Journal of Applied Biological Sciences
E-ISSN: 2146-0108 15(1): 20-36, 2021
Research Article

LONG-TERM ANALYSIS ON CLIMATE-DROUGHT-YIELD RELATIONSHIP; ESKISEHIR CASE STUDY

Zekiye Budak Basciftci[1], Murat Olgun[1], Mustafa Yalcin[2], Hikmet Korkmazer[3], Nazife Gozde Ayter Arpacioglu[1], Dogan Aydin[1], Okan Sezer[4,*], Murat Ardic[4], Ismuhan Potoglu Erkara[4], Onur Koyuncu[4]

[1]*Eskişehir Osmangazi University, Agricultural Faculty, Field Crop Department, Turkey*
[2]*Afyon Kocatepe University, Engineering Faculty, Geomatics Engineering Department, Turkey*
[3]*Regional Directorate of Meteorology, Eskişehir, Turkey*
[4]*Eskişehir Osmangazi University, Science and Letter Faculty, Biology Department, Turkey*

**Corresponding Author:*
E-mail: oksezer@ogu.edu.tr

(Received 18th July 2020; accepted 03th December 2020)

ABSTRACT. In this study, the structure of climate characteristics (precipitation, minimum, maximum and average temperature, relative humidity), their changes by years, and analysis for drought and stress analysis by SPI (Standard Precipitation Index), and for temperature stress by THI in Eskişehir province were analysed. In addition, the relationship between climate factors and yield was determined by factor analysis. Results showed that although precipitation appears slightly arid in the 50-year period, no excessive change or decrease was observed on precipitation in Eskişehir. In addition, about 2°C increase was recorded at minimum, maximum and mean temperatures. PCA analysis revealed that, the precipitations in March, April, May, June, October, March-June period and total precipitation are closely related to grain yield in wheat. When the mean, minimum and maximum temperatures are taken into consideration, the temperatures in May and June, October and March-June period and June-August period are also very effective in the development of the plant. Since, relative humidity is closely related to precipitation, relative humidity in June, July, October, March-June period and August-November period affects the yield together with precipitation. While there is not a big change in precipitation, almost 2ºC increase in temperatures is determined and this increase is the trigger of drought. There is an increase in evapotranspration more and more, that expresses water loss from soil and plants due to the gradual increase of temperature on a 50-year basis, it is highly probable that, the plant needs to use more water for transpration due to the increasing temperature. This shows that due to the increasing temperature, water loss increases and accordingly, there are gradual increases in drought.

Keywords: *Climate, drought, yield, long term, SPI, THI, factor analysis, Eskişehir, Turkey*

INTRODUCTION

Eskişehir is located in Turkey's Central Anatolia Region; it is surrounded by the Black Sea, Marmara and Aegean regions; It is surrounded by Bozdağ and Sündiken Mountains in the north, Emirdağ in the south, Central Asia Valley in the east and Turkmen Mountains in the west. For this reason, Eskişehir is under the influence of the dominant climates of these regions, and it shows a transition type of the Gateway [1, 2]. Occupying about 2% of Turkey's land, the size of the land area in Eskisehir is almost 13,500 km^2. The altitude is 792 m; 22% and 26% of the total area in the city are mountains and plains, respectively [2]. Eskişehir has the feature of land climate due to its geographical conditions, elevations, landforms, and distance to the sea. On the one hand, proximity to the Aegean and Marmara regions significantly affects the climatic conditions of Eskişehir [3, 4].

Annual total precipitation average, minimum and maximum temperatures in the city are about 360 mm, 11°C, -2°C and 25°C, respectively [4]. While December and January are the coldest months, the hottest days are experienced in June, July and August. The most obvious event showing the land climate feature in the city is that there are also large temperature differences between 10°C and 30°C at night and day temperature. Rains in Eskişehir are seen in the form of snow and rain in the winter. Since December, precipitation is mostly in the form of snow. The weather starts to warm up as of the end of April. Although snowfalls generally start in November and end in April in Eskişehir, significant decreases have been recorded in snowfall in recent years. In July and August, the Mediterranean shows summer drought characteristics [4, 5]. Wheat production is generally carried out in dry agricultural areas in the world, and drought that is one of the important environmental stresses, frequently causes serious problems in wheat production in these areas.

Drought is a change or decrease in water availability in the climate, and the dry climate refers to the regions with low precipitation. The severity of the drought event depends on the proportion of soil moisture deficit, duration and duration of the affected area. Besides, drought is one of the most important abiotic stress factors in bread wheat, and it is the most important factor limiting crop production in most of the agricultural areas. Most of the annual precipitation on drought prevailing areas in Eskişehir falls between November and April. Although there are arid periods in different plant growth periods due to the insufficient amount/ irregular distribution in precipitation, drought stress, that generally starts at the flowering and increases its effect in grain filling period. Moreover, mean, minimum and maximum temperatures prevailing during the wheat-grow season significantly affect the growth performance and hence crop yield [5, 6, 7, 8]. Therefore, precipitation and temperature are extremely important climate factors on wheat production in dry farming [5, 9]. In regions where continental climate prevails, September-November and March-June precipitation, snow-free in December-February and low temperatures below -10 / -15ºC, low temperatures below 0ºC during the flowering period and high temperatures above 30ºC greatly damage plant growth in wheat [3, 10, 11, 12, 13]. Therefore, it is very important to reveal the common characteristics of the prevailing precipitation and temperatures throughout the plant development circuits, to carry out a successful breeding program in that region, to develop novel genotypes and to maintain a healthy grain production [3, 14, 15]. In this study, the structure of climate characteristics (precipitation, minimum, maximum and average temperature, relative humidity), their changes by years, and analysis for drought and stress analysis by SPI (Standard Precipitation Index) [5, 16], and for temperature stress by THI (Thermal Heat Index) [17, 18] in Eskişehir province were analysed. In addition, the relationship between climate factors and yield was determined by factor analysis.

MATERIALS AND METHODS

Having a surface area of approximately 13,500 km², Eskişehir is located between 29-32 degrees east longitudes and 39-40 degrees north latitudes in the northwest of Central Anatolia Region. The city is surrounded by Bozdağ and Sündiken Mountains in the north, Emirdağ in the south, Central Asia Valley in the east, and Turkmen Mountains in the west (Fig 1). Therefore, the influence of the dominant climates of the Black Sea, Marmara and Aegean Regions are seen. Annual total precipitation, mean, minimum and maximum temperatures are about 360 mm 11°C, -2°C and 25°C, respectively.

***Fig. 1**. Map of Eskişehir province.*

In our study, precipitation, minimum, maximum, and average temperature and relative humidity data of Eskişehir were obtained from Eskişehir 3rd Regional Directorate of Meteorology and 49-year data (1980-2018) were used. The arithmetic mean was used to calculate means. Wheat yields (2004-2018) were taken from Turkey Statistical Institute (TSI). Standard Precipitation Index (SPI) [5, 16] for the precipitation and drought analysis and Thermal Temperature Index [17, 18] were used to stress analysis of temperatures for Eskişehir. Excel 13 package program [19] was used for the classification modelling of precipitation and temperatures, and the necessary information is given in Table 1. Spatial analysis and all cartographic designs made in the study were carried out in ArcGIS software. Besides, interpolations were made according to the IDW (Inverse Distance Weighting) method [20].

