Article citation info:
Kiliç C., Yildiz S. 2026. Natural Durability of Chestnut Wood in Soil Contact: A Comparative Study Across Different Climatic Regions of Türkiye. *Drewno. Prace naukowe. Doniesienia. Komunikaty.* https://doi.org/10.53502/wood-209645

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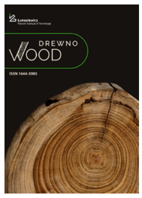
Journal website: https://drewno-wood.pl



Natural Durability of Chestnut Wood in Soil Contact: A Comparative Study Across Different Climatic Regions of Türkiye

Ceyhun Kiliç[a *]
Sibel Yildiz[b]

[a] Forestry Research Institute, General Directorate of Forestry, Turkey
[b] Forest Industry Engineering, Karadeniz Technical University, Turkey

Article info
Received: 30 July 2025
Accepted: 18 August 2025
Published: 22 January 2026

Keywords
chestnut
wood
natural durability
EN 252
wood properties

In this study, a total of 60 chestnut (Castanea sativa Mill.) wood samples were exposed to soil contact conditions for a period of three years in accordance with the EN 252 standard. The tests were conducted in four provinces of Türkiye: Trabzon, Muğla, Çanakkale, and Elazığ, representing the Black Sea, Mediterranean, mixed, and terrestrial climate zones, respectively, in order to assess the natural durability of the wood under different environmental conditions. At the conclusion of the three-year exposure period, several key parameters were assessed to evaluate the extent of degradation in the wood samples. These included visual decay rating, mass loss, density, bending strength, modulus of elasticity, compressive strength, and color change. In addition, the climatic indices and soil characteristics of each province were analyzed to contextualize the degradation results. Among the four locations, the lowest average visual decay rating was observed in chestnut wood tested in Elazığ (1.0), while the highest was recorded in wood of the same species in Çanakkale (3.6). Similarly, the greatest weight loss (35.96%) occurred in tested wood in Çanakkale, and the smallest (4.71%) in Elazığ. In the case of density, wood in Elazığ had the highest value (0.54 g/cm³), and wood in Çanakkale the lowest (0.39 g/cm³). The highest bending strength was obtained for wood in Elazığ (71.73 N/mm²), and the lowest for the Çanakkale wood (38.28 N/mm²). The highest elastic modulus was that of the wood in Elazığ (5965.89 N/mm²), and the lowest was that of the Çanakkale wood (3855.42 N/mm²). The highest values of compressive strength parallel to the fibers (underground and above-ground) were obtained for the Elazığ wood (48.25 and 50.87 N/mm², respectively); the lowest were those ofthe Çanakkale wood (13.51 and 40.59 N/mm²). The most significant color change was observed in the chestnut wood tested in Trabzon.

DOI: 10.53502/wood-209645

Introduction

Wood, as a renewable and sustainable material, is increasingly favored across engineering applications due to its lower environmental impact, carbon sequestration ability, energy efficiency in processing, and recyclability (Homan and Jorissen, 2004; Hill, 2007). Despite these advantages, wood remains vulnerable to biodegradation caused by environmental and biological agents (Ramage et al., 2017; Zhong and Ma, 2022). While indoor use typically exposes wood to stable humidity and temperature with limited UV exposure, outdoor applications subject it to complex weathering factors such as solar radiation, precipitation, freeze–thaw cycles, mechanical erosion, and microbial activity (Highley, 1995; Smit, 2010). Soil-contact

* Corresponding author: ceyhunkilic@gmail.com

conditions introduce additional challenges, including variable soil composition and climatic effects, which accelerate degradation and compromise structural integrity (Feist and Hon, 1984; Williams, 2005; Kılıç et al., 2023). The performance of timber in outdoor environments is influenced by species-specific properties, anatomical features, treatment methods, and site-specific climatic parameters. Numerous studies have shown that factors such as heartwood ratio, sample size, exposure duration, test location, and wood orientation significantly impact natural durability (Opoku, 2007; Highley, 1999). Chestnut is a highly prevalent species both in Türkiye, where it covers 73,610 ha (GDF, 2024), and across Europe, with a distribution spanning around 2.5 million ha (Conedera et al., 2016). Chestnut wood is highly regarded for its durability and favorable anisotropic characteristics. Throughout history, chestnut wood has been extensively utilized in outdoor settings that require durability, including infrastructure such as utility poles, stilt houses, and various structural components (Adua, 2000; Militz et al., 2003; Chavenetidou et al., 2020). Numerous published studies have examined the physical and mechanical properties of chestnut wood. Based on these studies, the main physical characteristics of this species of wood are presented in Table 1.

