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## RESEARCH ARTICLE

# Evaluation of Plant Species Diversity and Floristic Characteristics in Plant Ecological Group in Relation to Altitudinal Gradient, Kourdkoy Forest, North of Iran

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## ABSTRACT

Forest ecosystems have vegetation cover as their fundamental structural element that demonstrates how environmental parameters operate. This study investigated the effect of altitude variations on plant community and diversity patterns in the Kourdkoy Forest located in Golestan province of northern Iran. We established 48 circular plots with an area 1000 m<sup>2</sup> at each of the six different elevational belts from 500 to 1700 m above sea level at 200 m intervals using random-systematic sampling method. Tree species at each plot were measured, while the herbaceous species survey in 100 m<sup>2</sup> subplots. Using Two-Way Indicator Species Analysis (TWINSPAN) identified five plant communities known as Cyclameno-Fagetum community, Carexeto-Fagetum community, Athyriumeto-Fagetum community (appeared on two classes), and Galiumo-Fagetum community named according to their dominant and indicator species. among the 60 plant species belonging to 37 families and 55 genera which were found in the studied area. ANOVA test showed that altitude served as the significant variable leading to significant diversity index differences ( $P \leq 0.05$ ) among the communities for Shannon-Wiener, Smith-Wilson, and Margalef. The Raunkiaer method indicated hemicryptophytes prevailed as life-forms over cryptophytes by 43% and 22%, respectively and Euro-Siberian chorotype earned first place position with 40%. The research demonstrated that altitude-caused ecological transformations which occur in a vital forest system enabling understanding for temperate region conservation and management activities.

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**1. Introduction**

The most vital natural resources that support sustainable economic development are renewable forest resources (Kulakowski et al., 2017; Acwin Dwijendra et al., 2022). Natural resources attribute together with their changing patterns have increased human interest in understanding environmental effects on plant communities (Kulakowski et al., 2017; Acwin Dwijendra et al., 2022). Vegetation cover functions as an essential ecosystem element that both demonstrates environmental characteristics and serves as a secure

information base for ecological examination (Sun et al., 2015; Mucina et al., 2016). Plant communities use species recognition and classification activities at the plant community level to derive valuable health and biodiversity information about their ecosystems (Brosofske et al., 2001). Plants do not arrange themselves at random throughout environments since their spatial patterns align closely with environmental factors (Gao et al., 2015), while multiple important elements substantially influence their organization and species structures (Kraft et al., 2015; Bjorkman et al., 2018). Plant community distribution and species frequency patterns are closely associated with

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topographic and environmental factors, including altitude, slope, climate, and soil conditions (Jafarian et al., 2019). The substantial climatic effects caused by altitudinal gradients guide the formation of various vegetation classes and forest types (Krömer et al., 2013; Sinha et al., 2018).

The creation of different climatic zones across forest ecosystems at different altitudes influences plant diversity because results from Wani et al. (2023) and Rezende et al. (2015) show peak species diversity occurs in intermediate elevation areas. The importance of conducting thorough investigations about these gradients affecting biodiversity becomes clear (Zhang et al., 2021). The most vital natural economic development resource base consists of renewable timber resources along with forests (Kulakowski et al., 2017; Acwin Dwijendra et al., 2022). Researchers accelerate their research on environmental conditions and plant community responses through heightened interest in these resources (Kulakowski et al., 2017; Acwin Dwijendra et al., 2022). Environmental conditions influence vegetation covers and plant community structure, providing an important basis for ecological assessment (Gao et al., 2015; Kraft et al., 2015; Sun et al., 2015; Mucina et al., 2016; Bjorkman et al., 2018). The identification, and classification of plant communities helps scientists understand the biodiversity of ecosystems (Brososke et al., 2001).

Altitudinal gradients are important environmental factors that create climatic variation and provide valuable opportunities to study plant community responses to environmental change that develop unique vegetation groups and forest types (Krömer et al., 2013; Sinha et al., 2018). Research conducted by Wani et al. (2023) and Rezende et al. (2015) indicated that plant species diversity reaches its maximum peak at middle altitude levels across the world. Detailed research needs to focus on the impact of these gradients since they influence biodiversity patterns (Zhang et al., 2021). The Hyrcanian forest regions extend over 1.8 million hectares of north Iranian territory that accounts for 7% of the national landscape (Kooch et al., 2023; Pourghasemi, 2016). This forest ecosystem maintains 80 tree species combined with 50 shrub species (Ali et al., 2020; Bayat et al., 2020). The broadleaved deciduous forests of the Alborz Mountains' northern slopes overlooking the Caspian Sea because they possess wide-ranging climatic elements and terrain characteristics (Pourbabaei & Haghgoy, 2013).

