The effect of altitude above sea level on some structural characteristics, dynamics and diversity on Zagros forests in western Iran

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Abstract

Ecological conditions, such as environmental gradients, can affect the structural features and diversity of forests situated in altitude gradients. A study was conducted to examine the impact of altitude above sea level on certain structural features and diversity in Zagros forests in the Ghalajeh area of Kermanshah province. To analyze the effects of diversity on structural and habitat characteristics and their changes in different altitude gradients, eight sites were selected in four altitude ranges from sea level: 1200–1475 meters (low-land), 1475–1750 meters (low to mid-altitude), 1750–2025 meters (mid to high-altitude), and 2025–2300 meters (high-land), identified in both northern and southern slopes. In each site, three sample plots were chosen as replicates, and within each sample plot, all necessary characteristics of trees were measured. The results showed that with increasing altitude above sea level, the number and frequency of tree species increased, while the density of Iranian oak trees decreased. Species such as Almond tree (*Prunus elaeagrifolia)*, Italian Honeysuckle (*Lonicera nummulariifolia)*, and Maple tree (*Acer monospessulanum)* were predominantly present at higher altitudes. However, the presence of trees initially increased (in the mid-altitude elevation), then decreased (in the highland elevation) with increasing altitude, although this attribute was nearly equal in the lowland elevation in both northern and southern slopes. The study also found statistically significant differences ($p < 0.05$) in variables such as tree diameter at breast height, tree height, and tree dieback levels across different altitudes above sea level. These results are beneficial in addressing ecological issues such as forest conservation and management, as well as assessing favorable environmental conditions, providing insights to predict future trends based on these findings.

Introduction

Forests exhibit structural and species diversity, which is influenced by various factors. The impact of altitude gradients on climate can be clearly seen in vegetation patterns and types (Curtin, 1995). As we move higher above sea level, grasslands may abruptly transform into forests, and at even higher altitudes, forests may give way to grasslands. These sudden changes in vegetation are an indication of climatic variations in mountainous environments characterized by a drop in temperature, an increase in precipitation, and heightened wind speeds (Bowman & Hacker, 2021). Altitude gradients comprise a wide diversity of climatic and soil conditions within a relatively small range.

Mountainous regions create climatic gradients that have a more significant impact on temperature over a specific distance compared to changes related to geographical latitudes. This results in a decrease in temperature as altitude increases (Bowman & Hacker, 2021). Therefore, the plant communities found at the base and peak of a mountain range in temperate regions are similar to those found along a horizontal slope towards higher geographical latitudes.

Forests that are located in altitude gradients have unique characteristics due to the ecological conditions they face, including environmental gradients. One of the key factors that influences biomass accumulation in forest ecosystems is the stand structure (da Silva et al. 2017). Environmental conditions such as altitude gradients can have a significant impact on forest structure, making it a crucial aspect to examine when trying to revive and predict the future status of the forest. This examination involves looking at structural features, biomass, and other habitat characteristics such as ecological indices (Javanmiri Pour et al. 2019). To examine forest structure, various factors are considered, such as the spatial position diversity, heterogeneity mix, and differences in tree dimensions (diameter and height); (Suzuki et al., 2002). Key components concerning forest stand structure include the spatial arrangement of tree positions, the distribution pattern of different species, and the differences in tree dimensions. These components differ among different ecological conditions, including altitude gradients (Baddely 2010, Palik et al., 2020).

A research was carried out on the variety of tree and shrub species in the Oak forests situated between the narrow Shirvan-Chardavol in Ilam province. The study aimed to investigate the impact of topographic factors and stand characteristics on the diversity of tree and shrub species. The results indicated that the elevation above sea level had a significant influence on the diversity, richness, and evenness of tree species. The research discovered that the mid-elevation stratum, particularly within the range of 2000–2100 meters, displayed the highest diversity and species richness (Hosseini, 2014).

The study examined how different plant groups respond to specific environmental factors in the forests of Baghmalek County. The research found that the diversity of woody species was high up to an elevation of 2350 meters above sea level but decreased beyond that point. Grasses, on the other hand, showed less diversity at intermediate elevations ranging from 1300 to 1600 meters above sea level and elevations exceeding 2350 meters. Saplings had the highest diversity at middle elevations as per the study (Shahriari et al. 2019).

A study was conducted to consider the floristic composition and plant communities of Iranian Oak forests, with a focus on altitude gradients in the forests of Taft, Khorramabad County. The results of the study showed that 166 plant species from 35 families were observed across the altitude gradient in the region (Shabanirad et al., 2020).

A study was conducted in the Sari Siah forests in Sangdeh to determine the effect of altitude gradients on quantitative characteristics of forest stands. The findings showed that as the altitude increased, the number of stems per hectare decreased from 477 to 384 and then to 372. Similarly, the ground cover per hectare decreased from 6.25 m^2 to 4.29 m^2 and then increased to 8.30 m^2. The estimated volume of wood per hectare also decreased from 314.25 m^3 to 394 m^3 and then increased to 424.75 m^3. In terms of biomass, the study found that the amounts for each of the three strata were 7.406, 3.478, and 3.522 tons per hectare, respectively. Additionally, the carbon storage was estimated to be 203.34 tons per hectare, 239.12 tons per hectare, and 261.15 tons per hectare for the three different altitude strata, respectively. These findings revealed an increasing trend in carbon storage with elevation above sea level (Rezaei-Sangdehi et al. 2020).

It has been estimated that the average carbon storage in various forest masses in the northeastern mountains of Changbai, China is around 237 tons per hectare. The estimation was made based on three altitude classes: 1100 – 700, 1800 – 1100, and 2000 – 1800 meters above sea level. Researchers have identified that elevation above sea level is the most influential factor in changes in biomass. According to their findings, plant carbon storage decreases significantly with increased altitude (Zhu et al., 2010).

A study conducted in Central Africa, focused on studying aboveground biomass and tree species diversity, along an altitude gradient. The study found that the aboveground biomass decreased from 600 – 500 megagrams per hectare to 300 megagrams per hectare at lower altitudes. The decline was primarily attributed to the presence of trees with a diameter greater than 70 centimeters at lower elevations. Moreover, the study revealed that tree height and cross-sectional area decreased significantly with increased altitude, while biomass density increased (Gonmadje et al. 2016).

A study was conducted in Manipur, India to assess the biomass and carbon stocks in elevation gradients and ten forest stands. The study found that the basal tree densities were variable, ranging from 128 to 168 stems per hectare. Higher densities were observed at higher elevations (Thokchom and Yadava, 2017).

Researchers examined tree biomass diversity and carbon stocks across four altitude ranges in the Himalayas – 1000 – 500 m, 1500 – 1000 m, 2000 – 1500 m, and 2500 – 2000 m. They found that the altitude range of 2000 – 1500 m had the highest biomass and carbon content, with 474 megagrams per hectare (Mannan et al., 2018).

Based on the points mentioned above, it is clear that studying the impact of altitude from sea level and altitude gradients on the structural features and biodiversity of forests is crucial. In forested regions such as the Zagros forests which are characterized by varying altitudes, the quantitative values of the forest's characteristics and biological indices usually undergo significant changes that require further investigation.

