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Investigations of the spatial and climate characteristics of natural pure chestnut (*Castanea sativa* Mill.) forests: A case of Zonguldak Regional Directorate of Forestry

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Abstract: Chestnuts with high economic and socio-cultural value (*Castanea sativa* Mill.) must determine forests' spatial and climatic characteristics to improve them, increase fruit yield, and effectively combat diseases and pests. This study aimed to determine the spatial and climatic attributes of pure chestnut forests spreading within the borders of the Zonguldak Forestry Regional Directorate. A total of six criteria were used for spatial and climatic analyses: total precipitation (mm/year), annual mean temperature (C°), wind speed (m/s), altitude (m), slope (%), and aspect (°). Climate values were calculated as maximum, minimum, and average values, respectively; 1 619.25, 866.95, and 1 024.07 mm/year for total precipitation (mm/year), 13, 6 and 11.76 C° for annual mean temperature (C°), 6.62, 0.22 and 2.46 m/s for wind speed (m/s). The spatial characteristics were calculated as 1 221.68, 33.24, and 300.23 m for the height (m), 32.43%, 7.34%, and 18.63% for the slope (%) and finally, 338.63°, 18.18° and 184.18° for the angle (°), respectively, in terms of maximum, minimum and average values. Bartın Forest Management Directorate (FMD) ranks first with 57.18% of the natural chestnut forests spread the most in the study area, while Zonguldak FMD ranks second with 21.45% and Ulus FMD ranks third with 17.13%. The results obtained from the study based on the location and climate will contribute to the selection of the most suitable place for the new chestnut forest afforestation studies to be established and increase the percentage of success.
Keywords: Natural forests, GIS, Spatial analysis, Pure forests, Ecology

Doğal saf kestane (*Castanea sativa* Mill.) ormanlarının mekansal ve iklimsel özelliklerinin araştırılması: Zonguldak Orman Bölge Müdürlüğü örneği

Özet: Ekonomik ve sosyo-kültürel değeri yüksek olan kestane (*Castanea sativa* Mill.) ormanlarının iyileştirilmesi, meyve veriminin artırılması, hastalık ve zararlılar ile etkin bir şekilde mücadele edilebilmesi açısından, mekânsal ve iklimsel özelliklerinin belirlenmesi önemlidir. Bu çalışmada Zonguldak Orman Bölge Müdürlüğü sınırlarında yayılış gösteren saf kestane ormanlarının mekânsal ve iklimsel özelliklerinin belirlenmesi amaçlanmıştır. Mekânsal ve iklimsel analizler için toplam altı kriter kullanıldı: toplam yağış (mm/yıl), yıllık ortalama sıcaklık (C°), rüzgâr hızı (m/s), yükseklik (m), eğim (%) ve bakı (°). İklim değerleri maksimum, minimum ve ortalama değer olarak sırasıyla; toplam yağış (mm/yıl) için 1 619,25, 866,95 ve 1 024,07 mm/yıl, sıcaklık (C°) için 13, 6 ve 11,76 C°, rüzgâr hızı (m/s) için ise 6,62, 0,22 ve 2,46 m/s olarak hesaplandı. Mekânsal özellikler maksimum, minimum ve ortalama değer cinsinden sırasıyla; yükseklik (m) için 1 221,68, 33,24 ve 300,23 m, eğim (%) için 32,43%, 7,34% ve 18,63% ve son olarak bakı (°) için 338,63°, 18,18° ve 184,18° olarak hesaplandı. Çalışma alanında doğal kestane ormanları en fazla yayılışını 57,18% ile Bartın Orman İşletme Müdürlüğü'nde (OİM), Zonguldak OİM %21,45 ile ikinci ve 17,13% ile Ulus OİM üçüncü sırada yer almıştır. Çalışmadan elde edilen mekâna ve iklime dayalı sonuçlar yeni tesis edilecek kestane ormanı ağaçlandırma çalışmalarında en uygun yerin seçilmesine ve başarı yüzdesinin arttırılmasına katkı sunabilecektir.
Anahtar kelimeler: Doğal ormanlar, CBS, Mekânsal analiz, Saf ormanlar, Ekoloji