Biological management of variability occurs in forests alongside crucial nutrient cycling processes which support ecosystem development and maintain complete sustainability (Hosseini et al., 2024). Prior studies have reported varying peaks of diversity at different altitudes in the region, such as tree species richness peaking at 500 m in areas like Kourdkey Forest (Ahmadi et al., 2023), while other research indicates peaks at higher elevations, such as 2070 m in adjacent regions (Ataei et al., 2021), suggesting potential regional variation

(Mouquet et al., 2015; Zhou et al., 2020; He et al., 2023; Lu et al., 2023; Rahman et al., 2022; Schroeder et al., 2024; Su et al., 2024; Zhang et al., 2024).

Despite the ecological importance of Hyrcanian forests, detailed information on plant community classification and diversity patterns along altitudinal gradients in the Kourdkey forest remains limited. Research needs to address an essential knowledge gap because scientists have confirmed altitude's impact on worldwide plant diversity (Scherrer & Körner, 2011). Understanding how plant communities change along elevation gradients is important for improving ecological knowledge and supporting forest management and conservation (Noroozi et al., 2016). Therefore, this study aimed to classify plant communities using TWINSPLAN and to evaluate plant diversity patterns along an altitudinal gradient in the Hyrcanian forest ecosystem.

## 2. Materials and Methods

### 2.1. Study Area

The study was conducted in Kourdkey Forest where is situated in Golestan Province, northern Iran. It occurs at 36° 39' 00" to 36° 41' 30" N, 54° 04' 30" to 54° 07' 38" E of Golestan Province with an altitudinal gradient of 300 to 2000 m a.s.l. According to estimated climatic data from the nearest stations, annual precipitation, and mean annual temperature were 1240 mm and 12.6°C and also a 2.5-month dry season between June and August. Its temperate climate and varied topography support diverse vegetation typical of the Hyrcanian Forests (Department of Natural Resources and Watershed Management of Golestan Province, 2013).

### 2.2. Data Collection

Sampling was focused on the elevation range from 500 to 1700 m a.s.l. and the effects of altitude on plant community distribution were determined. The studied area was divided into six altitudinal classes at 200 m intervals according to previous methods (Pourbabaei & Haghgoy, 2013; Kessler et al., 2014). A random-systematic design established eight circular plots with a 1000 m<sup>2</sup> area in each altitudinal class through the use of 150 m spacing between the plots (Pourbabaei et al., 2019; 2020). The slope percentage and geographic aspect were documented for each plot. The diameter at breast height (DBH $\geq$ 7.5 cm) was measured for all trees (Pourbabaei et al., 2014). The Whittaker's nested plot sampling method provided a basis for choosing appropriate subplot sizes by determining the optimized subplot size to obtain representative herbaceous species data. Results from the analysis led researchers to choose 100 m<sup>2</sup> subplots as the proper size for herbaceous species estimation. We evaluated herbaceous species occurrence in every subplot using the Braun-Blanquet criterion to measure their cover percentage (Manish et al., 2017; Pourbabaei et al., 2019).

### 2.3. Data Analysis

Sampling was conducted in two seasons (spring and Summer), the species were dried and pressed before identifying by using Iranica Flora (Rechinger, 1963-1998), Turkey Flora (Davis, 1965-1988), Iran Flora (Assadi, 1988-2003) and the Colorful Flora of Iran (Ghahreman, 1975-2000) in the herbarium of the Faculty of Natural Resources in University of Guilan. Moreover, the chorology of species was determined according to the Zohary and Takhtajan method (Takhtajan, 1986). In order to determine the plant communities, analysis was done with Two-Way Indicator Species Analysis (TWINSPAN) using PC-ORD software for Windows, version 4.17 that the resulting groups are referred to as plant communities based on dominant and indicator species, rather than formal phytosociological associations (Hasanpori et al., 2014). In each community, Species Important Values (SIV) were computed for tree and herbaceous species using equations 1 and 2, respectively (Pourbabaei et al., 2014):

$$\text{SIV} = \text{relative frequency} + \text{relative dominance} + \text{relative density} \quad (1)$$

$$\text{SIV} = \text{relative frequency} + \text{relative dominance} \quad (2)$$

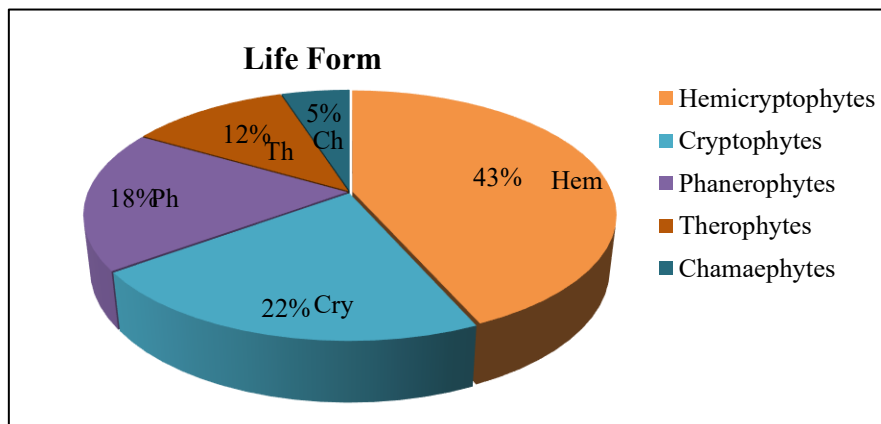
Finally, diversity indices including Shannon-Wiener ( $H'$ ) which is sensitive for comparison among plant communities (Kent, 2011), Smith-Wilson as it is mathematically independent