In recent years, chemical extraction from chestnut wood has yielded compounds such as tannins and catechins. While these substances are utilized in various industries, recent studies have demonstrated that chestnut wood extracts can also be used as effective wood preservatives (Yıldız et al., 2017). Its notable resistance to fungal decay and stable dimensional behavior are largely linked to its elevated levels of phenolic substances, particularly ellagitannins (Eichhorn et al., 2017; Chavenetidou et al., 2020). According to standardized fungal resistance assessments, it is categorized as moderately durable (Durability Class 2) (Gérard, 2011; EN 350, 2016), with laboratory findings consistently confirming its relatively high durability (EN 350, 2016). This study examines the natural durability of chestnut wood in contact with soil under varying climatic and soil conditions. It is well documented that both coniferous and deciduous wood species tend to degrade rapidly in outdoor environments, particularly when exposed to soil. In scenarios where chemical impregnation is not preferred or permitted—such as in environmentally sensitive applications—the use of wood species rich in natural extractives is considered a viable alternative. In this context, evaluating the long-term performance of chestnut wood in different climatic zones and soil types is expected to offer valuable insights for both academic research and practical applications. Although several studies have characterized the physical and mechanical properties of chestnut wood, there is a notable lack of comprehensive research conducted in accordance with the EN 252 standard, particularly focusing on its durability across diverse environmental conditions (Topaloğlu et al., 2021). Given Türkiye's climatic diversity—spanning four distinct climate zones—regional variation in wood degradation is expected. However, studies on soil-induced weathering remain limited. EN 252 (2014) provides a standardized method for assessing the durability of wood in ground contact through field testing. This study investigates the long-term durability of chestnut wood exposed to soil across four different climatic regions in Türkiye: Trabzon, Muğla, Çanakkale, and Elazığ. Following EN 252 (2014), samples were field-tested for three years to evaluate their visual decay rating, weight loss, density, bending strength, elastic modulus, compression strength and color change values, which were measured to determine performance loss over time.

Table 1. Principal wood properties of chestnut

Wood	**δ_{12} (gr/cm^3)**	**δ_0 (gr/cm^3)**	**β_v (%)**	**Bending strength (N/mm^2)**	**Modulus of elasticity (N/mm^2)**	**Compression strength (N/mm^2)**	**Shear strength (N/mm^2)**	**Authors**
Chestnut	0.54	0.51	11.47	77.47	-	57.07	5,53	Ay and Şahin, 2002
Chestnut	0.54		-	74.76	-	49.03	7,85	Berkel, 1970
Chestnut	0.54	0.46	-	70.1	6768.60	56.96	10,16	Efe and Çağatay, 2011
Chestnut	0.54	0.59	11.3	77	6170	50	8	As et al., 2001

δ_{12}: air-dry density; δ_0: oven-dry density; β_v: volumetric shrinkage

Material and methods

Material and research method

The experimental material consisted of chestnut logs harvested during the winter season. Heartwood of chestnut was used for all tests. All sapwood portions were carefully removed prior to specimen preparation to ensure consistency in the durability and mechanical property assessments. Measurements and analytical procedures were carried out in the Laboratory of Forest Industry Engineering at the Faculty of Forestry, Karadeniz Technical University (KTU). Specimens were prepared with dimensions of 20 × 20 × 300 mm and were partially embedded in soil (15 cm depth) in accordance with the EN 252 (2014) standard. For the purpose of assessing wood durability under varying environmental conditions, four geographically and climatically distinct provinces in Türkiye were selected as pilot regions: Trabzon (Black Sea climate), Muğla (Mediterranean climate), Elazığ (continental climate), and Çanakkale (transitional/mixed climate).