***Table 1.** Data on classification and modeling of precipitation and temperatures in Eskişehir province*

Standard Rain Index (SRI) and Classification			
$SRI = Xi - Xmean/\alpha$ — SRI: Standard rain index, Xi: Normalized amount of current annual precipitation, $Xmean$: Average rainfall in the selected time interval for each station, α: Standard deviation of values for each station over time.			
Class	**Index Values**	**Class**	**Index Values**
Extremely Dry	<-2,00	**Slightly Rain**	0,00- 1,00
Very Dry	-2,00- -1,50	**Moderate Rain**	1,00- 1,50
Moderate Dry	-1,50- -1,00	**Very Rain**	1,50- 2,00
Slightly Dry	-1,00- 0,00	**Extremely Rain**	>2,00
SRI Modelling Formula			
SRI=IF(X_{Value}<=-2;"**Extremely Dry**";IF(AND (X_{Value}>-2;X_{Value}<=-1,5);"**Very Dry**";IF(AND(X_{Value}>-1,5;X_{Value}<=-1);" Moderate Dry"; IF(AND (X_{Value}>-1; X_{Value}<=0); "**Slightly Dry**";IF (AND (X_{Value}>0; X_{Value}<=1); "**Slightly Rain**";IF(AND(X_{Value}>1;X_{Value}<=1,5);"**Moderate Rain**";IF(AND(X_{Value}>1,5;X_{Value}<=2);"**Very Rain**"; IF (X_{Value}>2; "**Extremely Rain**";""))))))))			
Thermal Heat Index (THI) and Classification			
$THI = (1.8 \times T + 32) - [(0.55 - 0.0055 \times RH) \times (1.8 \times T - 26.8)]$			
T: **Air temperature in**°C , RH: Relative humidity in %.			
Class	**Index Values**	**Class**	**Index Values**
No Stress	<66	**Heavy Stress**	80-89
Slightly Stress	66-71	**Extremely Stress**	>90
Stress	72-79		
THI Modelling Formula			
THI=IF(X_{Value}<=66;"**No Stress**";IF(VE(X_{Value}>66;X_{Value}<=71);"**Slightly Stress**"; IF(VE(X_{Value}>72;X_{Value}<=79);"**Stress**"; IF(VE(X_{Value}>80; X_{Value}<=89);"**Heavy Stress**";IF(X_{Value}>90;"**Extremely Stress**";"")))))			

RESULTS AND DISCUSSION

Drought is a phenomenon that creates significant results in agricultural production and causes serious problems in production and thus in the economy. The development of drought could take many years and its results could be serious and costly. The negative effects of drought are felt in the world due to climate changes. In fact, studies stated that the prevailing continental climate affects plant development negatively due to the increasing drought and temperature and there are significant decreases in crop production. In addition, drought intensities and duration in the world will increase [5, 7, 8, 21]. The 49-year climate data (1980-2018) of Eskişehir are evaluated in five-year periods, and the minimum, maximum, and average temperature and relative humidity changes are given in Fig. 2. Again, the evaluation of precipitation and mean temperature values for the 1980-2018 period according to SPI and THI index are given in Table 2, minimum and maximum temperature and relative humidity values are given in Table 3. Moreover, based on the period of 1980-84, the % increase and decrease in the minimum, maximum, and average temperature and relative humidity data in the next five-year periods are shown in Table 4.

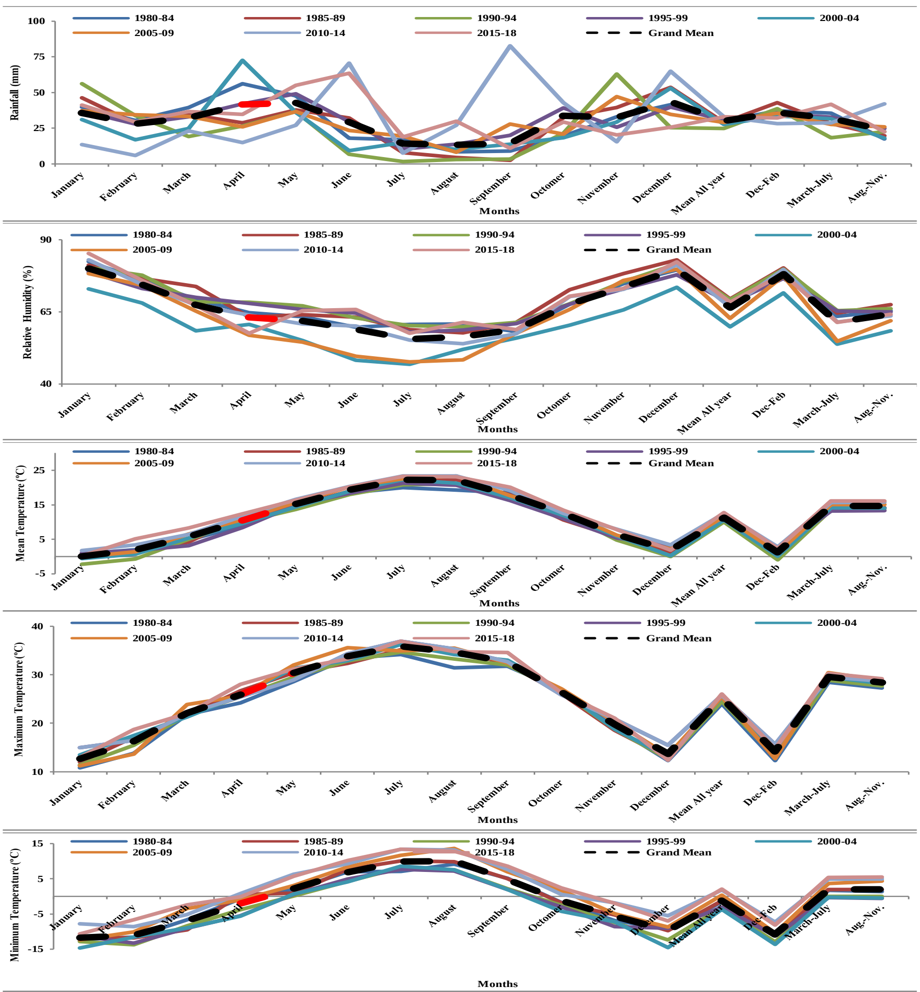

***Fig. 2**. The 49-year climate data (1980-2018) of Eskişehir province are evaluated as five-year periods, for minimum, maximum, and average temperature and relative humidity.*

Despite the increase in rains in the March-June period and December-February period, it has decreased significantly especially in the June-August period. Although similar trend is observed in relative humidity values, the variation in relative humidity values was not as high as the precipitation. Fig. 2. Periodic increases and decreases in precipitation did not occur similarly in 5-year periods, decreased considerably in some periods, and therefore there were wide variations between 5-year periods. Analyses in terms of mean, minimum and maximum temperatures, almost all similar impressions were seen at mean, minimum and maximum temperatures and typical continental climate characteristics appeared as an increase in the temperatures from February to July and a decrease towards December. Therefore, the highest temperature was determined as July-August and the lowest temperatures as December-January during the long-year period examined (Fig. 1). In Table 2, precipitation and average temperature values, SPI and THI indices are evaluated in 5-year periods. In the 1980-2018 precipitation period according to the SPI index, March, April, May, October, November, December and January are slightly rain; February, June, July and August are determined to be slightly dry. When evaluated all year, Eskişehir province is assumed as slightly dry with 362,36 mm. When monthly periods are analysed, it was determined that the months of December-February and March-June of June periods emerged as slightly rain and August-November period was slightly dry. Although some periods are slightly rain, droughts occurring from mid-May and June, cause a decline in the plant's development, grain filling period, and therefore low precipitation leads to diminutions in the photosynthetic ability of the plant and hinders reaching the desired level in crop yield. It has been revealed that plant development and therefore crop yield in dry farming are closely related to precipitation, and that increase in crop yield also takes place with the increase in precipitation in April-June period, called as plant development period [3, 14]. When the 49-year-long period is analysed, it was observed that the precipitation with 360.42 mm in 1980-84 period, was similar to the 2015-18 period with 395.65 mm, and variations on precipitations in 5-year periods were not much. However, the change in the five-year periods was determined to be more on a monthly basis. When the mean temperatures are analysed, during 1980-2018 period, great changes did not occur and similar synchronizations occurred on the basis of both months and five-year periods. According to the THI index, although slightly stress was observed only in July and August, no stress was observed in the other months. The important thing is that although the stress is not observed, a gradual increase in temperature occurred from 1980 to 2018 with almost 2°C (Table 2). The increase by years for mean temperature occurred mostly in March, April, June, July and August. When the long year period is examined in terms of minimum and maximum temperatures in Table 3, an increase in minimum and maximum temperatures are similar to the mean temperature with 1-2ºC. The highest increase also occurs in March, May, June, July, August and February. This reveals that; due to this increase in winter and spring, an increase in temperature continues towards a milder winter and a drier summer.