Material and Methods

Site description

The studied area is the Ghalajeh forest located southwest of Kermanshah province in Gilan-e-Gharb County (Fig. 1). It ranges in altitude from 1200 to 2350 meters above sea level. The region experiences an average annual precipitation of about 500 millimeters and an average annual temperature of 18.2 C, characterized by a semi-arid climate according to the Emberger method.

The Ghalajeh forest, situated in this region, is a natural museum of diverse tree and plant species. The forest is home to several species of trees, including Oak tree (Quercus brantii), Ash tree (Fraxinus rotundifolia), pear tree (Pyrus glabra), mountain almond types, Hawthorn (Crataegus aronia), pistachio (Pistacia atlantica), daphne (Daphene mucronata), and Maple tree (Acer monspessulanum). The forest also boasts of numerous plant species, such as licorice (Glycyrrhiza glabra), Poaceae, Acantholimon sp., Acanthophyllum sp., Onobrychis sp., Alopecurus sp., Thymes, and clover (*Trifolium*). These species have combined to create a breathtaking natural environment that is a remarkable sight. The Kalajah forest is a testament to the beauty and wonder of the region's flora.

Data collection

To examine how diversity affects the structure and characteristics of different habitats at varying altitudes, divided the study area into four altitude zones between 1200 and 2300 m, with intervals of 275 meters (1200–1475, 1475–1750, 1750–2025, and 2025–2300 m).

Altitude range determination was carried out in the north and south directions to analyze the ecological effects. Within each altitude zone, three sample plots were selected as replicates and relevant statistical studies were conducted regarding structure, composition, and habitat conditions. In simpler terms, triplicate plots were surveyed in each altitude zone resulting in 24 one-hectare plots collected for both northern and southern gradients in this study.

For every sample plot, a complete inventory of trees was carried out using the 100% survey method. This involved measuring all the trees within one-hectare plots. The measurement criterion used was the diameter at breast height (DBH), which was set at 7.5 cm. The diameter was measured using a caliper with centimeter precision.

The dried trees were measured in each of the one-hectare plots. For every dried tree, the diameter of three sections, its length or height, its type, and the degree of decay were recorded. The degree of dryness of the trees is determined by observing the proportion of dry branches to the total branches of the tree (Stringer et al., 1989). They divided the dryness of the trees into six different categories based on the intensity of dryness, ranging from less than 20% to more than 80%. Each tree was then classified into a specific category based on its degree of dryness.

The diameters of the trees were measured on the upper slope side using a caliper with an accuracy of centimeters. Similarly, the height of the trees was measured using a Suunto clinometer with cm precision. The following equation was used to estimate the standing volume of forest trees per hectare (Zabeiri, 2009).

$v = \frac{\pi}{4} d^2 \times h * 0.5$ Eq. 1

where v is the volume of the tree in m^3, h is the height in meters and d is the diameter of the tree in centimeters.

After collecting the data, species diversity indices, richness, and evenness in the forest tree canopy were computed. First, the values of these indices are calculated at the level of sample plots, and then at different altitude strata. To measure species diversity, Simpson's and Shannon-Wiener diversity indices were used. To determine species richness, Menhinick and Margalef indices were employed. furthermore, evenness using Pielou's indices was calculated. The following relationships were used to compute these indices.

This study utilized PAST and Ecological Methodology software to calculate diversity indices. The aim was to investigate whether there is a significant relationship between diversity and structural attributes such as diameter and height in altitude strata from sea level. To achieve this, one-way analysis of variance (ANOVA) and independent t-tests were conducted. Before these tests, the normality of the data was determined by performing the Kolmogorov-Smirnov test, and the equality of variances was assessed using Levene's test. All statistical tests were conducted at a probability level of $P > 0.05$ and performed in the R software environment (version 5.0.4).

Results

The distribution of species at different altitude levels indicates that the number of species increases with elevation. For instance, on the northern slope, the lowest number of species is found between 1200–1475 m, while the highest number of species is observed between 2025–2300 m. Similarly, on the southern slope, the minimum number of species is found between 1475–1750 m, while the highest number occurs between 1750–2025 m (Table 1).

Table 1
The number of species in the altitudes ranges in the northern and southern directions

Row	Northern direction				Southern direction			
	1200–1475	1475–1750	1750–2025	2025–2300	1200–1475	1475–1750	1750–2025	2025–2300
1	Oak	Oak	Oak	Oak	Oak	Oak	Oak	Oak
2	Hawthorn	Hawthorn	Hawthorn	Hawthorn	Hawthorn	Hawthorn	Pistachio	Pistachio
3	Pistachio	Pistachio	Pistachio	Pistachio	Pistachio	-	Almond tree	Almond tree
4	-	Almond tree	Almond tree	Almond tree	Almond tree	-	Daphne	Maple tree
5	-	Maple tree	-	Honeysuckle	-	-	Honeysuckle	Honeysuckle
6	-	-	-	Maple tree	-	-	Maple tree	-

Density of trees

The density of oak trees decreases as the altitude from sea level increases, on both the northern and southern slopes. The oak species 'pistachio' is less common at lower altitudes on both slopes, but becomes more prevalent at higher altitudes. On both slopes, Plum tree (Prunus incana), Lonicera nummularifolia, and Acer monspessulanum are mainly found at higher elevations (Table 2).

Table 2
Abundance of species in altitude classes above sea level and in north and south directions

Side	Altitude class	Abundance								Sum
		Oak	Pistachio	Hawthorn	Maple tree	Almond tree	Daphene tree	Pear tree	Plum tree	
Northern	1200–1475	296	3	6	-	-	-	-	-	305
	1475–1750	196	2	19	14	1	-	-	-	232
	1750–2025	204	22	38	-	-	-	-	4	268
	2025–2300	21	16	30	8	96	-	120	-	291
Southern	1200–1475	277	1	5	-	-	-	-	10	293
	1475–1750	220	-	22	-	-	-	-	-	242
	1750–2025	91	16	-	53	-	18	26	-	204
	2025–2300	2	16	-	6	89	-	48	-	161

The results of the significance test for comparing the frequency of trees in altitude strata and both main geographical directions indicate that there is a significant difference between the means among most of the studied groups with a probability of 95% (p = 0.05); (Figs. 2 and 3). However, there are two exceptions; there is no significant difference between the mean altitude strata of 1475–1750 and 1750–2025 m, and there is no significant difference between the northern and southern slopes in the altitude stratum of 1200–1475 m (see Fig. 3).

The species and indices, such as diversity, uniformity, and richness, tend to increase with altitude in both the northern and southern slopes. For example, in the northern slope, the Shannon-Wiener index increases from 0.22 at 1200–1475 m to 0.42 at 2025–2300 m (Table 3).

Table 3
Diversity of species in altitude classes and in northern and southern directions

Side	Altitude class	Species diversity indices		Richness indicators		Uniformity indices	
		Simpson	Shanon-Wiener	Menhinick	Margalef	Smith & Wilson	Modified Nee
Northern	1200–1475	0.058	0.219	0.17	0.34	0.153	0.079
	1475–1750	0.395	1.086	0.32	0.73	0.3	0.12
	1750–2025	0.277	0.84	0.24	0.53	0.18	0.094
	2025–2300	0.7	2.04	0.35	0.88	0.526	0.18
Southern	1200–1475	0.1	0.37	0.23	0.52	0.15	0.08
	1475–1750	1.66	0.44	0.12	0.18	0.41	0.136
	1750–2025	0.7	2	0.35	0.75	0.74	0.25
	2025–2300	0.59	1.58	0.39	0.78	0.31	0.12

The test results are significant in comparing the indices related to the diversity of woody species in different altitude strata. The means among most of the studied groups have a substantial difference with a probability of 95% ($p = 0.05$), (Fig. 4).

