between a dependent variable (Y) and more than one (for example k) independent variables (X_1, X_2, ..., Xk). A model that expresses it as a linear function is called. $\beta 0$, $\beta 1$, ... and βk are the unknown parameters of the model and ϵ is the error term (Yavuz, 2009). The Mann-Kendall test (Mann, 1945; Kendall, 1975) is the most widely used non-parametric test type for determining the presence of trends in hydro-meteorological data. With this test, whether there is a trend in a time series; It is controlled by "H0: no trend" (zero hypothesis) (Yenigün et al.,2008). If a trend is detected in time-dependent data series, the magnitude or trend of change can be estimated with a simple method proposed by Sen (1968). Sen's trend slope method, data at times j and k are xj and xk (with condition j¿k); N=n(n-1)/2 (n number of time periods) pieces, Qi (i-1, 2, N) value is calculated (Ahmad and Choi, 2018; Büyükkaracığan, 2019). Kendall and Sen's T-test pyMannKendall v1.4.2. library (Hussain and Mahmud, 2019), linear regression test was performed using the scipy.stats v.1.9.3 library (Virtanen et al. 2020). Python 3.11.1 was used as the programming language for using these libraries.

3 Results and discussion

The results of the monthly and seasonal reference evapotranspiration (ET_0) calculated by the Penman-Monteith method between 2011 and 2020 for the Tekirdag are given in figure 2. As can be seen from the figure, monthly reference evapotranspiration (ET_0) values decreased in winter months and increased especially in July and August. The annual ET0 values varied between 1.127.30 mm. year-1 and 1.324,12 mm. year-1 between 2011 and 2020 years.

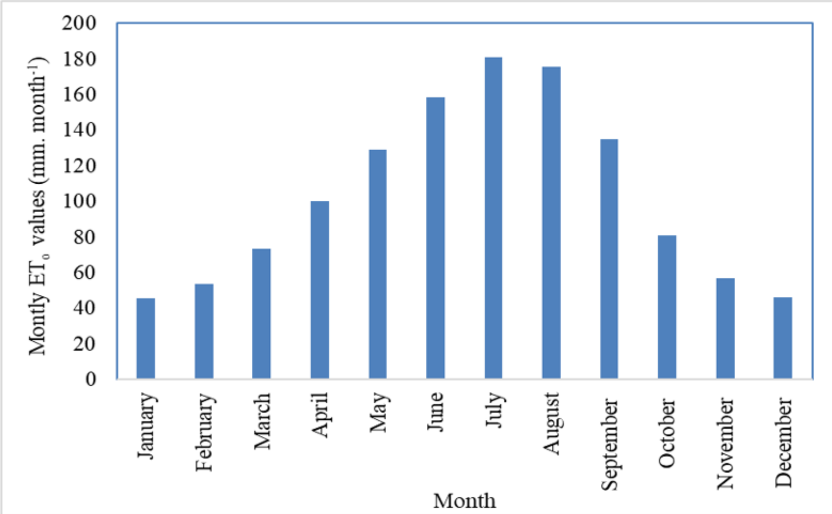

Figure 2: Change of monthly average ET_0 values between 2011-2020 years.

The results of Linear Regression Test, Mann-Kendall Test and Sen Trend Slope Test of monthly and seasonal reference evapotranspiration (ET_0) values calculated between 2011-2020 for Tekirdag are given in table 1. As a result of the linear regression test, Mann-Kendall Test and Sen's T Test change analyses applied according to monthly and seasonal ET0 values obtained between 2011-2020 years, it was determined that there was a decreasing change in July and June. The amount of change in ETo, which decreased in July, was found to be statistically significant at the 5% significance level according to the Linear Regression Test, Mann-Kendall and Sen T Test. The amount of decrease in June was found to be statistically significant at the 0.1% significance level, only according to the Sen's T Test. The linear regression graph for the annual reference ET_0 values calculated for the years 2011-2020 for Tekirdag is given in figure 3. The calculated annual ET_0 values showed significant variation between the years considered.

Table 1: Change analysis results of monthly and annual (ET_0) values.

Month	Change Analysis of Monthly and Annual ET_0 Values		
	Linear Regression Test	Mann-Kendall Test	Sen's T Test
January	0,90	0,89	1,08
February	1,15	0,36	1,17
March	0,47	0,01	0,28
April	1,16	0,36	0,92
May	0,88	0,54	1,26
June	-2,28	-1,43	-3,92 ***
July	-2,60*	-2,50*	-2,85*
August	-1,99	-0,36	-1,01
September	-0,11	-0,18	-0,37
October	-0,70	-0,36	-0,56
November	1,87	1,07	1,96
December	1,57	1,97 *	1,68
Yearly	-0,28	-0,18	-1,52

*: Significant at the 5% level, ***: Significant at the 0.1% level.