***Table 2**. Five-year precipitation and mean temperature values on long-term climate data (1980-2018) of Eskişehir province, according to the SPI and THI index*

Rainfall	January	February	March	April	May	June	July	August	September	October	November	December	All Year Mean	Dec-Feb	March-July	Aug.-Nov.	Total Rainfall
1980-84	39,80 *Slightly Rain*	30,50 *Slightly Rain*	39,60 *Slightly Rain*	56,04 *Moderate Rain*	47,66 *Slightly Rain*	18,16 *Slightly Dry*	17,08 *Slightly Dry*	8,52 *Slightly Dry*	9,00 *Slightly Dry*	19,56 *Slightly Dry*	32,98 *Slightly Rain*	41,52 *Slightly Rain*	30,04 *Slightly Dry*	37,27 *Slightly Rain*	35,71 *Slightly Rain*	17,52 *Slightly Dry*	360,42
1985-89	46,20 *Slightly Rain*	28,50 *Slightly Dry*	34,72 *Slightly Rain*	28,78 *Slightly Dry*	37,80 *Slightly Rain*	32,08 *Slightly Rain*	7,78 *Slightly Dry*	4,60 *Moderate Dry*	2,42 *Moderate Dry*	32,50 *Slightly Rain*	39,52 *Slightly Rain*	53,62 *Moderate Rain*	29,04 *Slightly Dry*	42,77 *Slightly Rain*	28,23 *Slightly Dry*	19,76 *Slightly Dry*	348,52
1990-94	56,30 *Moderate Rain*	33,90 *Slightly Rain*	19,30 *Slightly Dry*	26,50 *Slightly Dry*	36,80 *Slightly Rain*	6,90 *Moderate Dry*	1,80 *Moderate Dry*	3,00 *Moderate Dry*	3,40 *Moderate Dry*	21,40 *Slightly Dry*	63,00 *Moderate Rain*	25,50 *Slightly Dry*	24,82 *Slightly Dry*	38,57 *Slightly Rain*	18,26 *Slightly Dry*	22,70 *Slightly Dry*	297,80
1995-99	37,12 *Slightly Rain*	28,04 *Slightly Dry*	33,00 *Slightly Rain*	42,06 *Slightly Rain*	49,26 *Slightly Rain*	29,70 *Slightly Dry*	10,32 *Slightly Dry*	13,78 *Slightly Dry*	20,18 *Slightly Dry*	39,34 *Slightly Rain*	25,60 *Slightly Dry*	39,76 *Slightly Rain*	30,68 *Slightly Rain*	34,97 *Slightly Rain*	32,87 *Slightly Rain*	24,73 *Slightly Dry*	368,16
2000-04	30,94 Slightly Rain	17.06 Slightly Dry	24,92 Slightly Dry	72,60 Very Rain	36,16 Slightly Rain	9,44 Slightly Dry	15.00 Slightly Dry	10,20 Slightly Dry	13,96 Slightly Dry	18,28 Slightly Dry	29,36 Slightly Dry	52,98 Slightly Rain	27,58 Slightly Dry	33,66 Slightly Rain	31,62 Slightly Rain	17,95 Slightly Dry	330,90
2005-09	37,26 *Slightly Rain*	34,58 *Moderate Rain*	33,18 *Slightly Rain*	26,04 *Slightly Rain*	36,64 *Slightly Rain*	23,34 *Moderate Rain*	19.48 *Slightly Rain*	8,22 *Slightly Rain*	27,86 *Very Rain*	20,90 *Slightly Rain*	47,26 *Moderate Rain*	34,86 *Moderate Rain*	29,14 *Slightly Rain*	35,57 *Slightly Dry*	27,74 *Slightly Dry*	26,06 *Slightly Dry*	349,62
2010-14	13,60 *Slightly Rain*	5,80 *Slightly Rain*	23,10 *Slightly Rain*	15,00 *Slightly Rain*	27,20 *Slightly Rain*	70,50 *Slightly Rain*	7,50 *Slightly Dry*	27,00 *Slightly Dry*	82,70 *Slightly Dry*	42,90 *Very Rain*	15,60 *Slightly Dry*	65,00 *Moderate Rain*	32,99 *Slightly Rain*	28,13 *Slightly Dry*	28,66 *Slightly Dry*	42,05 *Slightly Rain*	395,90
2015-18	41,33 *Slightly Rain*	29.40 *Slightly Dry*	36,65 *Slightly Rain*	34,70 *Slightly Rain*	54,93 *Moderate Rain*	63,53 *Moderate Rain*	18.93 *Slightly Dry*	29,85 *Slightly Dry*	10.93 *Slightly Dry*	29,50 *Slightly Dry*	20,33 *Slightly Dry*	25,60 *Slightly Dry*	32,97 *Slightly Rain*	32,11 *Slightly Rain*	41,75 *Slightly Rain*	22,65 *Slightly Dry*	395,65
Mean	**35.79** *Slightly Rain*	**28,23** *Slightly Dry*	**32,35** *Slightly Rain*	**41,68** *Slightly Rain*	**42,89** *Slightly Rain*	**29,18** *Slightly Dry*	**14,33** *Slightly Dry*	**13,40** *Slightly Dry*	**14,35** *Slightly Dry*	**33,79** *Slightly Rain*	**32,68** *Slightly Rain*	**43,68** *Slightly Rain*	**30,20** *Slightly Dry*	**35,90** *Slightly Rain*	**32,09** *Slightly Rain*	**23,55** *Slightly Dry*	362,36

Mean Temp.	January	February	March	April	May	June	July	August	September	October	November	December	All Year Mean	Dec-Feb	March-July	Aug.-Nov.
1980-84	0,78 *No Stress*	1,96 *No Stress*	4,80 *No Stress*	9,00 *No Stress*	15,38 *No Stress*	18,50 *No Stress*	19,98 *No Stress*	19,30 *No Stress*	18,44 *No Stress*	13,00 *No Stress*	5,80 *No Stress*	1,72 *No Stress*	10,72 *No Stress*	1,49 *No Stress*	13,53 *No Stress*	14,14 *No Stress*
1985-89	0,96 *No Stress*	1,28 *No Stress*	4,22 *No Stress*	11,86 *No Stress*	14,90 *No Stress*	18,96 *No Stress*	21,88 *Slightly Stress*	22,36 *Slightly Stress*	17,92 *No Stress*	10,64 *No Stress*	5,68 *No Stress*	1,34 *No Stress*	11,00 *No Stress*	1,19 *No Stress*	14,36 *No Stress*	14,15 *No Stress*
1990-94	-2,22 *No Stress*	-0,68 *No Stress*	5,06 *No Stress*	10,04 *No Stress*	13,74 *No Stress*	18,06 *No Stress*	20,82 *Slightly Stress*	21,12 *Slightly Stress*	17,10 *No Stress*	12,64 *No Stress*	4,76 *No Stress*	-0,02 *No Stress*	10,04 *No Stress*	-0,97 *No Stress*	13,54 *No Stress*	13,91 *No Stress*
1995-99	1,10 *No Stress*	1,80 *No Stress*	3,22 *No Stress*	8,48 *No Stress*	14,96 *No Stress*	18,40 *No Stress*	21,24 *Slightly Stress*	20,74 *Slightly Stress*	16,22 *No Stress*	10,96 *No Stress*	5,34 *No Stress*	3,30 *No Stress*	10,48 *No Stress*	2,07 *No Stress*	13,26 *No Stress*	13,32 *No Stress*
2000-04	-0,56 *No Stress*	0,74 *No Stress*	5,44 *No Stress*	9,62 *No Stress*	14,36 *No Stress*	19,00 *No Stress*	22,38 *Slightly Stress*	21,24 *Slightly Stress*	17,02 *No Stress*	11,92 *No Stress*	5,98 *No Stress*	0,24 *No Stress*	10,62 *No Stress*	0,14 *No Stress*	14,16 *No Stress*	14,04 *No Stress*
2005-09	-0,12 *No Stress*	1,38 *No Stress*	6,50 *No Stress*	10,76 *No Stress*	15,72 *No Stress*	20,20 *No Stress*	22,56 *Slightly Stress*	23,42 *Slightly Stress*	17,66 *No Stress*	13,08 *No Stress*	6,22 *No Stress*	2,18 *No Stress*	11,63 *No Stress*	1,15 *No Stress*	15,15 *No Stress*	15,10 *No Stress*
2010-14	1,80 *No Stress*	3,38 *No Stress*	6,46 *No Stress*	11,70 *No Stress*	16,62 *No Stress*	20,30 *Slightly Stress*	23,42 *Slightly Stress*	23,38 *Slightly Stress*	19,16 *No Stress*	12,48 *No Stress*	7,98 *No Stress*	3,38 *No Stress*	12,51 *No Stress*	2,85 *No Stress*	15,70 *No Stress*	15,75 *No Stress*
2015-18	0,23 *No Stress*	5,13 *No Stress*	8,35 *No Stress*	12,45 *No Stress*	16,40 *No Stress*	20,20 *No Stress*	23,28 *Slightly Stress*	23,15 *Slightly Stress*	20,13 *No Stress*	13,40 *No Stress*	7,80 *No Stress*	1,85 *No Stress*	12,70 *No Stress*	2,40 *No Stress*	16,14 *No Stress*	16,12 *No Stress*
Mean	**0,04** *No Stress*	**1,96** *No Stress*	**5,84** *No Stress*	**10,51** *No Stress*	**15,30** *No Stress*	**19,36** *No Stress*	**22,28** *Slightly Stress*	**22,18** *Slightly Stress*	**17,88** *No Stress*	**12,41** *No Stress*	**6,35** *No Stress*	**1,82** *No Stress*	**11,33** *No Stress*	**1,27** *No Stress*	**14,66** *No Stress*	**14,70** *No Stress*

