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Some important parameters to display the effects of climate change on forest: a case study in Cerle planning unit, Antalya, Turkey

Ormanlarda iklim değişikliğinin etkilerinin belirlenmesinde bazı önemli parametreler: Cerle planlama birimi örneği, Antalya, Türkiye

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Abstract

Climate change is one of the most detrimental issues of the earth in this century. It is evident that a change in climate parameters would affect considerably the entire global ecosystem's environment. On the other hand, different forest related parameters such as natural disaster occurrence or land cover change of forest ecosystems could also help to understand the effects of climate change besides climate parameters such as temperature, precipitation or relative humidity. Therefore, in this study, selected parameters describing climate change were tried to display in a Mediterranean forest planning unit called "Cerle" located in Antalya. Firstly, trend analysis was carried out using climate parameters in the selected study area to detect the amount of climate change. Then, different natural disaster occurrences such as forest fire, windstorm, insects and pest attack evolution were displayed over a period of 30 to 50 years. Spatiotemporal changes for the same period were also tried to be demonstrated, based on historical and actual maps to identify the impact of climate change on the structure and composition of forest ecosystems. In brief, Mann-Kendall test results showed significant increasing trends in annual mean temperature and precipitation. Moreover, the natural development of crimean pine as a result of land use change analysis, as well as the increasing frequency of wildfires and windstorm leading to salvage cutting have been interpreted as the impact of climate change. It is concluded that changes in selected climate parameters are very important to display the climate change digitally. The outputs of this study could help in future forest management planning decisions and determination of silvicultural prescriptions. Furthermore, the obtained results might be the basis for the integration of climate change to forest management planning related to future climate projections and scenarios.

Özet

İklim değişikliği içinde bulunduğumuz yüzyılın en çok zarara yol açan sorunlarından biri olarak görülmektedir. İklim parametrelerinde meydana gelen değişimler tüm küresel ekosistemi önemli ölçüde etkilemektedir. Bununla birlikte; sıcaklık, yağış, bağıl nem veya rüzgâr gibi iklim parametrelerinin yanı sıra, doğal afetlerin oluşumu veya orman ekosistemlerinde meyana gelen arazi örtüsü değişimleri gibi ormanla ilgili farklı parametreler, iklim değişikliğinin etkilerini anlamada yardımcı olabilir. Gerçekleştirilen bu çalışmada, iklim değişikliğini tanımlayan bazı parametrelerin, Antalya'da tipik Akdeniz ekosistemi özelliği taşıyan "Cerle" planlama biriminde gösterilmesine çalışılmıştır. Bu amaçla ilk olarak, çalışma alanında meydana gelen iklim değişikliğini sayısal olarak belirlemek amacıyla, iklim parametreleri kullanılarak trend analizi yapılmıştır. Sonrasında, kuraklık, orman yangını, fırtına, böcek zararı gibi doğal afetlerin 50 yıllık gelişimi ortaya konmuştur. Aynı zamanda, iklim değişikliğinin orman ekosistemlerinin yapısı ve kompozisyonu üzerindeki etkisini belirlemek için aynı döneme ilişkin orman amenajman planı meşcere haritaları yardımıyla, zamansal ve konumsal değişim tespit edilmiştir. Gerçekleştirilen Mann-Kendall testi, yıllık ortalama sıcaklık ve yağışta anlamlı artış ortaya koymuştur. Ayrıca, arazi kullanım analizi sonucunda Karaçam'ın çalışma alanında meydana gelen doğal gelişimi ve olağanüstü etaya yol açan orman yangınlarının ve fırtınaların artan sıklığı, iklim değişikliğinin etkisi olarak yorumlanmıştır. Sonuç olarak, iklim parametreleri yanında, orman ekosistemi ile ilişkili diğer parametrelerde meydana gelen değişikliklerin, iklim değişikliğinin sayısal olarak kavranmasında çok önemli olduğu görülmüştür. Bu çalışmanın çıktıları, ormanların planlanması ve yönetimi konusunda alınacak kararlar ve farklı silvikültürel reçetelerin belirlenmesinde yardımcı olacaktır. Ayrıca, elde edilen sonuçlar, iklim değişikliğinin orman amenajman planlarına entegrasyonu ile, geleceğe ilişkin projeksiyon ve senaryoların hazırlanmasına temel oluşturabilecektir.

INTRODUCTION

Global climate change is seen as one of the world's common problems today that affect nearly almost all the global or regional forestry decisions. It can be mentionned that the number of large wild forest fires in Amazonia, Australia, USA, Congo basin and other forests in the world has abnormaly increased as a consequence of climate change impact on forest during this decade. It is estimated that, the world's major forests will be lost for more than 50%, if global temperatures rise by an average of 3 °C or more by the end of the 21st century (Scholze et al. 2009). Forest plays an important role in human livelyhood since it can provide many environmental services by purifying the air through photosynthesis, removing excess carbon from the atmosphere, storing it in forest biomass, soils and other forest products and by producing wood for furniture and fuel for clean and sustainable energy as an alternative to fossil fuel (Allen et al. 2010). Hence, the importance of forests in mitigating the negative effects of atmospheric carbon is well recognized today, more than before by the international public opinion. Countries try to fight against the increase of atmospheric carbon and put into practice some mechanisms as the Paris agreements on climate, which aims at limiting the increase of global temperature under 2 °C by 2050 (UNCC 2015). This target seems reachable by sustainable forest management and reducing forest degradation as well as taking other measures (UNFCCC 2018). On the other hand, integrating climate change into forest management plans is a challenging task and requires long-term interdisciplinary study.

The first step of defining climate change or the degree of climate change impact in a forest ecosystem passes through displaying the related parameters of climate change on forests (Lyndsey et al. 2012). In other words, quantifying the amount of climate change effects on forests can be displayed to guide the future decision-making in forest management. Some parameters help us to demonstrate this phenomenon in a better way. For instance, changing of climate parameters due to climate change will increase the frequency of occurrence of climate disasters such as droughts, floods, and windstorms, insect's invasion and infestations linked to extreme weather conditions that will destroy forest ecosystems (IPCC 2014a). Therefore, by the help of the interrelation between climate parameters and forest, climate change can be displayed in a rational manner through an investigation of forest related parameters and disturbances in forest ecosystems.

