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**Determination of the Effect of Climate Change on Wheat Yield in the Porsuk Creek Watershed**

**Abstract**

The wheat is one of the main agricultural products that will be affected by climate change. The aim of the study is to determine the effect of climate change on wheat yield in Porsuk Creek Watershed. In this study, wheat yield analyzes in the Porsuk Creek watershed had been conducted using the past (2016-2017) and future (2020-2100) climate data produced according to the optimistic (RCP4.5) and pessimistic (RCP8.5) scenarios of the HadGEM2-ES global climate model, with the help of the WOFOST model. In the Porsuk Creek Watershed, a +23.8% difference for 2016 and a +1.2% difference for 2017 was determined between the observed and predicted by WOFOST model wheat biomass values (2017 values>2016 values and estimated>observed). According to the optimistic scenario results in the watershed, 0.73% wheat yield increase is expected in the near future (2020-2045). In all other remaining periods; it is estimated that there will be a decrease in wheat yields (between 0.43-1.5%). Compared to reference period (1970-2000), the climate change in the creek watershed will occur in the manner of temperature and precipitation increases in the future. As a result, although WOFOST tends to predict wheat yields greater than the observed values, it is thought that the model can be used with confidence to predict future wheat yields. As a result of this study, important data about the planning of wheat agriculture were produced by estimating the plant yield for the use of decision makers.

## INTRODUCTION

Plant yield affected by climate change can be estimated using plant-climate models such as Simple and Universal Crop growth Simulator (SUCROS), Decision Support System for Agrotechnology Transfer (DSSAT), Agricultural Production Systems Simulator (APSIM), Environmental Policy Integrated Climate Model (EPIC), Simulation of Underground Bulking Storage Organs (SUBSTOR), Simulateur Multidiscplinaire pour les Cultures Standard (STICS) and World Food Studies (WOFOST) (Eyni-Nargeseh et al., 2020; Tie-cheng et al., 2020). SUBSTOR is a mechanistic, process oriented model for the prediction of tuber yield. The model simulates the daily phenological development, biomass and yield (Kumar et al., 2021). Besides, DSSAT models have some limitations, for example, crop rotation effects are poor in the models (Tran et al., 2020). The WOFOST model was developed for the quantitative test of the yield of annual field crops (Tie-cheng et al., 2020). Wheat is an important plant and is grown on more than 22 000 million da annually in the world (Eyni-Nargeseh et al., 2020). By 2028, the average yields of world wheat are foreseen to increase to 4257 kg ha$^{-1}$ (Cheng-zhi et al., 2020). Wheat is dramatically being affected by climate variables such as temperature, precipitation, solar radiation and relative humidity (Singh et al., 2021). Yield averages of the wheat (tons/ha) for some countries in last years are as follows (Taher et al., 2017; United States Department of Agriculture-USDA, 2019; Cheng-zhi et al., 2020). Iraq: 1.74, Turkey: 2.53, United States of America: 3.2, China: 5.42, Russia: 2.7, European Union: 5.4, World: 3.39 tons/ha. Many studies have been conducted on how climate change will affect agriculture in the world. In Turkey, wheat biomass is expected to positively be affected by increasing temperature by up to 17% according to RCP 4.5 and 26% according to RCP 8.5 scenarios (Yesilkoy and Saylan, 2020). In Iran, an increase of 1.6 and 2.3 ºC in annual temperature was