The field sites were located in close proximity to official meteorological stations and were chosen based on consistent criteria, including flat topography, absence of vegetation, uniform soil structure, good drainage, security, and minimal disturbance. Sample placement was conducted in May 2016. Each specimen was installed with its longitudinal axis aligned tangentially toward the south, and specimens were spaced 30 cm apart (see Fig. 1). A total of 120 wood samples were evaluated in the study. In addition, eight soil samples were randomly collected from each test location to determine the physicochemical properties of the soil, providing a basis for correlating soil conditions with wood degradation behavior. As seen in Table 2, these included soil texture, pH, electrical conductivity (EC), organic matter content, field capacity, wilting point, available water capacity, total water holding capacity, calcium carbonate ($CaCO_3$) concentration, and macronutrient content (Kılıç and Yıldız, 2024).

After a three-year soil exposure period, the wood specimens were retrieved in May 2019. Decay evaluation was performed in accordance with EN 252 (2014), employing a five-level grading system ranging from 0 (no visible degradation) to 4 (complete failure). Macroscopic assessments were based on parameters such as visual appearance, surface integrity, texture alteration, discoloration, and the presence of decay symptoms.

Tests

To evaluate weight loss and density, test specimens were oven-dried and evaluated before and after soil exposure. Determinations of the density, bending strength and modulus of elasticity of test samples were carried

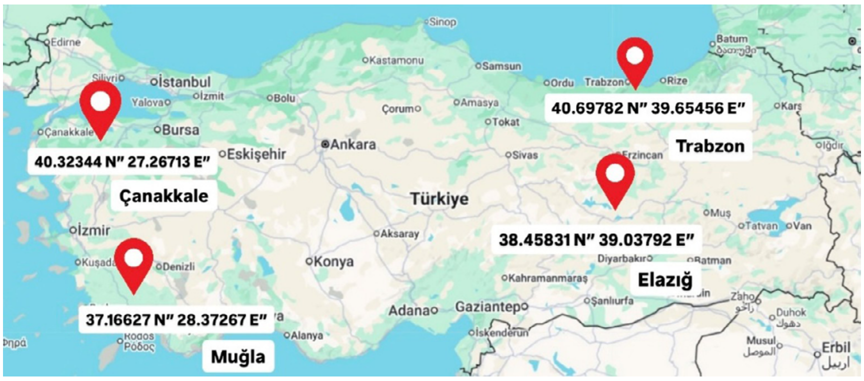


Fig. 1. Distribution of test plots on a map of Türkiye

Table 2. Soil analysis (Kılıç and Yıldız, 2024)

Location	Sand	Dust	Clay	Fc	Fp	Awc	pH	Ec	Organic	Lime	$CaCO_3$	Swhc
Trabzon	62.41^{b}	21.14^{b}	17.75^{b}	20.39^{b}	14.15^{b}	6.23^{b}	6.61^{a}	0.09^{b}	3.75^{b}	0^{a}	0^{a}	44.01^{c}
Muğla	67.79^{a}	20.22^{b}	11.99^{c}	12.35^{c}	4.91^{c}	7.44^{c}	7.53^{a}	0.16^{a}	1.19^{c}	28.03^{b}	70.27^{a}	23.78^{d}
Çanakkale	43.99^{c}	27.76^{a}	29.49^{b}	24.46^{b}	15.97^{a}	8.49^{a}	6.46^{b}	0.07^{b}	3.10^{b}	0^{a}	0^{a}	45.95^{b}
Elazığ	47.18^{c}	16.66^{c}	36.06^{a}	22.58^{b}	15.92^{a}	6.44^{b}	7.38^{b}	0.04^{c}	0.66^{c}	1.84^{c}	4.05^{b}	33.32^{c}

Fc: field capacity; Fp: fading point; Awc: available water capacity; Swhc: soil water holding capacity. Different letters in the same row indicate statistical difference ($p < 0.05$)