In fact, it is assumed that a change in forest cover will affect the climatic conditions in the area, while a change in climatic conditions will affect the structure and composition of the forest ecosystem, due to natural habitat condition changes for forest species (Allen et al. 2010). Climate change will influence differently the structure and distribution of forests in the world, and forest managers should elaborate strategies and techniques to adapt to and mitigate climate change. Turkey is one of the country's most vulnerable to the effects of climate change. In Turkey, the effects of climate change on forest are represented by an increasing frequency of wild fires, forest diseases, windstorms and new species development leading to the change in forest composition and configuration. Furthermore, extinction of some species, decrease of some habitats quality or drastic changes in some stand types are alarming signals announcing for climate change (Tüfekçioğlu et al. 2005). Although Turkish forests area is increasing over the last decade, the structure and composition is susceptible to the effects of climate change. Therefore, displaying the important parameters of climate change that affect the forest ecosystems is crucially important. For instance, if the parameters display bad scenarios for the future, forest management decisions should be reviewed or different actions should be implemented. Accordingly, displaying mentioned parameters expressing climate change are also important for the integration of that phenomenon into forest management plans.

Thus, different aims apart from classical management approach can be set or alternative silvicultural prescriptions can be implemented to reduce the negative effects of climate change. The problem is that there is no clear definition of adaptation strategy that could be used by forestry professionals in case of extreme climatic events in different regions (Hanewinkel et al. 2015), and the adaptation measures elaborated in order to integrate climate change to forest management practices need to be specific in each region, country, locality and climatic zone (FAO 2013).

Examining the mentioned parameters explaining climate change will provide arguments for adjustments in forest policies and changes in forest management planning and practices. On the other hand, there is no recorded study in Turkey investigating the outputs of a broad range of mentioned parameters on a landscape level. Therefore, the scope of this study is to display climate change parameters that affect considerably the structure and composition of forests in order to establish management strategies to integrate climate change in forest management practices on Cerle Forest Planning Unit (PU) in Antalya region, southern Turkey.

MATERIAL AND METHODS

Study Area

Cerle Planning Unit (PU) administratively works under Taşağıl State Forest Enterprise, Antalya Regional Directorate of Forestry (Figure 1). Cerle PU is 60 km far from the Antalya city. The study area has a 10254 ha general area of which 9222 ha is forested. Forests are dominated by pure stands of Calabrian Pine (*Pinus brutia*) and mixed stands of Calabrian Pine, Cremian Pine (*Pinus nigra*), Juniper (*Juniperus*), Cedar (*Cedrus libani*), Fir (*Abies cilicica*) and Plane (*Platanus orientalis*). According to the current forest management plan designed for the periods between 2011 and 2020, forest allocated to timber production and ecological values (old growth forests, soil conservation, fire prevention zone and forests with poor sites) are 45% and 55% respectively (GDF 2010). The population reaches nearly 5080 people within the planning unit. Most of the people support their lives by agriculture or working for the tourism sector. Few people work for the forestry sector such as timber production or planting activities.

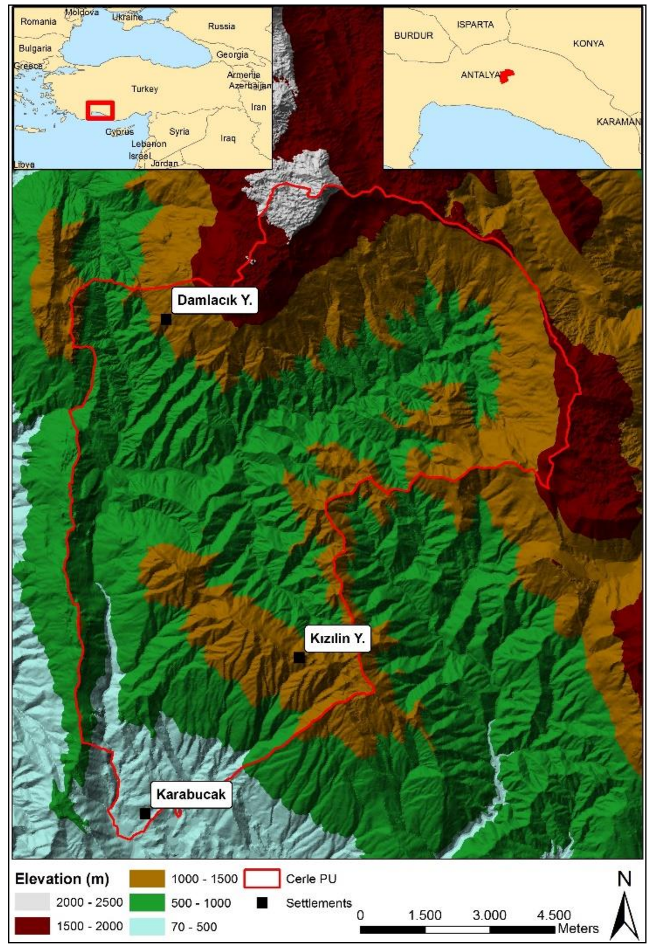


Figure 1. The spatial location of the Cerle PU

Methodology

Data was collected in two steps, firstly at the General Directorate of Meteorology in Ankara where the data on temperature, precipitations, relative humidity, and other climate parameters were collected for a period of 50 years from 1960 to 2010 at the Manavgat meteorological station only 45 km far away from Cerle PU. Afterwards, monthly averaged climatic parameters were analysed using Mann-Kendall (MK) non-parametric test to determine the rainfall and temperature trend. The MK test is a commonly used statistical test to investigate the trend in climatological and hydrological time series (Mann 1945, Kendall 1975, Oğuz and Oğuz 2017, Temur 2017, Şensoy et al. 2017, Demircan et al. 2017).

The purpose of the MK test is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time. A monotonic upward (downward) trend means that the variable consistently increases (decreases) through time, but the trend may or may not be linear. The MK test can be used in place of a parametric linear regression analysis, used to test if the slope of the estimated linear regression line is different from zero.

