THE EFFECT OF CLIMATE FACTORS ON THE YIELD OF SUNFLOWER AND SUNFLOWER YIELD PREDICTIONS BASED ON CLIMATE CHANGE PROJECTIONS: EXAMPLE OF MARMARA REGION

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ABSTRACT

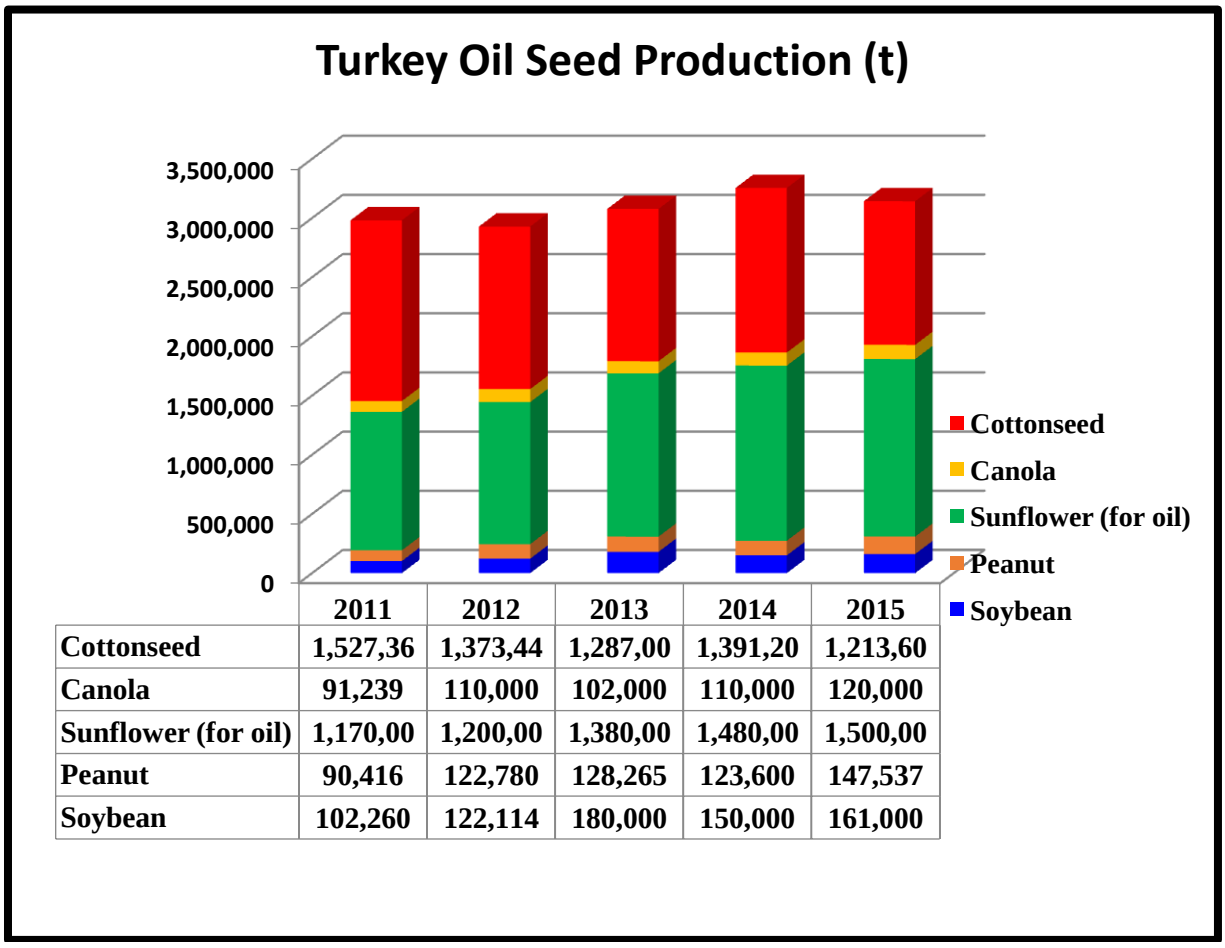
Sunflower is the raw material of vegetable oils sector in Turkey. Production is not sufficient even for domestic consumption. Therefore, it is necessary to carry out the projects to increase the yield and production areas. This study was carried out in order to identify the relationship between yield of sunflower and climate factors, also to determine the possible effects of the future climate changes on the sunflower yield. In the study, 10 provinces in Marmara region were evaluated. The following materials were used for this study; sunflower production values and meteorological data for the years of 1985-2014, climate projections that are based on HadGEM2-ES Global Climate Model with 20 km resolution, and RCP8.5 scenario that covers the period of 2016-2099. Climate parameters used in this study are number of days that minimum temperature below -5°C, monthly average temperature, number of days that maximum temperature above 35°C, monthly average relative humidity, number of days that average relative humidity above % 70, monthly total sunshine duration, monthly total precipitation. Firstly; single and multiple correlation analyses, the least-squares method with linear regression analyses were conducted between observation values and production data. Then, the potential impact of climate changes, that are projected for the future periods (2016-2040, 2041-2070 and 2071-2099), on yield of sunflower have been put forward with by using the generated high-rate regression equations and climate projection data. According to the results, it was determined that there is an important characteristic effect of climate factors on productivity With reference to the yield prediction analyses, Marmara region will be negatively affected.