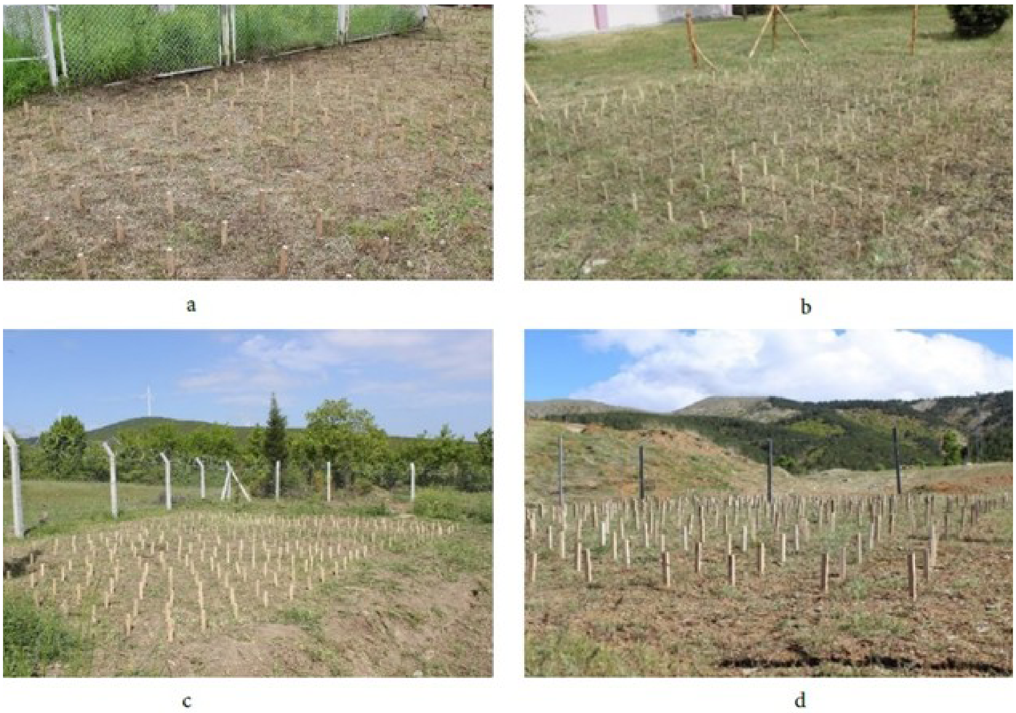


Fig. 2. Trial areas by province/region: a) Trabzon province, b) Muğla province, c) Çanakkale province, d) Elazığ province (Kılıç et al., 2023)

out accordance with the TS ISO 13061-2 (2021), TS ISO 13061-3 (2021) and TS ISO 13061-4 (2021) standards, respectively. The samples obtained after bending tests were separated into above-ground and underground, and tests of compression strength parallel to the grain were performed on both groups according to the TS ISO 13061-17 (2017) standard. The color properties of the samples were analyzed following the procedures outlined in ISO 7724-2 (1984). Test samples were measured with a Konica Minolta CR-400 device before and after exposure. All data were statistically analyzed using the SPSS 22.0 statistical software package, with a 95% confidence level taken as the basis for the evaluations. To determine the primary distributions within the dataset, as well as the relationships and differences among groups, a one-way analysis of variance (ANOVA) was initially performed. This preliminary analysis aimed to reveal whether there were any statistically significant differences among the data. When significant differences were detected, the Duncan multiple range test was applied to identify in detail which variations were responsible for these differences. In particular, for the data obtained from the soil-contact tests, special attention was given to evaluating whether the variations exhibited statistically meaningful differences. Furthermore, the temporal changes of the variations created in the study were examined in detail, and the statistical interpretability of these changes was also investigated. In this way, the research provided a comprehensive understanding of both the current differences among the variations and the changes observed over time.

Results and discussion

All experimental findings obtained throughout the study are consolidated and presented comprehensively in Table 3.