Stock volume

In the lower part of the area, the stock volume in the sample plots is almost the same on both the northern and southern slopes. However, in the altitude stratum of 1475–1750 m, the volume on the northern slope is higher (7.84 m^3) than on the southern slope (6.60 m^3). The stock volume on the south slope increases in comparison to the northern slope, as moved up the altitude gradient. For instance, in the altitude strata of 1750–2025 and 2025–2300 m, the stock volume on the southern slope is 9.67 and 34.48 m^3, respectively, while on the northern slope, it is 4.25 and 3.10 m^3, respectively (Fig. 5).

Diameter and height distribution

According to Table 4, the mean diameter of tree trunks varies depending on altitude and aspect. The highest mean diameter of 21 cm was observed in the altitude stratum of 2025–2300 m on the south slope, while the lowest mean diameter of 7 cm was found in the same altitude stratum on the northern slope (Table 4).

Table 4. Mean stem diameter by altitude class and slope direction.

Northern				Southern			
1200-1475	1475-1750	1750-2025	2025-2300	1200-1475	1475-1750	1750-2025	2025-2300
303	295	232	242	262	248	291	181
14.9545	18.6203	17.3082	21.0973	15.6649	15.6149	10.0275	7.0055
.65415	.55772	1.25000	.97838	.86482	2.05429	1.00972	1.11491
11.38667	9.57924	19.03945	15.21995	13.99826	32.35103	17.22461	14.99963

The mean height of trees in different altitude strata and slopes varies significantly. Trees on the south slope at an altitude of 2025–2300 m have the highest mean height of 4.6 meters. In contrast, the average height of trees on the northern slope at the same altitude range is the lowest, measuring 2.7 m (Table 5).

Table 5. Mean height by altitude class and slope direction.

		Northern				Southern			
		1200-1475	1475-1750	1750-2025	2025-2300	1200-1475	1475-1750	1750-2025	2025-2300
N	Valid	293	293	232	242	263	248	291	189
Mean		4.4476	4.7604	4.8537	6.4370	4.0297	3.3423	2.5649	2.2720
Std. Error of Mean		.16426	.07880	.17930	.17324	.14825	.11084	.10756	.08613
Std. Deviation		2.81162	1.34892	2.73103	2.69506	2.40427	1.74545	1.83476	1.18405

The distribution of trees across different altitude strata, from sea level and on northern and southern slopes, generally shows a pattern where the number of trees in higher diameter classes decreases. Similarly, the distribution of trees across height classes in altitude strata of 1200–1475 and 1475–1750 m displays a similar trend. However, in altitude strata of 1750–2025 and 2025–2300 m, the number of trees decreases as the altitude increases. These observations suggest that the forest stands are uneven-aged (Fig. 6).

The average diameter of tree trunks at breast height (DBH) in the altitude range of 1200–1475 meters above sea level is 8.16 cm. The maximum diameter value of 9.19 cm is observed in the altitude range of 1475–1750 m, while the minimum diameter value of 5.8 cm is observed in the altitude range of 2025–2300 m. Furthermore, a significant difference in tree diameter averages is observed across altitude strata (Fig. 7).

There is a significant difference between the average tree diameter and height for northern and southern aspects in most of the studied groups, with a 95% confidence level ($p = 0.05$). However, the comparison between the tree diameters in the altitude stratum of 2025–2300 m in the northern and southern slopes did not show any significant difference (Fig. 8).

Tree Dieback

In the lower altitude stratum, ranging from 1200–1475 m, the highest level of tree dieback is classified as dead grade 1, while the lowest level is classified as dead grade 4. The altitude strata of 1475–1750 and 1750–2025 meters on both slopes show considerable amounts of grade 5 dryness, whereas the least frequency is associated with dead grade 4. Across different dead grades, the least dead tress is observed in the higher altitudes, specifically the altitude stratum of 2025–2300 meters (Table 6).

Table 6. The frequency of degrees of dead trees in the altitude classes and in the northern and southern slopes of the study area

Degree of dryness	1200-1475 (m)				1475-1750 (m)				1750-2025 (m)				2025-2300 (m)			
	Northern		Southern		Northern		Southern		Northern		Southern		Northern		Southern	
	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)	Freq.	(%)
Grade 1	119	49.4	51	44.3	76	45.5	41	21.5	94	47.95	23	19.6	10	32.25	8	34.8
Grade 2	65	27	36	31.3	59	35.4	48	25.3	27	13.8	29	24.8	8	25	5	21.7
Grade 3	20	8.3	15	13	9	5.4	17	8.9	24	12.2	20	17	7	21.9	4	17.4
Grade 4	8	3.3	3	2.6	0	0	6	3.1	8	4	4	3.4	3	9.4	4	17.4
Grade 5	29	1.2	10	8.7	23	13.7	78	41	43	21.9	41	35	4	12.5	2	8.7
Sum	241	100	115	100	167	100	190	100	196	100	117	100	32	100	23	100

Typically, there are 6.35 tree stems in the altitude stratum of 1200–1475 meters. The maximum value of tree frequency is observed in the altitude stratum of 1475–1750 meters, where the average value is 7.35 tree stems per hectare. The minimum value is observed in the altitude stratum of 2025–2300 meters, where the average frequency is 5.5 tree stems per hectare (Fig. 7). Additionally, the ANOVA statistical test, which compares the average frequencies of dead trees across altitude strata, demonstrates significant differences (Fig. 9).

Discussion

According to the study, as the altitude increases from sea level, the number and diversity of species also increase. In lower altitudes, the forest cover is typically formed by only two or three species, while tree species increase at higher altitudes. These findings are consistent with the research of Mohammadi Zadeh et al. (2014), Hasanzadeh Navroudi and Safari (2018), and Rezaei Sangedehi et al. (2020).

As the altitude increases, the frequency of oak species decreases. Conversely, species such as Pistachio, Maple tree, Almond tree, and Italian Honeysuckle increase in frequency. Additionally, the frequency of hawthorn species is low in the lower band, but it increases in the middle altitude and decreases again at higher altitudes.

The status of the volume varies depending on the altitude. The volume is low in the lower altitude strata, reaches its maximum in the middle altitude, and then decreases again in the higher altitude. However, the northern and southern slopes studied do not follow the same pattern, mainly as a result of the direction of the slope.

The findings of this study are in agreement with the results obtained by Zhu et al. (2010), Gonmadje et al. (2017), and Mannan et al. (2018) regarding the decrease in volume along the altitude gradient. However, they do not align with the reports of Maza et al. (2022), Thokchom and Yadav (2017), and Cuni-Sanchez et al. (2017). Several factors could affect the increase or decrease in inventory along altitude gradients, including geographical latitude, forest type being studied, slope direction, soil type, and even the degree of slope (Soleimani et al., 2008).

