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Original Article

# An investigation on the climate change and drought types in the Porsuk Stream Watershed, west of Turkey

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**ABSTRACT**

Climate change is a major parameter affecting agriculture. The aim of the study is to determine the effect of climate change on agricultural and hydro-meteorological drought in the Porsuk Stream Watershed. In this study, drought analyses in the watershed had been conducted using the past (1970-2018) and future (2020-2100) climate data produced according to the RCP 4.5 and 8.5 scenarios of the HadGEM2-ES model, with the help of Standard Precipitation Index (SPI), Standard Runoff Index (SRI) and Palmer Drought Severity Index (PDSI). The analysis revealed that the watershed was located in a dry region, it was detected that agro-hydrological droughts were dominant, and a meteorologically normal climatic situation prevailed in the past. Sub-basin in the watershed where agricultural drought is experienced severely are Odunpazari, Alpu and Tepebasi, respectively. 1981, 1986, 1989, 2008, 2013, 2015 and 2018 years were arid, while the driest years are expected to be 2056, 2058, 2069, 2070, 2089, 2096, the wettest year is expected to be 2021. The Porsuk Stream Watershed inclines to be dry meteorologically and humid hydrologically in the future. From the point of agricultural drought, although there is a potential for a drought over time, it is detected that a normal climatic situation will prevail throughout the watershed. Compared to the reference (1970-2000) period, climate change will happen in the manner of temperature and precipitation increases in the future. As a result of the study, important data about drought were produced for farmers.

## 1. Introduction

Turkey is one of the countries that will be most affected by climate change [2; 24]. The Porsuk Creek Watershed in the Central Anatolia Region is important because it provides drinking water of Eskisehir Province. This watershed is one of the regions that will be most affected by the drought [9].

The primary way to identify droughts is to use drought indices. The result of Standard Precipitation Index is similar to the results of Z-Score Index (ZSI) and China Z Index (CZI). Even so, SPI seems to be the best indicator than the others and SPI has lots of advantages [31; 18]. PDSI and SPI are the most popular drought indices. PDSI does not consider the spatial change of soil, vegetation, topography, and physical feature of the watershed. Even so, PDSI has lots of advantages over SPI [32]. SPI, PDSI, Standard Precipitation Evapotranspiration Index (SPEI), Normalized Difference Vegetation Index (NDVI) and Vegetation Drought Response Index (VegDRI) are popular agricultural drought indices. VegDRI is a drought index that combines SPI, PDSI and NDVI [19].

Many studies have been conducted on drought in the world. In India, SPEI and SPI (meteorological drought) and Standard Soil moisture Index (agricultural drought) have been evaluated for 82 stations. The trends of rainfall and

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temperature (minimum and maximum) have also been analyzed. The minimum temperature has increased (0.03 to 0.07 °C $year^{-1}$) more as compared to the maximum temperature [36]. In northern Italy, the greatest drought tendencies occur in the southern and western parts of the area [7]. In China, drought frequency, duration and intensity were generally higher in the east and north than in the west and South. In Somalia, drought count was generally high in the southern parts of the country for the period between 1980 and 2015 [21].

In Iran, climate change impacts drought, runoff, evapotranspiration, and crop yield simulated for future periods according to climate scenarios using the SPI and Soil & Water Assessment Tool (SWAT) model. The results show that climate change has adverse effects on evapotranspiration and runoff. Moreover, the study area will be severe droughts in the future. The results showed that runoff will rise in autumn and spring while it will drop in winter and summer in the future. Future evapotranspiration will rise with a maximum increase in the period 2070–2100 according to RCP 8.5 [29]. In Oklahoma, an increase in both temperature (+1.8 ºC) and rainfall (+1.5%) was foreseen for the 2016–2040 period. This changing climate resulted in increased water yield (24%) and decreased evapotranspiration (3.7%) [10]. In Turkey (Gediz River Watershed), it was used SPI and SPEI for defining meteorological droughts, and the Standardized Runoff Index (SRI) method for defining hydrological droughts. It is determined that droughts occurred in the years after 2000 in the watershed. Also, hydro-meteorological drought trends of the Gediz River watershed are prone to dry conditions [17].

Many studies have been conducted on how climate change will affect drought in Turkey. It is stated that the lowest drought region is Bitlis and the highest drought regions are Diyarbakir, Batman and Cizre, respectively [11]. In the Cukurova region, future precipitation may decrease by 33% and temperature may increase by 3 ºC. In addition, there will be 10% reduction in the count of wheat tillering due to drought [14]. In the first half of the 21st century, precipitation will decrease by 25% in western cities of Turkey. Drought can be seen 7 months in the Mediterranean, Aegean, Central and Southeastern Anatolia, 5 months in Marmara and Eastern Anatolia and 3 months in the Black Sea region. Severe droughts are expected in the Akarcay Watershed in late 2020 [8]. In the future, especially the Mediterranean and Central Anatolian regions will be more affected by climate change. It is stated that the precipitation will increase throughout Turkey and decrease especially in the southern half of the country [33].