Climate and soil characteristics are critical factors influencing the durability of wood in ground contact applications. Regional analyses conducted across various provinces in Turkey indicate that Trabzon has the highest climate index, and Muğla the lowest (Kılıç et al., 2023). It is well documented that the mechanical strength and biological durability of wood tend to diminish as the duration of soil contact increases, varying by species (Highley, 1999; Gündüz, 2007). The rate at which wood deteriorates is heavily influenced by climatic parameters, particularly temperature and moisture dynamics, which govern the environmental conditions conducive to biological decay processes (Winandy and McDonald, 1993; Highley, 1999).

Soil texture also emerges as a determinant factor. According to the soil assessments, Muğla displayed the highest sand content and lowest clay proportion, indicative of a lower water holding capacity (WHC). In contrast, Elazığ had the highest clay content, while Çanakkale presented the lowest sand ratio (Kılıç and Yıldız, 2024). WHC is known to facilitate microbial activity and thereby accelerate wood decay processes (Jebrane et al., 2014; Meyer-Veltrup et al., 2017; Brischke and Meyer-Veltrup, 2017). Notably, the highest WHC values were observed in Çanakkale (45.95%)

Table 3. Test results for natural durability of chestnut wood

Chestnut	Trabzon			Muğla			Çanakkale			Elazığ		
	1*	2*	3*	1	2	3	1	2	3	1	2	3
Visual decay (scale point)	0.80^{b}	1.00^{bc}	1.60^{c}	0.00^{a}	1.00^{bc}	3.40^{e}	0.40^{ab}	2.60^{d}	3.60^{e}	0.40^{ab}	1.00^{bc}	1.00^{bc}
Weight loss (g)	4.82^{ab}	7.99^{bc}	11.23^{c}	4.78^{ab}	7.52^{ab}	14.69^{d}	5.44^{ab}	20.45^{e}	35.96^{f}	4.11^{a}	4.37^{ab}	4.71^{ab}
Density (g/cm^3)	0.49^{bcd}	0.47^{bc}	0.49^{bcd}	0.52^{de}	0.49^{bcd}	0.46^{b}	0.52^{cde}	0.54^{de}	0.39^{a}	0.52^{de}	0.54^{de}	0.54^{e}
Bending strength (N/mm^2)	68.13^{b}	49.12^{a}	41.31^{a}	68.21^{b}	63.80^{b}	47.09^{a}	74.54^{b}	38.28^{a}	-	75.28^{b}	87.26^{c}	71.73^{b}
Modulus of elasticity (N/mm^2)	5583.83^{cd}	4806.92^{b}	3781.85^{a}	5554.75^{cd}	4772.57^{b}	4926.76^{bc}	5827.21^{d}	3855.42^{a}	-	5638.46^{d}	5959.06^{d}	5965.89^{d}
Compression strength above-ground (N/mm^2)	45.88^{abcd}	41.14^{a}	42.54^{ab}	46.17^{abcd}	43.23^{abc}	43.17^{abc}	51.78^{d}	48.44^{bcd}	40.59^{a}	49.69^{cd}	50.87^{bcd}	44.16^{abc}
Compression strength underground (N/mm^2)	42.99^{def}	38.76^{cde}	35.70^{c}	44.57^{ef}	36.93^{cd}	24.61^{b}	44.79^{ef}	13.51^{a}	-	43.12^{def}	48.25^{f}	43.95^{ef}
Color change (ΔE)	28.00^{g}	26.28^{efg}	23.81^{cdef}	22.95^{cde}	25.19^{defg}	21.86^{cd}	19.94^{bc}	27.23^{fg}	23.09^{cde}	12.38^{a}	17.96^{b}	22.98^{cde}

* Duration of soil exposure (1 year, 2 years, 3 years). Different letters in the same line indicate statistical difference ($p < 0.05$). Due to the very small size of the mean and Duncan homogeneity groups, the letters are placed on a separate line

and Trabzon (44.01%). In the absence of climate and wood anatomical considerations, these elevated WHC levels suggest an increased risk of biodegradation for wood exposed to soil in these regions (Kılıç and Yıldız, 2024). In the first year of exposure, the greatest durability was observed in Muğla, with a visual decay index of 0.0, while the poorest durability was recorded in Trabzon, with an index of 0.8. By the second year, the index had risen to 1.0 in Muğla, Elazığ, and Trabzon, whereas in Çanakkale it had increased significantly to 2.6. In the third year, Elazığ maintained the best performance with an index of 1.0, while Çanakkale exhibited the most severe degradation, with an index of 3.6. Despite differing climatic conditions, no statistically significant difference was found between Muğla (Mediterranean climate) and Çanakkale (mixed climate), both of which had a decay index of 3.4. The elevated decay rate observed in the third year is thought to be closely linked to increased precipitation.