Various factors have contributed to the reduction of forest inventory in the lower regions of the study area. These include drought and recent climatic variations in the Zagros region (Javanmiri Pour et al., 2023), intensified duration and severity of dust storms (Shahbazi et al., 2016), seasonal wildfires (Javanmiri Pour et al., 2022), soil compaction due to agricultural practices, livestock presence in forests (Javanmiri Pour et al., 2022), and destruction resulting from developmental activities (Alireza et al., 2020). These activities have caused reduced tree fertility, increased soil erosion, weakened trees, and made them susceptible to pest infestation and diseases. Alterations in rainfall patterns and changes in climatic parameters such as air temperature, wind speed, solar radiation, evaporation, transpiration, and dust have led to variations in tree species and associated characteristics across altitude gradients.

The distribution of trees across various altitude gradients has been observed to follow a distinct pattern of diametric classes, primarily adhering to a reversed normal model, which forms a U-shaped curve. This pattern holds true for elevations ranging from 1200–1475 m to 1475–1750 m and 2025–2300 m. However, at the elevation class of 1750–2025 m, the pattern intermittently transforms into a reversed J-shaped or a reversed U-shaped model. Furthermore, the distribution of trees across different altitude zones exhibits a Gaussian trend or a reversed U-shaped pattern in the lower and middle altitude classes ranging from 1200–1475 and 1475–1750 m. Contrastingly, the trend is declining in the middle and high-altitude regions (1750–2025 and 2025–2300 m).

It is worth noting that the inconsistent pattern observed at the elevation class of 1750–2025 m may be the result of various environmental factors, such as moisture and soil type, which may play a significant role in shaping the distribution of trees. Nonetheless, the pattern observed across different altitude gradients provides valuable insights into the natural patterns of forest growth and can help us understand the dynamics of forest ecosystems better.

Over the past two decades, natural and human-induced disturbances have caused deviations from the natural structure of forest ecosystems, resulting in significant impacts on the distribution of trees in terms of diameter and altitude classes. One of the most notable factors contributing to this phenomenon is the presence of livestock grazing in forest areas. The effects of this activity have led to the depletion of scarce regeneration and the forest's support base, both of which are necessary for its sustainability.

In the region under consideration, various types of shepherd camps exist, which are located in different altitude classes and significantly influenced by environmental factors, especially their altitude above sea level. These camps play a vital role in the life cycle of forest trees. In particular, shepherds utilize them during the autumn and spring seasons. Autumn is the season when seeds are produced, while spring marks the budding season for saplings. However, due to the presence of livestock in forest areas, seeds and saplings become fodder for the animals, leading to a negative impact on the forest's regeneration capacity.

In conclusion, the natural and human-induced disturbances in forest ecosystems have caused significant changes over the past two decades, leading to a deviation from their natural structure. The presence of livestock grazing in forest areas is a notable factor contributing to this. The negative impact of this activity on the forest's regeneration capacity and support base is crucial for its sustainability. Shepherd camps play a crucial role in the life cycle of forest trees, but their utilization during the autumn and spring seasons needs to be managed carefully to mitigate the negative impact on seed and sapling availability.

The present study aims to scrutinize the degree of dieback among trees in different altitude regions. The results indicate that the dieback status is more severe in lower-altitude regions compared to the mid-altitude regions. Moreover, within the mid-altitude areas, the degree of dieback is higher compared to the higher-altitude areas. These findings are consistent with the results presented by Karamian and Mirzaei (2020). However, the results are inconsistent with the findings of Mirzaei et al. (2019).

These findings have important implications for policymakers and environmentalists. The study highlights the need for effective measures to mitigate the impact of dead trees in lower-altitude regions. Moreover, it underscores the importance of monitoring the degree of dieback in mid-altitude areas, which are critical for the survival and growth of trees. Future research should focus on identifying the underlying causes of dieback in different altitude regions and developing targeted interventions to address this issue.

It has been observed that an elevation increase of every hundred meters from the sea level results in a reduction of approximately 0.6 degrees Celsius in air temperature. This temperature change, in turn, significantly affects the distribution of vegetation cover. It is noteworthy that the temperature change can cause a significant shift in the type of vegetation, as different species of plants have varying temperature requirements for optimum growth and survival. Therefore, an accurate understanding of the relationship between elevation, temperature, and vegetation cover is crucial for effective land management and environmental conservation.

Notwithstanding the pervasive issues related to global warming and climatic changes observed at larger scales, such as the ones under scrutiny in this study, the most significant factor in reducing dieback is the elevation from sea level. This is due to the fact that at higher elevations, the air temperature is lower, resulting in the ecological cold requisite for the physiological dormancy of trees and concomitantly, minimizing pest activities.

During the winter months, insect activity is inhibited by the presence of colder temperatures, which forces them into hibernation. This phenomenon results in a decrease in insect activity, particularly at higher altitudes, where the freezing winter temperatures often lead to casualties among specific insect populations. However, at lower altitudes, the absence of typical cold spells during the winter months means that damaging agents can persist, causing harm to Iranian oak trees.

It is essential to note that while insect hibernation is a natural occurrence, the absence of this process in lower altitudes can have severe consequences for the ecosystem. The impact of damaging agents on Iranian oak trees highlights the need for a proactive approach to mitigate such threats. The application of appropriate pest control measures can help prevent the destruction of these essential trees, which are vital to the ecosystem's health and biodiversity. The presence of colder temperatures during the winter months can have a significant impact on insect populations, forcing them into hibernation. However, this phenomenon is not universal, particularly in lower altitudes, where damaging agents can cause harm to trees. Therefore, it is necessary to implement preventive measures to protect the ecosystem and mitigate potential threats.

As altitude increases from sea level, due to the thinning of the air and less heat absorption, coupled with increased ground reflection at night, the reduction in air temperature occurs largely. The alteration of elevation from sea level is a crucial environmental factor that provides insight into the distribution of living organisms across temporal and spatial dimensions (Azizi et al., 2020). This factor exerts a significant influence on the quantity and type of precipitation, evaporation, transpiration, and solar radiation intensity, which, in turn, affects the type and density of vegetation cover (Roupioz et al., 2016). Alterations in elevation have been shown to reduce tree growth (Cooms and Allen, 2007). With an increase in altitude from sea level, the average air temperature decreases, resulting in the formation of distinct climatic regions in conjunction with other climatic factors. This, in turn, leads to the creation of regions with species diversity and adaptation to specific cold conditions (Magurran, 1988), which are less susceptible to drought stress during global warming and climate change.

Conclusion

The Natural Resources Organization of the country has recently taken steps towards forest management and conservation. This initiative is particularly focused on the altitudinal range of the Zagros forests. To obtain a comprehensive analysis of the structural diversity and inventory levels within this altitude gradient, accurate and comprehensive information is required. The findings of this study can play a key role in addressing ecological concerns such as biodiversity conservation, natural resource management, and favorable environmental conditions. Furthermore, the findings of this study can aid in predicting future changes. As such, the results of this research hold significant value for further research and policy development in these areas.

Declarations

Author Contribution

R.H.H. and M.J. wrote the main manuscript text. All authors reviewed the manuscript.

The authors declare that they have no competing interests.