Table 3. *Five-year minimum and maximum temperature, relative humidity values of long-term climate data (1980-2018) of Eskişehir province*

Max.Temp.	January	February	March	April	May	June	July	August	September	October	November	December	All Year Mean	Dec-Feb	March-July	Aug.-Nov.
1980-84	10,86	13,82	21,78	24,22	28,62	33,38	34,14	31,40	31,74	26,90	19,10	12,30	24,02	12,33	28,43	27,29
1985-89	12,02	17,12	21,54	26,64	30,38	32,32	35,14	35,08	32,24	26,14	18,52	12,94	25,01	14,03	29,20	28,00
1990-94	11,44	15,47	21,66	25,43	29,50	32,85	34,64	33,24	31,99	26,52	18,81	12,62	24,51	13,18	28,816	27,64
1995-99	14,98	16,46	21,94	25,44	28,96	34,30	36,86	35,34	32,62	25,88	20,86	15,44	25,76	15,63	29,50	28,68
2000-04	13,5	17,4	21,3	25,8	31,4	32,9	36,2	34,2	33,0	26,9	18,8	13,1	25,4	14,7	29,5	28,2
2005-09	11,24	13,62	23,88	25,56	31,96	35,56	34,92	35,48	32,40	27,06	20,30	13,42	25,45	12,76	30,38	28,81
2010-14	14,98	16,46	21,94	25,44	28,96	34,30	36,86	35,34	32,62	25,88	20,86	15,44	25,76	15,63	29,50	28,68
2015-18	13,03	18,75	22,03	27,98	31,13	33,25	36,90	34,73	34,60	26,28	21,05	12,40	26,01	14,73	30,26	29,16
Mean	12,66	16,24	22,05	25,86	30,36	33,78	35,81	34,57	32,59	26,46	19,76	13,69	25,32	14,19	29,57	28,34
Min.Temp.	January	February	March	April	May	June	July	August	September	October	November	December	All Year Mean	Dec-Feb	March-July	Aug.-Nov.
1980-84	-12,26	-11,60	-6,62	-0,70	1,94	7,00	7,14	9,10	5,18	-1,70	-6,92	-9,34	-1,57	-11,07	1,75	1,42
1985-89	-11,48	-11,86	-9,56	0,58	0,96	7,70	10,08	9,84	4,98	-1,82	-5,28	-9,80	-1,31	-11,05	1,95	1,93
1990-94	-12,88	-13,74	-8,40	-3,78	0,08	4,20	8,08	7,58	2,16	-2,56	-7,46	-12,38	-3,26	-13,00	0,04	-0,07
1995-99	-11,24	-13,34	-9,10	-5,50	0,52	4,86	7,66	7,24	1,92	-2,96	-8,64	-9,06	-3,14	-11,21	-0,31	-0,61
2000-04	-14,70	-11,60	-8,94	-5,64	0,66	4,12	8,56	7,50	1,88	-4,26	-7,22	-14,58	-3,69	-13,63	-0,25	-0,53
2005-09	-12,36	-10,10	-3,50	-1,10	3,06	8,30	11,68	13,60	7,00	1,68	-4,94	-8,76	0,38	-10,41	3,69	4,34
2010-14	-7,78	-8,58	-5,12	0,78	6,32	9,28	13,34	13,14	7,62	0,52	-1,84	-5,54	1,85	-7,30	4,92	4,86
2015-18	-10,70	-6,70	-2,48	-0,18	5,68	10,15	13,43	12,80	8,63	2,35	-1,95	-6,98	2,00	-8,13	5,32	5,46
Mean	-11,72	-11,12	-6,90	-2,02	2,26	6,81	9,85	9,98	4,76	-1,24	-5,69	-9,67	-1,22	-10,84	2,00	1,95
Rel.Hum.	January	February	March	April	May	June	July	August	September	October	November	December	All Year Mean	Dec-Feb	March-July	Aug.-Nov.
1980-84	82,52	76,00	69,32	64,74	63,28	59,72	60,68	60,84	58,22	67,68	74,82	79,52	68,11	79,35	63,55	65,39
1985-89	81,26	76,60	73,78	63,14	64,06	63,16	58,90	57,76	61,40	72,76	78,34	83,00	69,51	80,29	64,61	67,57
1990-94	80,36	77,74	68,52	68,32	67,14	62,98	60,28	59,82	61,40	67,78	75,46	81,62	69,29	79,91	65,45	66,12
1995-99	78,92	73,14	70,00	67,96	65,86	64,64	58,06	58,76	61,02	67,62	72,94	77,84	68,06	76,63	65,30	65,09
2000-04	73,00	68,14	58,48	60,68	55,10	48,18	46,78	52,02	55,90	60,38	65,70	73,56	59,83	71,57	53,84	58,50
2005-09	78,32	74,24	65,24	56,90	54,48	49,64	47,68	48,42	57,62	65,86	76,00	79,88	62,86	77,48	54,79	61,98
2010-14	83,08	74,50	67,40	63,86	60,76	60,18	55,28	53,92	57,44	70,32	72,82	81,40	66,75	79,66	61,50	63,63
2015-18	85,28	75,98	67,28	57,68	65,43	65,80	57,68	61,33	58,85	70,43	73,10	82,38	68,43	78,13	61,42	64,20
Mean	80,13	74,48	67,51	63,14	61,86	59,00	55,58	56,40	58,99	67,74	73,67	79,79	66,52	78,13	61,42	64,20

Table 4. *Based on the period of 1980-84,% increases and decreases in precipitation, minimum, maximum, mean temperature and relative humidity data in five-year periods*