1. Introduction

Forests are one of the natural resources that can produce many products and services that society directly or indirectly benefits from within the natural process. Forests are the insurance for the future of the whole world, primarily because of their role in slowing down and preventing global and environmental disasters, which have made their impact and severity felt in recent years (Kaptan, 2018; Aksoy, 2022). From the beginning of human history to today, forest resources have been utilized primarily to meet the need for wood raw materials. At the same time, the form and intensity of utilization have changed over time. Population growth, rapid industrialization and the need for raw materials are increasing the danger of deforestation in a widespread manner (Allen and Barnes, 1985; Aksoy, 2023). As a requirement of sustainable forest management, it is necessary to reduce the pressure on forests and expand forest areas by encouraging the utilization of forests not only based on wood raw materials but also for other benefits and functions (Swamy et al., 2018; Sabir et al., 2022; Aksoy, 2023).

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From the past to the present, people have continued to utilize forests and forest resources irregularly, considering them as inexhaustible natural resources, and this way of utilization has caused deterioration in the forest ecosystem and destruction of the natural environment. Because of the durability and value of its fruit and wood, this species of chestnut, which continues to exist especially in Anatolia, continues to suffer from deterioration and destruction due to indiscriminate exploitation. The chestnut species, which originated approximately 60 million years ago, have rendered ecological services and catered to human resource requirements for millennia within various forest ecosystems and civilizations spanning three continents, namely Europe, Asia, and North America. (Mellano et al., 2012; Bonsignore et al., 2019; Pollegioni et al., 2020; Clark et al., 2023). In our country, the Anatolian chestnut (Castanea sativa Mill.) is a tree species that naturally spreads from the Bulgarian border to the Black Sea around Northern Anatolia to Western Anatolia and the Marmara region (OGM, 2013).

In particular, unlike the utilization of the wood of the Anatolian chestnut tree (timber, firewood, etc.), it is mainly utilized for fruit production. The Anatolian chestnut (*Castanea sativa* Mill.) differs from other chestnut species (Conedera et al., 2004; Krebs et al., 2022). Edible Anatolian chestnut fruits exhibit a nutritional composition consisting of 5% protein, 5% fat, 40-50% carbohydrates, 40-50% moisture content, and 1.5-2% clay. These fruits are also rich in a variety of vitamins, including vitamins A, B1, B2, B3, B6, and E, and essential minerals such as calcium (Ca), magnesium (Mg), potassium (K), manganese (Mn), phosphorus (P), sodium (Na), and zinc (Zn). Notably, they possess a high vitamin C content as well. Furthermore, these chestnut fruits are subjected to a diverse range of processing methods, creating approximately 150 distinct products. These processed derivatives encompass items such as candied chestnuts, chocolate-coated chestnuts, chestnut cream, and puree, contributing to their value and versatility. (Barreira et al., 2020; De Vasconcelos et al., 2010; Dinis et al., 2012; Serdar et al., 2018). However, over the years, wood and fruit yields have decreased in chestnut areas destroyed by human hands and by pests and diseases. In addition, especially in recent years, the possible effects of climate change on different ecosystems and life communities have also negatively affected chestnut forests (Çobanoğlu et al., 2023). Today, to improve chestnut forests, which have high economic value, to increase wood quality, and fruit yield, and to ensure that diseases and pests can be combated, the growing environment must first be analyzed well (Çepel, 1995; Büber, 2021).

Topography is the first of these factors that constitute the growing environment; it consists of landform (relief), slope, aspect, location, and height above sea level and affects climate and vegetation. The second factor; which is the climate factor, is formed by examining atmospheric events such as wind, precipitation, temperature, humidity, and frost, and revealing the relationships between them. To comprehend the conditions of the growth environment and its occurrences, it is imperative to scrutinize and interpret the constituent elements that constitute the growth environment (Büber, 2021). Distinctive characteristics of growing environment units are important in growing environment classification. Inventory of the growing environment differs for each tree species and is labor and time-intensive. In recent years, with technological and software developments, researchers have focused on research methods that can be an alternative to classical methods.

One of these methods is Geographic Information Systems (GIS). GIS is used effectively in many fields of science. Susam and Oğuz (2006), the importance of slope and aspect in agriculture, Sönmez and Sarı (2004), land use planning, Karabulut and Küçükönder (2008), erosion risk areas, Aksoy (2023), GIS was employed to delineate regions that are conducive to chestnut afforestation.

