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SPATIO-TEMPORAL CHANGE OF ANATOLIAN CHESTNUT (*Castanea sativa* Mill.) FORESTS UNDER CLIMATE CHANGE, NORTHEASTERN TURKEY

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Abstract

In this study, the effects of possible climate change in a 36-year period (1980-2015) in different sites on the spatial-temporal distribution of chestnut forests in the Eastern Black Sea region of Turkey were investigated. For this purpose, Giresun, Trabzon-Arsin and Artvin-Hopa in the Eastern Black Sea region were selected as the study areas. The Mann-Kendall and Sen's trend analyses were applied to the annual temperatures (average, maximum and minimum) and annual total precipitations. Two sets of forestry management plans, the first published in 1984-1987 and the second in 2009-2011, were used to extract forest stand maps and to determine change in chestnut distribution. In the time elapsed, chestnut forests increased from 3.58% to 10.05% in Giresun, from 1.28% to 5.31% in Trabzon-Arsin and from 5.44% to 7.53% in Artvin-Hopa. There were increases in chestnut forest areas along with the increasing temperatures. In the city centers, downward shifts occurred in Giresun (-46 m), Trabzon-Arsin (-185 m) and Artvin-Hopa (-168 m) in the minimum altitude against the increasing population. In rural areas, it was determined that there were upward shifts in Giresun (+371 m) and Trabzon-Arsin (+222 m) and downward shifts in Artvin-Hopa (-31 m) in the maximum altitude against the increasing population. Land abandonments and competition between species may have effects on the changes in the area and vertical spread of chestnut forests. However, when the evidences revealed by this study are considered, the changes in temperature and total precipitation in a 30-year period are more likely to affect the spread of chestnut which is a thermophilic species. This study is an exemplary study with respect to carrying out studies on climate change in the region, monitoring chestnut and other species in this regard and developing regional policies for climate change.

Key words: Castanea sativa, Eastern Black Sea, GIS, precipitation, temperature

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1. Introduction

Climate change, which affects ecosystems and living organisms in them (Walther et al., 2002), at the species level involves geographic displacement in altitudes and latitudes (Hughes, 2000). In line with the trends observed and temperature increase projections, it can be observed in the form of further extension of the growing season (early onset of spring-a delay in autumn) and also the northward shift of species. The length of the growing season is mainly affected by the temperature increase in autumn and spring (Ainsworth and Long, 2005; Jablonski et al., 2002; Kimball et al., 2002; Norby et al., 2003). Climate warming may change and shift the boundaries of certain species and ecosystems (McArthur, 1972; Peters and Darling, 1985). Recent climate change is usually considered to be the main factor of vegetation shifts. So far, most of the reactions of vegetation attributed to climate warming have been observed on the forest belts and it has been observed that direct anthropogenic effects related to land use changes may also play an important role (Bodin et al., 2013). The changes in land use, which will lead to upward shifts of the slope due to the replacement of trees in abandoned pastures, may have a similar effect as the global climate warming (Rabasa

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et al., 2013). In the Swiss Alps, Gehrig-Fasel et al. (2007) reported that land abandonment was the driving factor in 90% of the upward shifts detected at tree limits and that only a small proportion of upward shift depends on climate warming. As the altitude increases, the plant life in mountainous regions is limited due to the direct or indirect effects of low temperatures, radiation, wind and storm or insufficient water availability (Körner and Larcher, 1988). According to a first-order approach related to the response of vegetation to climate change, species will move upwards to find climate conditions similar to today's conditions in the climate of tomorrow (McArthur, 1972; Peters and Darling, 1985). Therefore, the effect of climate change, which manifests itself in the form of temperature increase today, especially on thermophilic species such as chestnut is likely to be further observed.

Anatolian chestnut is a broad-leaved and multipurpose forest tree which is mostly found in the Mediterranean basin and used in the production of both dried fruits and nuts and wood. This species does not prefer the areas with high late frost risk in spring (Konstantinidis et al., 2008; Oosterbaan, 1998). Chestnut, which is a thermophilic species, most frequently blooms in July. The fruits begin to mature from September to October or November. Chestnut is a wind pollinated (*Anemophilous*) species, however, it is also sometimes pollinated by insects. Results indicate that chestnut most probably survived the cold periods of the last glaciation in Europe, with other thermophilous European tree taxa such as Oak. In fact, niches with a suitable microclimate may be present on the edge of mountainous regions despite a generally dry and cool climate (Krebs et al., 2004; Krebs et al., 2019; Roces-Díaz et al., 2018). In these micro-environmental areas, small pockets where thermophilic tree species are present can survive (Willis et al., 2000).

It is assumed that chestnut was spread from Anatolia to Italy, then to Europe and to the North and to the West. Today's European populations originated from the eastern region of Turkey (Zohary and Hopf, 1988). Furthermore, the region in the west of Turkey is considered to be the area where chestnut is cultivated (Oosterbaan, 1998; Pigliucci et al., 1990; Seemann et al., 2001; Villani et al., 1999). In Turkey, the current distribution range of the species extends from Eastern Black Sea to the Mediterranean region. There are striking climatic differences between these two main areas, especially in precipitation. Chestnut was an important component of tertiary hardwood forests where average annual temperatures varied between 10 and 15ºC and average annual precipitation ranged between 500 and 2500 mm. The distribution of the genus *Castanea* underwent many changes in response to the geographical and climate changes of the northern hemisphere during the Tertiary period (Krebs et al., 2004).

The aim of this study was to investigate the effects of climate change on the spatial-temporal change of natural chestnut forests in a 36-year period (1980-2015) in some sites selected in the Eastern Black Sea region, which has an important place in the spread and emplacement of chestnut in Europe. For this purpose, sample areas were selected from three different sites (Giresun, Trabzon-Arsin, Artvin-Hopa) which are under the sea effect in the Eastern Black Sea region. In the climate change analysis, Mann-Kendall trend analysis was applied to average annual variables (maximum temperature, minimum temperature, average temperature, and total precipitation) of Giresun, Trabzon and Hopa meteorological stations. Furthermore, the temporal change of forest areas dominated by chestnut of two planning periods (1987-2011 for Giresun, 1984-2009 for Trabzon, 1984-2010 for Hopa) in the research area was determined by GIS.

In the study was based on natural chestnut forests in the Eastern Black Sea region. The Black Sea, Marmara, and Aegean regions are chestnut growing areas in Turkey. Many chestnut cultivars have been grown in Marmara region for centuries. In the Aegean region, grafted chestnuts are preferred (Serdar et al., 2014). On the other hand, in Turkey, private afforestation practices started in 1986. With permits issued by the General Directorate of Forest, pure and mixed chestnut private plantations had been established on 2500 ha. of land in western Turkey (Aegean and Marmara regions) until 2013 (GDF, 2013).