	Based on 1980-84 and compared to 1980-84 as %															
Rainfall	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**All Year Mean**	**Dec-Feb**	**March-July**	**Aug.-Nov.**	**Mean**
1985-89	6,40	-2,00	-4,88	-27,26	-9,86	13,92	-9,30	-3,92	-6,58	12,94	6,54	12,10	-0,99	5,50	-7,48	2,25	-0,79
1990-94	16,50	3,40	-20,30	-29,54	-10,86	-11,26	-15,28	-5,52	-5,60	1,84	30,02	-16,02	-5,22	1,29	-17,45	5,19	-4,93
1995-99	-2,68	-2,46	-6,60	-13,98	1,60	11,54	-6,76	5,26	11,18	19,78	-7,38	-1,76	0,64	-2,30	-2,84	7,21	0,65
2000-04	-8,86	-13,44	-14,68	16,56	-11,50	-8,72	-2,08	1,68	4,96	-1,28	-3,62	11,46	-2,46	-3,61	-4,08	0,43	-2,45
2005-09	-2,54	4,08	-6,42	-30,00	-11,02	5,18	2,40	-0,30	18,86	1,34	14,28	-6,66	-0,90	-1,71	-7,97	8,55	-0,80
2010-14	-26,20	-24,70	-16,50	-41,04	-20,46	52,34	-9,58	18,48	73,70	23,34	-17,38	23,48	2,96	-9,14	-7,05	24,54	2,92
2015-18	1,53	-1,10	-2,95	-21,34	7,27	45,37	1,85	21,33	1,93	9,94	-12,66	-15,92	2,94	-5,16	6,04	5,14	2,76
Mean	**-2,27**	**-5,17**	**-10,33**	**-20,94**	**-7,83**	**15,48**	**-5,54**	**5,29**	**14,06**	**9,70**	**1,40**	**0,95**	**-0,43**	**-2,16**	**-5,83**	**7,61**	**-0,38**
Mean Temp.	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**All Year Mean**	**Dec-Feb**	**March-July**	**Aug.-Nov.**	**Mean**
1985-89	0,18	-0,68	-0,58	2,86	-0,48	0,46	1,90	3,06	-0,52	-2,36	-0,12	-0,38	0,28	-0,29	0,83	0,02	0,26
1990-94	-3,00	-2,64	0,26	1,04	-1,64	-0,44	0,84	1,82	-1,34	-0,36	-1,04	-1,74	-0,69	-2,46	0,01	-0,23	-0,73
1995-99	0,32	-0,16	-1,58	-0,52	-0,42	-0,10	1,26	1,44	-2,22	-2,04	-0,46	1,58	-0,24	0,58	-0,27	-0,82	-0,23
2000-04	-1,34	-1,22	0,64	0,62	-1,02	0,50	2,40	1,94	-1,42	-1,08	0,18	-1,48	-0,11	-1,35	0,63	-0,10	-0,14
2005-09	-0,90	-0,58	1,70	1,76	0,34	1,70	2,58	4,12	-0,78	0,08	0,42	0,46	0,91	-0,34	1,62	0,96	0,88
2010-14	1,02	1,42	1,66	2,70	1,24	1,80	3,44	4,08	0,72	-0,52	2,18	1,66	1,78	1,37	2,17	1,62	1,77
2015-18	-0,56	3,17	3,55	3,45	1,02	1,70	3,30	3,85	1,69	0,40	2,00	0,13	1,97	0,91	2,60	1,98	1,95
Mean	**-0,61**	**-0,10**	**0,81**	**1,70**	**-0,14**	**0,80**	**2,25**	**2,90**	**-0,55**	**-0,84**	**0,45**	**0,03**	**0,56**	**-0,23**	**1,08**	**0,49**	**0,54**
Min.Temp.	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**All Year Mean**	**Dec-Feb**	**March-July**	**Aug.-Nov.**	**Mean**
1985-89	0,78	-0,26	-2,94	1,28	-0,98	0,70	2,94	0,74	-0,20	-0,12	1,64	-0,46	0,26	0,02	0,20	0,52	0,26
1990-94	-0,62	-2,14	-1,78	-3,08	-1,86	-2,80	0,94	-1,52	-3,02	-0,86	-0,54	-3,04	-1,69	-1,93	-1,72	-1,49	-1,70
1995-99	1,02	-1,74	-2,48	-4,80	-1,42	-2,14	0,52	-1,86	-3,26	-1,26	-1,72	0,28	-1,57	-0,15	-2,06	-2,03	-1,54
2000-04	-2,44	0,00	-2,32	-4,94	-1,28	-2,88	1,42	-1,60	-3,30	-2,56	-0,30	-5,24	-2,12	-2,56	-2,00	-1,94	-2,13
2005-09	-0,10	1,50	3,12	-0,40	1,12	1,30	4,54	4,50	1,82	3,38	1,98	0,58	1,95	0,66	1,94	2,92	1,93
2010-14	4,48	3,02	1,50	1,48	4,38	2,28	6,20	4,04	2,44	2,22	5,08	3,80	3,41	3,77	3,17	3,45	3,42
2015-18	1,56	4,90	4,15	0,53	3,74	3,15	6,29	3,70	3,45	4,05	4,97	2,37	3,57	2,94	3,57	4,04	3,56
Mean	**0,67**	**0,75**	**-0,11**	**-1,42**	**0,53**	**-0,06**	**3,26**	**1,14**	**-0,30**	**0,69**	**1,59**	**-0,25**	**0,54**	**0,39**	**0,44**	**0,78**	**0,53**
Max.Temp.	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**All Year Mean**	**Dec-Feb**	**March-July**	**Aug.-Nov.**	**Mean**
1985-89	1,16	3,30	-0,24	2,42	1,76	-1,06	1,00	3,68	0,50	-0,76	-0,58	0,64	0,99	1,70	0,78	0,71	1,00
1990-94	0,58	1,65	-0,12	1,21	0,88	-0,53	0,50	1,84	0,25	-0,38	-0,29	0,32	0,49	0,85	0,39	0,36	0,50
1995-99	4,12	2,64	0,16	1,22	0,34	0,92	2,72	3,94	0,88	-1,02	1,76	3,14	1,74	3,30	1,07	1,39	1,77
2000-04	2,64	3,62	-0,52	1,56	2,74	-0,46	2,10	2,76	1,26	-0,04	-0,34	0,76	1,34	2,34	1,08	0,91	1,36
2005-09	0,38	-0,20	2,10	1,34	3,34	2,18	0,78	4,08	0,66	0,16	1,20	1,12	1,43	0,43	1,95	1,53	1,40
2010-14	4,12	2,64	0,16	1,22	0,34	0,92	2,72	3,94	0,88	-1,02	1,76	3,14	1,74	3,30	1,07	1,39	1,77
2015-18	2,17	4,93	0,25	3,76	2,51	-0,13	2,76	3,33	2,86	-0,63	1,95	0,10	1,99	2,40	1,83	1,88	2,00
Mean	**2,17**	**2,65**	**0,26**	**1,82**	**1,70**	**0,26**	**1,80**	**3,37**	**1,04**	**-0,53**	**0,78**	**1,32**	**1,39**	**2,05**	**1,17**	**1,17**	**1,40**
Rel.Hum.	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**All Year Mean**	**Dec-Feb**	**March-July**	**Aug.-Nov.**	**Mean**
1985-89	-1,26	0,60	4,46	-1,60	0,78	3,44	-1,78	-3,08	3,18	5,08	3,52	3,48	1,40	0,94	1,06	2,18	1,40
1990-94	-2,16	1,74	-0,80	3,58	3,86	3,26	-0,40	-1,02	3,18	0,10	0,64	2,10	1,17	0,56	1,90	0,73	1,15
1995-99	-3,60	-2,86	0,68	3,22	2,58	4,92	-2,62	-2,08	2,80	-0,06	-1,88	-1,68	-0,05	-2,71	1,76	-0,30	-0,12
2000-04	-9,52	-7,86	-10,84	-4,06	-8,18	-11,54	-13,90	-8,82	-2,32	-7,30	-9,12	-5,96	-8,28	-7,78	-9,70	-6,89	-8,25
2005-09	-4,20	-1,76	-4,08	-7,84	-8,80	-10,08	-13,00	-12,42	-0,60	-1,82	1,18	0,36	-5,25	-1,87	-8,76	-3,41	-5,15
2010-14	0,56	-1,50	-1,92	-0,88	-2,52	0,46	-5,40	-6,92	-0,78	2,64	-2,00	1,88	-1,36	0,31	-2,05	-1,77	-1,33
2015-18	2,76	-0,03	-2,04	-7,07	2,15	6,08	-3,01	0,49	0,63	2,75	-1,72	2,86	0,32	-1,21	-2,13	-1,19	-0,02
Mean	**-2,49**	**-1,67**	**-2,08**	**-2,09**	**-1,45**	**-0,49**	**-5,73**	**-4,84**	**0,87**	**0,20**	**-1,34**	**0,43**	**-1,72**	**-1,68**	**-2,56**	**-1,52**	**-1,76**