In this study, the improvement and expansion of pure Anatolian chestnut (*Castanea sativa* Mill.) stands within the borders of the Zonguldak Regional Directorate of Forestry, and the control of diseases and pests It aims to determine the distribution areas and some of the growing environment characteristics of Anatolian chestnuts to help issues such as contributing to the national economy, contributing to the national economy, and making the best use of existing chestnut areas.

2. Material and method

2.1. Material

2.1.1. Study area

The study was conducted within the Zonguldak Regional Directorate of Forestry (RDF) boundaries. The study area is located between 31º 17' 33" and 32º 17' 25" east longitude and 41º 03' 21" and 41º 35' 29" north parallel (Figure 1). Of the forests, 70% are broadleaves, 30% are coniferous and coniferous+ broadleaves trees. The dominant tree species in the forests are mainly beech (*Fagus*), followed by fir (*Abies nordmanniana*), oak (*Quercus L.)*, larch (*Pinus nigra Arnold.)*, hornbeam (*Carpinus*), yellow pine *(Pinus sylvestris)*, chestnut (Castanea sativa), red pine (*Pinus brutia Ten*.), aspen (*Populus tremula*), sycamore (*Platanus orientalis L*.), linden (*Tilia*), coastal pine (*Pinus pinaster*), elm (*Ulmus*), and many other tree and shrub species (OGM, 2021).

2.1.2. Data

In the study, six criteria were used to determine the spatial and climatic characteristics of chestnut areas. These are slope, precipitations, aspect, wind speed, evolution, and temperature. A digital elevation model (DEM) was used to create slope, aspect, and evolution maps of the study area. DEM was obtained from the ALOS-PALSAR satellite image. Wind speed was obtained from wind data obtained from the official website of climatedata. Zonguldak RDF forest cover type map were used to determine the spatial distribution of chestnut areas.