The regression analysis requires that the residuals from the fitted regression line be normally distributed; an assumption not required by the MK test, that is, the MK test is a non-parametric (distribution-free) test. The MK test, tests whether to reject the null hypothesis (H_0) and accept the alternative hypothesis (H_a), where H_0: No monotonic trend and Ha: Monotonic trend is present. The initial assumption of the MK test is that the H_0 is true and that the data must be convincing beyond a reasonable doubt before H_0 is rejected and Ha is accepted. The Formula of MK test is given below:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(P_j - P_i),$$

where

$$\mathrm{sgn}(\theta) = \begin{cases} +1 \ldots \theta > 0 \\ -1 \ldots \theta < 0 \\ 0 \ldots \theta = 0 \end{cases} .$$

Under the hypothesis of independent and randomly distributed variable, the MK test (S) is computed with:

$$\sigma^2 = \frac{n(n-1)\,(2n+5)}{18},$$

Where ɑ is the standard deviation of the dataset. Therefore, the standardized Z statistics follow a normal distribution

$$Z = \begin{cases} \frac{S-1}{\sigma} \ldots S0 \\ \frac{S+1}{\sigma} \ldots S0 \\ 0 \ldots S = 0 \end{cases} ,$$

Where S is the MK statistic test. If the result of MK test indicates that, there is a trend of time series data then it is necessary to calculate the Sen's slope value.

$$\mathrm{TS} = \mathrm{median}\left(\frac{P_j - P_i}{j - i}\right) \quad \text{For } i < j.$$

For the calculation of Sen's slope value where TS is the slope estimate, Pj and Pi, the value of temporal change of meteorological data, i and j, the periods of data being analysed.

Climate data have been analysed with an open access tool called "AUTO_MK_Sen" software to see the trend and variation of climate over the period of past 50 years.

Secondly, forest management stand type maps were collected at the General Directorate of Forestry (GDF) in Ankara, and then other parameters such as fire records, the amount of salvage cutting were taken from the Regional Directorate of Forestry in Antalya, and Taşağıl State Forest Enterprise. Cerle forest management plan (GDF, 1965) prepared in 1965 was used as the main material for this study for the determined period to display the changes in terms of tree species class. In addition, the recent forest stand type map (GDF 2010) was obtained digitally from GDF.

A geographic information system was used for analysis and presentation of data to determine the temporal and spatial changes in Cerle forest resources. In this study, primarily the stand type map prepared in 1965 was scanned, coordinated with the help of topographic maps and finally digitized. Topographic maps as N26c1, N26c2, N26c3 and N26c4 were used for the coordination of previous stand type map. Databases were built considering forest tree species and land use (Table 1).

After completion of the previous period database, layers for 1965 and 2010 were both overlaid and exported in dbf format. After then, transition matrices were obtained using "Microsoft Excel 2016". In order to display spatial changes related to specified periods, "Patch Analyst" program were used which can operate as extension to ArcGIS software. Indexes such as number of patches, mean patch size and area weighted average shape index were used to evaluate the spatial changes Cerle PU for nearly 45 years.

Table 1. Land cover/Forest cover classes

Land Cover/Land Use Classes	Description
Open areas	Settlements, agriculture areas, bare lands, ranges, shrubs and grasslands, water, sand, erosion areas and timber yards
Degraded forests	Degraded stands with < 10% tree crown closure
Mixed forests	Mixed stands with > 10% tree crown closure
Calabrian Pine	Pure Calabrian pine stands with > 10% tree crown closure
Crimean Pine	Pure Crimean pine stands with > 10% tree crown closure
Plane	Pure Plane stands with > 10% tree crown closure

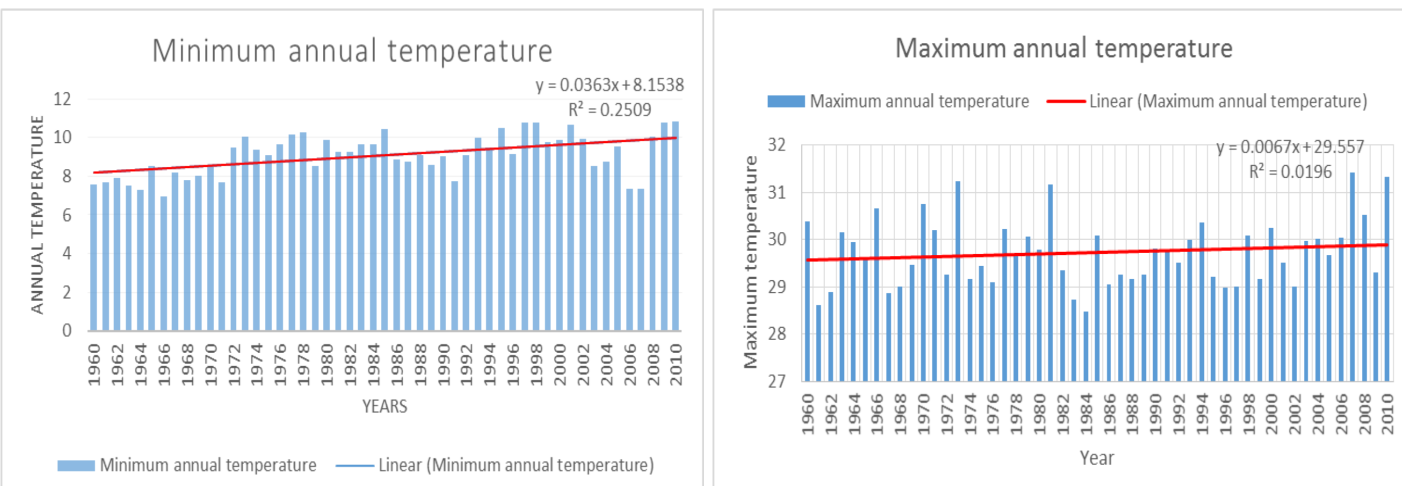
At the end, a comparison between the change in structure and composition of forest and the change in climate parameters have been established based on the literature and other research studies on the effects of climate change on forest ecosystems.

RESULTS

Climate Data Analysis for Cerle Planning Unit

Temperature Data Trend

The minimum annual mean temperature that is the lowest average temperature value recorded during the year increased from 7.8°C in 1960 to 11.2°C in 2010 with R^2 of 0.25. This increase is gradual and there is no tendency to decrease. It can also be observed that the maximum annual mean temperature that is the highest average temperature value recorded during the year is increasing progressively from 30.2°C in 1960 to 31.3°C in 2010 with R^2 of nearly 0.02. By comparing the tendencies looking at the slope and the relations coefficient (R^2), it can be mentioned that the minimum annual mean temperature is increasing faster than the maximum annual mean temperature (Figure 2).



(a) (b)

Figure 2: Minimum (a) and maximum (b) annual mean temperature trend from 1960 to 2010 in Cerle PU

This means that the gradient of temperature that is the difference between the maximum and the minimum annual mean temperature have been reducing between 1960 and 2010 in and around the Cerle PU. The annual mean temperature trend that is the average temperature value recorded every year is presented in the figure 3 below.