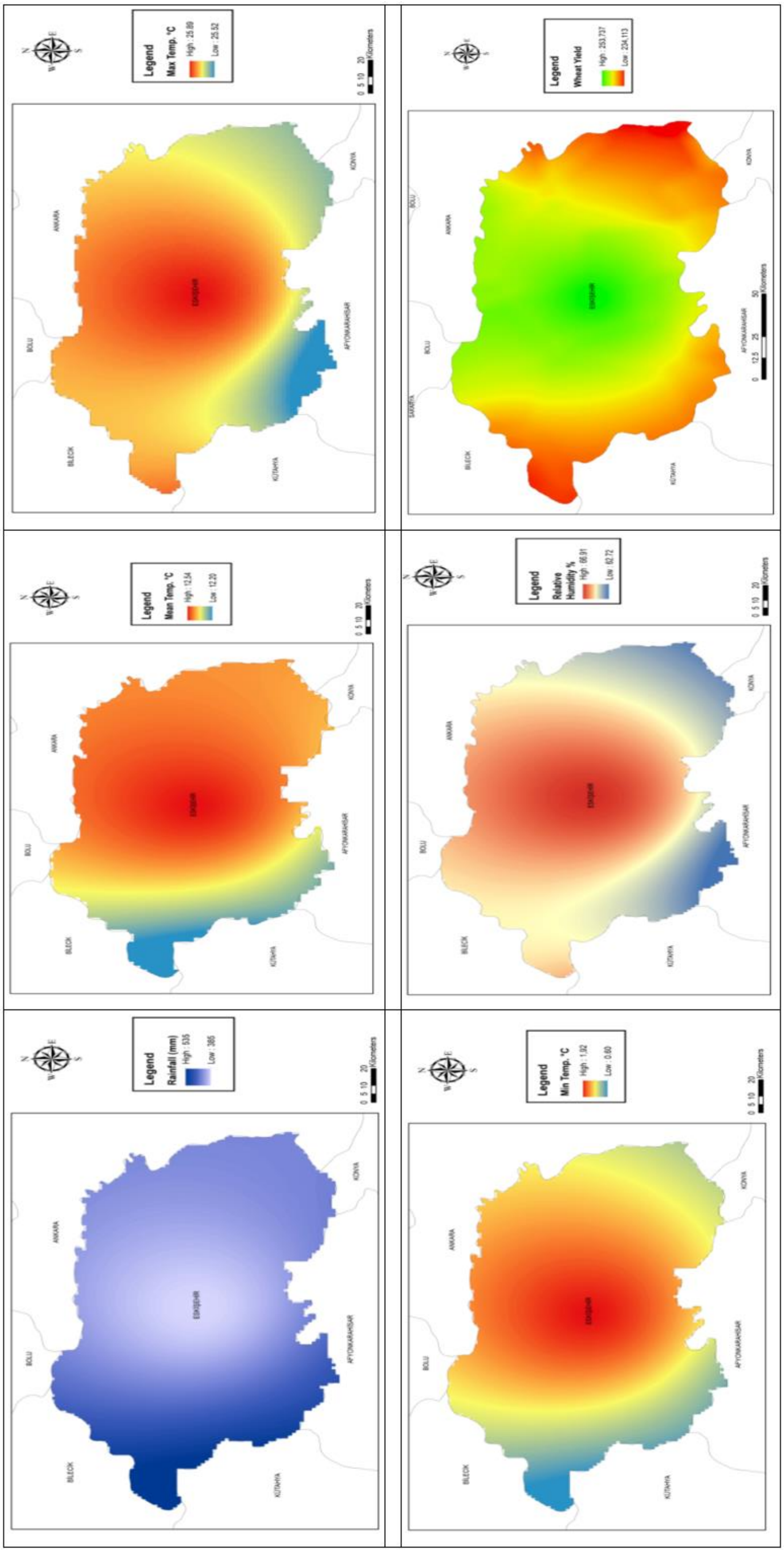

Fig. 3. *Climate (precipitation, minimum, maximum, mean temperature and relative humidity) and wheat yield map made using IDW (Inverse Distance Weighting) method.*

Indeed, researchers found that the increase in global world warming affects all countries and the climate towards a warmer world is observed [12, 13, 22]. Especially in countries such as Turkey, which dominates the continental climate, global warming due to climate change are felt in the visible. As a result of this situation, due to the decrease in crop available water, drought increases and crop production is affected especially in the places where agriculture is made. It was revealed in our study, although there was not much change in the precipitation that was insufficient for plant development, an increase of about 2°C occurred in the temperature. While an increase of 10-15% in precipitation, especially in June, August, September and October, a slight decrease was observed in other months and on average. While an increase of 1-2°C was detected in maximum, minimum and mean temperatures, this similar increase occurred in January, February, May, July, August, October and November. In this case, if the increase in the temperature increase continues in this way, the increase in drought will continue due to the decrease in the useful water to the plant that could decrease in agricultural production. There was not much change in relative humidity due to long years and similar relative humidity was observed in our study based on five-year periods (Table 3).

Again, based on the period of 1980-84, relative increases/decreases as percentage in precipitation, mean, minimum and maximum temperatures, relative humidity are given in Table 4. Because of these results, there was no significant change in precipitation and relative humidity on a provincial basis but increases of up to 2°C occurred in minimum, maximum and mean temperatures causing an increase in drought. Wheat is a crop that has a very important place in both the human nutrition and food industry and makes significant contributions to the economy. Adapting to the continental climate type in the Central Anatolia Region, including Eskisehir, wheat plays an important role in meeting the calorie and protein deficit and increasing livestock and industrial production [21, 23] In the last fifty years, the yield has increased with the development of high-yielding, quality, resistant to pests and diseases. Again, with the application of modern cultivation techniques that wheat needs for high yield, significant increases have been achieved in wheat production. Besides, the production is largely influenced by climatic conditions since it is based on dry agriculture. By using spatial analysis and in ArcGIS software and IDW (Inverse Distance Weighting) method [20], climate (precipitation, minimum, maximum, mean temperature and relative humidity) and wheat yield map are given in Fig. 3. IDW method, a deterministic method, is an interpolation technique used to determine the values of the points that are not sampled with the help of the values of the sample points whose value is known. The predicted values are a function of the distance and magnitude of the known points, and their importance and influence on the cell to be estimated decreases with increasing distance. Fig. 3 shows that although the rainfall increases towards the west side (Bilecik, Kütahya and Afyon), Northwest and Southwest directions, starting from Eskişehir center and towards Konya and Ankara, decrease in precipitation occurs. Once the maximum, minimum and mean temperatures are lower in the southeast and southwest directions and the west part of Eskişehir, higher temperatures are noticeable in the center and towards the north. While higher grain yield is obtained in the center and towards the north part of Eskişehir, locations that are east parts of the city, southeast and southwest directions towards Kütahya, Konya and Ankara have lower grain yield capacity (Fig. 3).

Climate is one of the most important factors that directly affects vegetative production and there is a high relationship between climate factors and crop yield. The factors are not effective on crop yield alone, therefore, multiple factors could be safer to analyse relationship between climate factors and grain yield, and this could be made by using multiple correlations and PCA analyses [24]. Principal Component Analysis is a mathematical technique to explain information in a multivariate data set with fewer variables and minimal loss of information. In other words, PCA is a transformation technique that enables the size of the dataset, which contains a large number of interrelated variables, to be reduced to a smaller size by preserving the data in the dataset. PCA reduces dimensionality in large datasets. The technique aims to reduce the number of variables in the dataset in the size reduction process. The variables obtained after the conversion are called the basic components of the first variables. As the first main component, the variance value is chosen the most and the other main components are listed in order to decrease the variance values [24]. PCA analysis showing the relationship between climate factors (precipitation, minimum, maximum and mean temperature, relative humidity) and crop yield is given in Table 5 and Biplot analysis is given in Fig. 4.

Table 5 shows that the precipitations in March, April, May, June, October, March-June period and total precipitation are closely related to the grain yield in wheat. Studies revealed that although the direct effect of precipitation on yield has been revealed, especially precipitations in the planting period and during the development period of the crop plays an important role in shaping the yield [5, 9, 13]. On the other hand, when the mean, minimum and maximum temperatures are taken into consideration, the temperatures in May and June, October and March, the temperatures between June, June and August are also very effective in the development of the plant.

***Table 5**. PCA analysis showing relationship between climate factors (precipitation, inimum, maxsimum and mean temperatures, relative humidity) and crop yield*

Eigenanalysis of the Correlation Matrix

	Rainfall –Seed Yield					Mean Temperature-Seed Yield		
	PC_1	PC_2	PC_3	PC_4		PC_1	PC_2	PC_3
Eigenvalue	6,342	2,753	1,753	1,448	Eigenvalue	7,161	2,716	1,960
Proportion	0,373	0,162	0,103	0,085	Proportion	0,421	0,160	0,115
Cumulative	0,373	0,535	0,638	0,723	Cumulative	0,421	0,581	0,696

PCA Analysis of Variables

	Rainfall–Seed Yield					Mean Temperature-Seed Yield		
Variables	PC_1	PC_2	PC_3	PC_4	Variables	PC_1	PC_2	PC_3
January	-0,106	-0,413	0,009	-0,124	January	0,146	0,482	0,123
February	0,032	-0,454	0,299	-0,178	February	0,238	0,396	-0,139
March	0,286	-0,173	-0,299	0,137	March	0,201	0,176	-0,366
April	0,302	0,032	-0,229	0,495	April	0,206	-0,129	-0,442
May	0,336	0,142	0,153	-0,009	May	0,267	0,03	0,075
June	0,313	0,014	0,23	0,065	June	0,203	-0,288	-0,283
July	0,069	0,015	0,569	-0,032	July	0,24	-0,141	0,285
August	0,252	-0,083	-0,199	-0,057	August	0,207	0,005	-0,066
September	0,074	0,167	-0,269	-0,596	September	0,199	-0,194	0,414
October	0,043	0,310	-0,109	-0,007	October	0,152	-0,405	0,009
November	-0,109	0,089	0,306	-0,103	November	0,29	-0,083	0,025
December	-0,061	-0,344	-0,278	0,115	December	0,159	0,076	0,273
Dec-Feb. Per.	-0,065	-0,588	0,005	-0,084	Dec-Feb. Per.	0,243	0,414	0,075
March-July Per.	0,373	0,033	0,184	0,283	March-July Per.	0,328	-0,081	-0,287
Aug.-Nov. Per.	0,128	0,106	-0,161	-0,488	Aug.-Nov. Per.	-0,151	0,312	0,128
Total Rainfall	0,061	-0,192	0,362	-0,164	Total Rainfall	0,369	0,061	-0,038
Seed Yield	0,338	-0,117	0,107	0,115	Seed Yield	0,232	0,015	0,335