Many studies have been conducted on drought in Turkey. In 2008, one of the driest times in Turkey, it is stated that droughts were experienced in Aegean, Thrace and Antalya in the winter season, in Ordu and Kirklareli in the autumn season, in Cappadocia, Gallipoli, around Artvin and Southeastern Anatolia in spring season [37]. It is stated that there will occur meteorological drought in Kirsehir Province [15]. Drought in Turkey is in the form of precipitation deficiency. The Black Sea region is the lowest drought place and the Marmara region is the highest drought place [1]. Many studies have been conducted on climate change in Turkey. In the 2070s, it is estimated that precipitation will decrease by around 30% on the Mediterranean coast and increase by 22% in the Black Sea region. Also, it is predicted that the temperature in Turkey may be 5 ºC higher in the 2070s, and droughts in all of Turkey, except for the Eastern Black Sea region, may intensify [22]. It is stated that climate change causes decrease in the sunflower yield up to 20% and in the cotton yield up to 14% in Turkey [12]. In addition, for studies on climate change in Turkey, Kapur [14] and Turkes [34] can be cited as examples. In studies on the Porsuk Creek Watershed, it was seen that the number of studies was insufficient and the subject examined had limitations [25]. Compared to such examples in the literature, this study is important because of its features such as examining all (meteorological, hydrological and agricultural) drought types, making county-based analysis and using new (current) climate scenarios for future predictions (such as RCP4.5 and RCP8.5). It is thought that this study, which is a comprehensive analysis of the study basin, will fill the gap in the literature with these features.

This study aims to determine the effect of climate change on the agricultural, meteorological and hydrological droughts in the Porsuk Creek Watershed. The aims and scope of the study are summarized as follows:

1) Within the scope of the analysis of drought (meteorological, hydrological and agricultural) from past to present (1970-2018) in the research area: *Drought analyses were made using the Standard Precipitation Index (SPI), Standard Runoff Index (SRI) and Palmer Drought Severity Index (PDSI).*
2) Within the scope of determination of climate change for different scenarios in the research area: *Climate change in the 2020-2100 period, rainfall and temperature data of Hadley Centre Global Environment Model version 2 (HadGEM2-ES) global climate model and Regional Climate Model 4.3 (RegCM 4.3), 25 year-long interval according to RCP 4.5 (optimistic) and RCP 8.5 (pessimistic)* scenarios *were analyzed.*

3) Within the scope of determining the effect of climate change on drought in the research area: *The effect of climate change on meteorological, hydrological and agricultural drought, which is estimated in 25 year-long intervals according to RCP 4.5 and RCP 8.5 scenarios in the 2020-2100 period, were determined by SPI, SRI and PDSI, respectively.*
4) Within the scope of precautions that can be taken to minimize the adverse effects of climate change and drought: *The most suitable cultivation areas and times for agriculture were determined by the PDSI in the study area.*

## 2. Materials and Methods

### *2.1. Material*

#### *2.1.1. Research area*

The Porsuk Creek Watershed is an important sub-basin of the Sakarya Basin, which covers 7% of Turkey's surface area. The research area, located in the center of the Porsuk Creek Watershed is located between the Marmara, Aegean and Central Anatolia regions (Research area is the Middle Porsuk Creek Watershed) (Figure 1).

Although a large part of this study area is located in Eskisehir, approximately 12% is located within the borders of Kütahya Province and 3% is located in Bilecik Province. A close view of the basin, including the basin height information, is shown on the right (Figure 1).

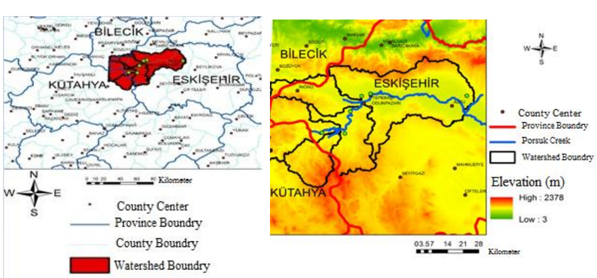


Fig 1. District boundaries and research area (Middle Porsuk Creek Watershed) map

The watershed characteristics determined with the help of Google Earth Pro and ArcGIS 10.4 programs are shown in Table 1.

Table 1. Characteristics of the watershed

| Minimum height (m) | Maximum height (m) | Mean height (m) | Area ($km^2$) | Slope (%) | Latitude | Longitude |
|---|---|---|---|---|---|---|
| 789 | 1176 | 933 | 441.18 | 9.9 | 39.8 | 30.24 |

Other characteristic features of the watershed are as follows:

Field soil characteristics: Some (arithmetic) average values for the basin soil are as follows: pH: 7.87, salt (%): 0.03, organic matter (%): 1.06. The Water Holding Capacity (WHC) of the field is 220 mm.$m^{-1}$

#### *2.1.2. Climate Data*

Climate data pertaining to the past: The past climatic data in the study were obtained from the State Hydraulic Works (SHW) and the General Directorate of Meteorology (GDM). Monthly total runoff data was obtained from SHW and monthly total precipitation and average temperature data were obtained from GDM.

For the determination of climate change, the past time period between 1970-2000 was accepted as the reference period and comparisons for the future were made accordingly. In the selection of the observation stations where the climate data of the reference period (1970-2000) is available, a homogeneity test was applied and non-homogeneous stations were excluded from the study.

