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CLIMATE CHANGES IN PROSPECT FOR THE WEST BLACK SEA FORESTS

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Abstract

The paper deals with the changes of annual temperatures and precipitations in West Black Sea Region of Turkey. The of climatic features of the region for the forest growth is analyzed by the distribution of different climatic types of years (CTYs) and classes according to the standardized precipitation index (SPI) for 1901 – 2009. Based on the obtained trends of temperature and precipitation curves for 43 years, the future climate changes are predicted. According to the survey it was found that in almost all studied sites the climate was dominated by the warm - dry climatic type. The established trend of increasing of average annual temperatures and reducing of annual precipitations will expose a high risk to the forest growth and economy in the region. Certain basic recommendations for forest management are given by the authors.

Key words: temperature precipitation, trend curve model, climate type of year, SPI, West Black Sea Region

Introduction

As well as around the world, the effects of climate change are also significantly manifested in Western Black Sea Region. Those climate changes show themselves as increases or decreased from normal climatic conditions.

Both of retrospective and predictive studies in Turkey have obtained various results. As well as those results are different in different regions, there are also different results for the same region in some studies. The climate dominating the shore line of all Black Sea Region is named "Black Sea Climate". In the Black Sea climate, all of the seasons are rainy along the Black Sea shore and the effect of the sea is seen obviously, the annual mean temperature is 8 - 12^{0}C. The rainiest region of Turkey is Black Sea region and most of the precipitation is seen in autumn and winter seasons (Anon. 2007). The regions in inner of Black Sea or the regions located behind the mountains display lower precipitation and colder air temperature than shore regions. But when determining the city-based climate types in Black Sea Region, it would be better to consider each of cities separately. In 5th climate change report of Turkey published in 2013, it was stated that there was a cooling trend of Black Sea Region climate. Again considering the previous data, it can be said that the rainiest regions of Turkey are shore and mountainside regions of Black Sea and Mediterranean. Evaluating the distribution of disaster events between 1940 and 2000 among Turkey, the leading region being affected from storm water in March-July period is Black Sea one rather than other parts of country. According to the 5th climate change report of Turkey, it is expected for future that the hydro-meteorological based landslips and rock falls will increasingly continue in inner parts of Black Sea Region (Anon. 2013).

Various results have been presented about Black Sea Region in recent studies focusing on climate of Turkey. In a study where the climate data of 2010 have been evaluated, while the average temperature values in Spring are above the normal values in other parts of country, those of Black Sea Region was within the normal limits. Again, while the regional annual mean precipitation in terms of agriculture/water year was normally 867 mm, it was 906 mm during 2009 - 2010 period. The precipitation has increased by 4.6% in 2010 in proportion to normal values. The precipitation level was below the normal limits in Giresun, Hopa, İnebolu and Zonguldak, within the normal limits in Artvin, Çorum, Düzce and Ordu, and above the normal limits in all other cities (ANON3 2011).

At the end of 2011, in an annual evaluation study about the climate of Turkey, it has been stated that the precipitation was below the normal limits in western Black Sea Region while most of Turkey have obtained normal or higher level of precipitation. While the mean temperature values in May 2011 were within the normal

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limits in most parts of our country, it was below the normal limits in a part of western Black Sea Region. In October 2011, while the mean temperature values were below the seasonal normals around western Black Sea Region, the mean temperature in summer was within normal limits in most of Turkey but above the seasonal normals in Black Sea Region (ANON4, 2012).