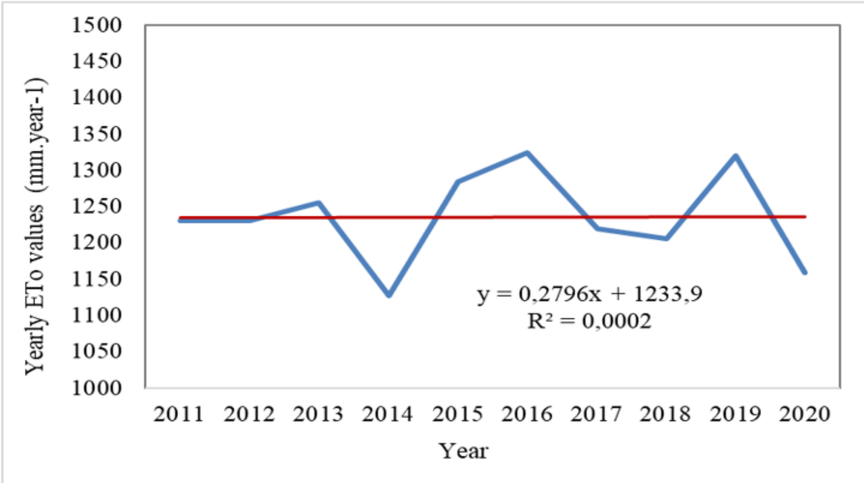

Figure 3: Change of annual ET_0 values between 2011-2020.

The results of the Linear Regression Test, Mann-Kendall Test and Sen's T Test of the minimum temperature values measured between 2011-2020 are given in table 2. It was determined that the changes that emerged as a result of the Linear Regression Test, Mann-Kendall Test and Sen's T Test change analyses applied to the monthly minimum temperature values obtained between 2011 and 2020 were not statistically significant. In addition, the linear regression graph prepared according to the annual average minimum temperature values of 2011-2020 is given in figure 4-a. As can be seen from the figure, it was observed that the annual average minimum temperature values between the measurement years did not change much, although there was an increasing trend. This result is similar to the results of the change analysis performed according to the monthly changes of the minimum temperature values.

Table 2: Change analysis results of minimum temperature values.

Month	Change Analysis of Monthly Minimum Temperature Values		
	Linear Regression Test	Mann-Kendall Test	Sen's T Test
January	0,29	0,72	0,30
February	-0,08	-0,54	-0,18
March	0,17	1,25	0,27
April	0,08	0,27	0,19
May	-0,05	-0,72	-0,10
June	-0,08	-0,63	-0,09
July	-0,14	-1,35	-0,16
August	0,16	0,72	0,17
September	-0,08	-0,63	-0,19
October	0,44	1,43	0,65
November	0,34	0,45	0,30
December	0,38	1,61	0,45

The results of the Linear Regression Test, Mann-Kendall Test and Sen's T Test of the maximum temperature values measured between 2011-2020 are given in table 3. As a result of the change analysis of the Linear Regression Test, Mann-Kendall Test and Sen's T Test applied to the monthly maximum temperature values obtained between 2011-2020, it was determined that the decreasing change in July was significant at the level of 5% compared to the Mann-Kendall test. In addition, the linear regression graph prepared according to the annual average minimum temperature values of 2011-2020 is given in figure 4-b. As can be seen from figure, it is seen that the annual average maximum temperature values are in a decreasing variation between the measurement years. This result is similar to the results of the change analysis performed according to the monthly changes of the maximum temperature values. It was determined that the maximum temperature values measured especially in July tended to decrease.

Table 3: Change analysis results of maximum temperature values.

Month	Change Analysis of Monthly Maximum Temperature Values		
	Linear Regression Test	Mann-Kendall Test	Sen's T Test
January	-0,30	-0,36	-0,26
February	0,02	0,63	0,25
March	-0,25	-1,17	-0,30
April	-0,08	-0,18	-0,10
May	0,15	0,72	0,24
June	-0,39	-1,43	-0,50
July	-0,31	-2,25*	-0,38
August	-0,07	-0,36	-0,03
September	0,09	0,27	0,02
October	-0,18	-0,63	-0,17
November	0,04	0,01	0,01
December	-0,02	-0,09	-0,06

*: Significant at the 5% level.