Chestnut wood demonstrated notable resistance under the terrestrial climate of Elazığ after three years of soil contact. This performance is attributed to the stability of its natural extractives, particularly tannins, which may be more susceptible to leaching under humid conditions. In Trabzon, Muğla, and Çanakkale, which are regions characterized by higher rainfall, the leaching of tannins likely reduced the wood's inherent resistance. Climate index values recorded throughout the study support this interpretation (Kılıç et al., 2023). Chestnut is known to contain high levels of tannins and other extractive compounds (Squillaci et al., 2018), which have been widely investigated for their protective efficacy. For instance, Olteanu (1997) demonstrated that extracts derived from chestnut wood, fir, and spruce bark have considerable antifungal properties even at low concentrations (1–2%). Similarly, Yıldız et al. (2017) reported that tannin-rich chestnut extracts provided substantial resistance against *Coniophora puteana*, a brown rot fungus, when applied to Scots pine sapwood. Further evidence is provided by Tomak and Gonultas (2018), who tested the efficacy of chestnut tannins against both brown rot fungi (*Coniophora puteana* and *Postia placenta*) and white rot fungi (*Trametes versicolor* and *Pleurotus ostreatus*). Their findings indicate that chestnut tannins offer superior resistance compared with other treatments. However, under high rainfall (e.g. in Trabzon) and warm, humid conditions (e.g. in Muğla), the degradation of these natural protective compounds likely reduced the wood's performance. Moreover, in Çanakkale, termite activity was observed in chestnut samples (Fig. 3).

In this context, alternative biological protectants have also been considered. Maistrello et al. (2011) compared the termite resistance of chestnut tannins with that of extracts obtained from *Vitellaria paradoxa*. Their results revealed that the *V. paradoxa* extract was significantly more effective in deterring termite attacks than *C. sativa* tannins. In another study, wood species such as *Larix kaempferi*, *Pinus densiflora*, *Abies holophylla*, *Pinus koraiensis*, and *Ginkgo biloba* were subjected to termite exposure. The average mass loss observed in these wood species ranged between 13% and 19%, whereas chestnut wood exhibited significantly lower mass loss values, averaging only 3–4%, indicating a higher level of natural resistance to termite attack (Im and Han, 2024).

The significant weight loss observed in Çanakkale can be attributed to termite activity. In contrast, similar weight loss values recorded in Muğla and Trabzon are likely due to the intrinsic durability of chestnut wood. In the absence of termite attacks, comparable degradation would be expected across these regions due to their similar climatic and edaphic conditions. Nevertheless, extended exposure to temperate climate conditions—including fungal and insect activity, precipitation, humidity, temperature variation, and ultraviolet (UV) radiation—can result in significant deterioration, even in chestnut wood, which is generally recognized for its inherent durability. For instance, in a stream restoration project in Italy, stakes made from chestnut were exposed to field conditions for durations ranging from 12 to 120 months. White rot fungi colonization was first observed after 30 months, with a progressive increase in cellulose and lignin degradation over time (Benfratello et al., 2017). Similarly, Thaler et al. (2014) reported that chestnut heartwood samples subjected to methanol and water extraction exhibited a weight loss of 11–15% upon drying, demonstrating the influence of extractive components on durability.