Key Words: The yield of sunflower, climate factors, HadGEM2-ES, RCP8.5, the effects of climate change

INTRODUCTION

There are three main groups in human nutrition. These are oils, proteins and carbohydrates. Oils are an important source of calories in the human diet (Hatırlı et al., 2002). Oil seeds are raw material for the vegetable oil industry at the same time also are the raw material of many different sectors. Oilseed meals having relatively high protein content are preferred in animal nutrition (İlkdoğan, 2008). Vegetable oils that are used in food, energy and chemical industries sectors are strategic products (Taşkaya Top and Uçum, 2012).

According to the Association of Vegetable Oil Industries (AVOI) report 2014; while sunflower takes the fourth place after soybean, canola and cottonseed in the world oilseed production, it takes the first place in Turkey (AVOI, 2015). The most intensive sunflower farming region is Marmara region in Turkey.



	2011	2012	2013	2014	2015
Cottonseed	1,527,36	1,373,44	1,287,00	1,391,20	1,213,60
Canola	91,239	110,000	102,000	110,000	120,000
Sunflower (for oil)	1,170,00	1,200,00	1,380,00	1,480,00	1,500,00
Peanut	90,416	122,780	128,265	123,600	147,537
Soybean	102,260	122,114	180,000	150,000	161,000

Figure 1: Turkey oil seed production (tons)

According to the Turkey Statistical Institute (TSI) reports in 2014, the top five most produced oil seed plants are in the order of sunflower, cottonseed, soybean, peanuts and canola (TSI, 2015). The production of 2.7 million tons from these top five plants in 2010 increased by 19% with a production of 3.25 million tons in 2014. In 2010-2014 periods, the sunflower (for oil) production growth rate is approximately realized as % 26.4. In the same period, the rate of increase in sunflower production of the world is approximately 20.3 %. According to the data from USDA published by AVOI, world crude vegetable oil production is around 176 million tones. Crude sunflower oil production in the years 2010-2014 has increased to 15 million tons from 12 million tons (AVOI, 2015).

Table 1: Turkey sunflower oil production data (TSI, 2016)