Climate data of the future: These climate data were obtained daily from the General Directorate of Water Management (GDWM). Future climate data from GDWM are total precipitation, solar radiation, minimum and maximum temperature. These data were produced daily by HadGEM2-ES and RegCM 4.3 climate models, covering the years between 2016 and 2096, according to the RCP4.5 and RCP8.5 scenarios. A statistical downscaling method is less reliable as it doesn't consider future physical relations [9; 5]. Instead of this method, the RegCM 4.3 regional climate model, which uses the dynamic downscaling method, was also used in this study, increasing the reliability of the research. With this regional climate model used in the study, 10x10 km resolution climate simulation data were produced. Before using the regional climate model results, the bias correction method was applied and the natural errors found in the climatic forecast data were corrected.

#### *2.1.3. Drought Prediction Models*

It was preferred to use PDSI, SPI and SRI in this study because they represent the drought types much better [35; 28]. SPI uses monthly total precipitation (mm) and SRI uses monthly total runoff (mm) while PDSI basically uses monthly total precipitation (mm) and potential ET (average temperature) data as the input parameter. As a result, the meaning of the index values produced as output is interpreted by looking at the tables of these methods.

*2.1.4. Climate Models*

Although the most widely used climate models in the world are HadGEM2-ES and RegCM 4.3, since RCP 4.5 and RCP 8.5 scenarios are up-to-date and popular, their use was also preffered in this study [9; 27; 4]. As a result, the outputs produced with the help of these climate models and used in this study are solar radiation (watt $m^{-2}$), total precipitation (mm), average wind speed (m $\sec^{-1}$), minimum and maximum temperature (ºC) data.

*2.2. Method*

*2.2.1. Drought Analysis*

Monthly total precipitation (mm), monthly total runoff (mm) and monthly average temperature (ºC) data supplied from SHW and GDM were used to determine past droughts. Climate data (Monthly total precipitation (mm), monthly total runoff (mm) and monthly average temperature (ºC)) taken from GDWM, which were produced according to RCP4.5 and RCP8.5 climate scenarios and were formed to represent the region by downscaling method, were used to determine future droughts.

In the selection of the observation stations where the climate data of the reference period (1970-2000) is available, a homogeneity test was applied and non-homogeneous stations were excluded from the study. Before using the regional climate model results, the bias correction method was applied and the natural errors that could be found in the climatic forecast data were corrected. To determine the effects of climate change on drought analysis, classification results of the drought were obtained by using climate data produced with the help of HadGEM2-ES and RegCM 4.3 climate models. These climate data are total rainfall data used in SPI, total runoff data used in SRI, total rainfall-average temperature-ET data used in PDSI. To analysis of these results pertaining to the future, calculations have been made for both the near (2020-2045), mid (2045-2070), far (2070-2095) future seasonally and calculations have been made for the years 2018-2096 annualy. For seasonally analysis, the average of the annual index results was taken. Also, the past drought analysis was made between 1970 and 2018 years.

*2.2.2. Modeling of Meteorological Drought with Standard Precipitation Index*

Only monthly precipitation data are needed for the Standard Precipitation Index. $X_i$ is precipitation amount (mm), $X_i^{mean}$ is mean precipitation amount (mm) and σ is standard deviation in Equation 1 [20; 13; 17].

The calculation steps of the SPI are as follow:

A distribution function is fitted to the rainfall data. The gama distribution is the most suitable function for rainfall data. Cumulative probabilities are calculated by fitted distribution function. Then, cumulative probabilities are converted to SPI values with a standard deviation of 1 and a mean of 0.

$$SPI = \frac{X_i - X_i^{mean}}{\sigma} \tag{1}$$

*2.2.3. Modeling of Hydrological Drought with Standard Runoff Index*

Only monthly runoff data are needed for the Standard Runoff Index. $X_a$ is runoff amount (mm), $X_a^{mean}$ is mean runoff amount (mm) and σ is standard deviation in Equation 2 [30; 17].

The calculation steps of the SRI and SPI are same. A distribution function is fitted to the runoff data. Generally, the gama distribution is suitable for runoff data, too. Lastly, cumulative probabilities are converted to SRI values with a standard deviation of 1 and a mean of 0.

$$SRI = \frac{X_a - X_a^{mean}}{\sigma} \tag{2}$$

*2.2.4. Modeling of Agricultural Drought with Palmer Drought Severity Index*

Potential ET values in PDSI (Palmer Drought Severity Index) were determined with Thornthwaite method. For this, Potential ET values, which were corrected with the latitude no of the meteorology station, were calculated by using average temperature data.

The data required by the PDSI are monthly mean temperature (ºC), monthly total amount of precipitation (mm), monthly mean Potential ET (mm), WHC **(**Water Holding Capacity**)** (mm) and latitude no of each meteorological station. These data are used in the PDSI equations with the help of Microsoft Excel software, and the index result was obtained according to the following steps. The index value obtained as a result of these calculations can be analyzed according to the PDSI drought classes in Table 2.