2. Material and methods

2.1. Study area

The study area is located between 38°14'-41°34' E longitudes and 41°28'- 40°30' N latitudes in the Eastern Black Sea region of Turkey (Fig. 1). The region has different sites. The site sub-regions formed by Kantarci (1995) for the Eastern Black Sea region were considered in the determination of research areas. These site sub-regions are Canik-Giresun Mountains, Trabzon Mountains and Rize-Kaçkar Mountains.

The areas within the boundaries of forest sub-district directorates where Giresun, Trabzon-Arsin and Artvin-Hopa settlements are located, representing different sites, were selected as research areas. Research areas are located in the Euro-Siberian floristic region from among 3 floristic regions determined for Turkey. Euro-Siberian region is represented by Auxin province in Turkey. A leafy forest formation mixed with coniferous species at higher sections is spread in the Auxin province. In these vegetation areas, there is usually no significant summer drought due to summer precipitation. The amount of annual precipitation exceeds 1000 mm in many places (Davis, 1971). The results of the research areas obtained as a result of the Thornthwaite climate analysis are presented in Table 1. The data of Giresun, Trabzon and Hopa meteorological stations were used in climate analysis (TSMS, 2016).

Fig. 1. Location of research area

Table 1. Spatial features of meteorological stations

Features	*Meteorological Stations*		
	Giresun	*Trabzon*	*Hopa*
Spatial			
Altitude (m)	38.0	25.0	33.0
Latitude	40°55'	40°59'	41°24'
Climate			
Average temperature (°C)	14.7	14.8	14.5
Total precipitation (mm)	1297.6	840.9	2293.5
Actual evapotranspiration (mm)	734.7	585.8	774.3
Water deficit (mm)	38.2	199.0	0.0
Excess water (mm)	562.9	255.0	1519.2

According to climate analyses, Giresun has a "humid, moderate temperature (mesothermal) climate close to the oceanic climate with little or no water deficient", Trabzon has a "semi-humid, moderate temperature (mesothermal) climate close to the oceanic climate with moderate water deficient in summer", and Hopa has a "very humid, moderate temperature (mesothermal) climate close to the oceanic climate with little or no water deficient".

Table 2. Temporal change of population in provinces and districts

	Centrum Population			*Rural _Population*		
Provinces/ Districts	1990	2000	2010	1990	2000	2010
Giresun-Centrum	67604	83636	96948	34690	28865	22729
Trabzon-Arsin	6705	6850	10326	26727	22825	17259
Artvin-Hopa	11507	15445	17433	19355	17139	14583

The population of the centers and villages of Giresun, Trabzon-Arsin and Artvin-Hopa between the years 1990 and 2010 was obtained from the Turkish Statistical Institute (TSI, 2018). The population of city centers increased in Giresun (43.4%), Trabzon-Arsin (54.0%) and Artvin-Hopa (51.5%). The village population decreased in Giresun (34.5%), Trabzon-Arsin (35.4%) and Artvin-Hopa (24.7%) (Table 2).

2.2. Data, trend, and climate analysis

The data of the years between 1980 - 2015 belonging to Giresun, Trabzon and Hopa meteorological stations in the Eastern Black Sea region were used (TSMS, 2016). In the study, Mann-Kendall and Sen's trend analyses were applied to the annual temperature (average, maximum and minimum) and annual total precipitation (1980-2015). The rapid increase in global average temperature after 1980 was effective in taking this period in trend analyses (Blunden and Arndt, 2012; WMO, 2012).

2.2.1. Mann Kendall trend analysis

This test is a commonly used method in determining the trends of hydro-meteorological time series (Yue et al., 2002; Zhang et al., 2001). The S statistics of the Mann-Kendall test, which is applied to the data in which seasonality is eliminated as in Sen's T test, is calculated by the following (Eq. 1) expression. The sign of the (xj-xk) value in this equation is found by the expression (Eq. 2).

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \tag{1}$$

$$\operatorname{sgn}(x_j - x_k) = \begin{cases} +1 \ if & (x_j - x_k) > 0 \\ 0 \ \ if & (x_j - x_k) = 0 \\ -1 \ if & (x_j - x_k) < 0 \end{cases} \tag{2}$$

Asymptotically, the variance of the S test statistics with a normal distribution and a mean of zero are calculated by the Eq. 3,

$$Var(S) = \frac{[n(n-1)(2n+5)]}{18} \tag{3}$$

If there are similar values (link state) in the time series, the variance is calculated by the Eq. 4,

$$Var\ (S) = \frac{[n(n-1)(2n+5) - \sum_t t(t-1)(2t+5)]}{18} \quad (4)$$

Whether the Mann Kendall test, the variance of which is determined, is significant is determined by the calculation of the standard normal variable z with the following equation and its comparison with the critical z value (Eq. 5).

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if\ S < 0 \end{cases} \quad (5)$$

If the selected α is at the |z| ≤ zα significance level, hypothesis Ho is accepted, otherwise it is rejected. There is an increasing trend if the value S calculated is positive and there is a decreasing trend if it is negative. This method is useful since it allows the presence of missing data and does not require data to be complied with a specific distribution (Yu et al., 1993). Trend analyses were performed using MAKESENS 1.0 (Salmi et al., 2002).

2.2.2. Sen's trend analysis

If there is a rectilinear trend in a time series, then the actual inclination (change in unit time) can be estimated using a simple nonparametric procedure developed by Sen (1968). The inclination estimates of the data pair N are calculated first (Eq. 6),

$$\beta = medyan\left[Q_i \frac{x_j - x_k}{j-k}\right] \quad (6)$$

Here, x is the data, it is j>k and i=1…. N. If N is an odd number, it is calculated as $Q_{med} = Q_{(N+1)/2}$. If N is an even number, the median is calculated by the $Q_{med}=1/2(Q_{N/2}+Q_{(N+2)/2})$ equation. The Sen Method allows statistical determination of the calculated inclination from zero. The upper and lower confidence limits are determined in the rank correlation, and the confidence interval and the inclination values corresponding to these rank limits are determined (Partal and Kahya, 2006).