In all of studies about the future estimations, an increase in temperatures in 21th century is expected for Turkey. According to the results of 5^{th} Turkey climate change declaration in 2013, it has been estimated that the decreases will occur in winter precipitation in Mediterranean region of Turkey, while increases have been estimated for Black Sea region. At the result of study, slight increases have been predicted for surface temperature of all of Turkey between 2011 and 2040. But the real increases have been predicted for second period (2040 - 2070) in that study. The increase in this winter is approximately 1.5°C, and approximately 2.4 °C in summer. The increases in surface temperature are expected to reach at 3.5°C in winter and 6°C in summer towards the end of 21^{st} century. The spring precipitations are expected to decrease in central and southern parts of Turkey in future. Despite that, it is predicted that the precipitation will increase in both of two seasons in northern parts of Turkey. Again for first 30 years, it is estimated that the surface flows will increase in western Black Sea region in both of two seasons (spring-autumn). From the forest growing environment, it is estimated that the upper forest level in southern parts of mountain series parallel with Black Sea shore will reach at 2800 m, and the forest lines of coniferous trees and coniferous + broad-leaved tree mixture are expected to enlarge in future (ANON2 2013).

In the next study based on meteorological data between 1961 and 1990, no significant trend could be detected for Turkey in precipitation series normalized according to averages. Considering the precipitation regions in terms of area, an increase has been detected in precipitation of Continental Eastern Anatolian region and the Black Sea region. While a slight decrease trend is observed in mean values of winter in general, a significant cooling trend was observed in temperatures in Sinop, Zonguldak and İnebolu (Demir et al. 2008).

According to another research on climate of Turkey, the most significant decreased in future precipitation will be observed in south-west coast. On the other hand, eastern Black Sea region is expected to obtain more precipitation in future (ANON1, 2007).

In another study of Türkeş et al. in 2002, they have stated that significant cooling trends have been found in mean temperature values of Black Sea Region and Eastern Anatolia's middle parts (Türkes et al. 2002). Also in a study of Türkeş et al. evaluating the long-term meteorological data of Turkey, differently from recent meteorological evaluation reports, it has been concluded that there were significant amount of stations with decreasing trend in winter and annual precipitation amount in rainy regime of Black Sea regions and Mediterranean regions. In precipitation density analysis in same study, besides the strong decrease trend in Black Sea rain regime region almost in every season, it has been found that the rate of decrease in all other rain regime regions are much higher (Türkeş et al. 2007). In this investigation, it was aimed to determine and discuss the changes in annual mean precipitation and mean temperature trends in Western Black Sea Region. The obtained results will compared with recent meteorological studies in Turkey. As a result of this study, we will be able to reveal the precipitation and temperature trend of Western Black Sea Region since 1970 and to make some prognoses about the future climatic variations.

Material and Methods

The object of study is Western Black Sea Region of Turkey. Six cities in the region were selected for the investigation of climate changes – Fig.1.,

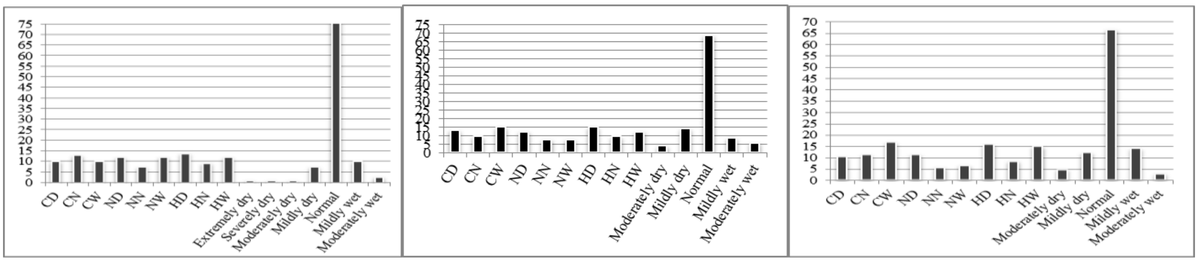
The mean annual temperature and total annual precipitation have been calculated by using the meteorological data for 43 years (1970 - 2012). Required climate data have been taken from General Directorate of Meteorology. Taking the data of this period as basement, the mean annual temperature and annual total precipitation amounts until 2025 were calculated applying a trend curve model.