The calculation steps of the PDSI method can be made in the following order [23; 6]: Calculation of the Potential ET with Thornthwaite method, Hydrologic calculations, Climate coefficient, Calculation of Climatically Appropriate For Exsiting Conditions variables, Moisture anomaly index (Z), Calculation of the PDSI ($X_j$)

Table 2. Classes of Palmer Drought Severity Index

| Results of PDSI | Drought Classes |
|---|---|
| 4 < | Extremely wet |
| Between 3 and 4 | Very wet |
| Between 2and 3 | Moderately wet |
| Between 1 and 2 | Light wet |
| Between 0.5 and 1 | Wet |
| Between 0.5 and -0.5 | Normal |
| Between -0.5 and -1 | Dry |
| Between -1 and -2 | Light dry |
| Between -2 and -3 | Moderately dry |
| Between -3 and -4 | Very dry |
| < -4 | Extremely dry |

*2.2.5. Modeling of Climate Change*

In the selection of the observation stations where the climate data of the reference period (1970-2000) is available, a homogeneity test was applied and non-homogeneous stations were excluded from the study. Due to the low resolution of the HadGEM2-ES global climate model predictions, more reliable and high-resolution climate data were obtained by dynamic downscaling in the RegCM 4.3 regional climate model. Before using the regional climate model results, the bias correction method was applied and the natural errors found in the climatic forecast data were corrected. Moreover, the precipitation and temperature values of the reference period estimated by the climate model were compared with the observed value, and it was determined that the difference between the averages of these two groups was not statistically significant.

## 3. Results and Discussion

*3.1. General Assessment Related to Current Drought*

As a result of general evaluations on an annual basis in terms of all drought types, 1981, 1986, 1989, 2008, 2013, 2015 and 2018 were dry years, 2000 and 2003 were wet, and it was determined that 1985 was a normal year. Moreover, it is seen that 1997, 1998, 1999 and between 2006 and 2011 were hydrologic dry and 2012 were hydrologic wet. 2016 and 2017 were meteorologic wet and agricultural dry.

According to the result, it was determined that drought prevailed in the watershed in terms of agriculture. Severe agricultural arid regions are Odunpazari, Alpu and Tepebasi Counties, respectively. The Counties were the main districts where agriculture was made in the watershed, so these were examined.

It can be interpreted that the study area is in an arid region. Compare to Tepebasi, Alpu is meteorologic dry. While Odunpazari and Alpu show similar characteristics in terms of hydrologic drought in the watershed, Tepebasi is much more arid than both of these regions. In terms of agricultural drought, the most wet region is Tepebasi.

Agricultural droughts in Tepebasi tend to exacerbate unevenly. Agricultural moisture was observed in the western part of the watershed covering Odunpazari and Tepebasi in 2016. The watershed was generally agricultural dry in 2017 and 2018 (Figure 2).

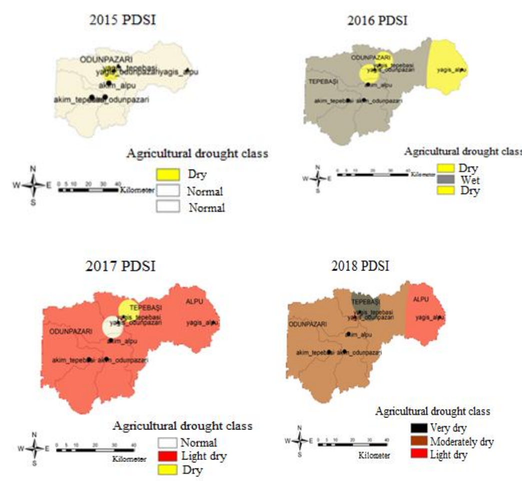


Fig 2. PDSI results in the watershed for the years 2015-2018

Studies of Musei et al. [21] and Kumanlioglu [17] were examined. In Somalia, drought count was generally high in the southern parts of the country for the period between 1980 and 2015. In Turkey (Gediz River Watershed), It is determined that droughts occurred in the years after 2000. Also, hydro-meteorological drought trends of the Gediz River watershed are prone to dry conditions. It is understood that the situation of the Porsuk Creek Watershed is similar to the drought situation of the Gediz River Watershed and situation of Somalia in these periods. Studies of Kokkokoglu [16] and Akbas [1] were examined. In accordance with the period between 1970 and 1990 mentioned in these studies but except for 1970, 1978 and 1990, this period of the Porsuk Creek Watershed can be defined as the dry period. In this case, condition of the study area is similar to average condition of Turkey.

*3.2. General Assessment Related to Future Drought*

While wet years are 2016, 2021, 2026, 2034, 2042 and 2052, dry years are 2056, 2058, 2063, 2069, 2070, 2077, 2081, 2082, 2089 and 2096 in terms of meteorological drought in the Porsuk Creek Watershed in the future.

In terms of hydrologic drought, it is estimated that 2015, 2021, 2088 and 2090 will be wet in the future. Moreover, it is estimated that 2031, 2032, 2038, 2057, 2059, 2060, between 2064 and 2069, 2073, 2074, 2078 and 2083 will be dry in the future.

In terms of agricultural drought, it is estimated that 2021, 2023, 2027, 2030, 2045, 2046, 2048 and 2084 will be wet in the future. Moreover, it is estimated that 2018, 2019, 2020, 2035, 2044, between 2053 and 2056, 2058, 2062, 2065, between 2070 and 2074, 2083, between 2089 and 2092, 2096 and 2097 will be dry in the future in the Porsuk Creek Watershed (Figure 3).