The results of the Linear Regression Test, Mann-Kendall Test and Sen's T Test of the relative humidity values measured between 2011 and 2020 are given in table 4. Linear Regression Test, Mann-Kendall Test and Sen's T Test applied to monthly average relative humidity values; it was determined that the Mann-Kendall Test for January, April, October and November and the values for October were statistically significant according to the Sen's T Test. In addition, the linear regression graph prepared according to the annual average relative humidity values is given in figure 4-c. As can be seen from figure, it is seen that the annual average relative humidity values are in a decreasing variation between the measurement years. This result is similar to the results of the change analysis performed according to the monthly changes of the average relative humidity values. It was determined that the relative humidity values measured especially in October and November tend to decrease.

Table 4: Change analysis results of average relative humidity values.

Month	Change Analysis of Monthly Relative Humidity Values		
	Linear Regression Test	Mann-Kendall Test	Sen's T Test
January	-1,65	-1,97*	-1,60
February	-1,24	-1,25	-1,28
March	-1,10	-0,45	-0,20
April	-1,15	-2,15*	-1,30
May	-0,89	-1,07	-0,60
June	-0,42	-0,89	-0,65
July	-0,15	-0,54	-0,35
August	-0,04	-0,54	-0,20
September	-0,15	-0,81	-0,55
October	-1,07	-1,97*	-0,94
November	-2,02	-2,68**	-2,04*
December	-1,93	-1,53	-1,80

*: Significant at the 5% level, **: Significant at the 1% level.

The results of the Linear Regression Test, Mann-Kendall Test and Sen's T Test of the wind speed values measured between 2011 and 2020 are given in table 5. Linear Regression Test, Mann-Kendall Test and Sen T Test applied to monthly wind speed values; January was determined to be statistically significant according to the Mann-Kendall Test for the month. The linear regression graph prepared according to the annual average wind speed values is given in figure 4-d. It is seen that the annual average wind speed values are in an increasing change between the measurement years. This result is similar to the results of the change analysis performed according to the monthly changes in the average wind speed values. It has been determined that the wind speed measured especially in January has an increasing trend.

Table 5: Change analysis results of average wind speed values.

Month	Change Analysis of Monthly Wind Speed Values		
	Linear Regression Test	Mann-Kendall Test	Sen's T Test
January	0,07	2,27*	0,07
February	0,03	0,90	0,05
March	0,08	1,56	0,05
April	-0,01	-0,54	-0,03
May	0,03	1,82	0,05
June	0,01	0,36	0,01
July	0,04	1,09	0,04
August	0,06	1,26	0,05
September	0,08	1,92	0,08
October	-0,03	-0,64	-0,03
November	0,03	0,54	0,03
December	0,01	0,75	0,01

*: Significant at the 5% level.

The results of the Linear Regression Test, Mann-Kendall Test and Sen's T Test of the sunshine duration values measured between 2011 and 2020 are given in table 6. Linear Regression Test, Mann-Kendall Test and Sen's T Test applied to monthly sunshine duration values; it was determined to be statistically significant according to the Mann-Kendall Test for July and August. The linear regression graph prepared according to the annual average sunshine speed values is given in figure 4-e. It is seen that the annual average sunshine duration values are in a decreasing change between the measurement years. This result is similar to the results of the change analysis performed according to the monthly changes in the average sunshine duration values. It was determined that the sunshine duration values measured especially in July and August have a decreasing trend.