Fig. 1. Objects of investigation

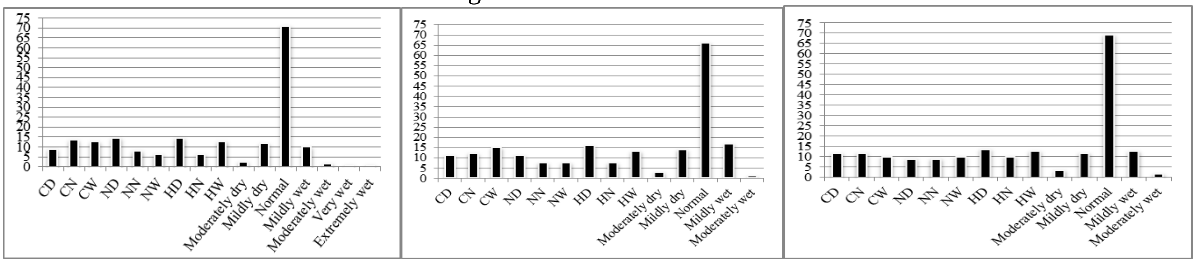
Time trend curves are applied as method for climate parameters prediction. This model has been used in a similar study of Bahadır (2011). The structuring of analysis was carried out via R -Package software (http://act-r.psy.cmu.edu/software/). Climatic types of years (CTYs), as well as the climatic background for forest vegetation (predominance of CTYs) were defined for the period 1901 - 2009 using SPPAM software The climatic type of year is described by the deviation of average annual temperature (dT) and annual sum of precipitation (dP) of year from the respective climatic norm. The average annual temperature ($T_{avg.}$) and precipitation ($P_{avg.}$) and their confidence intervals (μ_{ti} and μ_{pi} at the level of significance - $\alpha = 0.05$) for every 30 years were calculated, starting from 1901. The confidence interval, μ, is calculated by the formula - $\mu = 1.96\frac{\sigma}{\sqrt{n}}$, where σ is the standard deviation of average values of It, T and P. Values inside the intervals: $T_{avg.} \pm \mu_{ti}$ and $P_{avg.} \pm \mu_{pi}$ respectively are considered as climatic norms for temperature and precipitation (Lyubenova et al. 2014). The used climatic types of years are: hot (H) – $dT > \mu_{ti}$, cold (C) – $dT < -\mu_{ti}$, wet (W) – $dP > \mu_{pi}$ and dry (D) – $dP < -\mu_{pi}$. The year is with normal (N) average temperature, when $-\mu_{ti} \leq dT \leq \mu_{ti}$, and with normal sum of precipitation, when $-\mu_{pi} \leq dP \leq \mu_{pi}$. The standardized precipitation index (SPI) was also calculated (Naresh et al. 2009). The CTYs and SPI classes of cites climate for the period 1991 – 2009 was discussed. The climatic database CRU – TS was used as a source of temperature and precipitation for 1901-2009.

Results

The climate for 109 years in the western Black Sea region of Turkey is characterized by the predominance of HD climatic types for most of the studied cites, except in Bartin, where CW prevails. The studied sites have arranged in the following order of decreasing percentage participation of dry climatic types: Zonguldak, Bolu, Karadak, Duzce and Kastamonu (respectively 40 - 35% from all types). The cold CTYs tacked the second place (38 – 35%) respectively for the sites: Karadak, Zongurlak, Balu and Duzce. In Bartin (39%) and Kastamonu (37%) the second place by participation was taken by the hot CTYs - Fig. 2. The significant and variable local role have had also cold - dry, cold - wet, cold and dry years. According to SPI, most years belonged to the normal class. The participation of mildly dry and mildly wet classes was noticeable and in most cases mildly wet class prevailed, except Zongurlak and Kastamonu. In Duzce the participation of extremely and severely dry classes and in Bolu – of very wet and extremely wet classes was found.



1. Duzce 2. Zonguldak 3.Bartin



4. Bolu 5. Karabük 6. Kastamonu

Fig. 2. Ratio (%) between CTYs and SPI classes for 1901 – 2009 in studied cites

Although the cities located in the same region, the climate has local features and the obtained results have been very different. Considering the city-based temperature values, increase is estimated for Kastamonu, Düzce, Bartın, Zonguldak and Karabük until 2025, and it is estimated that the increase in Bolu between 1970s and end of 1980s which transformed into decrease between 1990s and today will become increase again until 2025 – Fig.2.