References

1. Soleymani, N., Dargahi, D., Pourhashemi, M., & Amiri, M. (2008). Effects of physiographical factors on oak sprout-clumps structure in Baba-Kooseh forest; Kermanshah province. *Iranian Journal of Forest and Poplar Research*, *16*(3), 477-467.
2. Shabanirad, B., Pilehvar, B., Jafari Sarabi, H., & Veiskaramii, G. (2020). Floristic composition and plant communities along an altitude gradient in Quercus brantii forests. *Forest Research and Development*, *6*(1), 57-74.
3. Shahbazi T, Saiedi M, Nosratti I, alali Honarmand S J. Evaluation the Effect of airborne dust on physiological characteristics and yield of different wheat varieties (Triticum sp.). Plant Process and Function 2016; 5 (15) :195-204.
4. shahriary, H., abrari, K., pilehvar, B., & heydari, M. (2020). Response of plant functional groups to some environmental variables i. *Journal of Plant Research (Iranian Journal of Biology)*, *32*(4), 798-814.
5. Javanmiri pour, M., Valipour, J., & Hasanzadeh, A. (2022a). Study of structural factors and effective motives in causing forest and pasture fires in semi-arid ecosystems of the Zagros mountain. *Journal of Arid Biome*, *11*(2), 15-27.
6. Javanmiri Pour, M., Hassanzadeh, A., Parvaneh, R., & Mashayekhi, Z. (2022b). Quantification of the destruction of structural characteristics in the areas of Brant`s oak (Quercus brantii Lindl.) slash and burn agricultural areas in Zagros ecosystems. *Iranian Journal of Forest and Poplar Research*, *30*(2), 164-179.
7. Javanmiri pour M, Valipour J, Hasanzadeh A. (2023). Study of Climate Change on the Structure and Decline of Persian Oak (Quercus brantii Lindl.) in Zagros Ecosystems (Case study: Forests of Gilan-e-Gharb County). *ifej*. *11*(21), 12-23.
8. Hassanzad Navroodi, I. (2019). Study of altitude effect on abundance and composition of tree regeneration in natural forest stands of Astara. *Journal of Plant Research (Iranian Journal of Biology)*, *31*(4), 781-790.
9. hosseini, A. (2014). Diversity of tree and shrub species in relation to topographic factors and stand characteristics in oak forests of Ilam province. (Case study; Miantang forests in shirvan-chardavol). *Journal of Plant Research (Iranian Journal of Biology)*, *27*(2), 194-203.
10. Karamian, M., Mirzaei, J. 2020. The Most Important Factors Affecting Persian Oak (Quercus brantii) Decline in Ilam Province. Ecology of Iranian Forests, 93-103: (15) 8.
11. Mohammadzadeh, A., basiri, R., & torahi, A. (2015). Evaluation of biodiversity of plant species in Arasbaran zone using noun parametric measures With Respect to Ecological Factor of Altitude. *Cellular and Molecular Research (Iranian Journal of Biology)*, *27*(5), 949-963.
12. Mirzaei, M., Bonyad, A. E., Akhavan, R., & Naghdi, R. (2019). Decline modelling of Quercus brantii under effects of physiographic factors in Dalab forests of Ilam. *Forest Research and Development*, *5*(2), 329-342.
13. Alirezai, Z., Gandomkar, A., khodagholi, M. and Abbasi, A., 2020. Studying spatiotemporal changeability of oak forests in zagros in response to rainfall variation. Geography and sustainability of environment 34: 93-107.
14. Azizi, K., Naji, H.-R., Hassaneian-Khoshroo, H. and Heydari, M., 2020. Effect of altitude and growing season on some physiological properties of leaf from Persian oak (*Quercus brantii*) in Zagros forest (Case study: Ilam). Plant process and function 9 (35): 101- 114.
15. Baddeley, A. (2010). Analysing Spatial Point Patterns in R. Version 4.1. Perth: CSIRO and University of Western Australia.

http://research.csiro.au/software/wp-content/uploads/sites/6/2015/02/Rspatialcourse_CMIS_PDF-Standard.pdf

16. Bowman, W., Hacker, S. 2021. Ecology. Oxford University Press. 744 p.
17. Cooms, D. A. and Allen, R. B., 2007. Effects of size, competition and altitude on tree growth. Journal of Ecology 95: 1084-1097.
18. Cuni-Sanchez, A., Marion Pfeifer, Rob Marchant, Kim Calders, Cathrine L. Sørensen, Patrícia V. Pompeu, Simon L. Lewis, Neil D. Burgess, 2017. New insights on above ground biomass and forest attributes in tropical montane forests. Forest Ecology and Management, 399, 235-246.
19. Curtin, G. G., 1995. Can landscapes recover from human disturbance? Long-term evidence from disturbed subalpine communities. Biological Conservation, 74: 49-55.
20. da Silva, R. L., Leite, M., Muniz, F., de Souza, L., de Moraes F.and C, Gehring. 2017. Degradation impacts on riparian forests of the lower Mearim River, eastern periphery of Amazonia. Forest Ecology and Management 402: 92-101.
21. Gonmadje, C., Picard, N., Gourlet-Fleury, S., Réjou-Méchain, M., Freycon, V., Sunderland, T., McKey, D., & Doumenge, C. (2017). Altitudinal filtering of large-tree species explains above-ground biomass variation in an Atlantic Central African rain forest. *Journal of Tropical Ecology*, *33*(2), 143–154. https://www.jstor.org/stable/26563666
22. Javanmiri Pour, M.J., Mohadjer, M.R.M., Etemad, V. et al. Determining structural variation in a managed mixed stand in an old-growth forest, northern Iran. J. For. Res. 30, 1859–1871
23. Magurran, A. E., 1988. Ecological diversity and its measurement. Springer, England.
24. Mannan, A., Zhongke, F., Ullah Khan, T., Saeed, S., Amir, M., Asif Khan, M., and Tariq Badshah, M. 2018. Variation in tree biomass and carbon stocks with respect to altitudinal gradient in the Himalayan forests of Northern Pakistan. J. of Pure and Applied Agriculture. 4: 1. 18-26.
25. Maza B, Rodes-Blanco M and Rojas E (2022) Aboveground Biomass along an Elevation Gradient in an Evergreen Andean–Amazonian Forest in Ecuador. Front. For. Glob. Change 5:738585.
26. Brian J. Palik, Anthony W. D'Amato, Jerry F. Franklin, K. Norman Johnson. 2020. Ecological Silviculture, Foundations and Applications. Waveland press. 343 p.
27. Shabani Rad, B., Pilehvar, B., Jafari Sarabi, H. and Veiskarami,Gh. H. 2014. Floristic composition and plant communities along an altitude gradient in *Quercus brantii* forests. Journal of Forest Research and Development, 6 (1), 57-74.
28. Stringer, J. W., Kimmerer, T. W., Overstreet, J. C. and Dunn, J. P., 1989. Oak Mortality in Eastern Kentucky .Southern Journal of Applied Forestry 13 86-91.
29. Suzuki, W., Osumi, K., Masaki, T., Takahashi, K., Daimaru H. and K, Hoshizaki. 2002. Disturbance regimes and community structures of a riparian and an adjacent terrace stand in the Kanumazawa Riparian Research Forest, northern Japan. Forest Ecology and Management 157: 285-301.
30. Rezaei Sangdehi, S.M., Fallah, A., Oladi J. and Latifı. H. 2020.Determination of altitude gradient effect on quantitative characteristics of forest stands (Case study: District 3 of Sangdeh forests). J. of Wood & Forest Science and Technology, Vol. 27 (1), 1-16.
31. Roupioz, L., Jia, L., Nerry, F. and Menenti, M., 2016. Estimation of Daily Solar Radiation Budget at Kilometer Resolution over the Tibetan Plateau by Integrating MODIS Data Products and a DEM. remote sensing 8 1-24.
32. Thokchom, A., and Yadava, P. S. 2017. Biomass and carbon stock along an altitudinal gradient in the forest of Manipur, Northeast India. Tropical
33. Ecology. 58: 2. 389-396.
34. Zhu, B., Wang, X., Fang, W., Piao, S., Shen, H., Zhao, S., and Peng, C. 2010. Altitudinal changes in carbon storage of temperate forests on Mt Changbai, Northeast China. Carbon Cycle Process in East Asia. 123: 439-452.