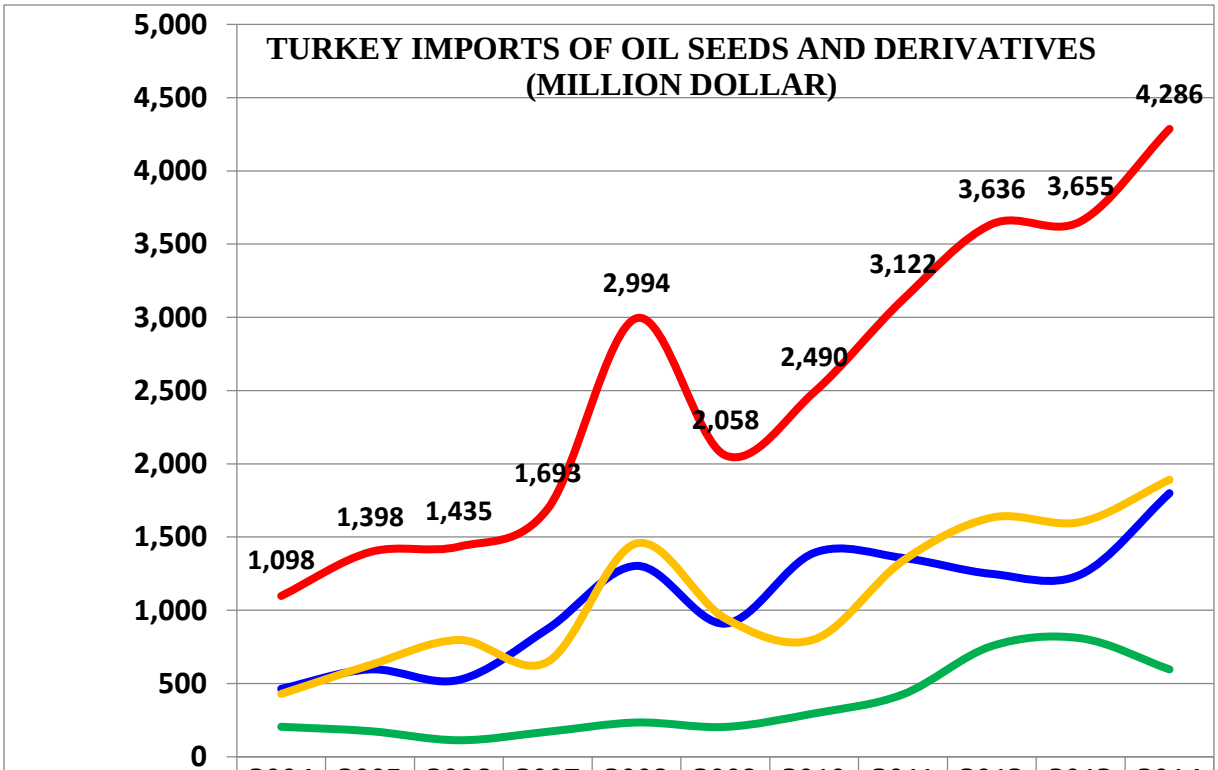
Year	Area(da)	Product(t)	Yield(kg/da)
2006	5,100,000	1,010,000	198
2007	4,857,000	770,000	159
2008	5,100,000	900,387	177
2009	5,150,000	960,300	186
2010	5,514,000	1,170,000	212
2011	5,560,000	1,170,000	210
2012	5,046,160	1,200,000	238
2013	5,202,600	1,380,000	265
2014	5,524,651	1,480,000	269
2015	5,689,013	1,500,000	264

During the last decade of sunflower cultivation (2006-2015), an increase of approximately 12% in the harvested areas, % 48.5 in the amount of production and 33% in the yield has been achieved. Turkey continuously increases the supply for increased consumption of crude vegetable oil production but it is not enough to cover domestic demand. The most important raw material in crude oil production industry has been provided from the production of sunflower oil in Turkey. But a serious vulnerability exists due to domestic consumption and exports vegetable oil in our country. Therefore, every year, vegetable oil imports are made.

Table 2: Crude sunflower oil balance of supply-demand for the season 2015/2016

Sunflower oil production from the domestic harvest	430 thousand tons
Sunflower oil consumption in Turkey	900 thousand tons
Turkey sunflower oil exports	500 thousand tons
Total sunflower oil demand	1,400 thousand tons
Deficient of based on sunflower	970 thousand tons

According to the Trakya Birlik sources, we have a deficient of approximately 970 thousand tons of sunflower oil on an annual basis (Tekçe, 2015). The main strategy of our country is to produce demanded oily seeds and to become a self-sufficient state by reducing imports as much as possible (Kolsarıcı et al, 2015).



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Oil seed	464	597	525	874	1,304	910	1,393	1,358	1,249	1,245	1,800
Crude oil	429	626	797	648	1,456	944	801	1,338	1,632	1,602	1,890
Oil cake	205	175	113	171	234	204	296	426	755	808	596
TOTAL	1,098	1,398	1,435	1,693	2,994	2,058	2,490	3,122	3,636	3,655	4,286

Figure 2: Turkey imports of oil seeds and derivatives (million dollar)

According to the Association of Vegetable Oil Industries report; imports of oilseeds and their derivatives were 4,286 million dollars in 2014. Due to increasing demand, the rate of imports has been increasing every year.