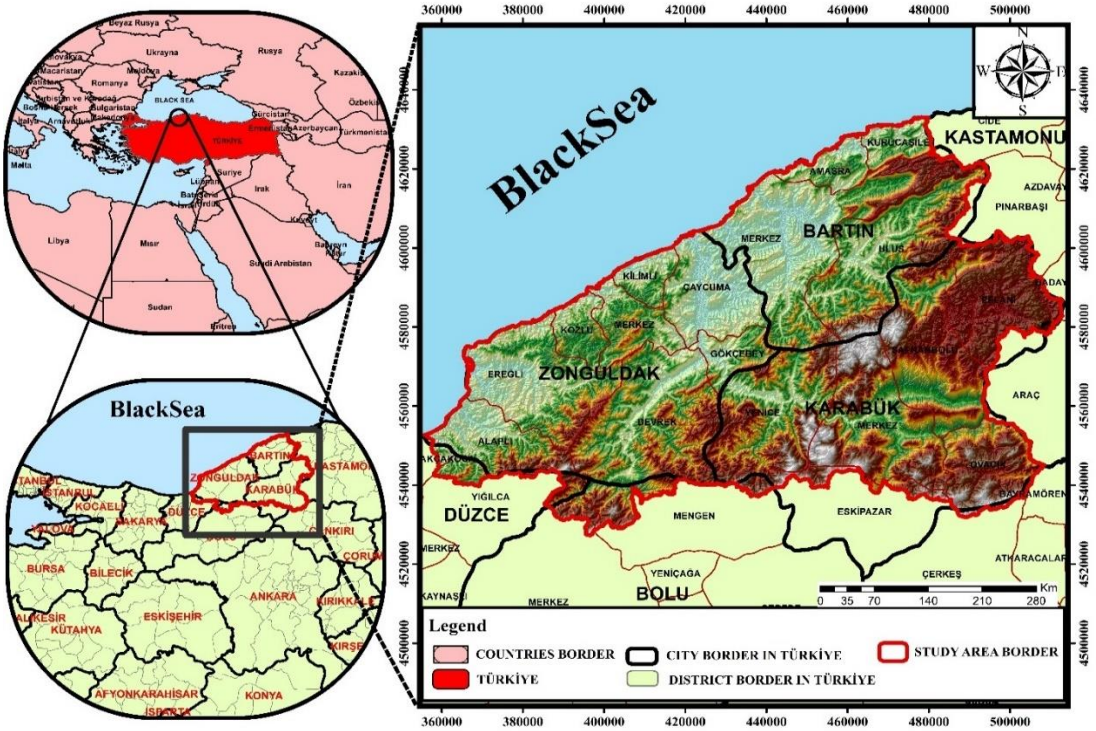

Figure 1. Geographic location of the study area

2.2. Method

In the study, firstly, chestnut distribution areas were extracted using the Zonguldak RDF forest cover type map. Then, areal distribution amounts were determined based on province, district, forest management directorate, and forest planning units. In the second stage, the DEM obtained from the ALOS-PALSAR satellite image was cropped according to the study boundary, and slope, aspect, and elevation maps were created for the study boundary. Analyses were performed in ArcGIS software. DEM and ArcGIS software were used for the precipitation map of the study area. First, the fixed meteorological station data was obtained (Table 1). Then, the number of stations was increased by randomly assigning points in the study area. Based on the elevation in the fixed station data, the total precipitation amount of each station was calculated by the Schreiber formula (Eq.1) for each 100 m elevation interval ± 54 mm up or down according to the elevation interval. Finally, using the precipitation data for each point, a general precipitation map of the study area was created with the IDW tool.

$$P_h = P_0 + (54 \times h) \quad (1)$$

In the formula, P_h is the precipitation (mm) of a point with known elevation, and h is the elevation difference (hectometer) between P_h and P_0. P_0 is the precipitation amount (mm) of the comparison station with known precipitation value and elevation. Temperature and wind speed maps were also created by cropping according to the study area using climate data. Finally, the data related to the criteria obtained overlapped with the chestnut in region the study area, and the criteria values for the areas were obtained and interpreted. The methodology used in the study is shown in Figure 2.

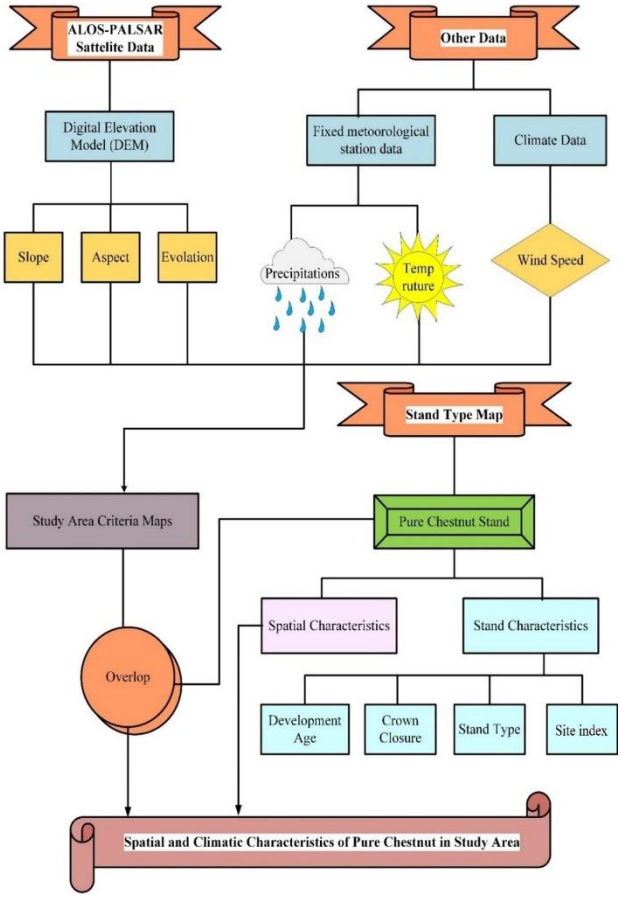

Figure 2. General workflow diagram for the study

Table 1. Meteorological data related to the study area (Climate Data, 2022)

Stable meteorological station data			
Province name	Annual total precipitation (mm)	Annual mean temperature (C°)	Altitude (m)
Zonguldak	915	12.4	9
Bartın	842	13.6	13
Karabük	1 048	10.5	259

3. Result

Firstly, spatial analysis was performed in the analyses. Zonguldak RDF forest stand type map was used for spatial analysis. The study was made based on the management directorate and planning unit. Spatial values of pure chestnut areas in Zonguldak RDF are shown in Table 2. When Table 2 was analyzed, it was determined that the highest spatial distribution was in Bartın Forest Management Directorate (FMD). Afterward, it was determined that it was mainly within the borders of Zonguldak and Ulus Forest Management Directorate.