2.2.3. Spatio-temporal change

The stand maps in ArcGIS database of the management plans of Giresun-Central (GDF, 1987; GDF, 2011), Trabzon-Arsin (GDF, 1984a; GDF, 2009) and Artvin-Hopa (GDF, 1984b; GDF, 2010) Forest sub-district Directorates were used as sources of spatial data for assessing changes in the distribution range of the species. The temporal change of chestnut forests of two planning periods (1987-2011 for Giresun, 1984-2009 for Trabzon, 1984-2010 for Hopa) was determined by GIS and transition matrix. The transition matrix is the cross tabulation of the two views, that each LULC type will change to every other type. The transition areas matrix saves the number of pixels that are anticipated to change over the specified of time (Mondal et al., 2019). The stands dominated by chestnut species were taken into account in temporal change.

A systematic grid of points (20x20 m) was generated within polygons representing chestnut forests. The altitude of the points was obtained using SRTM data with a resolution of 30 m (USGS, 2013). For interpolating altitude and assign an elevation value to every point were used nearest neighbor method.

3. Results and discussion

Chestnut species is pure or dominant in approximately 90% of chestnut forests. Chestnut usually grows with other thermophilic broad-leaved species such as oriental beech, hornbeam, black alder, elm, maple and oak (Nakhutsrishvili, 2013). Increased temperatures and thus extended vegetation period are expected to affect the spread of the chestnut, which is a thermophilic species. However, this expectation may exhibit different behaviors especially in the sites that are under the influence of temperate climate. According to Thornthwaite climate analyses, it was determined that Giresun was a "humid" site, Trabzon was a "semi-humid" site and Hopa was a "very humid" site.

Ecosystem may react to increasing temperatures as a result of climate change. As ecosystems respond to climate change, both positive (that will increase the warming trend) and negative feedback (that will mitigate the warming trend) may emerge (Bonan et al., 1992; Chapin et al., 2000; White et al., 2000). The response of certain species and ecosystems to climate warming may also lead to the change in the boundaries of the relevant ecosystem (Lloyd and Fastie, 2002). There is no doubt that ongoing climate change is largely influential in the spread of species and thus the rearrangement of plant communities (Sheldon et al., 2011; Urban et al., 2012). IPCC reported that global temperatures recorded since 1850 were not higher than the last 30 years and that the period between 1983 and 2012 was probably the hottest 30-year period of the last 1.400 years in the Northern Hemisphere (IPCC Report, 2013). In the study, the period (1980-2015) studied corresponds to the period during which there were significant increases in average temperatures on a global basis.

Average annual maximum temperature (MxTemp), minimum temperature (MnTemp), average temperature (AvTemp) and total precipitation (PTotal) are important climate variables in the determination of climate change. With regards to Mann-Kendall trend analysis applied to the annual values of climate variables in the 1980-2015 period, important and significant increases were obtained (Table 3, Figs. 2-4). Significant increases were determined in MxTemp ($p<0.01$), MnTemp ($p<0.001$) and AvTemp ($p<0.001$) variables in Giresun (Table 3). No important and significant relationship was found for PTotal. According to Sen's trend analysis, 1.43°C increase in MxTemp, 1.61°C increase in MnTemp, 1.71°C increase in AvTemp were observed (Fig. 2). Significant increases were determined in MxTemp ($p<0.01$), MnTemp ($p<0.001$) and AvTemp ($p<0.001$) variables in Trabzon (Table 3). No important and significant relationship was found for PTotal. According to Sen's trend analysis, 1.77 °C increase in MxTemp, 1.44 °C increase in MnTemp and 1.61 °C increase in AvTemp were observed (Fig. 3). Significant increases were determined in MxTemp ($p<0.01$), MnTemp ($p<0.05$), AvTemp ($p<0.05$), AvTempSp ($p<0.1$) and PTotal ($p<0.1$) variables in Hopa (Table 3). According to Sen's trend analysis, 1.58 °C increase in MxTemp, 1.36 °C increase in MnTemp, 1.26 °C increase in AvTemp and 302.94 mm increase in PTotal were observed (Fig. 4).

In the study, significant increases were obtained in annual temperature variables (MxTemp, MnTemp, AvTemp) in all research areas, according to Mann Kendall trend analysis. In the analyses, it was determined that highest increases and lowest increases in temperature variables (MnTemp, AvTemp) except for MxTemp variable (highest in Trabzon) were in Giresun and Artvin-Hopa, respectively. Climate and climate variables act as a control mechanism in the geographical spread of plants. Specifically, plant species may be expected to be redistributed in response to climate change.

The variables AvTemp, MxTemp and MnTemp represent the average and extreme values of temperature in a certain region, and these variables are highly associated with other known climate controls on tree distribution, such as the length of the growing season (McKenney et al., 2007a; McKenney et al., 2007b). According to projection (for the year 2100), it is suggested that an increase of 3 °C in average annual temperatures will cause the distribution of species to shift to 300–400 km north or 500 m higher altitudes in temperate regions (Hughes, 2000). The migration of species in response to warming manifests itself in several ways. In the simplest cases, species can show upward movement of the lower and upper range limits. Alternatively, many species may be inadequate to respond to climate changes through rapid migration due to limited distribution. In their study on 134 tree species in the USA, Iverson et al. (2008) reported that more than a quarter of these species could experience a shift of 400 km to the north depending on the climate change scenario resulting from the doubling of existing atmospheric carbon dioxide (CO_2) levels.

Table 3. Trend statistics of climate variables

Climate variables	***Giresun***				***Trabzon***				***Hopa***			
	Z	*Sig.*	*Q*	*β*	*Z*	*Sig.*	*Q*	*β*	*Z*	*Sig.*	*Q*	*B*
MxTemp	2.90	**	0.04	15.9	3.09	**	0.05	15.8	2.72	**	0.05	17.1
MnTemp	4.14	***	0.05	9.9	3.91	***	0.04	9.8	2.26	*	0.04	9.5
AvTemp	4.21	***	0.05	12.3	4.02	***	0.05	12.6	2.15	*	0.04	13.1
PTotal	1.51	Ns	3.01	1138.7	1.13	ns	2.87	699.9	1.72	+	8.66	1973.9

*ns: non-significant, +: 0.1, *: 0.05, **: 0.01, ***: 0.001, Z: The presence of a statistically significant trend is evaluated using the Z value (Mann Kendall method), Q: Slope (Sen's Method), β: Constant (Sen's Method)*