Eigenanalysis of the Correlation Matrix

	Minimum Temperature–Seed Yield			Maximum Temperature-Seed Yield			
	PC_1	PC_2		PC_1	PC_2	PC_3	PC_4
Eigenvalue	9,931	2,350	Eigenvalue	3,979	3,203	2,839	1,7781
Proportion	0,584	0,138	Proportion	0,234	0,188	0,167	0,105
Cumulative	0,584	0,722	Cumulative	0,234	0,422	0,59	0,694

PCA Analysis of Variables

	Minimum Temperature–Seed Yield			Maximum Temperature-Seed Yield			
Variables	PC_1	PC_2	Variables	PC_1	PC_2	PC_3	PC_4
January	0,117	0,562	January	0,293	0,337	-0,064	0,007
February	0,212	0,35	February	0,376	0,117	-0,177	-0,211
March	0,237	-0,211	March	0,029	-0,197	-0,462	0,097
April	0,263	-0,048	April	0,053	-0,383	0,040	-0,127
May	0,248	-0,053	May	-0,470	-0,121	-0,220	-0,028
June	0,284	0,007	June	-0,113	-0,260	0,251	0,104
July	0,279	0,024	July	0,299	-0,165	0,127	0,024
August	0,171	0,027	August	0,216	-0,191	-0,121	0,325
September	0,226	-0,205	September	0,178	-0,125	0,303	-0,375
October	0,177	0,450	October	-0,251	-0,188	0,314	-0,008
November	0,270	-0,012	November	0,072	-0,147	0,311	0,142
December	0,221	0,015	December	0,194	-0,084	0,144	0,532
Dec-Feb. Per.	0,222	0,447	Dec-Feb. Per.	0,441	0,200	-0,082	0,081
March-July Per.	0,307	-0,077	March-July Per.	0,126	-0,469	-0,25	-0,144
Aug.-Nov. Per.	0,283	-0,223	Aug.-Nov. Per.	0,095	-0,329	0,402	0,043
Total Rainfall	0,214	0,073	Total Rainfall	0,441	-0,24	-0,034	0,002
Seed Yield	0,201	0,065	Seed Yield	0,262	0,192	0,263	-0,186

Eigenanalysis of the Correlation Matrix/ Relative Humidity–Seed Yield				PCA Analysis of Variables/ Relative Humidity–Seed Yield			
	PC_1	PC_2	PC_3		PC_1	PC_2	PC_3
Eigenvalue	7,161	2,716	1,960	January	0,291	-0,218	-0,044
Proportion	0,421	0,160	0,115	February	0,117	-0,442	0,13
Cumulative	0,421	0,581	0,696	March	0,283	0,258	0,174

PCA Analysis of Variables/ Relative Humidity–Seed Yield

	PC_1	PC_2	PC_3		PC_1	PC_2	PC_3
April	0,17	-0,281	-0,179	November	0,104	-0,009	0,551
May	0,229	-0,09	-0,205	December	0,24	0,048	0,436
June	0,339	0,156	0,207	Dec-Feb. Per.	0,279	-0,267	0,231
July	0,093	0,320	-0,21	March-July Per.	0,317	-0,085	-0,217
August	0,256	0,059	-0,278	Aug.-Nov. Per.	0,275	0,335	0,153
September	0,155	0,417	0,191	Total Rainfall	0,338	-0,01	0,001
October	0,185	-0,014	0,388	Seed Yield	0,210	0,19	0,076

In the studies conducted, the minimum temperatures below 0°C in April and May in the flowering time and the maximum temperatures above 30 ° C have a negative effect on wheat [25, 26, 27]. Since relative humidity is closely related to precipitation, relative humidity in June, July, October months, in the March-June period and in the August-November period affect the crop yield.

Once the lower the relative humidity is, the higher the evaporation rate is; when the relative humidity in the March June period is so high (above 70%), this may cause a significant increase in the rust diseases in the wheat leaves [28, 29, 30]. The relationship between yield, months and years in terms of precipitation, mean, minimum and maximum temperatures and relative humidity are given on the Biplot chart in Fig. 4 that also shows the stability of months and years. When the crop yield-precipitation relationship is examined, crop yield is more closely related to precipitations in October, November, March, April, and June months, March-June period and August-November periods. Besides, the March-June period and August-November periods are found as so stable periods. In terms of years, 2018, 2017, 2014, and 2006 seem that precipitation is favorable and yield is more than the other years. In terms of mean, minimum and maximum temperatures, October, November, March, April and May, periods of March- June and August-November are to be important months and periods in terms of both the low temperatures below zero and the temperatures above zero that encourage optimum development. The years 2008, 2010, 2013, 2014 and 2018 are determined as the years that the temperature has a positive effect on yield. A similar impression has also appeared in relative humidity, that is high a certain level having a positive effect on crop yield. Crop yield in terms of relative humidity in 2010, 2014, 2015 and 2018 are determined as so high. Precipitation, the temperature and relative humidity has positive effects within certain limits on crop yield in countries where the total annual precipitation is below 500 mm. Results showed that since October is the first development period, wheat needs to have a certain rate of precipitation and temperature in this period. In the same way, the months of March, April, May and June or March-June period are so vital tfor tillering, generative development and grain filling period. Minimum and maximum temperatures play an essential role on crop yield. Therefore, it is desired to have a certain level of precipitation and temperature in this period [22]. In our study, the August-November period ocupying the first development phase of the wheat, March-June period covering crop generative development, are determined as important factors.

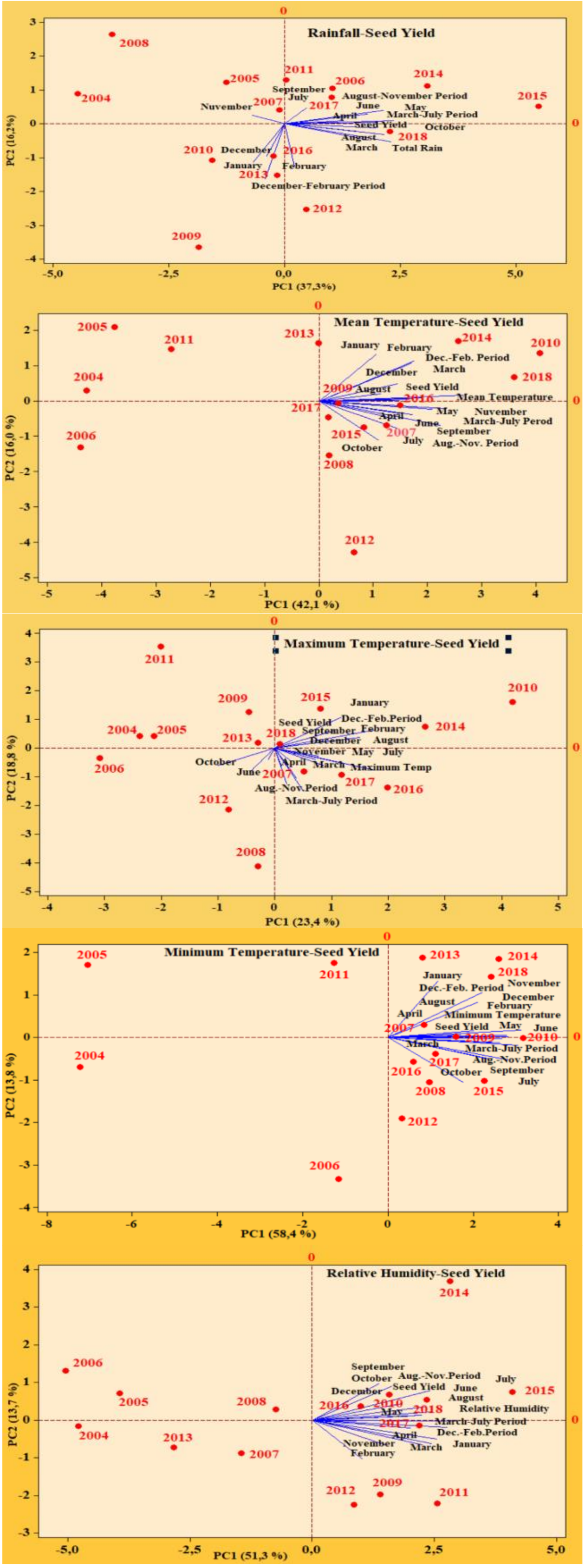

***Fig. 4**. Biplot analysis showing the relationship between climate factors (precipitation, minimum, maximum and mean temperature, relative humidity) and wheat yield.*