foreseen according to RCP4.5 and RCP8.5 in the mid-21st century, respectively. The mean radiation is expected to decreased between 11.6 and 14.3% in all areas according to RCP scenarios. Grain yield is expected to decreased in all areas for RCPs. The greatest decrease in wheat yield was projected according to RCP4.5 and RCP8.5 (7.9 and 9.3%) for the 2040–2070 period (Eyni-Nargeseh et al., 2020). In Nepal, drought years for wheat in the central, western and eastern regions increased from the past (1987–2000) to now (2001–2017) by 7.5%, 12.5% and 8%, respectively. Besides, the drought sensibility for wheat decreased in the western region but dramatically increased in the central and eastern regions of Nepal (Hamal et al., 2020). 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%), decreased evapotranspiration ( 3.7%) and decreased wheat yield ( 5.2%) (Gharibdousti et al., 2019). Turkey is one of the countries that will be most affected by climate change (Anonymous, 2010; GDWM-General Directorate of Water Management, 2016; Polat, 2017; Yesilkoy and Saylan, 2020; Konukcu et al., 2020). The Porsuk Creek Watershed in the Central Anatolia Region is important because it provides the drinking water of Eskisehir. This basin is one of the regions that will be most affected by drought (GDWM, 2016). Many studies have been conducted on how climate change will affect agricultural production in Turkey. It is stated that the maize yield models in the Aegean region can only explain 40% of the yield changes. The remaining yield deviation rate is due to variables other than climate (Isildar, 2010). In the Cukurova region, future precipitation may decrease by 33% and temperature may increase by 3 ºC. For the wheat crop, it is stated that an increased temperature of 1 ºC shortens the time to flowering by 5 days and the time to maturity by 9 days. In addition, there will occur a 10% reduction in the

count of wheat tillering due to drought (Kapur, 2010). In Kirklareli Province, a 40% precipitation decrease may cause a decrease of $5 \, \text{kg.ha}^{-1}$ in winter wheat yield, and increase of an 2 ºC temperature and 10% radiation will result in an increase of 23% in the yield (Koc, 2011). In the Thrace region, it is stated that sunflower yield first increased up to 9.4% and then decreased up to 22%. For the wheat crops, a yield increase of over 50% is expected due to climate change in the future (Deveci, 2015). Future climate change could reduce the production area of the opium poppy in Turkey (Yildirim et al., 2016). For studies on the impact of climate change on agriculture in Turkey, Onder et al. (2009), Isildar (2010), Kapur (2010) and Caylak (2015) can be cited as examples. 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 (Onder et al., 2009). In Kirklareli Province, it is stated that the increase of 5 ºC temperature cause a 36% loss of wheat yield, and $CO_2$ and solar radiation cause an increase in wheat yield (Caylak, 2015). In studies on the Porsuk Creek Watershed, it was seen that the number of studies was insufficient and the subject examined had limitations (Saris, 2016). The annual average water potential of the Porsuk Creek Watershed, which provides the water demand of a large population and is greatly affected by drought, is $481 \, \text{hm}^3$. The research area, located in the center of the Porsuk Creek Watershed is located between the Marmara, Aegean and Central Anatolia regions. For these reasons, this important watershed needs to be examined in detail (Saris, 2016). As a result, the effect of climate change on crops varies considerably due to the use of different crop yield model and different climate models (Eyni-Nargeseh et al., 2020; Tie-cheng et al., 2020). Moreover, the

location of the research area also affects the crop yield (Gharibdousti et al., 2019). In this study is important because it uses new (current) climate scenarios for future predictions (such as RCP4.5 and RCP8.5) compared to such examples in the literature. Moreover, in this study, an important watershed for Turkey was analyzed with a reliable model such as WOFOST (Eitzinger et al., 2004; GDWM, 2016). The general aim of this study is to determine the effect of climate change on wheat yield in Porsuk Creek Watershed. The aims and scope of the study are summarized as follows:

1) Within the scope of determining the wheat yield in the past (2016-2017) in the research area: *Wheat yields were determined by the WOFOST crop yield estimation model.*

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 version 4.3 (RegCM 4.3) regional climate model, 25 year long interval according to RCP 4.5 (optimistic) and RCP 8.5 (pessimistic) scenarios were analyzed.*

Within the scope of determining the effect of drought due to climate change on wheat yield in the research area, *the effect of climate change on wheat yield, which is estimated in 25 year long interval according to RCP 4.5 (optimistic) and RCP 8.5 (pessimistic) scenarios, was determined by WOFOST crop yield estimation model.*