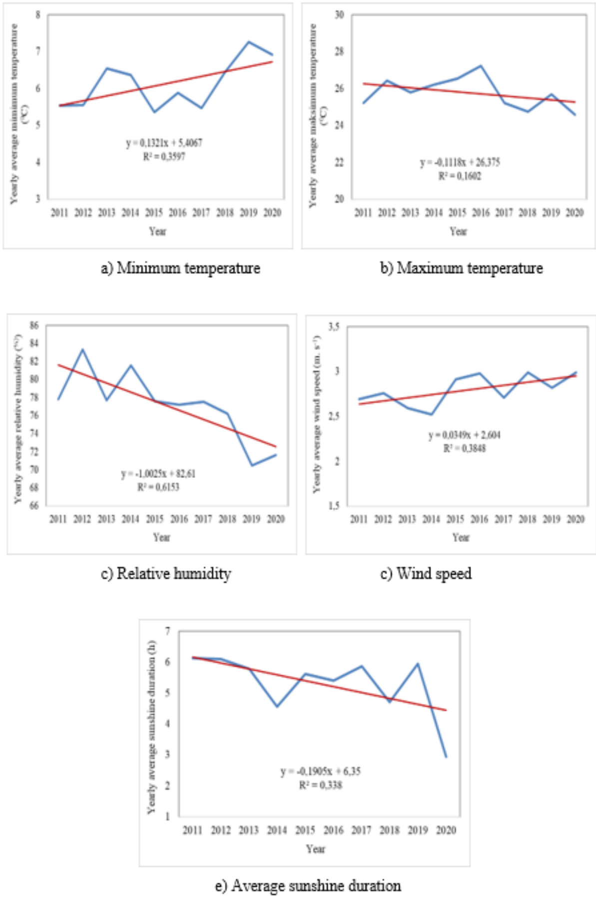

Figure 4: Change of monthly meteorological values between 2011-2020.

Table 6: Change analysis results of average sunshine duration values.

Month	Change Analysis of Monthly Wind Speed Values		
	Linear Regression Test	Mann-Kendall Test	Sen's T Test
January	0,02	0,09	0,02
February	0,01	0,01	0,03
March	-0,04	-0,54	-0,11
April	0,11	0,54	0,18
May	-0,20	-1,25	-0,16
June	-0,26	-1,25	-0,28
July	-0,32	-2,33*	-0,31
August	-0,50	-2,25*	-0,31
September	-0,55	-1,79	-0,51
October	-0,23	-0,89	-0,15
November	-0,13	-0,72	-0,15
December	-0,18	-0,89	-0,18

*: Significant at the 5% level.

The graph prepared according to the monthly precipitation amounts measured between 2011 and 2020 in the Tekirdag is given in figure 5. As can be seen from the figure, it has been observed that monthly precipitation amounts reach maximum values in October and December and minimum values in July and August. The results of the Linear Regression Test, Mann-Kendall Test and Sen's T Test of monthly precipitation values measured between 2011-2020 for Tekirdag are given in table 7. Linear Regression Test, Mann-Kendall Test and Sen's T

Test applied to monthly precipitation values as a result of change analyses in the decreasing direction; It was determined to be statistically significant according to Linear Regression Test, Mann-Kendall Test and Sen T Test for April, September, October and December. In addition, the linear regression graph prepared according to the annual precipitation values of 2011-2020 is given in figure 6. It is seen that the annual precipitation values are in a decreasing change between the measurement years. This result is similar to the results of the change analysis performed according to the monthly changes of annual precipitation values. It has been determined that the monthly precipitation values measured especially in October and December have a decreasing trend.

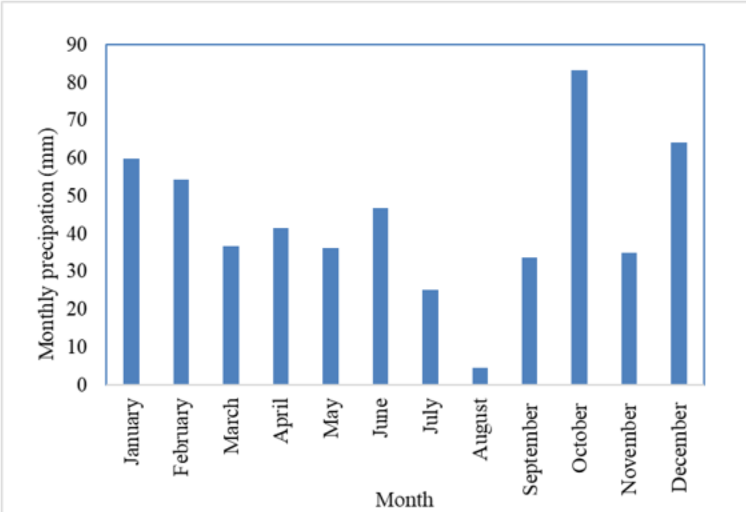

Figure 5: Change of monthly precipitation values between 2011-2020.

Table 7: Change analysis results of average precipitation values.

Month	Change Analysis of Monthly Precipitation Values		
	Linear Regression Test	Mann-Kendall Test	Sen's T Test
January	0,37	0,18	0,55
February	0,43	0,01	0,01
March	0,11	0,01	0,05
April	-3,13	-1,25	-3,46***
May	0,41	0,36	1,8
June	-0,29	0,18	0,2
July	2,02	-0,18	-0,03
August	-0,79	-1,54	-0,38
September	-8,15***	-0,72	-1,80
October	-9,72***	-2,33*	-9,68***
November	1,47	0,36	2,30
December	-6,25***	-0,18	-4,01***

*: Significant at the 5% level, ***: Significant at the 0.1% level.