Sunflower (*Helianthus annus* L.) has a large natural habitat in various parts of our country. At sunflower cultivation (for oil) dry farming is applied extensively in our country. In regions where irrigation opportunities are available, a significant increase in yield can be achieved. Sunflower can grow in all geographies and adapt to different climatic conditions, however it also can be affected by changing climate conditions. Today, especially last quarter of the 20th century, climate change has become an important problem worldwide. The rising in global mean temperatures since 1850s is the most important indicator of climate change.

According to the World Meteorological Organization (WMO) resource; the global average surface temperature in 2015 broke all previous records by a strikingly wide margin, at 0.76±0.1° Celsius above the 1961-1990 average. Fifteen of the 16 hottest years on record have all been this century, with 2015 being significantly warmer than the record-level temperatures seen in 2014. Underlining the long-term trend, 2011-15 is the warmest five-year period on record. The record temperatures over both land and the ocean surface in 2015 were accompanied by many extreme weather events such as heatwaves, flooding and severe drought (WMO, 2016).

According to "State Of The Climate in Turkey in 2015" report; Turkey annual mean temperature in 2015 has been 14.3°C. This value is 0.8°C above from 1981-2010 normal (13.5°C). This makes 2015 the fifth warmest year since 1971 (TSMS, 2016).

TSMS published as a report which name is “Climate Projections with New Scenarios for Turkey and Climate Change (TR2015-CC)” in 2015. This report includes temperature and precipitation projections of three Global Climate Models (GCM) based on scenarios of RCP4.5 and RCP8.5.

In this study, the results of HadGEM2-ES, which is one of the three GCMs mentioned above, will be shared. HadGEM2-ES projections based on scenarios of RCP8.5 shows that;

- Average temperature of overall Turkey is expected to increase between 0.9-7.1°C and an average of 3.6 °C in the period of 2016-2099.
- Positive anomalies are expected at the amount of precipitation based on RCP8.5 by the end of 2035 but it is also estimated that decreases may occur in subsequent periods (Akçakaya et all., 2015).

This study was carried out in order to determine the possible effects of the future climate changes on the sunflower yield.

MATERIAL and METHODS

Material

Sunflower Production Data

10 provinces, with intensive production of sunflower in the Marmara region, were evaluated (TSI, 2015). Evaluated 10 provinces are: Balıkesir, Bilecik, Bursa, Çanakkale, Edirne, İstanbul, Kırklareli, Kocaeli, Sakarya ve Tekirdağ. In order to confirm the relationship between climate factors and the yield the period of 1985-2014 (30 years) have been analyzed.

The Meteorological Parameters

Climate, sometimes understood as the "average weather,” is defined as the measurement of the mean and variability of relevant quantities of certain variables (such as temperature, precipitation or wind) over a period of time, ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). Therefore, 30 years of meteorological parameters are preferred in order to determine relationship between crop yield and meteorological parameters. In the study, the parameters that are thought to have an effect on the yield of sunflower were selected. The data of selected meteorological parameters were obtained from TSMS. In order to determine the relationship between yield – climatic factors;

- The number of days daily minimum temperature < -5 ° C,
- Monthly Average Temperature (° C)
- The number of days daily maximum temperature > 35 ° C,
- Monthly average relative humidity (%)
- The number of days daily average relative humidity > %70,
- Monthly Total Sunshine Duration (hour)
- Monthly Total Precipitation (mm) parameters are preferred.

Projection Data of HadGEM2-ES Global Climate Model

Climate modeling is the most important work for predicting the future climate (Demircan et all., 2014). Nowadays climate modeling studies are performed in order to determine the possible effect of climate change in future periods. Turkey is located in the eastern Mediterranean basin, one of the most vulnerable regions to climate change as stated in the

IPCC report (Gürkan H. et all., 2015). In Turkey, climate modeling studies have been conducted within TSMS and the final results have been shared in 2015.