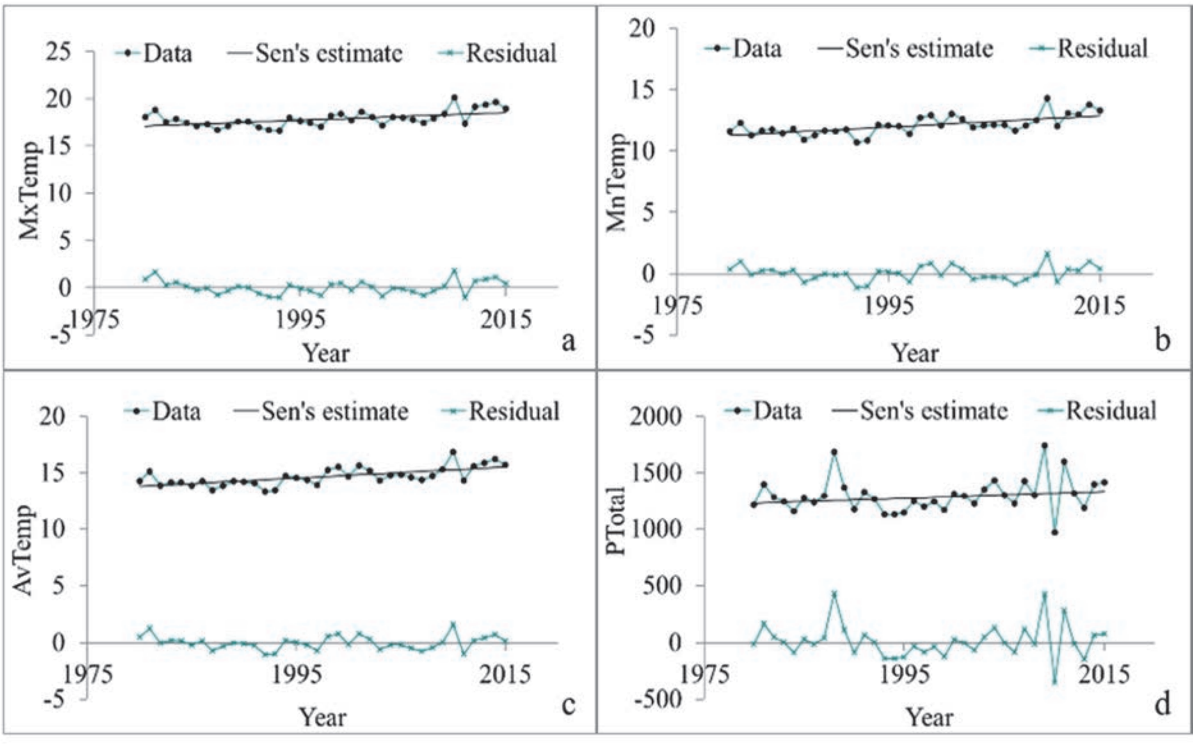

Fig. 2. Trends of climate data for Giresun: (a) MxTemp, (b) MnTemp, (c) AvTemp, (d) PTotal

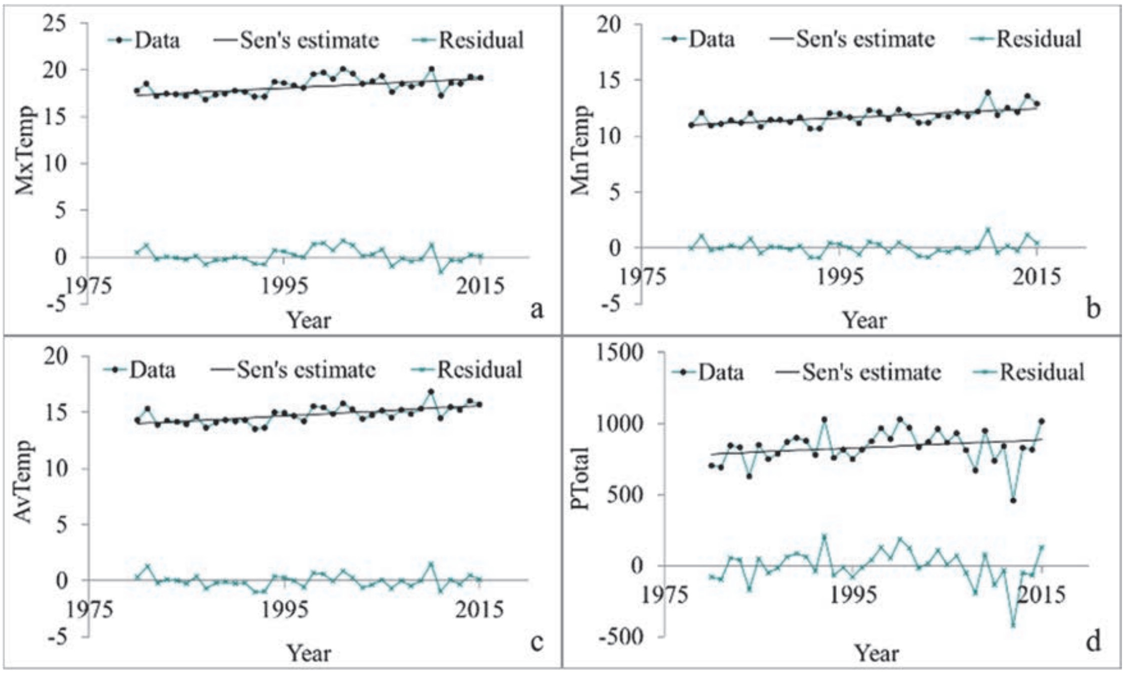

Fig. 3. Trends of climate data for Trabzon: (a) MxTemp, (b) MnTemp, (c) AvTemp, (d) PTotal