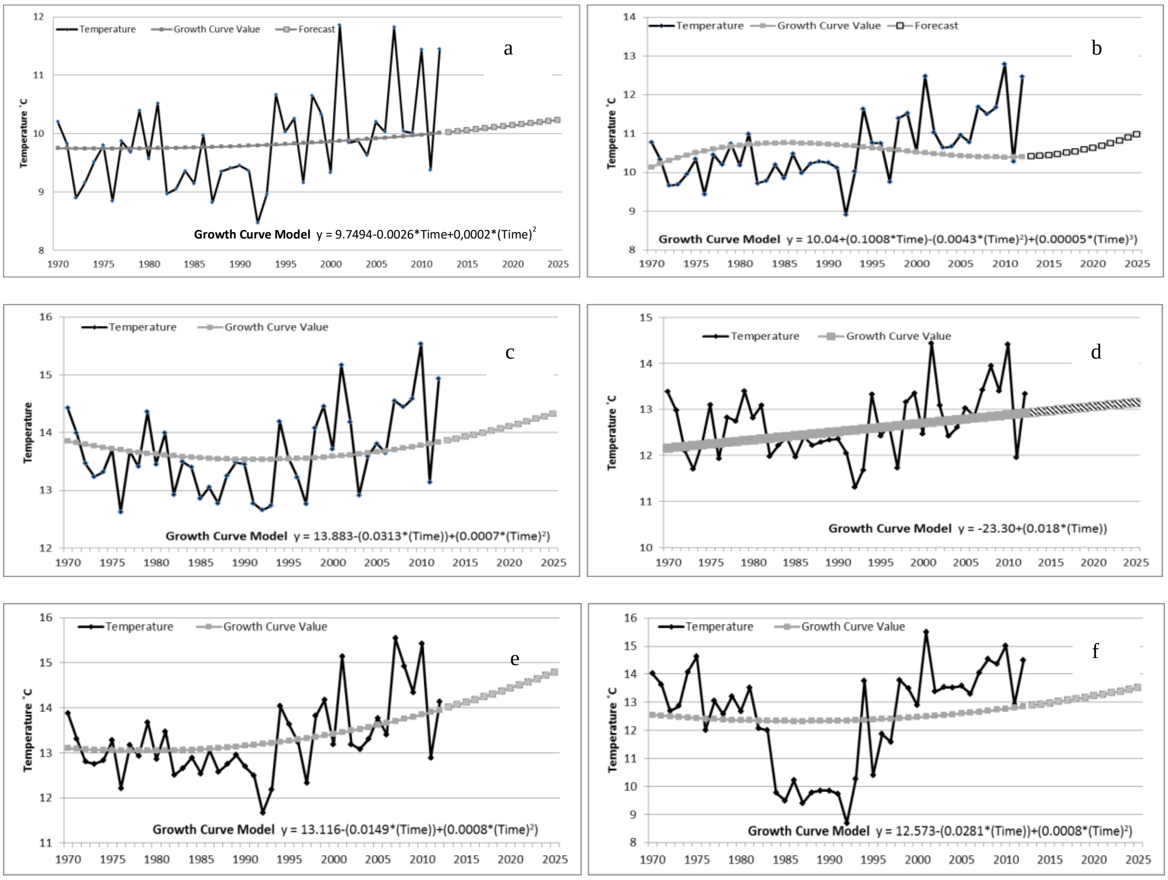


Fig. 3. Trend model of mean annual temperature variation for investigated cities (a: Kastamonu, b: Bolu, c: Zonguldak, d: Bartın, e: Düzce, f: Karabük)

For precipitation, while an increase is estimated in Kastamonu, the decrease is estimated for Bolu, Bartın, Zonguldak, Karabük and Düzce. Considering the trend curves, the lowest annual mean temperature of Kastamonu belongs to year 1992, while other lowest values belong to 1993, 1987, 1982, and 1976. A below-average trend has been observed between 1981 and 1994 especially in temperatures – Fig.3. But in following 20 years, a continuously above-average trend has been observed in mean temperature values. The hottest years were 2007, 2010 and 2012. But while there has been a fluctuating course in precipitation curve without extreme fluctuations in long term, the lowest precipitation value during 43 years of data belongs to 2007, while the highest annual mean precipitation value belongs to 2010. Differently from other 5 cities in study, an increase trend in precipitation is observed only in Kastamonu.