## MATERIALS and METHODS
### 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 (The research area is the Middle Porsuk Creek Watershed) (Figure 1). Although a large part of this research

area is located in Eskisehir, approximately 12% of it is located within the borders of Kütahya and 3% of it is located in Bilecik. A close view of the basin, including the basin height information, is shown on the right (Figure 1). The watershed characteristics determined with the help of Google Earth Pro and ArcGIS 10.4 programs are shown in Table 1.
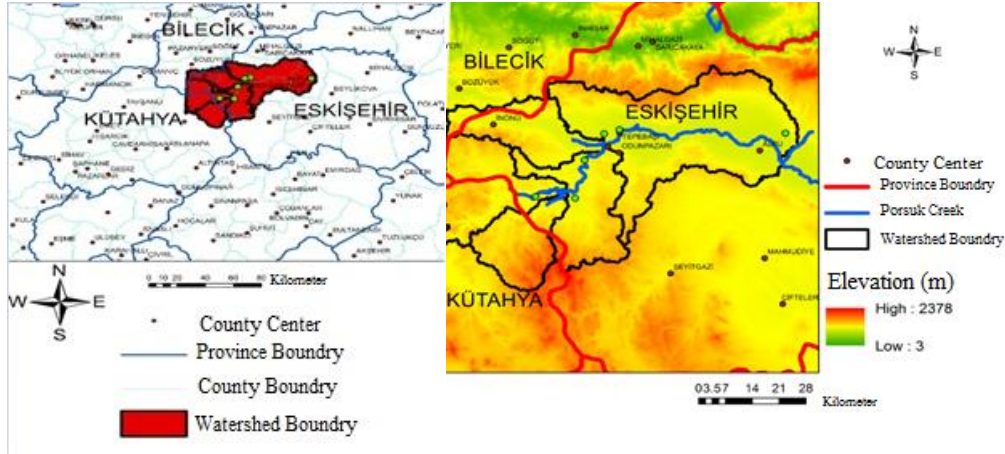


**Figure 1.** District boundaries and research area (Middle Porsuk Creek Watershed) map

**Table 1.** Characteristics of the research area

| Minimum height of watershed (m) | Maximum height of watershed (m) | Mean height of watershed (m) | Area of watershed ($km^2$) | Slope of watershed (%) | 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*: The research area where the wheat data were taken is located in the land in the center of Transitional Zone Agricultural Research Institute (TZARI) in Eskisehir-Tepebasi. Some (arithmetic) average values of field soil, from which Bezostaja wheat observation data are taken, are as follows: pH: 7.87, salt (%): 0.03, organic matter (%): 1.06. The Usable Water Holding Capacity of this wheat field is 220 mm m$^{-1}$. The other basic soil properties of the research area were shown in Table 2.

**Table 2.** Soil properties of the research area

| Depth (cm) | Sand (%) | Loam (%) | Clay (%) | Field capacity (Moisture, %) | Wilting point (Moisture, %) |
|---|---|---|---|---|---|
| 0-30 | 23 | 26 | 51 | 44 | 28 |
| 30-60 | 18 | 22 | 60 | 41 | 30 |
| 60-90 | 17 | 22 | 61 | 42 | 28 |

**Climate data**

*Climate data pertaining to the past*: The climatic data of the past in the study were obtained from the Transitional Zone Agricultural Research Institute (TZARI). Bi-annual climate data such as solar radiation, precipitation, minimum and maximum temperature from the TZARI were obtained on daily basis from the institute's own meteorological station. 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. The statistical downscaling method is less reliable as it doesn't consider future physical relations (GDWM, 2016; Batibeniz, 2014). 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 that could be found in the climatic forecast data were corrected.

**Climate models**

The most widely used and reliable climate modeling tools in the world are HadGEM2-ES and RegCM 4.3 models,

RCP 4.5 and RCP 8.5 scenarios. So, utilization of the output data of these tools was prefered in this study (GDWM, 2016; Sen, 2016; Anonymous, 2018). The output data produced from these climate modeling tools were used as input data in order to the prediction of the future wheat yields in this study. 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.