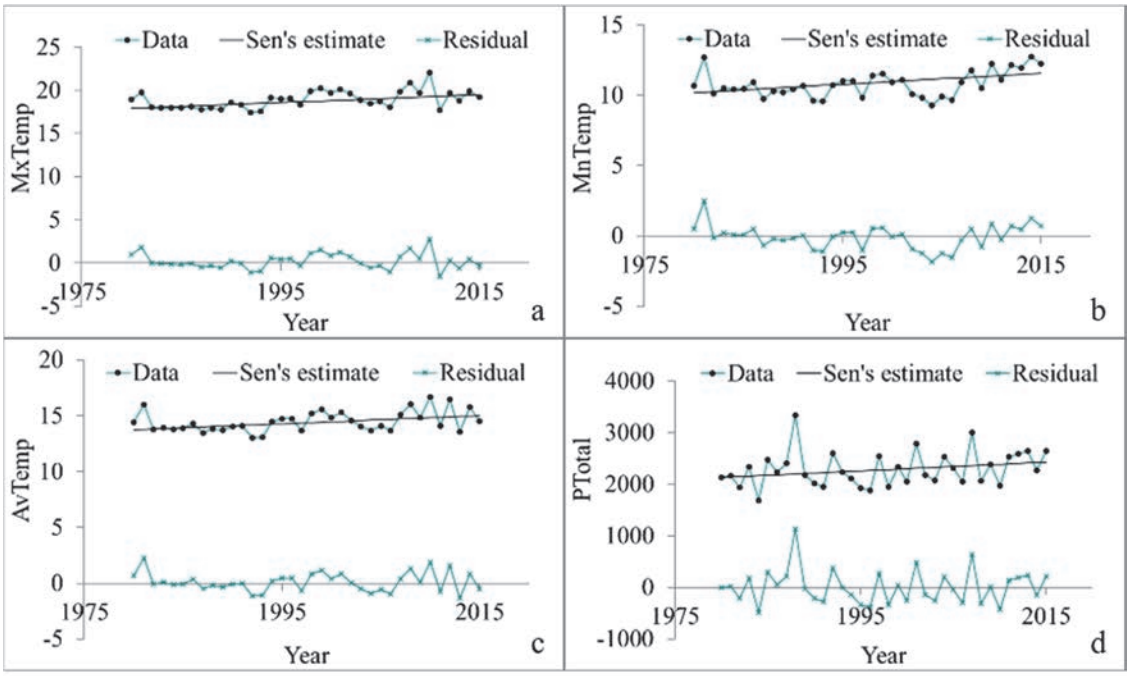

Fig. 4. Trends of climate data for Hopa: (a) MxTemp, (b) MnTemp, (c) AvTemp, (d) PTotal

3.1. Spatio-temporal change

In a 36-year period, chestnut forests increased from 3.58% to 10.05% in Giresun, from 1.28% to 5.31% in Trabzon-Arsin and from 5.44% to 7.53% in Artvin-Hopa (Table 4).

The highest increase (314.84%) was in Trabzon-Arsin while the lowest increase was (38.42%) in Artvin-Hopa. spatio-temporal change is presented in Fig. 5. In the time elapsed, the area that remained unchanged as chestnut forest in both forestry management plans looks quite small when compared to the area of new chestnut forests resulting from the conversion or colonization of other land cover types. In fact in Giresun we found 623.7 ha (2.57%) of pre-existing chestnut forests and 1817.1 ha (7.48%) that were recently colonized by this tree species, while in Trabzon-Arsin and Artvin-Hopa there is respectively 378.3 ha (0.68%) and 192.7 ha (1.47%) of pre-existing chestnut forests against 2586.0 ha (4.63%) and 792.2 ha (6.06%) of new chestnut forests. In fact, this situation indicating that chestnut forests in research areas are in a constant change may result from different ecological and social factors.

In Giresun, while 54.28% of the area that turned into chestnut forests originates from Open spaces, 40.11% and 5.6% of them originate from Degraded Forests and Other Species, respectively. In Trabzon-Arsin, the spatial conversion to chestnut was in the form of Degraded Forest (43.20%), Open Space (34.56%), and Other species sites (22.24%), respectively. In Artvin-Hopa, maximum conversion to chestnut was from Other Species sites by 50.82% and minimum conversion was from Open spaces sites by 22.28%.

In this research area, the area converted from Degraded Forests into a chestnut forest is 26.90%. Chestnut forest areas that developed with the change of Degraded Forest and Other Species sites were 45.72% in Giresun, 65.44% in Trabzon-Arsin and 77.72% in Artvin-Hopa (Table 4). In general, the change in climate mostly affects the vegetation (Hobbs and Humphries, 1995; White, 1979; White et al., 2005). Degraded Forest and Other Species areas are the forest areas where chestnut and other species live together. Biological species competition is likely to be present especially in Other Species and Degraded Forest areas. According to these areas that turned into chestnut forests, the possible species competition is maximum in Artvin-Hopa and minimum in Giresun. The ways of adaptation against the changing environmental conditions require the gradual change of currently dominant species by more thermophilic species. The observations on the European Alps (Grabherr et al., 1994; Keller et al., 2000) indicate that some plants responded to warming in this way in the 20th century (Beniston, 2003). On the other hand, this is not the case in Open Space (agriculture, grassland, etc.) areas. It may be in the form of the emplacement of chestnut species in these areas with the abandonment and non-use of Open Space areas. This can also be explained by the presence of possible niches with a suitable microclimate in proximity to mountainous regions despite a generally cool climate (Krebs et al., 2004). In these micro-climatic areas, sheltered small pockets where thermophilic tree species are present can survive (Willis et al., 2000) and increasing temperatures along with climate change may promote the re-spread of chestnut species. Open Space areas which turned into chestnut forest are 54.28% in Giresun, 34.56% in Trabzon-Arsin and 22.28% in Artvin-Hopa. Accordingly, they are maximum in Giresun and minimum in Artvin-Hopa.

The relationships between the population change of centers and villages of research areas (%) and the altitude (min. and max.) change of chestnut forests (m) are presented below to see the effect of social pressure (Figs. 6-7). The city centers of Giresun, Trabzon-Arsin and Artvin-Hopa are on the Black Sea coast and at the sea level. For this reason, the change in minimum altitude was taken against the change in city population, and the change in maximum altitude was taken against the change in village population. The population of the city center increased in Giresun (43.4%), Trabzon-Arsin (54.0%) and Artvin-Hopa (51.5%), and rural population decreased in Giresun (34.5%), Trabzon-Arsin (35.4%) and Artvin-Hopa (24.7%) (Table 2). In the change in the minimum altitude against the increasing population in the city center in research areas, downward shifts took place in Giresun (-46 m, -1.84 m/year), Trabzon-Arsin (-185 m, -7.12 m/year) and Artvin-Hopa (-168 m, -6.22 m/year) (Fig. 6). Accordingly, population in the city center increased in the period investigated, however, the population in rural areas decreased.

Despite the increasing social pressure in city centers, chestnut forests could increase their downward spread in the vertical direction. In maximum altitude against decreasing population in rural areas in research areas, upward shift was determined in Giresun (+371 m, 14.84 m/year) and Trabzon-Arsin (+222 m, 8.54 m/year) while downward shift was determined in Artvin-Hopa (-31 m, -1.15 m/year). Although chestnut forests increased their upward spread in the vertical direction in Giresun and Trabzon-Arsin along with the decreasing social pressure in rural areas, they decreased their upward spread in Artvin-Hopa (Fig. 7). Along with the decrease in population, reduction in social pressure (Kadıoğulları et al., 2008; Perz, 2007; Perz and Skole, 2003; Rudel et al., 2005,) and forest management studies may contribute to the increase in forest areas. Furthermore, vertical upward and downward shifts may occur by the reduction in social pressure due to climate change and land abandonment. Because rural residents in Turkey abandoned their lands and migrated to city centers since the 1980s. Human impact and grazing pressure on forests decreased, and in particular, this situation resulted in the expansion of forested areas in marginal regions (Açıkgöz Harşit et al., 2018).