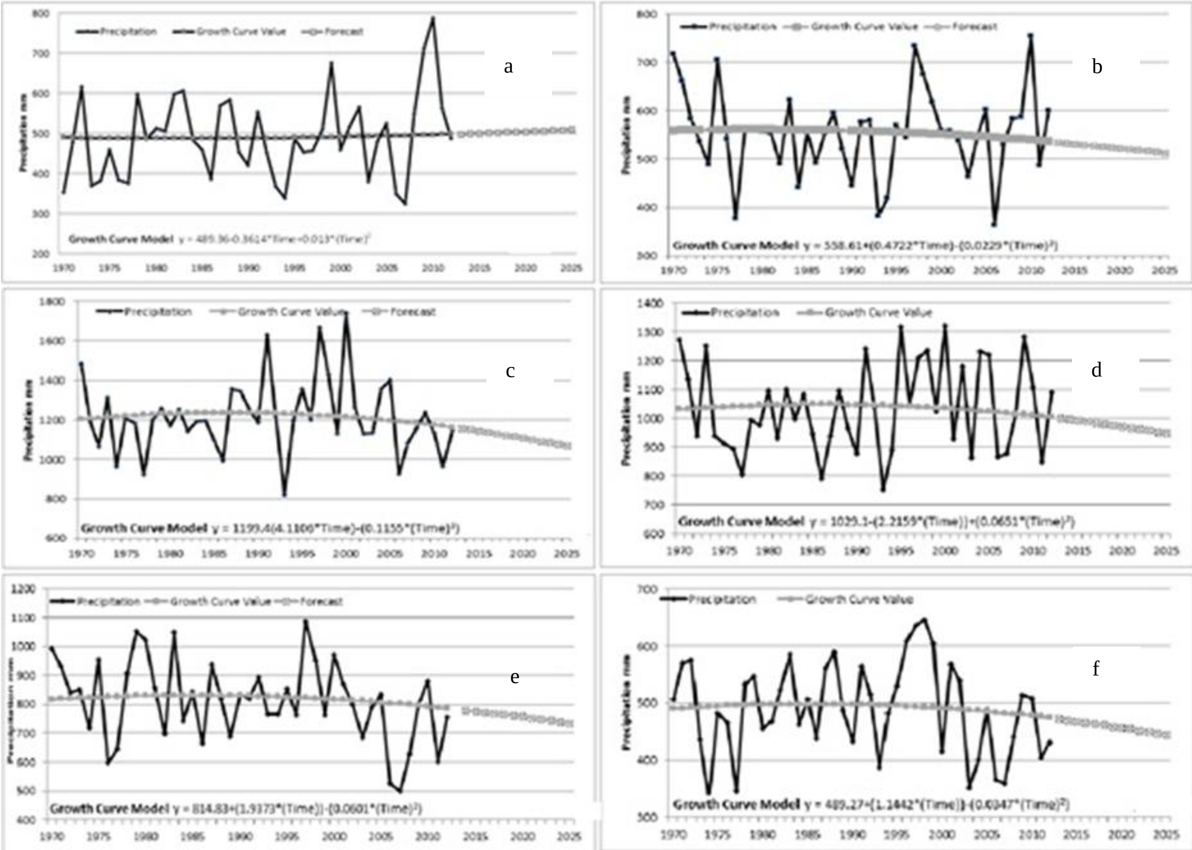


Fig. 4. Trend model of mean annual precipitation of investigated cites (a: Kastamonu, b: Bolu, c: Zonguldak, d: Bartın, e: Düzce, f: Karabük)

By averaging the mean values of all of the monthly data during 1970 - 2012 period, the annual mean temperature values were 12.75^{0}C for Bartın, 10.58^{0}C for Bolu, 13.32^{0}C for Düzce, 13.54^{0}C for Karabük, 9.8^{0}C for Kastamonu, and 13.64^{0}C for Zonguldak. The annual mean precipitation values during those 43 years are as follows: Bartın – 1035 mm, Bolu -554 mm, Düzce - 822mm, Karabük – 486 mm, Kastamonu – 490 mm and Zonguldak – 1222 mm.