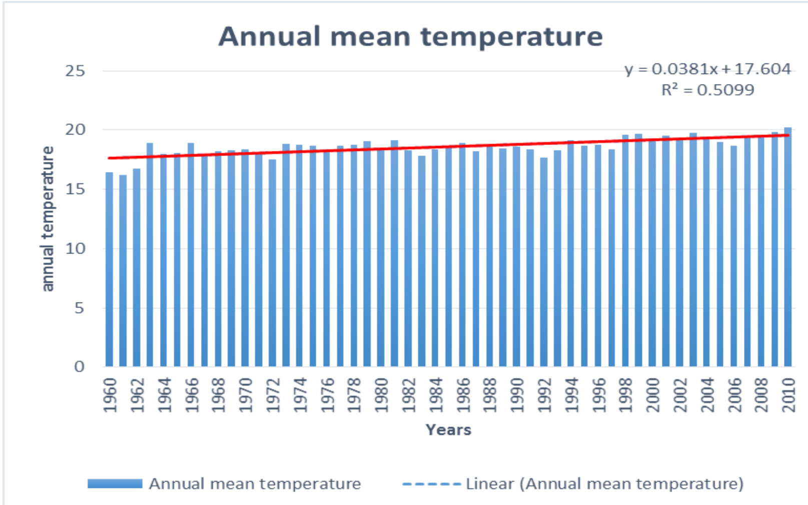


Figure 3: Annual Mean temperature trend from 1960 to 2010 in Cerle PU

The annual mean temperature of Cerle PU has increased gradually from 17.6 to 19.5 °C from 1960 to 2010 with a strong relationship R^2 of 0.51. The increase of annual mean temperature over the whole period is 1.9 °C in the past 50 years (Figure 3).

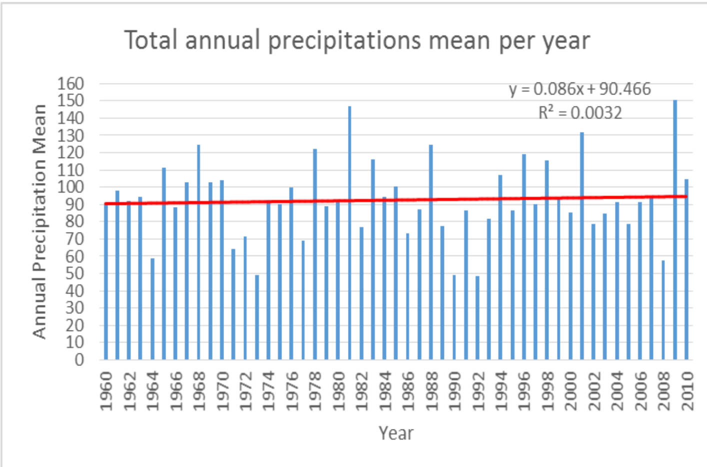
Mann-Kendall test results for the annual mean temperature around the Cerle PU showed that there is an increasing temperature trend in september, spring, fall and the full year. An increase of 0.077 °C was found on a yearly basis, meaning to be 3.85 °C of increase in the following 50 years (Table 2). This means that according to the Sen slope projection, the increase in annual mean temperature will double from 1.9°C to 3.85°C for the next 50 years.

Table 2. Mean temperature Mann-Kendall and Sen slope results for 1960-2010 periods

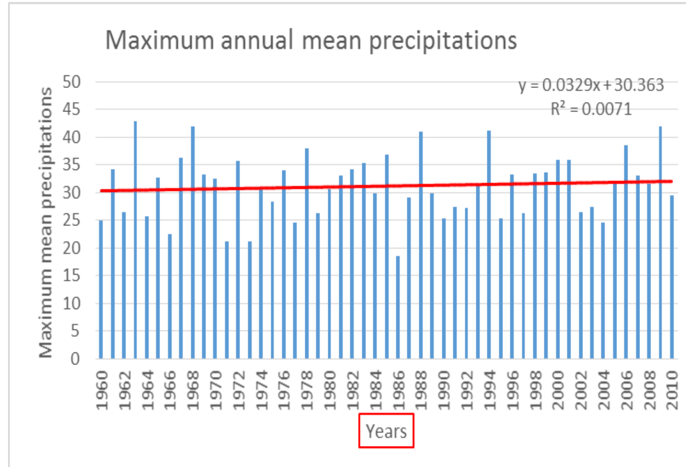
Month/Season/Year	S	Variance	Z	Mann-Kendall Test	Sen Slope
January	204	13686.0	1.74	Neutral	0.000
February	81	14041.0	0.68	Neutral	0.000
March	155	13664.3	1.32	Neutral	0.000
April	-56	13991.3	-0.46	Neutral	0.000
May	222	13666.6	1.89	Neutral	0.026
June	-178	14095.3	-1.49	Neutral	-0.061
July	184	13752.6	1.56	Neutral	0.023
August	-19	14083.0	-0.15	Neutral	0.000
September	**271**	**13923.6**	**2.29**	**Positive**	**0.049**
October	14	14084.6	0.11	Neutral	0.000
November	151	13989.6	1.27	Neutral	0.027
December	26	14070.6	0.21	Neutral	0.000
Spring	**302**	**13905.3**	**2.55**	**Positive**	**0.048**
Summer	90	14118.6	0.75	Neutral	0.000
Fall	**275**	**14026.3**	**2.31**	**Positive**	**0.067**
Winter	-19	14138.3	-0.15	Neutral	0.000
Full Year	**290**	**14098.6**	**2.43**	**Positive**	**0.077**

Precipitation and humidity data trend

The total annual mean and maximum precipitation data from 1960 to 2010 in Cerle PU is presented in figure 4 below. The tendency of precipitation seems slightly constant for both total and maximum precipitation (Figure 4a and Figure 4b). Looking at the trend in figure 4, it can be noticed that the total annual mean precipitation is slightly decreasing from 90 to 87 mm/m²/year over 50-year period.