Table 4. The transition matrix of LULC change

Second Plan	***First Plan (Giresun: 1987, Trabzon-Arsin: 1984, Artvin-Hopa: 1984)***									
	Open Space		***Degraded Forest***		***Chestnut***		***Other Species***		***Total***	
	Ha	***%***	***Ha***	***%***	***Ha***	***%***	***Ha***	***%***	***Ha***	***%***
Giresun (2011)										
Chestnut	987.2	4.06	727.5	3.00	623.7	2.57	102.4	0.42	2440.8	10.05
Total	20780.9	85.56	2412.4	9.93	869.0	3.58	225.9	0.93	24288.2	100.00
Trabzon-Arsin (2009)										
Chestnut	894.6	1.60	1116.3	2.00	378.3	0.68	575.1	1.03	2964.3	5.31
Total	39185.0	70.30	10915.1	19.58	713.7	1.28	4927.5	8.84	55741.3	100.00
Artvin-Hopa (2010)										
Chestnut	176.7	1.35	212.4	1.63	192.7	1.47	403.1	3.08	984.9	7.53
Total	5800.7	44.37	1924.5	14.72	711.1	5.44	4637.2	35.47	13073.5	100.00

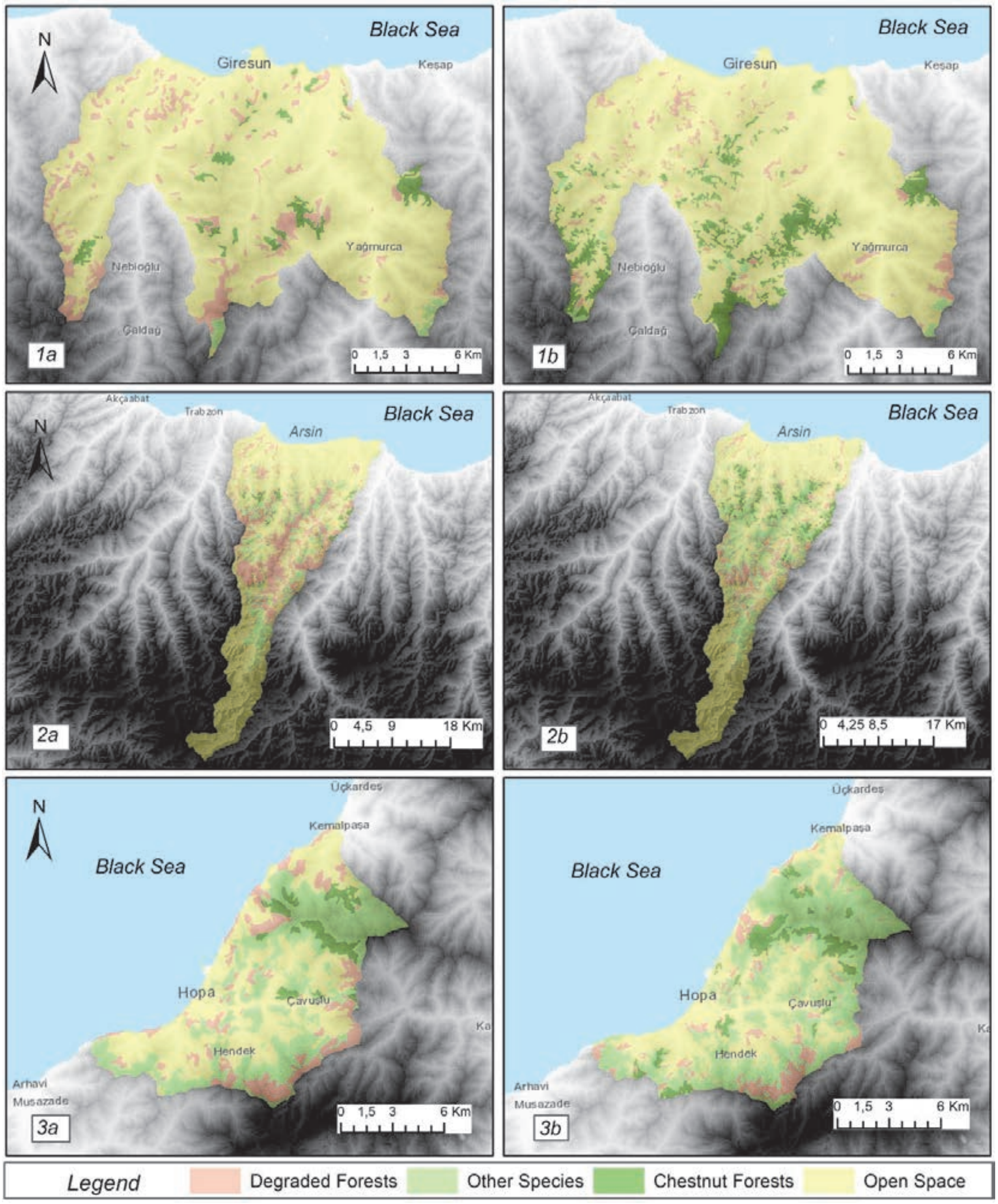

Fig. 5. Spatio-temporal change of land use/cover map (1a-1b: Giresun 1987-2011, 2a-2b: Trabzon-Arsin 1984-2009, 3a-3b: Artvin-Hopa 1984-2010)

However, the fact that chestnut forests increased their downward spread in the vertical direction despite the increase in the population of the city center in the study and also decreased their vertical upward spread in Artvin-Hopa despite the decreasing social pressure is contrary to this conclusion. Here, it should be noted that the effects of climate and climate change on chestnut forests were not neglected as well as the increasing/decreasing social pressure.

The results of altitude changes of chestnut forests for two planning periods are presented in Table 5. When comparing the two sets of forestry management plans, the first published in 1984-1987 and the second in 2009-2011. At average altitude in vertical distribution, 75 m (+3 m/year) upward shift in Giresun and 17 m (+0.65 m/year) upward shift in Trabzon-Arsin were determined while 144 m (+5.33 m/year) downward shift in Artvin-Hopa was determined (Table 5, Fig. 8). In their analysis, Parmesan and Yohe (2003) determined that 20% of the species they studied shifted altitude ranges towards lower altitudes and/or southern latitudes. Similarly, Lenoir et al. (2010) reported that 65% of the species they studied increased their average distribution, 10% of them had no change, and the average distributions of 25% of them showed a decreasing trend. They showed that most of the tree species in the Tropical and Mountain changed their average distributions in the study period and that the average migration rate was 2.5-3.5 meters per year in the vertical direction (Feeley et al., 2011).