According to data of previous years, a floating course is observed in temperature values of Bolu. The lowest temperature among the years belongs to 1992, while the highest value belongs to 2010 and 2012. During the 43 years of study, the annual mean temperature values have exceeded 12^{0}C only in these two years. Also since 1998, the mean temperatures have never fallen under 10.5^{0}C. Although there was a decreased trend seen since early 1990s in Bolu's growth curve analysis, it is estimated that the increase trend will be seen in the period until 2025. Considering the historical graphic of Bolu in terms of precipitation, positive extreme values were see between 1970 and 1975 and negative extreme values were observed between 1977 and 1993, while the lowest annual mean precipitation value belonged interestingly to 2006 and the highest one - to 2010.

Evaluating the temperature graphic of another investigated city, Zonguldak, it is seen that the highest temperature values belong to 2010 and 2012 although the temperature trend follows a narrow course. When evaluating the precipitation graphic, it is seen that the extreme values were negative in 1993 and positive in 1991, 1997 and 2010. Although the temperature values haven't showed a high fluctuation, the hottest year was interestingly 2010 despite of decrease trend. Considering the precipitation status of Bartın during 43 years, it is seen that the lowest precipitation belonged to 1993, while the highest precipitation belonged to 1995 and 2000. Considering the trend curve, it is seen that there is a decrease in precipitations and also there is a very low amount in 2011 despite of high annual mean precipitation values in recent years.

Table 2. The mean annual temperature estimations for cities

YEARS	BARTIN	BOLU	DUZCE	KARABUK	KASTAMONU	ZONGULDAK
2013	12.93	10.41	14.01	12.89	10.02	13.86
2014	12.95	10.42	14.07	12.93	10.04	13.89
2015	12.97	10.44	14.12	12.97	10.05	13.92
2016	12.99	10.47	14.18	13.02	10.07	13.96
2017	13.01	10.50	14.24	13.07	10.09	13.99
2018	13.02	10.54	14.31	13.12	10.10	14.03
2019	13.04	10.58	14.37	13.17	10.12	14.07
2020	13.06	10.63	14.44	13.22	10.14	14.11
2021	13.08	10.68	14.50	13.28	10.16	14.15
2022	13.10	10.75	14.57	13.33	10.17	14.19
2023	13.11	10.82	14.64	13.39	10.19	14.23
2024	13.13	10.90	14.72	13.45	10.21	14.28
2025	13.15	10.98	14.79	13.51	10.23	14.33

Table 3. The annual total precipitation value estimations for cities

YEARS	BARTIN	BOLU	DUZCE	KARABUK	KASTAMONU	ZONGULDAK
2013	1000.57	535.05	783.72	472.44	498.63	1156.66
2014	996.99	533.49	780.31	470.49	499.42	1150.49
2015	993.28	531.87	776.77	468.48	500.24	1144.09
2016	989.44	530.22	773.12	466.40	501.09	1137.46
2017	985.47	528.51	769.35	464.24	501.96	1130.60
2018	981.37	526.76	765.46	462.02	502.86	1123.50
2019	977.15	524.97	761.45	459.73	503.79	1116.18
2020	972.79	523.13	757.31	457.37	504.74	1108.63
2021	968.30	521.24	753.06	454.94	505.72	1100.84
2022	963.68	519.31	748.69	452.44	506.72	1092.82
2023	958.93	517.33	744.19	449.87	507.75	1084.57
2024	954.05	515.31	739.58	447.23	508.81	1076.10
2025	949.04	513.24	734.85	444.53	509.89	1067.39

When the temperature graphic of Düzce was evaluated, the significant increase draws attention, and it is estimated that this trend will continue until 2025. Considering the aspect of temperature, the lowest temperature belonged to 1992, while the highest temperatures have been seen in recent years, as well as other cities. The decrease trend in precipitation is seen also. Considering the aspect of extreme values, while the extremely high precipitation values have been obtained especially in 1979, 1980 and 1983, the significant decrease in annual mean precipitation amount of Düzce draws attention in recent years.