The most minor extent was observed in the Yenice Forest Management Directorate. Based on planning unit, it was determined that the highest distribution was in Kurucaşile (183.50 ha). The second largest distribution was found in the planning unit of Ulus Forest Management Directorate, Kumluca (176.93 ha). The most minor spread based on the planning unit was determined in the Yalnızçam unit (1.56 ha). The areal values of pure chestnut stands in terms of stand characteristics are shown in Table 3. The areal distribution graph of general pure chestnut stands is shown in Figure 3.

The distribution of chestnut forests in four classes regarding stand characteristics in terms of development stage, crown closure, stand type and site index were analyzed. The results of the developmental age analyses showed that pure chestnut forests were predominantly in the b (279.65 ha) and c (627.34 ha) ages. This showed that Zonguldak GDF, pure chestnut mainly composed of young stands. When analyzed in terms of crown closure, it was seen that the highest area consisted of stands with 2 (41% - 70%) and 3 (71% - 100%) closures. Regarding stand type, the highest area was found in Kscd2, Kscd3, and Ksbc3 stands and was calculated as 319.646 ha, 307.695 ha, and 218.197 ha, respectively. Finally, for site index, it was observed that the highest distribution was observed in the II (285.28 ha) and III (557.50 ha) site index. The spatial and spatial distribution graph of general pure chestnut stands is shown in Figure 3.

Descriptive statistics for geographical and topographical analyses of the areas where pure chestnut forests are distributed are shown in Table 4.

According to the results of climatic and topographic analyses, the minimum, maximum, and average annual total precipitation amounts of pure chestnut forests were calculated as 866.95, 1,619.25, and 1,024.07 mm/year, respectively. The study area's minimum, maximum, and average temperature values were calculated as 6.00 C°, 13.00 C°, and 11.76 C°, respectively. The minimum, maximum, and average wind speed values for wind speed, which affects respiration in trees, were 0.22 m/s, 6.62 m/s, and 2.46 m/s, respectively. The results of high data analysis from the topographic data of the study area showed that pure chestnut forests spread at a maximum altitude of 1 221.68 m, the lowest altitude was 33.24 m and the average altitude was 300.23 m. The results of the slope analysis for pure chestnut forests showed that the minimum, maximum, and average slope values were 7.34%, 32.43%, and 18.63%, respectively. Finally, the results of the aspect values showed that the most minor spread was in the North East (18.18°), the most spread was in the South East (338.63°), and generally in the South West (184.18°). Maps of precipitation, temperature, wind speed, elevation, slope, and aspect maps of the study area are shown in Figure 4.

Table 2. Spatial distribution of pure chestnut stands

Bartın		Zonguldak		Ulus		Kdz. Ereğli	
Planning unit	Area (ha)	Planning unit	Area (ha)	Planning unit	Area (ha)	Planning unit	Area (ha)
Amasra	85.91	Çaycuma	14.59	Kumluca	176.93	Yalnızçam	1.56
Arıt	14.32	Göldağı	126.71	Sökü	1.81	Dirgine	
Bartın	3.02	Kozlu	17.15	Ulusçayı	1.91	Planning Unit	Area (ha)
Gölderesi	197.17	Saltukova	1.13	Devrek		Karadere	11.34
Günye	30.76	Zonguldak	58.98	Planning Unit	Area (ha)		
İnkum	2.76	Yenice		Akçasu	22.40		
Kozcağız	65.24	Planning Unit	Area (ha)				
Kurucaşile	183.50	Kızılkaya	1.87				

Table 3. Areal distribution of pure chestnut stands in terms of stand characteristics

Development Age	Area(ha)	Stand Type	Area(ha)	Site index	Area(ha)
a (>7.9 cm)	51.14	Ksa	28.126	I	5.99
b (8 – 19.9 cm)	279.65	Ksa0	5.332	II	285.28
c (20 – 35.9 cm)	627.34	Ksa-1	7.989	III	557.50
d (36 cm >)	60.94	Ksa3	9.692	IV	147.08
Total	1 019.07	Ksbc2	61.451	VI	23.21
Crown Closure	Area(ha)	Ksbc3	218.197	Total	1 019.07
1 (10% - 40%)	41.45	Kscd2	319.646		
2 (41% - 70%)	381.10	Kscd3	307.695		
3 (71% - 100%)	596.53	Ksd3	60.944		
Total	1 019.07	Total	1 019.07		