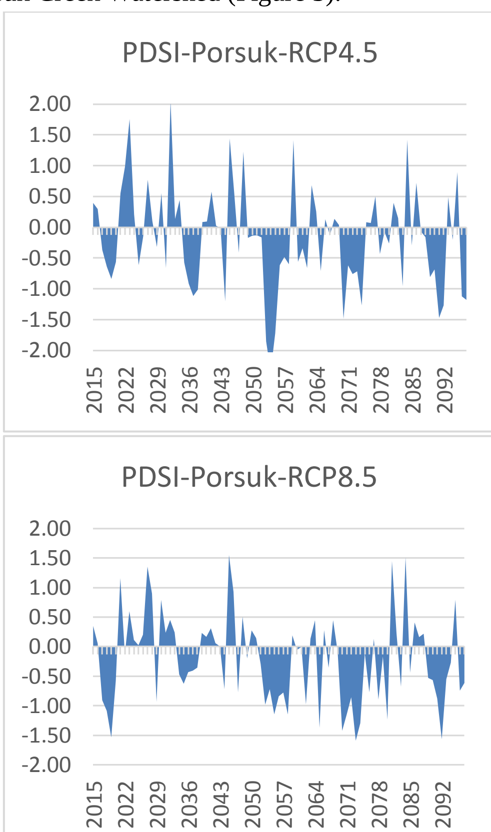


Fig 3. Results of optimistic (RCP4.5) and pessimistic (RCP8.5) PDSI in the future

When the Porsuk Creek Watershed is evaluated in terms of all drought types (Meteorologic, hydrologic and agricultural) in the future, it is estimated that 2056, 2058, 2069, 2070, 2089 and 2096 will be the driest years. Moreover, it is estimated that 2021 will be the wettest year in the future.

When it is generally evaluated in terms of all drought types in the future, the following results is obtained. According to the results of all drought types and scenarios (optimistic RCP4.5 and pessimistic RCP8.5) except the SRI results calculated via RCP8.5 scenario, it is expected that there will be wetting in the near (2020-2045) future, and will be drought in the mid (2045-2070) future and in the far (2070-2095) future (Table 3).

Table 3. Change of future drought index results compared to the past situation

| Porsuk Creek Watershed | Scenario | Period | | |
|---|---|---|---|---|
| | | 2020-2045 (Near future) | 2045-2070 (Mid future) | 2070-2095 (Far future) |
| Meteorologic drought (SPI) | RCP4.5 | Increase (Wetting) | Decrease (Aridification) | Decrease (Aridification) |
| | RCP8.5 | Increase (Wetting) | Decrease (Aridification) | Decrease (Aridification) |
| Hydrologic drought (SRI) | RCP4.5 | Increase (Wetting) | Decrease (Aridification) | Decrease (Aridification) |
| | RCP8.5 | Decrease (Aridification) | Decrease (Aridification) | Increase (Wetting) |
| Agricultural drought (PDSI) | RCP4.5 | Increase (Wetting) | Decrease (Aridification) | Decrease (Aridification) |
| | RCP8.5 | Increase (Wetting) | Decrease (Aridification) | Decrease (Aridification) |

When the research study of Shahvari et al. [29] in the literature is analyzed by comparing it with this study, severe droughts will occur in the future in Iran. Future evapotranspiration will rise with a maximum increase in the period 2070–2100. It is understood that the situation of the Porsuk Creek Watershed is similar to Iran in the period. Saygili [26], using the outputs of the MPI-ESM-MR climate model and using the RegCM4.4 regional model, predicted the future drought for the Middle East and North Africa with the help of SPI and SPEI methods. Both indexes were calculated by using RCP 8.5 scenario. After all, it is estimated changing climate conditions from normal to drought in the far future (2070-2095) in Turkey. Moreover, it is determined that this drought might occur severely in this period. If it is considered that SPEI method in the study represents the agricultural drought, it can be said that finding similar to meteorological and agricultural drought results in this study were obtained. But, it is understood that there will be more arid climate in terms of agro-meteorological drought when compared with general climate condition of Turkey in the far (2075-2095) in the Porsuk Creek Watershed.

### *3.3. Findings Related to Climate Change*

For the determination of climate change, the annual averages of the future are compared to the precipitation, minimum and maximum temperature averages of the 1970-2000 reference period.

According to the HadGEM2-ES climate model in the

Porsuk Creek Watershed, an increase in future precipitation, minimum and maximum temperatures is expected when compared with past (1970-2000) climate data. The increase in maximum temperatures is expected to be within the range of 3.47 ºC to 6.7. The increase in precipitation is expected to be within the range of 18.71% to 46%. As a result, as time passes, it is expected that temperature increases will increase and precipitation increases will decrease (Table 4).