Having more continental climate structure in proportion to other cities in western Black Sea Region, Karabük's mean annual temperature values show increasing trend. Considering especially recent years, it is seen that temperature values have showed above-average course continuously after late 1990s. The mean annua temperature of Karabük in 2010 has exceeded 15^0C, the highest level of 43 years of study data. In contrast with temperature, the precipitation values are in decrease trend. It is estimated that this situation will continue until 2025.

Evaluating the tables presented for future of those 6 cities via trend curve analysis, it is seen that there is a general increase trend in temperature and decrease trend in precipitation in western Black Sea Region – Table 3 and 4. First of all, when considering the cities where the increases are observed in temperature, the highest increase is in Düzce (0.78^0C). Although this value is not seen to be very high, when considering that it is estimated for 13 year, it draws attention that there will possibly be a very high increase until the end of century. The temperature increase of Düzce is followed by Karabük (0.62^0C), Bolu (0.57^0C), Zonguldak (0.47^0C), Bartın (0.22^0C) and Kastamonu (0.21^0C).

In precipitation table decrease is estimated for 5 cities of western Black Sea region and increase is estimated for 1 city. The estimated decreased are as follows: 89.27 mm for Zonguldak, 51.53 mm for Bartın, 48.87 mm for Düzce, 27.91 mm for Karabük and 21.81 mm for Bolu. From the aspect of precipitation, among those 6 cities, the increase is estimated for only Kastamonu. That increase is 11.26 mm for the end of 2025.

Discussion

The analyzes of regional climate for 109 years by the distribution of climatic types of years provides an opportunity to assess the risk of predicted changes as the vegetation cover of area and the agricultural practices are largely adapted to this climate background. The predominance of hot - dry climatic type along almost all the cites, despite differences in the proportion of other climatic types, will put at a risk the area, if the trend of temperatures increasing and precipitation reducing will continue. Most affected will be the sites with high participation of dry CTYs and the sites where there was found the presence of Extremely dry SPI class – Duzce.

The climate change is a frequently spoken situation affecting the entire world. The changes in climate of our world don't show itself only in temperature and precipitation but also in natural life, drought, agriculture, forestry, human health, sea water level, and many other fields in long-term. This change occurs especially due to human-originated CO_2 and other sera gases. The chemical signature of natural sera gases is different from that of human-originated gases**.** The heating trend in recent decades is estimated to continue increasingly if the required measures are not taken (Nychka et. al. 2008). In IPCC report in 2013, it has been stated for the first time that there is climate change, it arises mainly due to human-originated activities, and continue increasingly (Mackenzie 2008).

Climatologists and mathematicians use various methods for estimating our future climate. Mathematic plays the major role in climate estimations (URL1 2014)**.** For this purpose, it was aimed to estimate possible changes in temperature and precipitation in near future by profiting the existing climate data of western Black Sea region which can be accepted as a small area.

The analyses evaluated show a temperature increase for 5 out of 6 cities, while precipitation decrease is also estimated for 5 out of 6 cities, in parallel with trends seen in western Black Sea region in recent years.

When evaluating the data of previous years, it is seen that a milder change has occurred in temperature of western Black Sea region in proportion to southern and western parts of Turkey. It draws attention that there is an inconsistent trend in same region in proportion to previous years; rather than a balanced rain regime, an excessively rainy month follows a drought month.