**Crop yield estimation model: WOFOST**

The WOFOST model generates very successful results in terms of sunlight assimilation and under drought conditions (Koc, 2011; Palosuo et al., 2011; Caylak, 2015). Moreover, when compared with other plant-climate models, WOFOST's menus are easy to use, WOFOST does not necessitate an excessive number of meteorological parameters, and has the feature to visualize the results (Koc, 2011). *WOFOST*: The main climatic inputs of WOFOST are daily precipitation, solar radiation, wind speed, minimum and maximum temperatures. The main outputs of WOFOST are biomass, yield, leaf area index (LAI), and harvest index (H INDEX) values.

**Wheat crop**

Crops grown in the research watershed are wheat, sunflower, corn, sugar beet and barley. The use of the Bezostaja wheat variety was preferred within the scope of this study due to its suitability for drought studies incidental to being one of the main food sources and low irrigation requirement. The general phenological period dates of wheat in the Porsuk Creek Watershed are as follows: Planting date: 15 October-25 November, First sprouting date: 15 November-10 December, Blooming: Late April-Early May, Harvest date: 15 July- Early Agust. The wheat data were taken from the land in the center of Transitional Zone Agricultural Research Institute (TZARI) in Eskisehir-Tepebasi.

## METHOD
### 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. For the period between 2016 and 2096, the required unit conversion process was carried out so that the climate data produced by GDWM with a resolution of 10 km can be used in the WOFOST model and drought indices. For this purpose, solar radiation values were converted from $W.m^{-2}$ to $kJ.m^{-2}$. 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.

### Crop yield estimation with WOFOST model

In this study, the cultivated field data of the Bezostaja wheat variety for the years 2016 and 2017 in the Eskisehir TZARI campus were used. Wheat planting in the research area was carried out on 18.10.2015 and 14.10.2016. The years 2016 and 2017 representing the general climate of the study area were chosen as the test period (2016 was used for calibration, 2017 was used for verification). In the calibration phase, Bezostaja wheat yield values in the field of TZARI were used. It was calibrated by comparing the observed yield values for the years 2016-2017 with the WOFOST model. The wheat yields were very sensitive to wind speed and varied widely. Therefore, the calibration was done by changing the average wind speed ($m.sec^{-1}$). It was understood that the discord index (d) and the observed and predicted values as a result of the analysis were very close to each other

and the WOFOST model was reliable in predicting the future wheat yield. In order to determine the effect of climate change on wheat yield and to predict future wheat yields, the observed wheat yields of 2016 and 2017 in the TZARI field were calibrated with the WOFOST model prediction values. Then, climate data produced according to RCP 4.5 and RCP 8.5 scenarios of HadGEM2-ES and RegCM 4.3 climate models, which are solar radiation (converted from $watt.m^{-2}$ to $kilojoule.m^{-2}$), total precipitation (mm), average wind speed ($m.sec^{-1}$), minimum and maximum temperature (ºC) daily data were used in the WOFOST model and yield results were obtained. In the future analysis of these results, periodic wheat yields were calculated for the near (2020-2045), mid (2045-2070) and far (2070-2095) terms. While making these calculations, the climate data produced by the climate models for the near, mid and far terms were used by entering them into the WOFOST model data files. The water or fertilizer limitation status of the simulation is selected from the general data tab of the WOFOST model. Crop phenological period dates can be selected from the crop data tab. The period of precipitation data is selected from the climate data tab. Soil type is selected from the soil data tab (Koc, 2011; Konukcu et al., 2020). During the modeling of future wheat yields, the units of the 3-hour solar radiation values in the climate model outputs were $watt.m^{-2}$ while the units of these values entered into the WOFOST model were converted as $kilojoule.m^{-2}.day^{-1}$