Table 4. 25-year long changes in some climate parameters according to the HadGEM2-ES model compared to the past climate in the Porsuk Creek Watershed

| Period | Minimum temperature (ºC) | | Maximum temperature (ºC) | | Precipitation (%) | |
|---|---|---|---|---|---|---|
| | RCP4.5 | RCP8.5 | RCP4.5 | RCP8.5 | RCP4.5 | RCP8.5 |
| 2020-2045 | 2.66±0.11 increase | 2.69±0.13 increase | 3.47±0.13 increase | 3.52±0.15 increase | 41±7.1 increase | 46±6.3 increase |
| 2045-2070 | 3.47±0.11 increase | 4.19±0.15 increase | 4.4±0.17 increase | 5.25±0.16 increase | 22.13±6 increase | 22.06±3.7 increase |
| 2070-2095 | 3.69±0.09 increase | 5.58±0.13 increase | 4.55±0.1 increase | 6.7±0.14 increase | 31.47±5.3 increase | 18.71±5.6 increase |

When the research study of Vishwakarma et al. [36] in the literature is analyzed by comparing it with this study, unlike the situation in the Porsuk Creek in the future, the minimum temperature has increased more as compared to the maximum temperature in India. When the research studies of Anonymous [3] and Dabanli [8] in the literature is analyzed, it is stated that precipitation decreases in Turkey in the future. Consistent with the results of these studies, the decrease is expected to become more evident in the second half of the 21st century although rainfall decreases are also seen in the Porsuk Creek Watershed. Onder et al. [22] predict that in the 2070s, precipitation will decrease by 30% on the Mediterranean coast and increase by 22% in Black Sea region. In addition, the researchers, who stated that the temperatures in Turkey might be 5 ºC higher in 2070s, predict that the droughts may intensify throughout Turkey, except for the Eastern Black Sea region. Kapur [14] states that precipitation may decrease by 33% in the future and average temperatures may increase by 3 ºC. When these results in the literature are compared with the results in Table 4, it is thought that the Porsuk Creek watershed will approach the Black Sea climate due to the increase in temperature and precipitation.

### 3.4. General Evaluation of the Findings

Consistent results were obtained in all period and scenario comparisons. Future meteorological and agricultural droughts are compatible with each other in all periods and scenarios in the watershed in terms of drought. According to only the pessimistic scenario (RCP8.5), unlike drought is expected in the near future and far future in terms of hydrological drought expectation, which is very similar to these results. These results show that SPI and PDSI can be used safely in the watershed to predict meteorological and agricultural droughts (Table 5). These results are also compatible with the climatic change data in Table 4.

In addition, temperature and precipitation increases are expected in the future. However, these increases are proportional as time passes, in the form of an increase in temperature and a decrease in precipitation. This is consistent with future wheat yield declines (Table 5).

Table 5. Periodic analysis of future drought results and climate change results in the Porsuk Creek Watershed

| Scenario | Period | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2020-2045 (Near future) | | | 2045-2070 (Mid future) | | | 2070-2095 (Far future) | | |
| | Result of SPI and PDSI (Agro-meteorological drought) | Result of SRI (Hydrological drought) | Result of climate change | Result of SPI and PDSI (Agro-meteorological drought) | Result of SRI (Hydrological drought) | Result of climate change | Result of SPI and PDSI (Agro-meteorological drought) | Result of SRI (Hydrological drought) | Result of climate change |
| RCP4.5 | Wetting | Wetting | Temperature increase, precipitation increase | Aridification | Aridification | Temperature increase, precipitation increase | Aridification | Aridification | Temperature increase, precipitation increase |
| RCP8.5 | Wetting | Aridification | Temperature increase, precipitation increase | Aridification | Aridification | Temperature increase, precipitation increase | Aridification | Wetting | Temperature increase, precipitation increase |

Studies of Crespi et al. [7] and Musei et al. [21] were examined. In northern Italy, the most significant drought tendencies occur in the southern and western parts of the area. In China, drought is generally higher in the east and north than in the west and south. These results indicate that drought varies even within the same region. Gharibdousti et al. [10] determined that an increase in both temperature (+1.8 ºC) and rainfall (+1.5%) was foreseen for the 2016–2040 period in Oklahoma. This changing climate resulted in increased water yield (24%) and decreased evapotranspiration (3.7%). This result means a decrease in hydrological and agricultural drought in Oklahoma. Saygili [26] determined that droughts to be experienced would be severe by predicting a climate shifting from normal to arid for the far (2075-2095) future in Turkey. It can be said that the meteorological and agricultural drought findings in this study are parallel with these results. It is stated that precipitation decreases in Turkey will occur in the future [3; 8]. Consistent with the results of these studies, the decrease are expected to become more evident in the second half of the 21st century although rainfall decreases are also seen in the Porsuk Creek Watershed. Onder et al. [22] predict that in the 2070s, precipitation will decrease by 30% on the Mediterranean coast and increase by 22% in Black Sea region. In addition, the researchers, who stated that the temperatures in Turkey may be 5 ºC higher in 2070s, predict that the droughts throughout Turkey may intensify, except for the Eastern Black Sea region. Kapur [14] states that precipitation in the future may decrease and temperature in the future may increase. The literature supports a climate prediction shifting from normal to arid, when all results are analyzed. So, the literature confirms precipitation decreases in addition to temperature increases. But, the precipitation decreases in the Porsuk Creek Watershed manifests itself as a decrease in the amount of increase. Also, another issue supported by the literature is that SPI and PDSI results, which directly represent precipitation and temperature changes, produce more reliable results in parallel with climate change as compared with the SRI results representing flow changes.