Figures

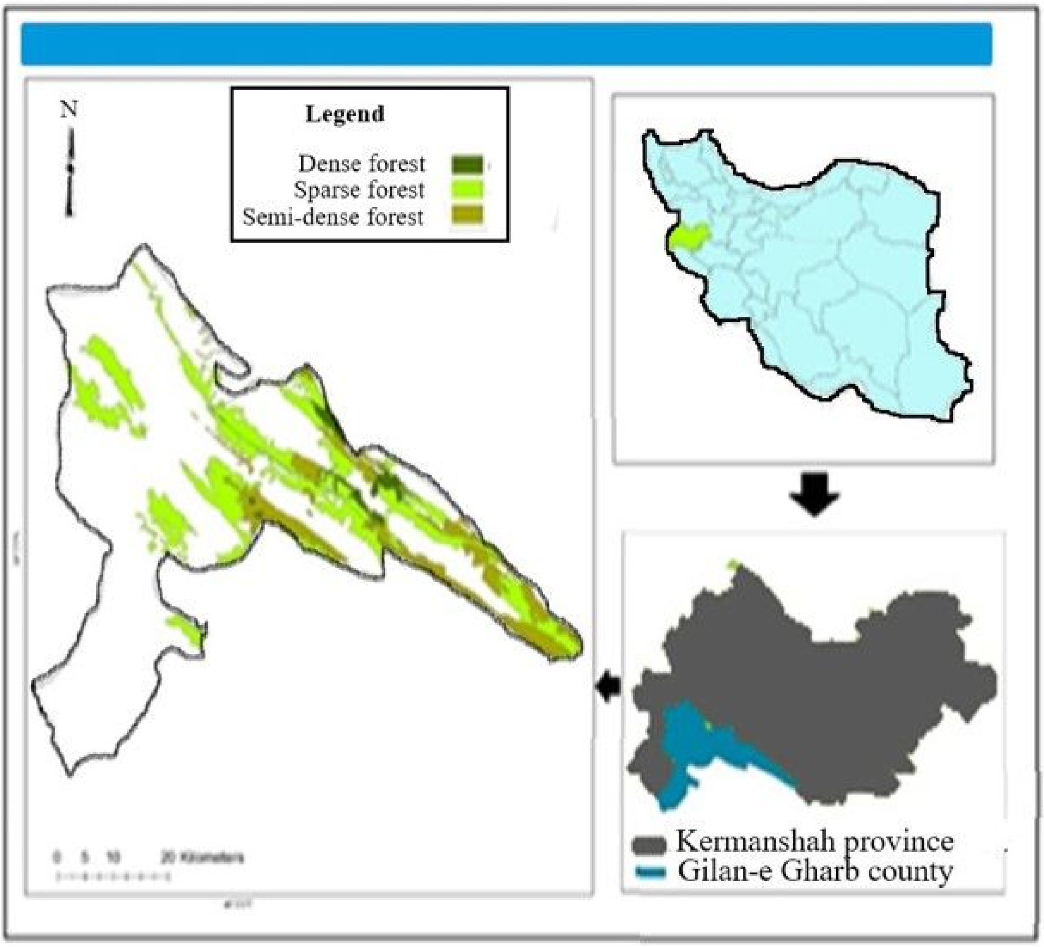

Figure 1

The studied area, located in Gilan-e Gharb, Kermanshah province in western Iran.

Figure 2

Distribution status of tree abundance in height classes (Latin numbers indicate significance).

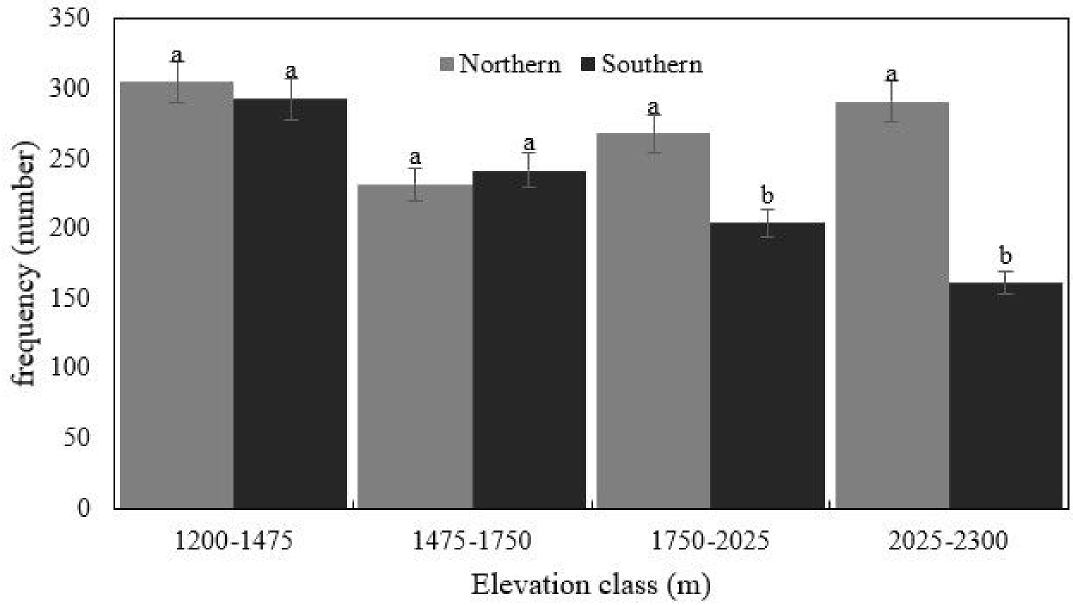

Figure 3

Distribution status of tree abundance in elevation classes in geographic ranges (Latin numbers indicate significance).