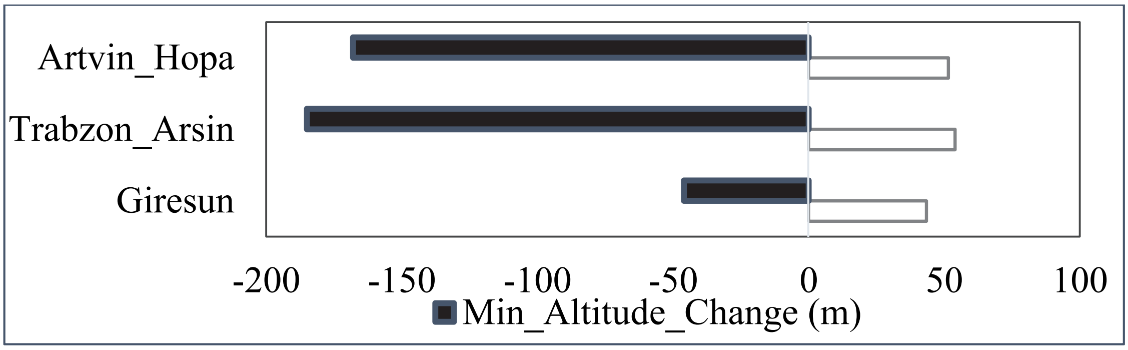

Fig. 6. Relationship between central population change and minimum altitude change

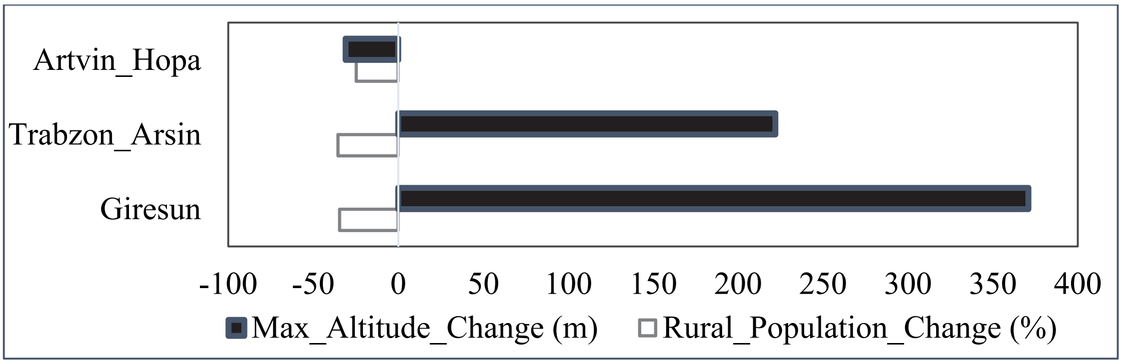

Fig. 7. Relationship between village population change and maximum altitude change

Table 5. Spatial-temporal change in altitude of chestnut areas

			95% Confidence Interval			
Sites	***Mean***	***SD***	***Lower Bound***	***Upper Bound***	***Min.***	***Max.***
Giresun						
Chestnut 1987	588	186.7	468	702	128	849
Chestnut 2011	663	222.1	500	793	82	1220
Trabzon-Arsin						
Chestnut 1984	701	215.3	617	838	290	1132
Chestnut 2009	718	234.6	571	886	105	1354
Artvin-Hopa						
Chestnut 1984	593	167.8	485	696	176	1012
Chestnut 2010	449	195.4	335	594	8	981

In the last twenty years, it has been stated that vegetation in the mountains was gradually shifted since the climate was warmer (Kullman, 2008). Kullman (2008) emphasized that thermophilic tree-type seedlings, such as european oak, scotch elm, and norway maple, grow in the southern Scands region where the existing study field is located, and that climate warming even in a short period of 10-15 years could provide the occurrence of thermophilic species found in mountainous regions. In the study on climate change in the southeastern France (0.5 ºC increase in 10 years), Bodin et al. (2013) determined that 175 species that responded to altitude were shifted by 17.9 m on average. In the study, it was determined that the species that were optimum below an average of less than 1300 m showed a greater shift (+35.4 m) compared to the optimum ones over 1300 m. Vitasse et al. (2012) determined an upward shift in the vertical spread of *Abies alba* which was consistent with current warming in the Alps. In the study, the relationship between average altitude change (%) of chestnut forests and AvTemp change (%) according to research areas is presented in Fig. 9. While the average altitude increase was maximum in Giresun where increase in AvTemp was maximum, there was a decrease in average altitude in Artvin-Hopa where increase in AvTemp was minimum (Fig. 9).

In the time elapsed, AvTemp increased by 1.71ºC in Giresun, 1.61 ºC in Trabzon-Arsin and 1.26 ºC in Artvin-Hopa. Although the increase in AvTemp was lower in Artvin-Hopa compared to Trabzon-Arsin and Giresun, an upward shift would be expected to in average altitude, even if just a little. Indeed, the areas that remained as chestnut forest in both planning periods decreased from 3.58% to 2.57% (28.2%) in Giresun, from 1.28% to 0.68% (46.9%) in Trabzon-Arsin and from 5.44% to 1.47% (73.0%) in Artvin-Hopa.