(a)



(b)

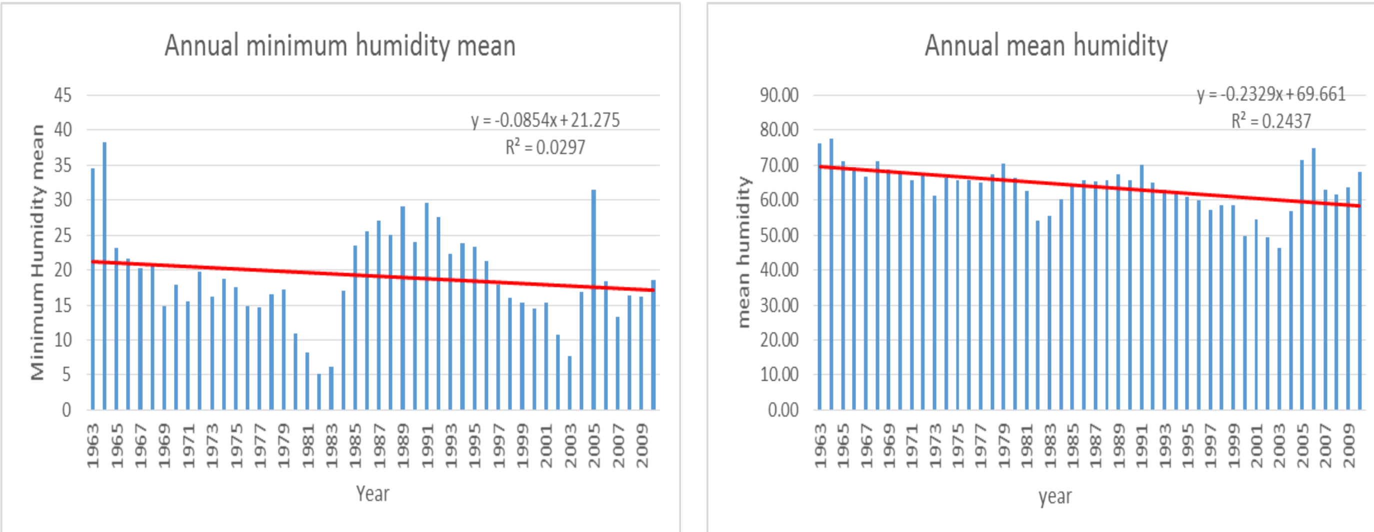
Figure 4: Total annual mean (a) and 10 years average (b) precipitation trend from 1960 to 2010 in Cerle PU

This tendency to decrease of total annual mean precipitation is also observed when the monthly distribution of precipitation is analysed, where the beginnings of winters and summer periods have shifted for about 49 days over 50 years (Table 3). When looked at Mann-Kendall test results for mean precipitation, there is a positive decreasing trend in spring (Table 3).

Table 3. Mean precipitation Mann-Kendall and Sen slope results for 1960-2010 periods

Month/Season/Year	S	Variance	Z	Mann-Kendall Test	Sen Slope
January	-2	14290.6	-0.01	Neutral	-0.034
February	-190	14139.3	-1.59	Neutral	-0.064
March	-103	14287.0	-0.85	Neutral	-1.000
April	83	14179.6	0.69	Neutral	0.029
May	29	14279.0	0.23	Neutral	0.071
June	-183	14175.6	-0.69	Neutral	-0.030
July	-94	14254.0	-0.78	Neutral	-0.111
August	-75	14120.3	-0.62	Neutral	0.000
September	-179	14178.3	-1.49	Neutral	0.095
October	-158	14032.6	-1.33	Neutral	-0.042
November	-190	13165.3	-1.65	Neutral	0.000
December	-23	12405.6	-0.20	Neutral	0.000
Spring	**354**	**11975.3**	**3.23**	**Positive**	**0.000**
Summer	-40	13294.0	-0.34	Neutral	0.000
Fall	100	14040.6	0.84	Neutral	0.025
Winter	154	14182.6	1.28	Neutral	0.069
Full Year	146	14274.0	1.21	Neutral	0.478

As well, relative humidity data have been collected from the directorate of meteorology in Ankara for the Cerle planning Unit from 1960 to 2010. The annual minimum humidity mean (figure 5a) that is the lowest value of humidity recorded during the year, and the annual mean humidity trend (figure 5b) that is the total annual mean of humidity data recorded during the year are presented in figure 5. It can be mentioned that the trend of both annual minimum humidity mean and the total annual mean humidity have the tendency to decrease over the 50 years period. (Figure 5).



(a) (b)

Figure 5: Annual minimum (a) and total annual (b) mean humidity from 1960 to 2010 in Cerle PU

However, the regression test on relative humidity data is not significant for the annual minimum and the total annual mean humidity that gave R^2 values of 0.029 and 0.243 presented in figure 5. So it is not possible to conclude that there is a decreasing trend in humidity data, even if the figure 5a and 5b show it. The decrease in annual mean humidity can affect the water availability to plant. Therefore, this is also an important parameter that could affect forest ecosystems.

The data on climate parameter analysed present the past and actual climate conditions in the Cerle Forest PU, and show how they have changed over a period of past 50 years. These changes can affect forest ecosystem that are widely related to climatic conditions. This can be the basis to investigate changes in the Cerle PU forest stand structure and composition in order to find a relation with the change in climate parameters over the same period.

Landscape Level Parameters for Cerle Planning Unit

Land Cover Change

During our data collection, map data have been collected at the General directorate of forestry in Ankara. According to the forest management plan of the Cerle PU, five period maps from 1960 to 2010 have been collected and digitalised. The outputs of the spatiotemporal analysis in Cerle PU presented in table 4 below displayed drastic changes in the examined period.

Table 4. Land-cover change in Cerle PU from 1965 to 2010

					2010				
		Open L.	**Degrad.**	**Mixed**	**Cal. P.**	**Cri. P.**	**Plane**	**Total**	**% Change**
1965	**Open lands**	676.3	98.5	55.0	154.7	0.6	3.3	**988.3**	**+4.20%**
	Degraded for.	204.1	2051.3	230.1	984.2	14.5	0.8	**3484.9**	**-48.16%**
	Mixed forest	59.1	55.5	527.7	302.7	-	1.1	**946.0**	**+22.81%**
	Calabrian P.	92.1	147.0	412.7	4162.1	3.9	17.3	**4835.1**	**+13.71%**
	Total	**1031.6**	**2352.2**	**1225.5**	**5603.6**	**19.0**	**22.5**	**10254.4**	

In table 4, it can be mentioned that open lands have increased of 4.20% over 50 years, from 988.3 ha in 1965 to 1031.6 ha in 2010. On the other hand, degraded forest area has decreased of 48.16% over the same period, from 3484.9 ha in 1965 to 2352.2 ha in 2010. As well, mixed forest areas have increased of 22.81% from 946 ha in 1965 to 1225.5 ha in 2010. In 1965, the forest was monospecific mainly covered by Calabrian pine, occupying 4835.1 ha in the Cerle PU. This counted for an increase of 13.71% over the period. The forest structure and composition have changed over the 50 years period with the increase of mix forest stands of about 23% with dominant forest species occupying 5603.6 ha in 2010 and the emergence of pure Crimean pine stands and Plane occupying respectively 19.0 and 22.5 ha in 2010. The change in landscape can also be due to natural conditions becoming favourable for the development of new species like the Crimean pine and the Plane (Table 4).