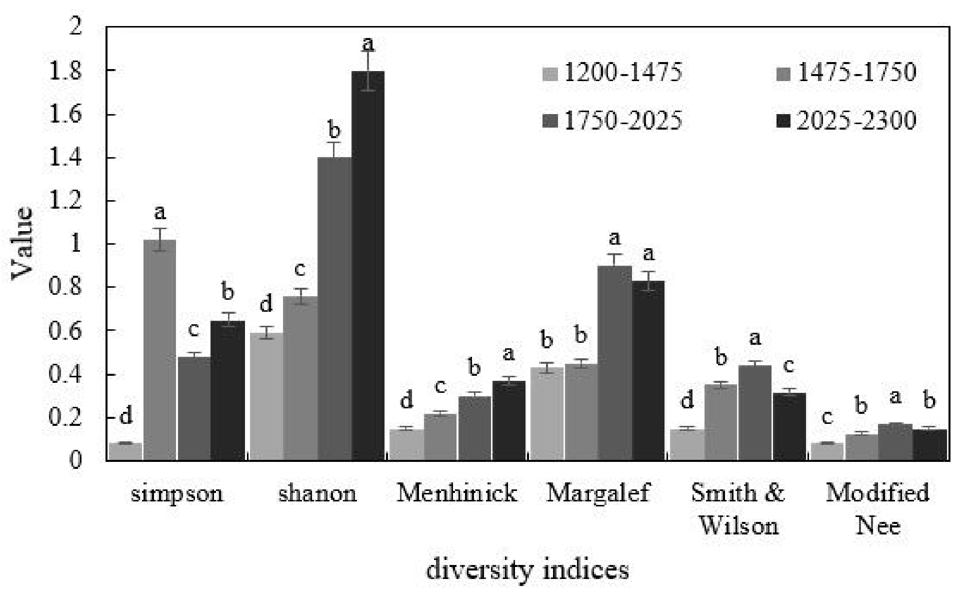

Figure 4

Status of diversity indices in altitude classes (Latin numbers indicate significance).

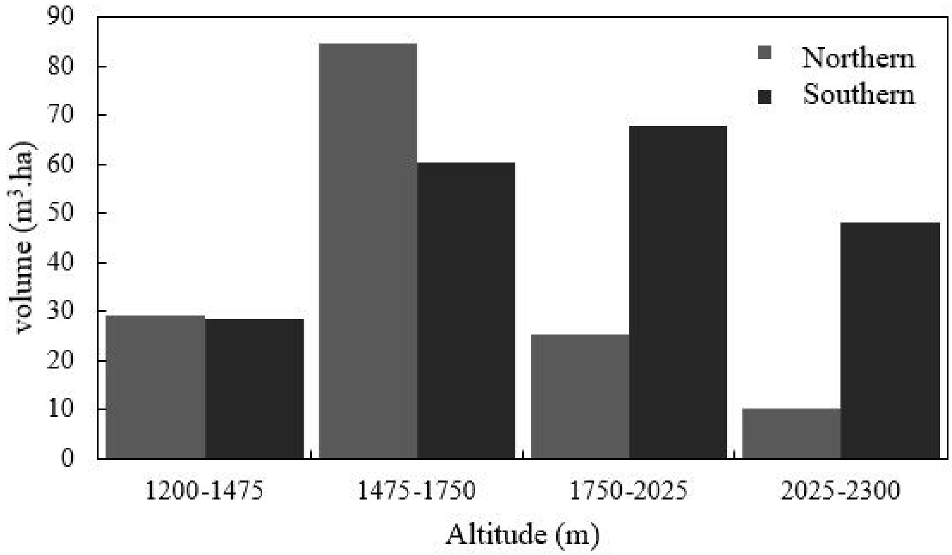

Figure 5

The total amount of volume in the elevation classes and in the northern and southern slopes

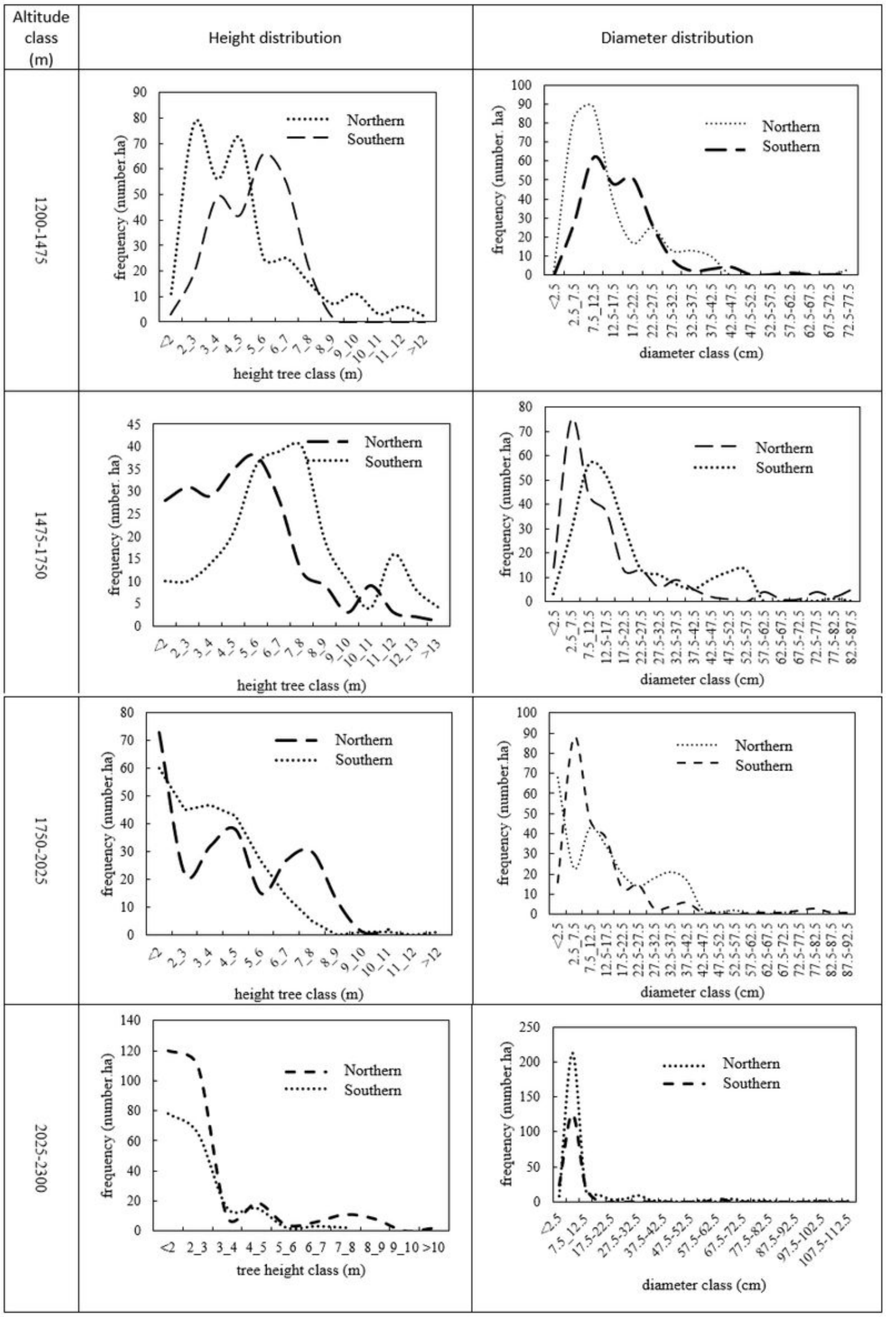

Figure 6

Number distribution in diameter and height classes of trees in northern and southern slopes