## RESULTS and DISCUSSION
### Current wheat results determined by WOFOST crop yield estimation model

In the statistical evaluation of the results in this section, the discord index (d) was used. According to Isildar (2010), the discord index (d), which gives information about the closeness of the predicted and observed values, was also used in this study to determine the accuracy of past and future

wheat yield and climate predictions (modeling). The fact that these index results take values between 0.5 and 1 will be an indication of successful estimation (modeling). The main districts where agriculture is made in the watershed are Alpu, Odunpazari and Tepebasi. In 2016, a large amount of yield were achieved with large proportional yield increases. It is understood that agricultural droughts are effective in Tepebasi and the region is more sensitive to agricultural drought. Although there was no agricultural drought in Tepebasi in 2015, the decrease in wheat yields may have been caused by the wrong wheat variety selection and the wrong cultural practices of the farmers (irrigation, spraying, fertilization, etc.) during that year (Table 3). In the past years, yield losses are more frequent. Especially in 2010, great yield losses were experienced in Alpu. The yield decreases observed in Odunpazari and Tepebasi in the same year support the assumption that agricultural droughts were prevalent in the region in 2010. The regions most affected by these agricultural droughts are Alpu, Odunpazari and Tepebasi, respectively (Table 3).

**Table 3.** Change rate of wheat yield compared to average yield in the watershed

|  | Alpu | | Odunpazari | | Tepebasi | |
|---|---|---|---|---|---|---|
|  | Wheat yield (kg. decare$^{-1}$) | Wheat yield change compared to average (%) | Wheat yield (kg. decare$^{-1}$) | Wheat yield change compared to average (%) | Wheat yield (kg. decare$^{-1}$) | Wheat yield change compared to average (%) |
| 2010 | 129 | -51% | 135 | -46% | 276 | -2% |
| 2011 | 212 | -19% | 247 | -2% | 324 | + 15% |
| 2012 | 336 | + 28% | 273 | + 9% | 316 | + 12% |
| 2013 | 385 | + 47% | 255 | + 2% | 302 | + 7% |
| 2014 | 314 | + 20% | 282 | + 12% | 285 | + 1% |
| 2015 | 325 | + 24% | 309 | + 23.1% | 222 | -21.3% |
| 2016 | 348 | + 33% | 332 | + 32.3% | 287 | + 1.8% |
| 2017 | 314 | + 20% | 300 | + 19.5% | 302 | + 7.1% |
| 2008-2017 (Average yield for multi-year) | 262 |  | 251 |  | 282 |  |

In the study, when wheat yield observations were made, the year 2016 was used for calibration and 2017 was used for verification. For the precision of the results, the discord index (d) was used. Since the discord index (d) value was between 0.5 and 1 in this study in terms of biomass results (d=0.84), the results of the WOFOST model in this study are considered successful. That is, the estimated wheat biomass values can represent the observed wheat biomass values (Table 4). When the results of drought indices are examined in the Porsuk Creek Watershed, 2017 was drier compared to 2016. The WOFOST estimates for the arid year 2017 were much closer to the observed values. It has been understood that the observed and predicted values are very close to each other and the WOFOST model is reliable in predicting future wheat yield. It is also thought that the WOFOST model tends to predict wheat yields greater than observed values (Table 4). In the Porsuk Creek Watershed, a + 23.8 % deviation for 2016 and a +1.2 % deviation for 2017 were determined between the observed and estimated biomass values as a result of comparing the WOFOST model results of wheat with the observation values. It can also be said that the estimation results in 2017 are more successful compared to the data of 2016 (Table 4).

**Table 4.** Bezostaja wheat biomass observed in the resarch field and estimated by the WOFOST model

| Year | Observed biomass (kg. decare$^{-1}$) | Biomass predicted by WOFOST (kg. decare$^{-1}$) | Observed and predicted percentage of biomass change |
|------|------|------|------|
| 2016 | 848 | 1050 | + 23.8% |
| 2017 | 1284 | 1300 | + 1.2% |

Studies by Quiring and Papakryiakou (2003), Eitzinger et al. (2004) and Isildar (2010) were examined. When the results in the literature are analyzed, it is expected that the index estimation differences of plants may be high because no crop yield estimation model is perfect and variables other than climate are very effective on plant yields. Moreover, the potential of the WOFOST model to generate spatially unsuccessful results and the model's potential to predict greater plant yields than observed has also been confirmed by literature results.