## 4. Conclusion

As a result of the study, it was understood that the Porsuk Creek Watershed was located in an arid region. In addition, when the past years were generally evaluated, it was determined that especially hydrological and agricultural droughts prevailed, a typical climate prevailed meteorologically, and the driest County hydrologically was Tepebasi. Regions, where severe drought occur in agriculture, are Odunpazari, Alpu and Tepebasi, respectively. It is understood that today there are more count and more severe droughts compared to the past.

As a result of general evaluations on an annual basis in terms of all drought types, 1981, 1986, 1989, 2008, 2013, 2015 and 2018 were dry years, 2000 and 2003 were wet, it was determined that 1985 was a normal year (The literature supported that 2008 for Turkey was very dry, already). When the Porsuk Creek Watershed is evaluated in terms of all drought types (Meteorologic, hydrologic and agricultural) in the future, it is estimated that 2056, 2058, 2069, 2070, 2089 and 2096 will be the driest years. Moreover, it is estimated that 2021 will be the wettest year in the future. The Porsuk Creek Watershed tends to become meteorologically dry and hydrologically wet in the future when it is generally evaluated. Alpu tends to become wetter and Odunpazari tends to become drier in terms of hydrological drought in the future. It is determined that a normal climate will prevail throughtout the watershed terms agriculturally.

It is determined that PDSI can be used safely in the watershed to predict agricultural droughts. In addition, an increase in future precipitation-minimum temperature-maximum temperature of the Porsuk Creek Watershed is expected.

It is suggested that the agriculture pattern suitable for climate change for the region should be arranged according to the dry periods obtained as a result of this study. In these arid times, plant disease-pest control should be done meticulously, quality fertilizer should be used and drought-resistent crop varieties should be grown. Because, since climate change can not be prevented, crop yield should be tried to be increased in order to improves the factors other than the climate at least and reduce the drought damage.

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## Conflict of Interest

The authors declare that they have no conflict of interest

## References

1. Akbas A. Investigation of spatiotemporal variation of Palmer drought index in Turkey [MSc dissertation]. Canakkale Onsekiz Mart University, Social Science Institue, Department of Geography; 2013.
2. Anonymous. Turkey climate change strategy 2010-2020. Ministry of Environment and Urban, Ankara; 2010.
3. Anonymous. Agrometeorological yield forecast bulletin: Bulletin No-2014 /1. General Diroctorate of Meteorology, Field Crop Central Research Institute, Department of Geographic Information Systems and Remote Sensing, Ankara. pp13; 2014.
4. Anonymous. 2018 [cited 2018 June 4] Climate change projections for Turkey with new scenarios. Available from: https://www.mgm.gov.tr/FILES/iklim/IKLIM_DEGISIKLIGI_PROJEKSIYONLARI.pdf–
5. Batibeniz F. Defining extreme indices by using high resolution regional climate model simulation [MSc dissertation]. Istanbul Technical University, Graduate School of Natural and Applied Science, Department of Meteorology Engineering; 2014.
6. Cakal S. Palmer drought analysis of North Cyprus [MSc dissertation]. METU-North Cyprus, Graduate School of Natural and Applied Science, Department of Sustainable Environment and Energy Systems, 2016.