Considering from the aspect of forest fires, western Black Sea Region is an area which has not been well studied because it is relatively secure region. But because of gradually increasing temperature, summer droughts, and black pine fields, there can be large forest fires in and around Karabük. Becoming a potential fire area with the effects of factors mentioned above, Karabük will possible face with bigger forest fires in future if the trends in temperature and precipitation will continue in same way.

Eastern Black Sea region is thought to be affected from global warming because of its geographical structure, but in recent years it is seen that winters are warmer and the duration of snow cover on surface is getting shorter. It is stated that the temperature of region increases by 0.54^0 C annually (URL-2 2014). The frequency of local but destructive floods increases, the annual precipitation distribution varies depending on precipitation index. An increase is observed in downpours with short duration. As a result of rapid melting of snow because of vaporization increase depending on temperature, the above-/below-surface water resource balance is affected negatively. Even though the precipitation amount won't decrease, the inconsistent and excessive precipitation increases the risk of landslide and flood in region.

In coordination of public institutions, universities, non-governmental organizations, and manufacturer representatives, the early warning system based on estimation of actual and future meteorological events out of seasonal normal limits should be prepared and the agricultural production should be planned. In Black Sea region where the out-of-season excessive precipitation increase is expected, the implementations which harm the natural structure and superficial soil cover must be avoided in soil processing, infrastructure and industry investments. As a result of wrong and unconscious implementations, the erosion, mass soil movements and consequently destructive floods in slopes and agricultural areas having destroyed balance will inevitably lead to live and capital losses. Within this scope, as a result of cooling in recent years and consequently the precipitation, there are many advantages for the protection of mixed stands. The resistance of mixed stands against especially flood, avalanche and landslide is higher than that of pure stands because the inter-individual cooperation is at maximum in mixed stands. So, in order to ensure the sustainability of mixed stands consisting of needle-leaved and broad-leaved trees and light-shadow tree species, the natural and artificial regeneration efforts should be continued via combined group methods by considering the age-length superiority determined according to ecological actual conditions.

Also, depending on the growth phases, it is very important to sustain mild and continuous maintenance effort in form of frequent maintenance and spacing in both of pure and mixed stands. The implementation of regular selective lumbering activities in pure abies stands which is suitable for selection business in higher altitudes (forest border-tree border) in all western Black Sea Region and being operated according to vertical closure and diameter classes can protect the middle and bottom covers, and is one of the leading natural silvicultural measures against climate change.

As well known, forests are not only a natural resource consisting of trees. Besides the trees, forests are dynamic creatures changing continuously and consisting of above- and below-surface micro and macro fauna and vegetation structure. That's why; the protection of species in underbrush of forests such as common burdock, hedera, holly, scarlet firethorn, woadwaxen, sword fern, rose hip, boxwood in bush form, and taxus in shrub form is very useful for both of protection of biological diversity and for tolerating the armful results of climate change.

Conclusion

The evaluated analyses demonstrated that the temperature will increase for 5 out of 6 cities, while precipitation will decrease also for 5 out of 6 cities, in parallel with trends seen in western Black Sea region in recent years. The studied sites are in the same geographical area, but there are local variations in regional climate. However, in investigated 109-year period prevailed hot and dry climatic types and SPI classes in almost all sites. The forecasted increase in temperature and decrease in precipitation will affect a stress on the forest ecosystems – a reduction of the forest production, also an amendment in the species composition, a reduction in the biodiversity, a reduction of the total forest area and thus affect the economy of area. Most at risk are the forests along the sites with higher participation of dry CTYs and these near Duzce where it was detected the existence of Extremely dry SPI class for a period of 109 years.

In relation to the the predicted climate changes, the maintenance of mixed stands and complicated form of tree layer (multi-species and multi-aged stands) for greater sustainability of natural and cultural forest ecosystems will be of a great importance. The regular fellings must be planned so as to preserve the environment-forming role of trees in first and second Krafts classes, which is essential to maintaining the productivity of forest stands

The retaining of shrub and herbaceous layers will contribute to the conservation of biodiversity, forest ecosystem itself and to mitigate the climate changes.

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