Table 4. Descriptive statistics for topographic and climatic data

Variables	Stand type area	Min.	Max.	Mean	Mean standard error	Standard deviation	Variance
Total Precipitation (mm/Year)	165	866.95	1 619.25	1 024.07	8.08	103.81	1 0776.29
Annual mean Temperature (C°)	165	6.00	13.00	11.76	0.08	1.06	1.13
Wind Speed (m/s)	165	0.22	6.62	2.46	0.10	1.24	1.54
Elevation (m)	165	33.24	1 221.68	300.23	15.74	202.12	40 852.63
Slope (%)	165	7.34	32.43	18.63	0.41	5.22	27.23
Aspect (degrees)	165	18.18	338.63	184.18	7.79	100.10	1 0020.04

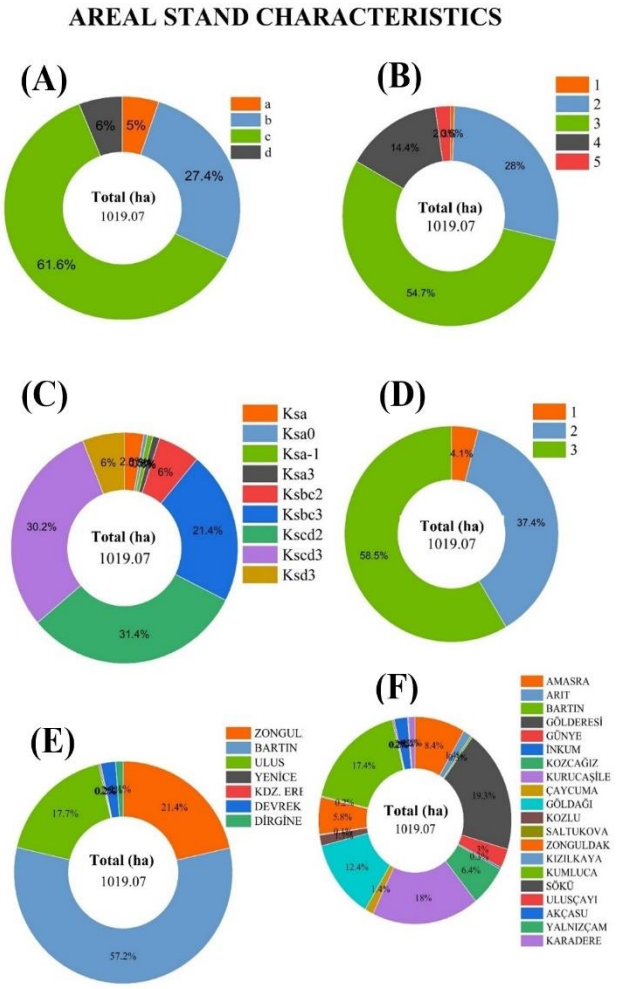

Figure 3. Areal distribution graph of stand characteristics of pure chestnut forests. (A) Development Stage, (B) Site Index, (C) Stand Type, (D) Crown Closure, (E) Forest Management Directure, (F) Planing Units.

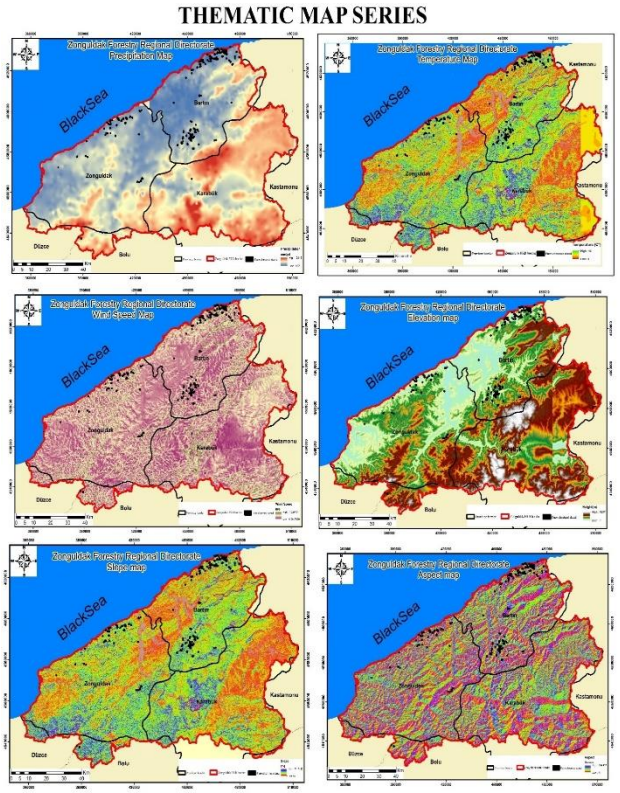

Figure 4. Areal distribution graph of stand characteristics of pure chestnut forests