7. Crespi AB, Facchi A, Gandolfi C, Maugeri M. Spatio-temporal variability and trends of drought indices over Lombardy plain (northern Italy) from meteorological station records (1951–2017). *Italian Journal of Agrometeorology.* 2020; (2): 3-18. doi: 10.13128/ijam-1101
8. Dabanli I. Climate change impact on precipitation-temperature in Turkey and drought analysis: Akarcay case study [doctoral dissertation]. Istanbul Technical University, Graduate School of Natural and Applied Science, Department of Civil Engineering, 2017.
9. GDWM (General Directorate of Water Management). Impact of climate change on water resources Project: Final report of the project. T.R. Ministry of Forestry and Water Affairs, General Directorate of Water Management, pp389; 2016.
10. Gharibdousti SR, Kharel G, Miller RB, Linde E, Stoecker A. Projected climate could increase water yield and cotton yield but decrease winter wheat and sorghum yield in an agricultural watershed in Oklahoma. *Journal of MDPI-Water*. 2019; doi:10.3390/w11010105
11. Gulsever H. Temperature-precipitation and drought analysis in Tigris basin [MSc dissertation]. T.R. Dicle University, Graduate School of Natural and Applied Science, Department of Civil Engineering, 2006.
12. Gurkan H, Bayraktar N, Bulut H. Effects of Increasing Drought on Sunflower and Cotton Yield Due to Climate Change. *KSU Journal of Nature Science.* 2017; 20: 216-221.
13. Hasaniha H. Analysis drought and yield relationship in Northwestern Iran [doctoral dissertation]. Ankara University, Graduate School of Natural and Applied Science, Department of Agricultural Structures and Irrigation, 2008.
14. Kapur B. Enhanced CO2 and global climate change effects on wheat yield in Çukurova region [doctoral dissertation]. Çukurova University, Graduate School of Natural and Applied Science, Department of Agricultural Structures and Irrigation, 2010.
15. Kiymaz S, Gunes V, Asar M. Determination of Drought Periods for Seyfe Lake by Standardized Precipitation Index. *Journal of Gazi Osmanpaşa University Faculty of Agriculture*. 2011; 28(1): 91-102.
16. Kokkokoglu N. An analysis of drought durations in the Inner Anatolia region with parametric and nonparametric approach [MSc dissertation]. Kirikkale University, Graduate School of Natural and Applied Science, Department of Civil Enginering, 2006.
17. Kumanlioglu AA. Characterizing meteorological and hydrological droughts: A case study of the Gediz River Basin, Turkey. *Meteorological Applications*. 2020; https://doi.org/10.1002/met.1857
18. Kumar U, Singh S, Bisht JK, Kant L. Use of meteorological data for identification of agricultural drought in Kumaon region of Uttarakhand. *J. Earth Syst. Sci.* 2021; https://doi.org/10.1007/s12040-021-01622-1
19. Lee SJ, Kim N, Lee Y. Development of integrated crop drought index by combining rainfall, land surface temperature, evapotranspiration, soil moisture and vegetation index for agricultural drought monitoring. *Journal of Remote Sensing.* 2021; https://doi.org/10.3390/ rs13091778
20. McKee TB, Doesken NJ, Kleist J. The relationship drought frequency and duration to time scales. In procedings of the 8th Conference of Applied Climatology, 17-22 January, Anaheim, California, American Meteorogical Society, 179-184; 2013.
21. Musei SK, Nyaga JM, Dubow AZ. SPEI-based spatial and temporal evaluation of drought in Somalia. *Journal of Arid Environments.* 2021; https://doi.org/10.1016/j.jaridenv.2020.104296
22. Onder D, Aydin M, Berberoglu S, Onder S, Yano T. The use of aridity index to assess implications of climatic change for land cover in Turkey. *Turk Journal of Agriculture Forest.* 2009; 33, 305-314. TUBITAK, DOI: 10.3906/tar-0810-21
23. Palmer WC. Meteorological Drought. U.S. Department of Commerce. Research paper no: 45. February 1965, Washington. pp58; 1965.
24. Polat K. The role of good agricultural practices for mitigation and adaptation with climate change in ramsar sites: Case study in Goksu delta [doctoral dissertation]. Ankara University, Graduate School of Natural and Applied Science, Department of Agricultural Eeconomy, 2017.
25. Saris F. Low flow analysis in Porsuk Creek Basin. *Istanbul University Faculty of Literature Journal of Geography.* 2016; 33, 73- 81. ISNN 1305- 2128
26. Saygili F. S. Determination of the changes of drought occurrence in middle east and north africa using regional climate modeling [MSc dissertation]. Bogazici University, Graduate Program in Computational Science and Engineering, 2017.
27. Sen Z. Course Notes. "Drought, Modeling, Forecasting, Combating and Planning Methods Short Course". Water Foundation, Istanbul, (Course Date: 2016, May 23-26); 2016.
28. Shahabfar A, Eitzinger J. Spatio-Temporal Analysis of Droughts in Semi-Arid Regions by Using Meteorological Drought Indices. *Journal of Atmosphere.* 2013; 2013, 4, 94-112;doi:10.3390/atmos4020094, ISSN 2073-4433. doi:10.3390/atmos4020094
29. Shahvari N, Khalilian S, Mosavi SH, Mortazavi SA. Assessing climate change impacts on water resources and crop yield: a case study of Varamin plain basin, Iran. *Journal of Environ. Monit. Assess.* 2019; https://doi.org/10.1007/s10661-019-7266-x
30. Shukla S, Wood AW. Use of a standardized runoff index for characterizing hydrologic drought. *Geophysical research letters*. 2008; 35; doi: 10.1029/2007GL032487
31. Sridhara S, Chaithra GM, Gopakkali P. Assessment and monitoring of drought in Chitradurga district of Karnataka using different drought indices. *Journal of Agrometeorology.* 2021; 23 (2): 221-227.
32. Tufaner F, Ozbeyaz A. Estimation and easy calculation of the Palmer Drought Severity Index from the meteorological data by using the advanced machine learning algorithms. *Journal of Environ. Monit. Assess.* 2020; https://doi.org/10.1007/s10661-020-08539-0
33. Turan ES. Turkey's Drought Status Associated with Climate Change. *Artvin Coruh University Journal of Natural Hazards and Environment*. 2018; 4(1):63-69. doi: 10.213247/dacd.357384
34. Turkes M. Observed and Projected Climate Change, Drought and Desertification in Turkey. *Ankara University Journal of Environmental Science*. 2012; 4(2):1-32.

35. Vasiliades L, Louksas A. Hydrological response to meteorological drought using the Palmer drought indices in Thessaly, Greece. *Journal of Desalination*. 2009; 237, 3–21. doi:10.1016/j.desal.2007. .012 19
36. Vishwakarma A, Choudhary MK, Chauhan MS. Trend analysis of meteorological variables and drought indices in the Bundelkhand region using the non-parametric approach. *Journal of Russian Meteorology and Hydrology*. 2020; 45 (12): 870-875. ISSN 1068-3739
37. Yetmen H. Drought analysis in Turkey [doctoral dissertation]. Ankara University, Social Science Institue, Department of Geography, 2013.

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