The figure 6 below is presenting the land use/land cover change from the digitalized maps of Cerle Planning Unit of 1965 and 2010. From the figure, it can be seen that the degraded stands in the lowlands was replaced by Calabrian pine, however, the same species changed to mixed stands in the highlands. Moreover, spatial composition was represented by a more fragmented structure (Figure 6).

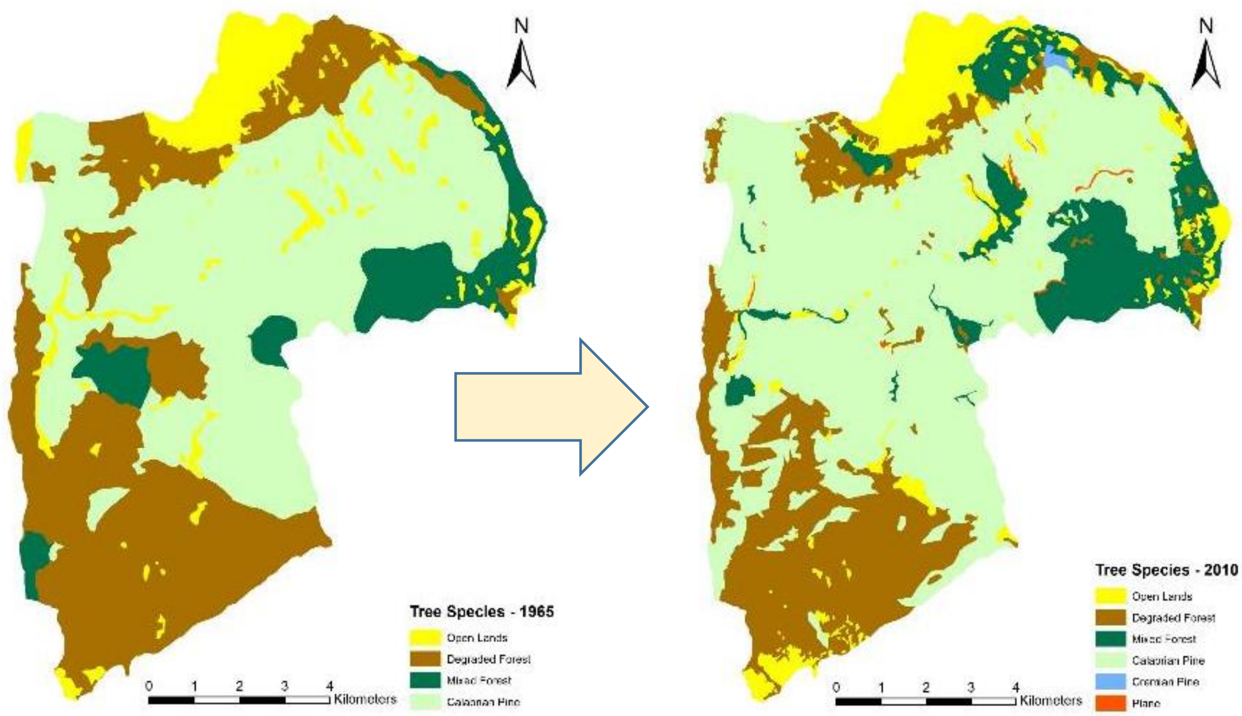


Figure 6: Land use/land cover change in Cerle PU between 1965 and 2010

According to climate data analyzed over the same period from 1960 to 2010, it can be mentioned that the increase in temperature could be favorable for the development of well-adapted tree species like the Calabrian pine and the Crimean pine in the Cerle forest PU. Nevertheless, this can also be due to the human activities in the forest, which are responsible for the regeneration or the dynamic of the forest over times.

Change of Landscape Pattern

The patch analysis of figure 6 is presented in table 5 below.

Table 5: Change of some landscape pattern metrics in Cerle from 1965 to 2010

Land Cover Type	Number of Patches (#)		Mean Patch Size (ha)		Mean Shape Index		Area Weighted Mean Shape Index	
	1965	2010	1965	2010	1965	2010	1965	2010
Open Lands	82	169	12.1	6.1	1.44	1.47	2.08	2.31
Degraded	7	42	497.8	56.0	2.20	1.86	2.75	4.55
Mixed	4	16	236.5	76.6	2.03	2.55	3.15	4.15
Calabrian Pine	4	14	1208.8	400.3	2.16	2.06	4.65	6.25
Crimean Pine	-	1	-	19.0	-	1.67	-	1.67
Plane	-	10	-	2.2	-	2.23	-	2.78
Total	97	252	1955.2	560.2	7.83	11.84	12.62	21.70

Looking at table 5, the spatial metrics mentioned that the landscape in 2010 is more fragmented than in 1965 with an increase from 97 to 252 patches between the two periods. Open lands have 169 patches of 6.1 ha in mean size, which is more than the 82 patches of 12.1 ha mean size. The number of patches of degraded forest has increased from 7 to 42 between the same periods, but the mean size has considerably reduced from 497.8 ha per patch to 56.0 ha per patch (Table 5).

Wild Fires occurrence frequency

Fire records presented in table 6 showed that the number of fires gradually increased from 1979 to 2015 except the last period (Table 6).

Table 6: Fire occurrence within Cerle from 1979 to 2015

Years	Number of wild fires (#)	Area (ha)	Mean affected area per fire (ha)
1979-1980	3	45.9	15.3
1981-1985	9	23.9	2.7
1986-1990	3	29.1	9.7
1991-1995	2	4.0	2.0
1996-2000	6	11.2	1.9
2001-2005	6	4.1	0.7
2006-2010	10	8.2	0.8
2010-2015	3	0.6	0.2

Looking at table 6, it can, however, been mentioned that the mean affected area per fire gradually decreased within the same period. Because of strong efforts by GDF against forest fires and with the help of technological advances, fires have been successfully kept out of these systems over the last several years. On the other hand, the number of wild fires seems to be increasing comparing the two periods of 20 years each. This will increase within the next period if this tendency will continue (Figure 7).

It can be mentioned from the Figure 7 that the frequency of forest fire is increasing from the period (1978-1998) to the period (1998-2018).