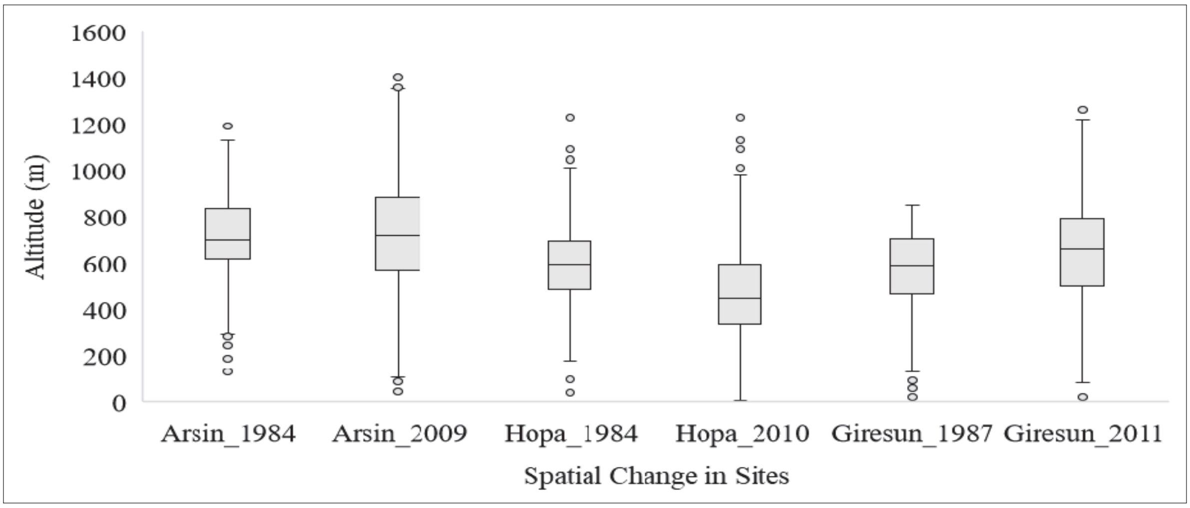

Fig. 8. Average altitude changes of chestnut forests for two planning periods

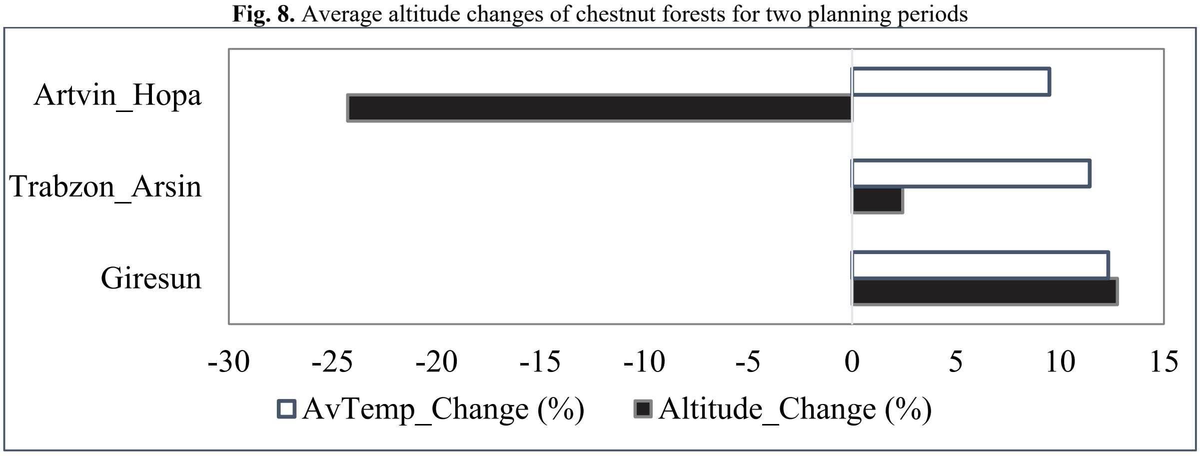

Fig. 9. Relationship between AvTemp and altitude

In other words, during the two planning periods in Artvin-Hopa, it is seen that even the areas that previously remained as chestnut forests were decreased/lost by 73.0% in the next plan. It is thought that this situation may be mostly caused by the differences in the sites of the research areas in the Eastern Black Sea Region which is under the influence of temperate climate. With respect to total amount of precipitation, the amount of PTotal was 840.9 mm in Trabzon, 1297.6 in Giresun and 2293.5 mm in Artvin-Hopa. Artvin-Hopa has quite higher amount of precipitation compared to Giresun and Trabzon. The flowers of chestnut species develop at the end of June-July and can be pollinated mainly by the winds (more normal in dry weather during the flowering) or sometimes by insects (Conedera et al., 2016). Almost all year is rainy in Artvin-Hopa. Precipitation during the pollination and flowering periods (July-August) may have limited the spread of chestnut species. In the trend analysis, a statistically important and significant increase was determined in Artvin-Hopa for the PTotal variable. In a 36-year period, the PTotal variable increased by 302.94 mm in Artvin-Hopa. No important and significant relationship was found for this variable in Trabzon and Giresun. Furthermore, the fact that the PTotal amount of Artvin-Hopa is 2293.5 mm may lead to root rot disease. The first record of the presence of Phytophthora in chestnut trees in Turkey belongs to Erdem (1951). In his study on chestnut tree deaths, Erdem (1951) stated that the local people said that tree deaths began 40 years ago. Indeed, root rot (Phytophthora) disease was mostly detected in the areas above 1000 mm in chestnut forests.

These conditions increase the possibility of the formation of suitable soil moisture levels and infection in root systems for the production and dissemination of zoospores (Erwin and Ribeiro, 1996). High precipitation (above 1000 mm/year) has been reported to be a useful index in the classification of the regions under disease risk. Furthermore, it has been stated that seasonal or local heavy precipitation may increase both Phytophthora proliferation and sensitivity to Phytophthora infections due to storms (Davison and Tay, 1987; Shearer and Tippett, 1989).

4. Conclusions

In the 30-year (1980 - 2015) period elapsed, there was an increase in temperature variables in research areas. In general, the highest temperature increases occurred in Giresun. The annual total precipitation increased only in Artvin-Hopa (302.94 mm).

According to management plan stand maps, chestnut forest areas increased from 3.58% to 10.05% in Giresun, from 1.28% to 5.31% in Trabzon-Arsin and from 5.44% to 7.53% in Artvin-Hopa during the time periods elapsed. Chestnut forest areas increased in parallel with the increase in temperature variables. Population changes in city centers and rural areas were taken for the population status, which is a criterion in testing the presence of social pressure. For this purpose, the correlations between minimum altitude-city center and maximum altitude-rural population change were evaluated.

In the research areas, downward shifts occurred in Giresun (-46 m), Trabzon-Arsin (-185 m) and Artvin-Hopa (-168 m) in the minimum altitude against the increasing population in the city centers. In rural areas, it was determined that there were upward shifts in Giresun (+371 m) and Trabzon-Arsin (+222 m) and downward shifts in Artvin-Hopa (-31 m) in the maximum altitude against the increasing population. Despite the increase in social pressure in city centers, chestnut continued to spread downward in the study areas. Despite the decrease in social pressure in rural areas, chestnut increased its upward spread in Giresun and Trabzon-Arsin, however, chestnut spread decreased in the vertical direction in Artvin-Hopa.

Land abandonments and competition between species may have effects on the changes in the area and vertical spread of chestnut forest areas in the research area. However, when the evidences revealed by this study are taken into account, the changes in temperature variables and total precipitation in a 30-year time period (increase only in Artvin-Hopa) are more likely to affect the spread of chestnut which is a thermophilic species. There is a need for further research studies that integrate the effects of both natural and anthropogenic forces on the distribution of plant species and promote the interpretation of potential climate change responses within the context of time-oriented and ongoing land-use change.

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