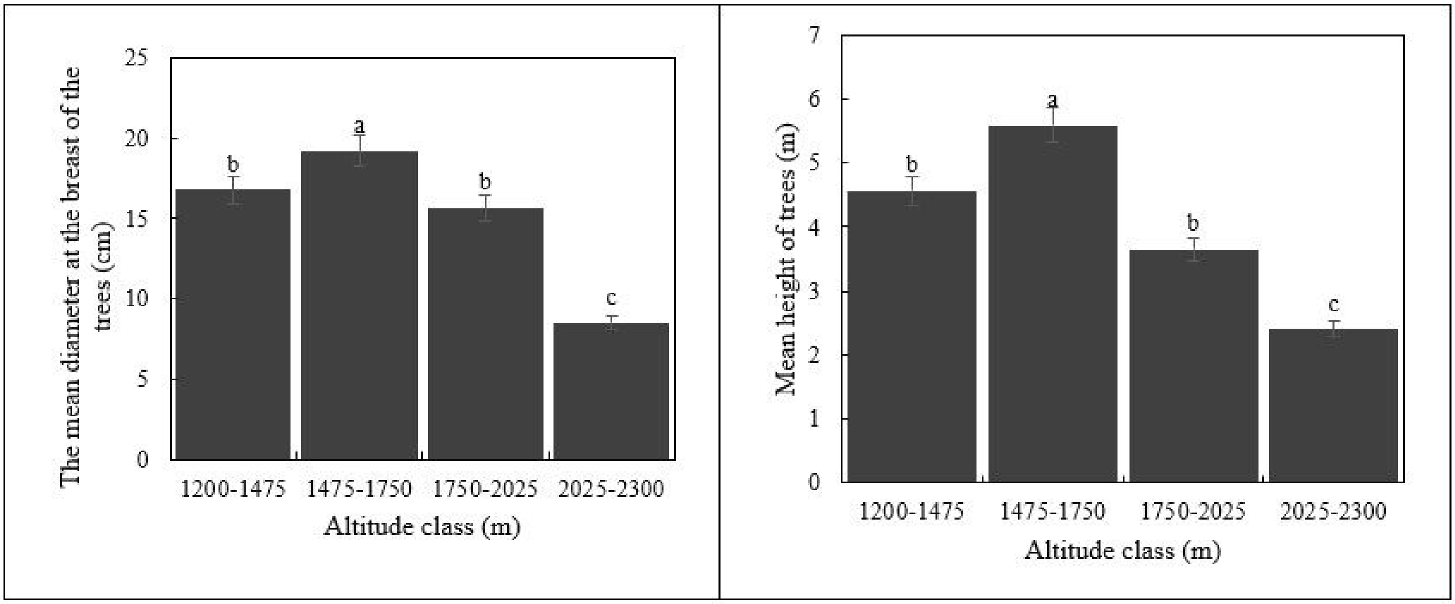

Figure 7

Mean diameter of trees (right) and average height of trees (left) in altitude classes above sea level

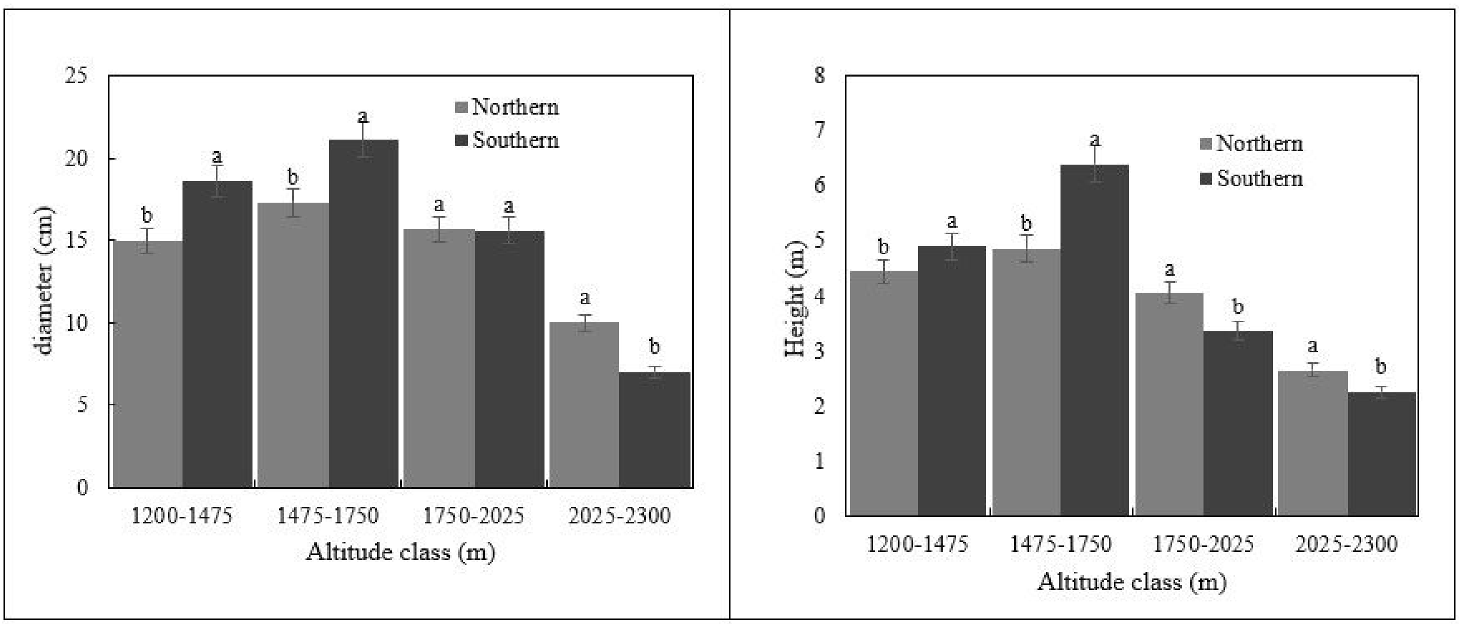

Figure 8

The average diameter of trees (right) and the average height of trees (left) in the altitude classes located in the northern and southern geographical ranges.

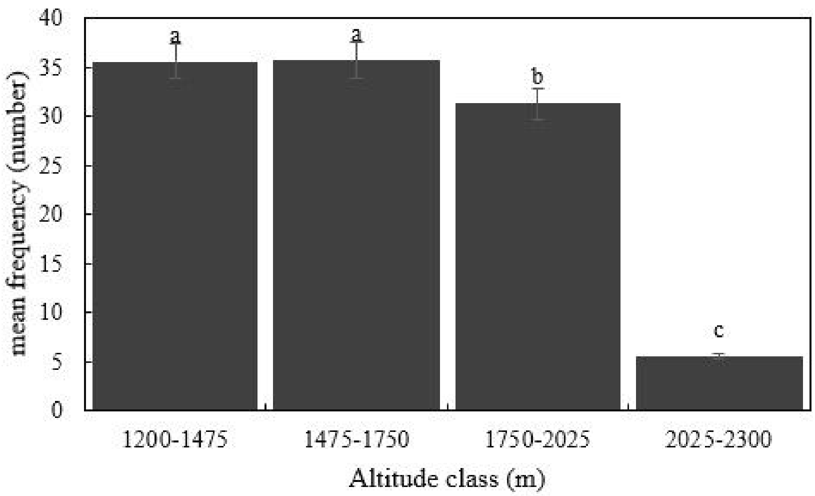

Figure 9

The average abundance of dead trees in the height classes