HadGEM2-ES GCM projection data based on RCP8.5 for the chosen meteorological parameters' has been published as a report titled "Climate Projections with New Scenarios for Turkey and Climate Change". In this study, these projection data is used.

According to sources at TSMS; HadGEM2-ES is the second generation Global Climate Model which is developed by the Hadley Centre that is related with UK Meteorological Service-Met Office (TSMS 2013).

Methods

Correlation Analysis

In the first section of study, the relationship between meteorological parameters that occurred between the years 1985-2014 and the sunflower yield values between these years were determined by the method of multiple correlation analysis.

r: Correlation Coefficient
X: Independence Variable
Y: Dependence Variable

$$R_{Y.X_1X_2} = \sqrt{\frac{r^2_{YX_1} + r^2_{YX_2} - 2r_{YX_1}.r_{YX_2}.r_{X_1X_2}}{1 - r^2_{X_1X_2}}}$$

Regression Analysis

In the second part of the study, first of all, provinces based regression equations were established using selected seven climate parameters and sunflower yield values between the years 1985-2014 with the method of least squares (LSM) for 10 provinces. Secondly, the potential impact of climate changes that are projected for the future periods (2016-2040, 2041-2070 and 2071-2099), on yield of sunflower have been put forward with using the generated high-rate regression equations and climate projection data.

In the study, analysis of the regression equation generated by LSM as follows:

y = As + Bp+Ch+Dk+Et+Fm+Gv+H

Dependence Variable;
y = Yield

Independence Variables;
s = Monthly Total Sunshine Duration (hour)
p = Monthly Total Precipitation (mm)
h = Monthly average relative humidity (%)
k = The number of days daily average relative humidity > %70
t = Monthly Average Temperature (° C)
m = The number of days daily maximum temperature > 35 ° C
v = The number of days daily minimum temperature < -5 ° C

A, B, C, D, E, F, G, H = Coefficients

The coefficients of the linear multiple regression equation generated on a provincial basis obtained by solving the following matrix formed by the method of least squares.

$Z*X = W$
$Z^{-1}*W = X$ X matrix: Coefficients

Table 3: Parameter matrix used in the least squares method

Z matrix									W matrix		X matrix
$\sum s_i^2$	$\sum p_i s_i$	$\sum h_i s_i$	$\sum k_i s_i$	$\sum t_i s_i$	$\sum m_i s_i$	$\sum v_i s_i$	$\sum s_i$		$\sum s_i$		A
$\sum s_i p_i$	$\sum p_i^2$	$\sum h_i p_i$	$\sum k_i p_i$	$\sum t_i p_i$	$\sum m_i p_i$	$\sum v_i p_i$	$\sum p_i$		$\sum p_i$		B
$\sum s_i h_i$	$\sum p_i h_i$	$\sum h_i^2$	$\sum k_i h_i$	$\sum t_i h_i$	$\sum m_i h_i$	$\sum v_i h_i$	$\sum h_i$		$\sum h_i$		C
$\sum s_i k_i$	$\sum p_i k_i$	$\sum h_i k_i$	$\sum k_i^2$	$\sum t_i k_i$	$\sum m_i k_i$	$\sum v_i k_i$	$\sum k_i$		$\sum k_i$		D
$\sum s_i t_i$	$\sum p_i t_i$	$\sum h_i t_i$	$\sum k_i t_i$	$\sum t_i^2$	$\sum m_i t_i$	$\sum v_i t_i$	$\sum t_i$		$\sum t_i$		E
$\sum s_i m_i$	$\sum p_i m_i$	$\sum h_i m_i$	$\sum k_i m_i$	$\sum t_i m_i$	$\sum m_i^2$	$\sum v_i m_i$	$\sum m_i$		$\sum m_i$		F
$\sum s_i v_i$	$\sum p_i v_i$	$\sum h_i v_i$	$\sum k_i v_i$	$\sum t_i v_i$	$\sum m_i v_i$	$\sum v_i^2$	$\sum v_i$		$\sum v_i$		G
$\sum s_i$	$\sum p_i$	$\sum h_i$	$\sum k_i$	$\sum t_i$	$\sum m_i$	$\sum v_i$	n*		$\sum v_i$		H

*****Number of the years

FINDINGS and DISCUSSION

In the first part of the research, multiple correlation analyses were conducted between the yield and meteorological parameters, due to the effect of meteorological parameters on yield as a whole. According to the results of multiple correlation analysis; the highest correlation between yield - meteorological parameters in Bilecik (0.62) and the lowest correlation have been identified in the province of Sakarya (0.36).