**Wheat yields estimated by WOFOST crop yield estimation model**

The data obtained from GDWM regarding future (monthly total precipitation (mm), solar radiation (kilojoule.$m^{-2}$), average wind speed (m.$sec^{-1}$), minimum and maximum temperatures (ºC)) are entered into the WOFOST model and, future wheat yields has been estimated. According to the result of the WOFOST model in the Porsuk Creek Watershed, a 0.73% wheat yield increase is expected in the near future, according to the optimistic scenario (RCP4.5). In all other periods, it is estimated that wheat yields will decrease between -0.45% and 1.5% (Table 5).

**Table 5.** Periodic variation trend of future WOFOST results (Wheat biomass-kg.decare$^{-1}$) in Porsuk Creek Watershed compared to the current situation

| Area | Scenarios | Period | | |
|------|-----------|--------|--------|--------|
| | | 2020-2045 (Near future) | 2045-2070 (Mid future) | 2070-2095 (Far future) |
| Porsuk Creek watershed | RCP4.5 | (Increase) ↑ | (Decrease) ↓ | (Decrease) ↓ |
| | RCP8.5 | (Decrease) ↓ | (Decrease) ↓ | (Decrease) ↓ |

Studies by Cheng-zhi et al. (2020), Eyni-Nargeseh et al. (2020), Gharibdousti et al. (2019) and Hamal et al. (2020) were examined. It is expected that temperature increase and decrease in grain yield will occur in the future in the Porsuk Creek Watershed and Iran. In the mid future (2040-2070), a decrease in wheat yield will occur at 8.6% in Iran while it will occur at 1.5% in the Porsuk Creek Watershed. An increase in both temperature and rainfall is expected in the near future (until 2040) in the Porsuk Creek Watershed and

Oklahoma. Besides, a decrease in wheat yield will occur at 5.2% in Oklahoma while it will occur at 0.43% in the Porsuk Creek Watershed. As time passes, as the situation in the Porsuk Creek Watershed, drought years for a wheat increase in Nepal. In addition, it is expected that wheat yields will increase in the world and the Porsuk Creek Watershed in the near future (until 2028). As a result of these studies, it is understood that the results of the Porsuk Creek Watershed are similar to the other results in the world. Besides, as time passes,

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drought will intensify everywhere. When the research study of Caylak (2015) in the literature is analyzed by comparing it with this study, unlike the situation in Kirklareli, wheat yields in Eskisehir are not expected to be affected excessively by temperature change. When the research study of Konukcu et al. (2020) is analyzed by comparing it with this study, it is understood that climate change will have a positive effect on increasing wheat yield in the Thrace Region, while it will have a negative effect on the Porsuk Creek Watershed. In terms of the climatic conditions of the region, it is seen that Porsuk Creek Watershed is more sensitive to drought compared to the Thrace Region. Considering that the climatic scenarios used and the examined time periods will affect the results, it will be beneficial to use the same period, climate model and the same scenarios for interregional comparison.

**Results related to climate change**

For the determination of climate change, the annual averages of the future are compared to the precipitation, minimum and maximum tempereture 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 temperetures is expected when compared with past (1970-2000) climate data. The increase in maximum temperetures is expected to occur within the range of 3.47 ºC to 6.7. The increase in precipitation is expected to occur within the range of 18,71% to 46%. As a result, as time passes, it is expected that tempereture increases will increase and precipitation increases will decrease (Table 6).