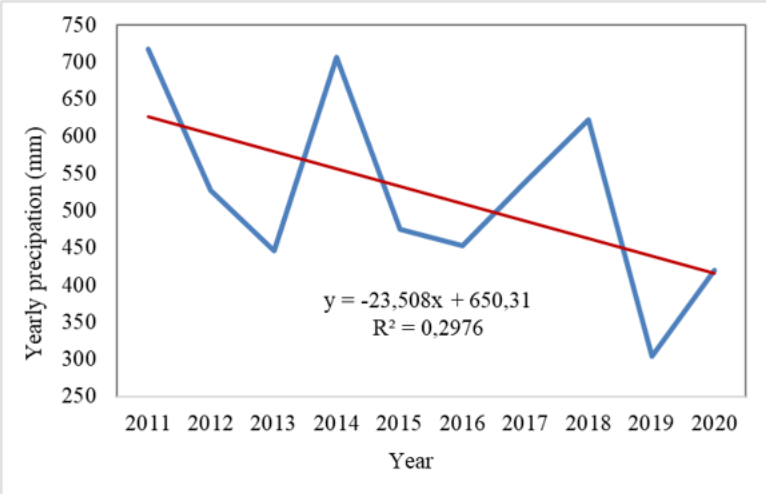

Figure 6: Change of annual average precipitation values between 2011-2020.

4 Conclusions

Climate change has a significant impact on the hydrological cycle, water resources, their local-regional-global management and distribution. The aforementioned effects are expected to occur very slowly and over many years. However, humanity has become aware of its harmful warnings from today. Many changes occur in streams, streams, streams and streams throughout the year. River flow regimes are changing, and the frequency of natural disasters such as floods and droughts is increasing. It creates forward and backward shifts in river flows over time. In addition, stream flows change, groundwater recharge increases or decreases depending on regional precipitation regimes. Global warming is certain to have significant impacts on water supply, and increased precipitation variability will pose significant problems in the agricultural sector. The warmer climate will accelerate the hydrological cycle, and there will be an increase in global amounts of precipitation and evapotranspiration (ET). Like runoff from melting snow in the mountains, the temporal distribution of precipitation may differ from its historical forms. Although some of these changes have occurred, their regional implications are not well-known Hydrological uncertainties arise mainly from the fact that relatively small changes in precipitation and temperature, especially in arid and semi-arid regions, have large effects on runoff and the volume and timing of ET. In short, global warming confronts irrigation practices and society as a whole with important new uncertainties and problems (Kanber et al., 2010). In the research carried out for this purpose, in order to determine the adaptation of Tekirdag to global climate change, the analysis of the change in the reference plant water consumption (ET0) values used to determine the plant water requirement of the plants in the local conditions was carried out. As a result of the research, as a result of the Linear Regression Test, Mann-Kendall Test and Sen's T Test change analyses applied according to the reference evapotranspiration values calculated between 2011-2022, it was determined that the decreasing change in July and June was significant. Although the minimum temperature values, one of the climate parameters used in the reference evapotranspiration calculation, have an increasing trend, it has been observed that this change is not statistically significant. It was determined that the maximum temperature values were in a decreasing trend between the evaluation years and the change in July was statistically significant. It has been determined that the average relative humidity values are in a decreasing trend and the change in January, April, October and November is statistically significant. It has been observed that the change in average wind speed values is in an increasing trend and the changes especially in January are statistically significant. It has been determined that the average sunshine duration, which is another parameter used in the calculation of reference plant water consumption, has a decreasing trend and the changes especially in July and August are statistically significant. Determining the changes in the amount of natural precipitation is important in determining the amount of irrigation water to be applied in irrigated agricultural areas and in terms of plant growth in dry agricultural lands and the yield and quality of the product to be obtained. In the study carried out, the change of monthly precipitation amounts in the measurement periods was also examined. As a result of the analysis of the changes, it was determined that the monthly precipitation amounts have a decreasing trend and the changes especially in April, September, October and December are statistically significant. It is important to consider this decrease in regional conditions, especially in the periods that include wheat and sunflower growing months in the production planning for the coming years. In today's conditions, where global climate change is important, it has been concluded that the change in climate parameters in Tekirdag is important. It is thought that the results obtained will contribute to the future agricultural production planning in the regional conditions.

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