4. Discussion and Conclusions

This study, it was aimed to determine the climatic and spatial characteristics of the existing pure chestnut forests and to provide information in terms of the utilization of existing chestnut forests and new forests to be established in high yield. It is thought that the changes that may occur due to climate change will cause the transformation of suitable spreading areas for some tree species into suitable spreading areas for the spread of other tree species. Dyderski et al., (2018) analysed the changes in pessimistic, average, and optimistic categories for 12 tree species until 2061-2080. The results showed that Anatolian chestnut will be among the pessimistic category of losers in Türkiye. Again, since Türkiye is highly vulnerable to climate change and among the "countries at risk" (UNDP, 2019) and the natural distribution areas of Anatolian chestnut are concentrated in the northern coastal regions of Türkiye, it is considered among the species expected to be most affected by this process (Çobanoğlu et al., 2023). Especially since global climate change will significantly change climatic factors, there is a threat of significant individual and population losses in Anatolian chestnut. Other studies have also emphasized that the Anatolian chestnut is expected to decline significantly in the southern regions of the Northern Hemisphere (Sarıkaya and Orucu, 2019, Barnes and Delborne, 2019, Noah et al., 2021;

Clark et al., 2023). Considering the above-mentioned risks and threats, it is of vital importance to provide information in terms of determining the correct climate and location selection in the studies to be carried out for the continuity of the Anatolian chestnut. Büber, (2021) the topographical distribution, long-term climatic data, some soil properties and soil organic carbon and total nitrogen stocks of Anatolian Chestnut (*Castanea sativa* Mill.), which is distributed within the borders of Bursa Regional Directorate of Forestry, were analysed according to different elevation and soil depth levels. The results showed that about 71% of the chestnut stands were located in shady aspects, 22% in sunny aspects, and 7% in flat areas. Anatolian chestnut has the highest distribution between 400 m and 600 m elevation (47%), followed by 100 m and 300 m elevation (41%). The mean annual temperature varied between 13.9 °C and 15.5 °C. The results of the research are similar to the results of our study. In addition, the increase in chestnut forests and afforestation also provides benefits in terms of slowing down global climate change. Menéndez-Miguélez et al., (2023) in a study they conducted, aimed to calculate the above- and below-ground biomass of chestnut plantations. Thus, they aimed to calculate the carbon sequestration role of young chestnut areas using the models they developed. Another study, it was tried to determine the potential chestnut production areas in Aydın province with geographical information systems. In the research, they used 6 criteria precipitation, temperature, soil structure, wind direction, slope, and elevation (Demirtaş, 2013).

Çobanoğlu et al., (2023) tried to predict for the years 2040, 2060, 2080, and 2100 how the growing areas of Anatolian chestnut, one of the most important species to be affected by climate change, will be affected in Türkiye. The results of the study predicted that the distribution areas suitable for Anatolian chestnut cultivation will significantly decrease especially after 2060-2080, and even completely disappear in 2080 according to the most extreme scenario. When all these research results are evaluated, it will not only provide important information for high productivity in the establishment and management of private or public chestnut forests but also facilitate acting with the awareness of forestry close to nature. In particular, it will be an important source of information for multi-criteria decision support systems to be used for the establishment of chestnut plantations.

With the results obtained, information was provided to determine of priority areas for chestnut afforestation for rural and local people within the borders of the Zonguldak Regional Directorate of Forestry. Thus, areas, where higher yield and gain can be obtained in chestnut afforestation, can be selected with the awareness of forestry close to nature. In particular, the opportunities offered by the General Directorate of Forestry to the public with the condition of afforestation of income-generating species in the forest openings within the forest boundaries will greatly contribute to selecting of the right place for chestnut. In addition, our results will contribute to the development of approaches to taking measures against the effects of climate change and improving the existing areas.

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