**Table 6.** 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 tempereture (ºC) | | Maximum tempereture (ºC) | | Precipitation (%) | |
|---|---|---|---|---|---|---|
| | RCP4.5 | RCP8.5 | RCP4.5 | RCP8.5 | RCP4.5 | RCP8.5 |
| 2020-2045 | 2.66 increase | 2.69 increase | 3.47 increase | 3.52 increase | 41 increase | 46 increase |
| 2045-2070 | 3.47 increase | 4.19 increase | 4.4 increase | 5.25 increase | 22.13 increase | 22.06 increase |
| 2070-2095 | 3.69 increase | 5.58 increase | 4.55 increase | 6.7 increase | 31.47 increase | 18.71 increase |

When the research study of Yesilkoy and Saylan (2020) in the literature is analyzed by comparing it with this study, unlike the situation in the Porsuk Creek Watershed, wheat biomass is expected to positively be affected by increasing temperature by up to 21.5% in Thrace region (Turkey) in the future. Onder et al. (2009) predict that in the 2070s, precipitation will decrease by 30% on the Mediterranean coast and increase by 22% in the Black Sea region. In addition, the researchers, who stated that the temperatures in Turkey may be 5 ºC higher in the 2070s, predict that the droughts throughout Turkey may intensify, except for the Eastern Black Sea region. Kapur (2010), using the results of the TERCH-RAMS climate model, 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 5, it is thought that the Porsuk Creek watershed will approach the Black Sea climate due to the increase in temperature and precipitation. Moreover, wheat biomass affected by climate change will be affected differently from region to region in Turkey.

**General evaluation of the findings**

Except for the optimistic (RCP4.5) wheat yield estimations in the near future (2020-2045), consistent results were obtained in all periods and scenario comparisons (Table 7). Accordingly, possible changes in wheat yield (Table 7) in the research area are expected to be compatible with the results of climate change (Table 6). When the climate change in the watershed is compared to the reference period (1970-2000), a decrease in wheat yields is expected depending on the future. 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 increases and a decrease in precipitation increases. This is consistent with future wheat yield declines (Table 7).

**Table 7.** Periodic analysis of future climate change results and wheat biomass results in the Porsuk Creek Watershed

| Scenario | Period | | | | | |
|---|---|---|---|---|---|---|
| | 2020-2045 (Near future) | | 2045-2070 (Mid future) | | 2070-2095 (Far future) | |
| | Result of WOFOST (Wheat yield) | Result of climate change | Result of WOFOST (Wheat yield) | Result of climate change | Result of WOFOST (Wheat yield) | Result of climate change |
| RCP4.5 | Yield increase | Temperature increase, precipitation increase | Yield decrease | Temperature increase, precipitation increase | Yield decrease | Temperature increase, precipitation increase |
| RCP8.5 | Yield decrease | Temperature increase, precipitation increase | Yield decrease | Temperature increase, precipitation increase | Yield decrease | Temperature increase, precipitation increase |

With respect of the literature, Koc (2011), Atay (2015), Yildirim et al. (2016), Konukcu et al. (2020)'s research is analyzed by comparing it with this study, it is understood that even a small amount of radiation increase can significantly increase crop yields. In addition to the decrease in wheat production in the future on the research area due to climate change, it is expected that the opium poppy production areas in Turkey will also decrease. Finally, it is understood that climate change will have a positive effect on increasing wheat yield in the Thrace Region and a negative effect in the Porsuk Creek Watershed.

**CONCLUSIONS**

According to the results of the WOFOST model in the Porsuk Creek Watershed, the WOFOST estimate in the past arid year was much closer to the observed value. In the future, it is estimated that there will be a decrease in wheat yields. Contrary to the situation in the Thrace region, in the Porsuk Creek Watershed, wheat yields are expected to be severely affected by temperatures change, and climate change is expected to reduce wheat yield. An increase is expected in future precipitation, maximum and minimum temperatures of the Porsuk Creek Watershed. As a result, wheat yields in Eskisehir are not expected to be affected excessively by temperature changes. However, it is expected that the wheat production fields in the research will decrease. It is suggested that the agriculture pattern suitable for climate change for the region should be arranged according to the climate change results 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-resistant crop varieties

should be grown. Because, since climate change can not be prevented, crop yield should be tried to be increased in order to at least improve the factors other than climate and reduce the drought damage.

**ACKNOWLEDGEMENT**

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