During the first year of exposure, the lowest wood density was recorded under Black Sea climatic conditions (Trabzon) at 0.49 g/cm³, while other climates produced a uniform density of 0.52 g/cm³. In the second year of exposure, Trabzon again had the lowest mean wood density (0.47 g/cm³), while the highest density values (0.54 g/cm³ in each case) were recorded in samples from the terrestrial climate region (Elazığ) and the transitional climate region (Çanakkale). By the third year, the lowest density was measured in Çanakkale (0.39 g/cm³), with Elazığ maintaining the highest

Fig. 3. Termite activity on chestnut samples

density. Over the course of the study, density losses were 4% in the Black Sea climate, 10% in the Mediterranean climate, and 24% in the mixed climate, while in the terrestrial climate, by contrast, the recorded density increased by 6% relative to the control. This anomaly is likely due to the heterogeneous nature of wood and variations in sampling location within the tree. According to Bektaş et al. (2018), changes in wood density may result from factors such as temperature, the proportion of summerwood, anatomical texture, and fiber structure. The substantial density reduction in Çanakkale is primarily attributable to termite infestation.

In the first year, samples from all climates were statistically similar in terms of bending strength, with the highest value (75.28 N/mm²) recorded in the terrestrial climate (Elazığ), and the lowest (68.13 N/mm²) in the Black Sea climate (Trabzon). In the second year, a notable increase in bending strength was observed in Elazığ (to 87.26 N/mm²), while the lowest value (38.28 N/mm²) was recorded in the mixed climate (Çanakkale). Çanakkale and Trabzon were grouped together statistically. In the third year, Elazığ again produced the highest bending strength (71.73 N/mm²), while the mixed climate samples were excluded due to severe decay. Of the remainder, Trabzon produced the lowest value (41.31 N/mm²), statistically similar to that of Muğla (47.09 N/mm²). While bending strength loss was minimal in the first year, significant reductions were recorded in humid regions in the subsequent years: 49% in Trabzon, 42% in Muğla, and complete degradation due to termites in Çanakkale. The Elazığ samples experienced only a 12% loss. Interestingly, the Elazığ samples exhibited a 13% increase in bending strength in the second year compared to the first, and a 6% increase relative to the control. This may be attributed to cyclical swelling and shrinkage during natural leaching, as also reported by Kerimoğlu (2019), which may enhance mechanical resistance. Despite the general durability of chestnut wood, the literature indicates susceptibility to termite damage. For example, Ngee et al. (2004) reported the highest mass loss (13.44%) in Japanese chestnut (*Castanea crenata*) during a 30-day termite exposure test among 15 durable wood species.

In the first year, the highest modulus of elasticity (5827.21 N/mm²) was recorded in the mixed climate (Çanakkale), and the lowest (5554.75 N/mm²) in the Mediterranean climate (Muğla). The terrestrial and mixed climates formed one homogeneity group, while the Black Sea and Mediterranean climates constituted another. In the second year, Elazığ (terrestrial climate) produced the highest value (5959.06 N/mm²), and Çanakkale (mixed climate) the lowest (3855.42 N/mm²). The results for the Mediterranean (4772.57 N/mm²) and Black Sea (4806.92 N/mm²) climates were statistically similar. In the third year, Elazığ again achieved the highest modulus of elasticity (5965.89 N/mm²), while the mixed climate samples were excluded due to severe decay. Among the remainder, the lowest value was obtained in the Black Sea climate (3781.85 N/mm²).

In the first year, the highest above-ground compression strength parallel to the grain (51.78 N/mm²) was recorded in the mixed climate (Çanakkale), and the lowest (45.88 N/mm²) in the Black Sea climate (Trabzon). In the second year, Elazığ (terrestrial climate) produced the highest value (50.87 N/mm²), and Trabzon the lowest (41.14 N/mm²). In the third year, the highest value was again recorded in Elazığ (44.16 N/mm²), and the lowest in Çanakkale (40.59 N/mm²). Statistically, the climates were grouped together based on similarities in performance. At the end of the third year, compressive strength loss was smallest in Elazığ (20%) and greatest in Çanakkale (26%). Compared with previous studies reporting up to 80% loss over 120 months under Mediterranean conditions and direct soil contact (Benfratello et al., 2017), the present results indicate relatively moderate degradation, likely due to shorter exposure and lack of direct soil contact.