Adequate rainfall or irrigation water during these periods will trigger the crop yield positively. Having both positive and negative effects, the temperatures above zero during the flowering period positively affect cop growth and yield. The analysis results showed that in the 50-year period precipitation is slightly arid, no excessive change or decrease in precipitation was observed in Eskişehir province. In addition, with approximately 2°C, a gradual rise in minimum, maximum and mean temperatures occurred. This shows that an increase of 2°C may cause significant negative changes in crop performance and grain yield. An increase in temperature helps to increase the evapotranspiration values (water loss from the soil and the crop) cause the drought to become more common. It is necessary to take into account that there must be sufficient precipitation as well as optimum temperatures in order to obtain genotypes having high quality and yield. For Eskişehir, where dry agriculture prevails, inadequate precipitation in SPI is termed as slightly arid. The SPI index values, that are determined as slightly rainy especially based on months, have been determined as slightly arid in the autumn and spring periods. While there is not a big change in precipitation, almost 2ºC increase in temperatures is determined and this increase is the trigger of drought. There is an increase in evapotranspration more and more, that expresses water loss from soil and plants due to the gradual increase of temperature on a 50-year basis, it is highly probable that, the plant needs to use more water for transpration due to the increasing temperature. This shows that due to the increasing temperature, water loss increases and accordingly, there are gradual increases in drought. It is a fact that the water required for higher crop yield must be given externally by irrigation in dry farming. A drier world agriculture is waiting in the coming years, whether this scenario continues in this way, more detailed studies are required on this subject and the studies to be conducted will shed light on the better understanding of the subject.

CONCLUSION

Analysis of long term climatic data of Eskişehir province and the relationship between climate factors and the yield which was determined by factor analysis of these climatic data showed that the 50-year period precipitation is slightly arid, no excessive change or decrease in precipitation was observed. In addition, about 2°C gradually rise in minimum, maximum and mean temperatures was determined. In the light of these findings, it is clear that in the future, more drought resistant genotypes will need to be used in Eskişehir.

REFERENCES

[1] Şahin, C. (2011). Bir Göçmen Kenti Olarak Eskişehir ve Eskişehir'in Sosyo-Kültürel Yapısında Tatar Kimliği. İdeal Kent, Kent Araştırmaları Dergisi, 3, 220-242.

[2] Anonymous, (2014). Annual Report, 2014. Eskişehir provincial directorate of food agriculture and livestock, http://eskisehir.tarim.gov.tr

[3] Acevedo, E. H., Silva, P. C., Silva, H. R., & Solar, B. R. (1999). Wheat production in Mediterranean environments. Wheat: ecology and physiology of yield determination, 295-331.

[4] Anonymous, (2019), Geographical structure of Eskişehir. https://eskisehir.ktb.gov. tr/TR-70841/ cografya-yapisi.html.

[5] Gürler, Ç., (2017), Beyşehir and Konya-Çumra-Karapınar hydraological drought evaluation with the standardized indis approach in the subwatches. Ministry of forestry and water management, General directorate of water management. Master Thesis. 155 p.
[6] Dogan, O., & Denli, O. (1999). Precipitation–Aridity–Erosion Indices and Arid Periods in Turkey. General Directorate of Rural Services. Technical Publication, (60), 209.
[7] Bakker, M. M., Govers, G., Ewert, F., Rounsevell, M., & Jones, R. (2005). Variability in regional wheat yields as a function of climate, soil and economic variables: assessing the risk of confounding. Agriculture, ecosystems & environment, 110(3-4), 195-209.
[8] Özdoğan, M. (2011). Modeling the impacts of climate change on wheat yields in Northwestern Turkey. Agriculture, ecosystems & environment, 141(1-2), 1-12.
[9] Herdem, Z., Doğan, M., Yeşilyurt, N., Akçı, M., Çelenk, H., Keskin, S., Pasin, V., Duman, H., Egemen, M., Doğan, O., Tutar, S., Kuzuoğlu, E., Odabaşı, A. ve Koç, M., (2002). Wheat and Barley Production. General directorate of agricultural enterprises, Ankara.
[10] Smith, M. (1992). Expert Consultation on Revision of FAO Methodologies for Crop Water Requirements: Meeting: Report. Food and Agriculture Organization.
[11] Easterling, W. E., Mearns, L. O., Hays, C. J., & Marx, D. (2001). Comparison of agricultural impacts of climate change calculated from high and low resolution climate change scenarios: Part II. Accounting for adaptation and CO2 direct effects. Climatic Change, 51(2), 173-197.
[12] Brown, L. R. (2002). Water deficits growing in many countries: Water shortages may cause food shortages. Washington (DC): Earth Policy Institute. (5 August 2004).
[13] Liu, J., Williams, J. R., Zehnder, A. J., & Yang, H. (2007). GEPIC–modelling wheat yield and crop water productivity with high resolution on a global scale. Agricultural systems, 94(2), 478-493.
[14] Döll, P. (2002). Impact of climate change and variability on irrigation requirements: a global perspective. Climatic change, 54(3), 269-293.
[15] Solomon, S. (2007). The physical science basis: Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change (IPCC), Climate change 2007, 996.
[16] Wilks, D. S. (1995). Statistical methods in the Atmospheric Sciences, 1995. Library of Cataloging-in-publication, Academic Press: San Diego, CA, 465.
[17] Anonymous, National Research Council. (1971). A guide to environmental research on animals. National Academies.
[18] Mader, T. L., Johnson, L. J., & Gaughan, J. B. (2010). A comprehensive index for assessing environmental stress in animals. Journal of Animal Science, 88(6), 2153-2165.
[19] İltir, Cenk, (2018). Statistical Data Analysis with Excel. Seçkin Pub., 337 p., Ankara.
[20] Isaaks, E. H., & Srivastava, R. M. (1989). An introduction to applied geostatistics: Oxford University Press, 561.
[21] Watson, R. T. (2001). 'Climate Change 2001,' presented at the resumed Sixth Conference of Parties to the United Nations Framework Convention on Climate Change, July 19, 2001, Bonn.
[22] Aykanat, S., Barut H., (2016). Effects of changes in Adana Province's precipitation regime on wheat yield. 1st International Mediterranean Science and Engineering Congress (IMSEC), October 26, 2016, Adana/Turkey.
[23] Güven, F. (2010). General status of agricultural enterprises and determination of self sufficient enterprise size in Turkey (in Turkish). Ministry of Agriculture and Rural Affairs, General Directorate of Agrarian Reform.
[24] Jónsdóttir, A. H. (2005). Statistical analysis of ECG signals with focus on QT (Master's thesis, Technical University of Denmark, DTU, DK-2800 Kgs. Lyngby, Denmark).
[25] Pingali, P. L. (1999). World Wheats Facts and Trends Global Wheat Research in a Changing World: Challenges and Achievements. CIMMYT, Mexico.

[26] Ayeneh, A., Van Ginkel, M., Reynolds, M. P., & Ammar, K. (2002). Comparison of leaf, spike, peduncle and canopy temperature depression in wheat under heat stress. Field Crops Research, 79(2-3), 173-184.
[27] Grigorova, B., Vaseva, I., Demirevska, K., & Feller, U. (2011). Combined drought and heat stress in wheat: changes in some heat shock proteins. Biologia Plantarum, 55(1), 105-111.
[28] Braun, H. J., & Saari, E. E. (1992). An assessment of the potential of Puccinia striiformis f. sp. tritici to cause yield losses in wheat on the Anatolian Plateau of Turkey. Vortraege fuer Pflanzenzuechtung (Germany).
[29] Bahri, B. A., Leconte, M., Rebai, H., & de Vallavieille, C. P. (2016). Wheat yellow rust dynamics in Tunisia since 2013 and resistance genes in durum wheat.
[30] Anonymous, (2016). Crop protection for cereal diseases and pests. Ministry of Food, Agriculture and Livestock, General Directorate of Food and Control, https://www.tarimorman.gov.tr /GKGM /Belgeler/Bitki Sagligi Hizmetleri/hastalik zararlilari ile_mücadele dokumanlari/hububat.pdf