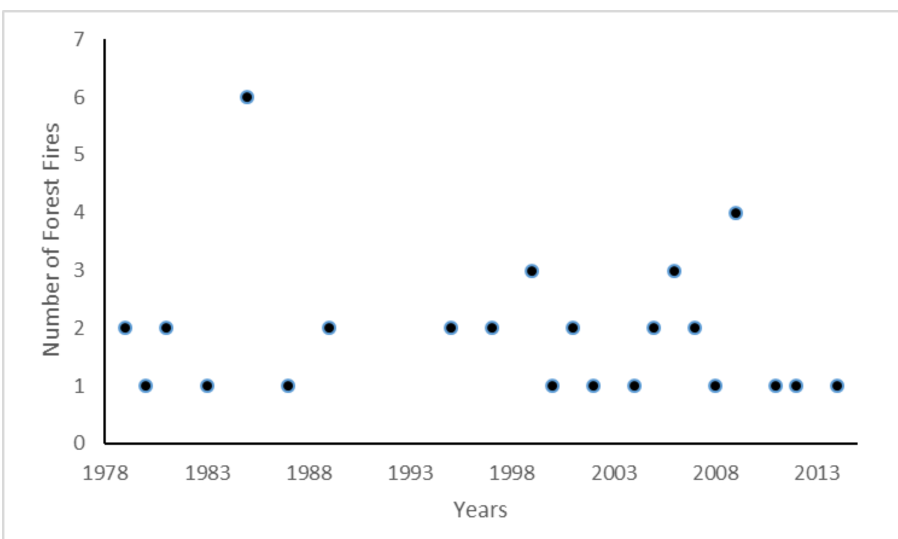


Figure 7: Forest fire frequencies in Cerle PU from 1978 to 2015

Salvage Cuttings

The table 7 below present the wood production and the reasons of massive wood extraction during the period 2011 to 2015. Unfortunately, previous data for the period 1960 to 2010 have not been shared by the forest administration of the Cerle PU. It can be mentioned in table 7 that, 2308 m^3 (47.5%) wood material taken from the forest to create front for preventing from wild fires in the last period. In addition, 252 m^3 (5.2%) salvage cutting draw the attention, due to the wind damage in the same period. A huge amount of forest land, totally 361.7 hectares, affected by this natural phenomenon. Besides, 37 m³ standing dead trees, probably dead by bark beetles or drought covering 109.2 hectares removed from the Cerle planning unit (Table 7). These are some important parameters that could display the effect of climate change on forest.

Table 7: Wood production values for the Cerle PU in recent years

Year	The Reason for Selvage Cutting	The amount of cutting (m³)	Affected area (ha)	Total cut (m³)
2011	Forest Fires	2308	12.9	2318
	Illegal cutting	10	0.1	
	Forest road and facility	330	1.7	
2012	Forest road and facility	516	1.1	1112
	Forest road and facility	276	0.9	
	Forest road and facility	162	0.4	
	Standing dead trees	37	109.2	
2013	Forest road and facility	145	0.7	403
	Sampling tree	39	0.5	
	Illegal cutting	20	26.3	
	Other reasons	9	24.4	
	Wind damage	12	9.7	
2014	Other reasons	74	139.0	365
	Other reasons	54	0.5	
	Forest road and facility	216	0.6	
	Wind damage	240	352.0	
2015	Forest road and facility	86	0.9	681
	Forest road and facility	355	2.0	

DISCUSSION

The increasing trend of annual mean temperatures around Cerle forest planning unit of about 1.9°C over the past 50 years and the projection for the next 50 years showing a double increasing trend from 1.9°C to 3.85°C, can help to understand the long-term change of extreme temperature events that have occurred and will continue to occur in the area due to climate change. The same observations have been done by Öndeş (2017) studying the trend of minimum and maximum temperatures based on data from 1970 to 2014 around Adana, Antalya and Mersin using the Makesens Trend statistical test for trend analysis. They found that the monthly variation of temperatures is significant affecting the normal distribution within seasons that may have a great impact on agriculture and forestry. As well, Demircan et al. (2017) have displayed the trend analysis of minimum mean temperatures from 1971 to 2014 around Ankara and İstanbul using MK statistical test to see whether urbanization is affecting temperature changes and accelerate climate change. They found significant results in the increasing trend of minimum temperature with 1.0°C more and 2.0°C more increase in Ankara and İstanbul. The trend analysis in the present study has displayed an increase of 1.9°C on the annual mean temperature and 0.07°C yearly increase in temperature around Cerle forest planning in Antalya. This is scientifically comparable to the world global warming observed by NASA, 2017 stating that the global average surface temperature has increased of 0.6 to 0.9 °C within 1951 to 2001 (Lindsey et al. 2012). This simply means that temperature change in Turkey is faster compare to global mean change in temperatures. The temperature increase around the Cerle PU is projected to double by 2050 as projected with MK test analysis. This will be more than the expectations according to the Paris agreement and some solutions must be applied to reduce the rate of climate change in Turkey.

In MK test, a threshold has been defined as 5% with our null hypothesis (there is no trend), the trend have been judged based on this threshold. This means that if a time series is analysed and want see the trend at 5% significance level and get the Mann-Kendall test statistic (Z) as +1.645, then based on the null hypothesis, there is no trend at 5% significance level. However, there may have a trend in the data behind the selected threshold. Statistical test can reveal that there is a positive trend, which is significant at 10% significant level. Therefore, calculation of the changing rate/slope is needed. This is a novel approach for statistical trend analysis, especially for large distribution data like meteorological and climatological data.

The trend analysis observed on precipitations data (with a relatively decreasing tendency) with a positive increasing trend in spring is an anormality due to climate change in the area. Güçlü (2014) has observed this situation, studying rainfall abnormalities at the Mediterranean coast of Turkey from 1950 to 2010. He has found that rainfall anomalies have shown an increasing tendency around Fethiye and Alanya and a decreasing tendency in Fethiye, Alanya and Anamur. While it was increasing during summer and decreasing during winter at all stations around the Mediterranean coast of Turkey, an increasing tendency of precipitations during spring (autumn) at all stations in the Mediterranean coast of Turkey has been observed.

Furthermore, the decreasing tendency of humidity observed around Cerle forest planning unit can be compared to the results of a study carried by Temur (2017) in Susurluk watershed. Temur (2017) has founded that the monthly and yearly decrease of humidity and precipitation around Susurluk in Turkey was -1.24 mm/year only for the month of December, from 1963 to 2015, and the annual total humidity and precipitation mean decrease was -2.90 mm/year using Mann Kendall trend analysis at 5% significance. For this study, we have found that the Mann Kendal trend analysis of precipitation data is significant at 5% for spring, due to a shifting date of precipitation monthly period for about 49 days between summer and winter seasons over the 50 years (1960-2010) period of analysis. As well, Coşkun (2017) found a significant decrease tendency in the trend of climate indices for annual precipitation in Karapınar and Karaman watershed in Turkey over a period of 100-years data analysis. They found a decrease in annual precipitation by 25 and 83 mm/100 years, an increase in the number of consecutive dry days by 21 and 15 days/100 years, an increase in the number of summer days by 32 and 33 days/100 years, an increase in the number of Tropical nights by 1.2 and 7 days/100 years respectively in Karapınar and Karaman watershed, closed to Konya in Turkey.