In the second part, it is aimed to assess the quality of the relationship between variables with using the method of regression analysis. Regression analysis that were performed with LSM; the highest value in Kırklareli (0.80) and the lowest value is determined in Sakarya (0.60). This situation is an indicator that the relationship between yields - climate factors can be modeled and can be converted to the equation.

Table 4: Provincial-based multiple correlation and multiple regression analysis

Provinces	Multiple Correlation	Multiple Regression
Balıkesir	0.55	0.74
Bilecik	**0.62**	0.79
Bursa	0.49	0.70
Çanakkale	0.56	0.75
Edirne	0.55	0.74
İstanbul	0.39	0.62
Kırklareli	0.65	**0.80**
Kocaeli	0.38	0.62
Sakarya	**0.36**	**0.60**
Tekirdağ	0.51	0.65

In the last part of the research, the potential impact of climate changes, that are projected for the future periods (2016-2040, 2041-2070 and 2071-2099), on yield of sunflower have been put forward with by using the generated high-rate regression equations and climate projection data.

As climate projection data, HadGEM2-ES Global Climate Model data (20 km resolution) based on RCP8.5 were used which is belongs to named "Climate Projections with New Scenarios for Turkey and Climate Change" released by TSMS.

Table 5: Provincial based sunflower (for oil) yield predictions

SUNFLOWER (FOR OIL) YIELD PREDICTIONS				
Provinces	Yield of Reference Period (kg/da)	Yield Change in Future Periods (%)		
	1985-2014	**2016-2040**	**2041-2070**	**2071-2099**
Balıkesir	111	15	-5	-28
Bilecik	107	15	19	-41
Bursa	147	-24	-14	-23
Çanakkale	171	-22	-9	19
Edirne	170	26	55	85
İstanbul	171	53	32	-33
Kırklareli	164	0	6	26
Kocaeli	129	-16	-9	-7
Sakarya	136	-21	9	31
Tekirdağ	179	-26	-41	-51

CONCLUSION

There is a high correlation between climatic factors and yield. Due to lack of individual determining factor, single correlation analysis is not very meaningful between climatic factors-yield. Therefore, level of relationship between climate factors-yield can be determined in a healthy way with multiple correlation analysis (Bulut et all., 2016).

In Marmara region; According to the assessment results of the researched 10 provinces; the region is expected to be affected adversely by climate changes in the future periods. Correspondingly, a decrease in the average yield of sunflower is estimated in the future. Increase in the number of days daily maximum temperature > 35 ° C is estimated to have a negative effect on yield by adversely affecting the pollination period of plants.

According to compared results of the yield prediction analysis performed on a regular basis with average yield values of the period of 1985-2014;

- In the period 2016-2040; decrease in 5 provinces, increase in 4 provinces and there will be any change in 1 province,
- In the period 2041-2070; decrease in 5 provinces, increase in 5 provinces,
- In the period 2071-2099; decrease in 6 provinces and increase in 4 provinces expected.

The province of Edirne is expected to be positively affected by possible climate changes in the future periods. Besides, the province of Tekirdağ is expected to be negatively affected by possible climate changes in the future periods.

As a result, it has been revealed that climate factors although they are not the sole determining factor, have significant effects on yield of sunflower. According to the results of this analysis, it is concluded that particularly temperature and humidity parameters have serious impact on the yield of sunflower.

According to yield estimates that using HadGEM2-ES global climate model projections which is based on RCP8.5 scenario; sunflower farming regions will be affected by climate changes likely to occur in future periods.

The results of this research can be used as a substrate in studies to determine the relationship by taking all the factors affecting the yield of sunflower. Also the results of this research can be used in future product planning across the country or on a regional basis and in the determination of regions that can be encouraged.

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