In the first year, the highest underground compression strength parallel to the grain (44.79 N/mm²) was recorded in the mixed climate (Çanakkale), while the lowest (42.99 N/mm²) was observed in the Black Sea climate (Trabzon). In the second year, the terrestrial climate (Elazığ) produced the highest value (48.25 N/mm²), whereas in the mixed climate (Çanakkale) a sharp decline was recorded (to 13.51 N/mm²). By the third year, Elazığ maintained the highest strength (43.95 N/mm²), while the Çanakkale samples were excluded due to advanced decay. The next lowest value (24.61 N/mm²) was recorded in the Mediterranean climate (Muğla). At the end of the third year, the smallest strength loss was observed in the terrestrial climate (20%), while complete degradation (100%) had occurred in the mixed climate, followed by 55% loss in the Mediterranean climate. The limited decay in Elazığ is attributed to its low relative humidity, which inhibits fungal activity, whereas the warmer and more humid conditions in Çanakkale and Muğla create favorable environments for biodegradation (Taştan, 2009).

In the first year, the highest color change (ΔE) value (28.00) was recorded in the Black Sea climate (Trabzon), and the lowest (12.38) in the terrestrial climate (Elazığ). In the second year, the highest ΔE value (27.23) was observed in the mixed climate (Çanakkale), and the lowest (17.96) again in Elazığ. In the third year, Trabzon produced the highest color change (23.81), and the Mediterranean climate (Muğla) the lowest (21.86). Statistically, the mixed and terrestrial climates were grouped together, with similar ΔE values in the third year. Previous studies reported lower ΔE values for chestnut wood than for Scots pine and oak (Budakçı and Karamanoğlu, 2014). Additionally, Karamanoğlu and Kaymakçı (2018) found that prolonged exposure to outdoor conditions leads to darkening of chestnut wood, correlating with increased time and temperature.

Conclusion

This study has evaluated the durability and mechanical performance of chestnut heartwood under different climatic conditions over a three-year natural exposure period. Mechanical parameters such as bending strength, modulus of elasticity, above-ground and subsoil compressive strength, as well as color stability, were monitored annually across four distinct climatic zones: terrestrial (Elazığ), Black Sea (Trabzon), Mediterranean (Muğla), and mixed (Çanakkale). The results demonstrated that the terrestrial climate (Elazığ) consistently provided the most favorable conditions for preserving the mechanical integrity of chestnut wood. Notably, the Elazığ samples retained relatively high bending strength and modulus of elasticity throughout the study period, and exhibited the lowest degradation rate in both above-ground and subsoil compressive strength tests. In contrast, the mixed climate (Çanakkale) was associated with severe biological deterioration, particularly due to termite activity, leading to total structural loss in some samples. Significant mechanical losses were observed in humid climates such as Trabzon and Muğla, suggesting that fungal decay and termite activity are major contributors to strength reduction in chestnut wood under these conditions. In terms of aesthetics, color change (ΔE) was most pronounced in the Black Sea and mixed climates, indicating higher photodegradation or surface weathering under more humid and moderate temperature conditions. Overall, the findings highlight the critical influence of climatic conditions on the durability of chestnut wood, particularly in long-term applications. The wood tested in the terrestrial climate region achieved the best performance, confirming its suitability for outdoor uses where durability is essential. In contrast, the wood tested in mixed and Mediterranean climates was found to be subject to greater risks due to higher decay rates, emphasizing the need for additional protective treatments for wood in these regions, such as heat treatments, modern nanopreservative chemicals, and environmentally friendly impregnations.

Conflict of interest

The author(s) declare(s) that there is no conflict of interest concerning the publication of this article.

Acknowledgements

This study was performed under a research project of the General Directorate of Forestry, Head of Foreign Relations, Training and Research Department, on behalf of and funded by the General Directorate of Forestry of Türkiye and titled "Determination of Natural Resistance of Some Wood Types in Different Geographical Regions by Field Tests" (03.7706/2015-2020). I would like to express my gratitude to Prof. Dr. Eylem DIZMAN TOMAK, Prof. Dr. Ergün BAYSAL, and Dr. Ayşenur GÜRGEN who contributed greatly to the study.

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