Although some forests will benefit from increasing temperatures and changes in precipitation, most of the other world's forests will experience losses of important species, decline in yields, and increases in the frequency and intensity of storm, forest fires, water scarcity and other disturbances (IPCC 2014b). The mentioned driven factors of climate change on Turkey's forest can be specified giving some figures. Global warming is causing an increase in the frequency of forest fires in Mediterranean and boreal coniferous areas. In dry areas in Anatolian region, climate change may accelerate the frequency of forest fires, increasing soil erosion, reducing plant regeneration and advancing desertification (Lindsey et al. 2012). In Turkey this represents 1007 forest fires on 24414 ha annually with an average area burned of 24 ha per fire. Antalya forest fire in 2008 has burned down about 60 houses and destroyed about 24000 ha of land of which 16000 ha was woodlands (Karahalil and Köse 2015). Many others forest fires occur every year around Turkey: Sürmene-Maçka (in winter 2016), Ankara, Konya and Antalya forest fires (in 2014). It can be mentioned that the frequency of forest fires in Cerle forest planning unit has increase within the same period (1978-2015) necessitating a double effort for salvage cutting due to forest fire occurrences and management. Furthermore, the changing climatic conditions will increase the abundance of insects, pests and pathogens to forest plant species (Lindsey et al. 2012). In Turkey's forest, there will be an increasing rate of death wood due to drier climate conditions leading to the venue of wood decomposers such as fungi. A typical example occurred in Hatilla national park in Turkey due to the effects of *Ips typographus L*. beetles, where moreover than 100000 Oriental spruces died. Insect damage was responsible for 289934 m^3 of wood with a ratio of 54% between the periods of 2005 and 2011 in the Trabzon Regional Directorate of Forestry (Tüfekçioğlu et al. 2005, Çil 2012). These figures confirm the relationship of climate change to the increase in the number of forest fires.

Moreover, forest and climate change are interrelated; deforestation and degradation of forest ecosystems contribute to carbon emission that enhance the greenhouse effect and global warming, climate variability and climate change (NASA 2015). For instance, deforestation and forest degradation account for about 20% of global GHG emissions (Tautenhahn et al. 2016). Integrating climate change to forest management practices is a very crucial issue. Looking at the results of land cover change in Cerle planning unit from 1965 to 2010, it can be stated that the change in land use and land cover in this area is both man made and due to the change in natural climate conditions. This has been stated in a study made by Karahalil et al. (2015) investigating the transition ratio of changes in selected land use land cover classes for different planning units in Trabzon (respectively Of, Çaykara, Yomra and Akçabaat planning units). From that study it has been found that open lands changed to another land use classes with a ratio of 13.8, 13.8, 66.7 and 15.5 respectively with human intervention (foresters, land owners) and natural climate change. On the other hand, degraded stands changed to another land use classes with a higher value as 73.4, 83.5, 67.1 and 86.6 respectively for Of, Çaykara, Yomra and Akçaabat planning units with an average ratio of 77.6. Moreover, changes in mixed stands was occurred with a ratio of 50.9, 40.6, 75.8 and 34.7 respectively again for Of, Çaykara, Yomra and Akçaabat planning units with an average ratio of 48.0. When looking at the basic tree species in that area, beech changed with a ratio of 63.3 in Of, 93.5 in Çaykara and 99.8 in Akçaabat planning units with an average ratio of 85.5. However, Spruce changed with a ratio of 55.4 in Of, 44.9 in Çaykara, 100 in Yomra and 24.4 in Akçaabat planning units with an average ratio of 56.1 over the same evaluation period. In this study the changes are attributed to forest management interventions and to natural climate change.

The spatial analysis of landscape maps shows an increasing fragmentation of the forest area in Cerle forest planning unit from 1965 to 2010. The increasing patches from 97 to 252 may be the resulting change in habitat suitability in the area due to increasing temperature. According to Lindsey et al. (2012), the eventual change in habitat suitability will increase tree species diversity within the same forest type. This can be observed on tree distribution in Cerle Forest Planning Unit Land cover change maps: in 1965, there were only Calibrean pine as main tree species, then in 2010; there are Crimean pine and Plane, which appear in the spatial distribution maps. This can be explained by the change in habitat condition suitability as explained by Lindsey et al. (2012). As well, the reduction of degraded areas in Cerle forest planning can be the combination of change in habitat suitability and human activities in forest through tree planting and harvesting. The salvage cutting activities have increase in Cerle forest-planning Unit within the same period due to an increasing frequency of forest fire related to the increasing temperatures. Human activities are the factor of influence shaping the structure and composition of forests within a period, but climate change impacts are also to be considered.

CONCLUSIONS

This study aimed at contributing to increase awareness of the impact of climate change on forest ecosystems by investigating the different parameters that are important to display the effect of climate change on forests using Mann-Kendall statistical test for trend analysis. At the end of this study, it has been observed that there is a real change in climate parameters with an increasing trend in annual mean temperature for September, spring and fall with an increase of 0.077 degree Celsius per year. In addition, a relatedly positive increasing trend in annual mean precipitation have been found around Cerle Forest Planning Unit. It has also been clearly observed that there is a real change in forest structure and composition due to land use land cover change and mainly due to the change in landscape pattern from 1965 to 2010. There are also some changes that can be related to the change in natural or ecological conditions like the development of new and abundant forest species well adapted to the natural conditions such as Crimean pine. The migration of trees from one area with unfavourable conditions to another where the conditions are more appropriated for the establishment, the increasing forest fire frequency and salvage cutting activities in Cerle forest planning unit are some related impacts of climate change on forest. However, this statement is limited because it is not easy to establish the change in forest structure and composition due to natural climate change and due to human-made activities. As conclusion, we can state that human intervention in the forest can help to manage sustainably the effects of climate change on forest ecosystems. As recommendation, specific studies must be carried out in different forest ecosystems in order to observe the different impacts of climate change on forests and the possible specific management activities that can be scheduled to reduce the future impacts of climate change on forests around the world.

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