of species richness and therefore allows a more reliable assessment of abundance distribution patterns among plant communities (Smith & Wilson, 1996), and Margalef indices that diminish the bias associated with differences in total abundance among plant communities (Gómez et al., 2000) were calculated using Ecological Methodology software for Windows, version 6.0 (Hosseinzadeh et al., 2016). Kolmogorov-Smirnov and Levene's tests demonstrated that the data passed the requirements of normality and homogeneity of variances. The analysis consisted of One-way ANOVA at  $\alpha = 0.05$  with Tukey's post-hoc tests for mean comparisons between communities and altitudinal classes in SPSS v16.0.

## 3. Results

### 3.1. Floristic Composition

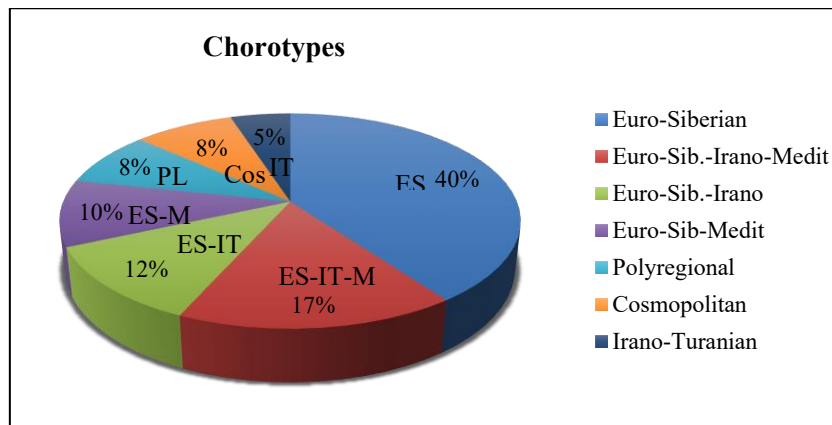
It has been identified 60 species belonged to 37 families, and 55 genera (6 trees, and 54 herbaceous species). The prominent families were Rosaceae (5 species), Lamiaceae (4 species), Apiaceae, Aspleniaceae, Asteraceae, Brassicaceae, and Fabaceae (each family with three species), which had the highest frequency. The result of life form classification indicated that hemicryptophytes (26 species), cryptophytes (13 species) were dominance. Other life forms were present with lower frequency, including phanerophytes (11 species), therophytes (7 species), and chamaephytes (3 species) (Figure 1).



**Figure 1.** Life forms of trees and herbaceous species in the study area, Hem: Hemicryptophytes; Ch: Chamaephytes; Th = Therophytes; Ph = Phanerophytes; Cry: Cryptophytes.

The chorotype indicated that Euro-Siberia was dominant with 24 species (40%), Euro-Siberian-Irano-Turanian-Mediterranean with 10 species (17%), Euro-Siberian-Irano-Turanian with 7 species (11%), Euro-Siberian-Mediterranean

with 6 species (10%), Polyregional with 5 species (8%), Cosmopolitan with 4 species (7%), and Irano-Turanian with 3 species (5%) (Figure 2).

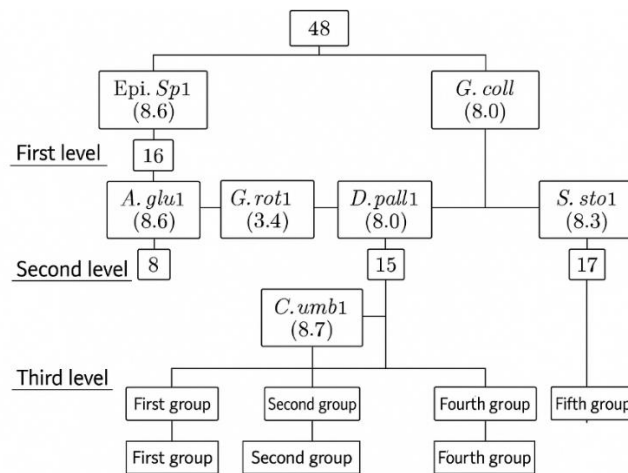


**Figure 2.** Chorotype of trees and herbaceous species in the study area, note: ES: Euro-Siberian; ES-M-IT: Euro-Siberian-Mediterranean-Irano-Turanian; ES-IT: Euro-Siberian-Irano-Turanian; IT: Irano-Turanian; Cos: Cosmopolitan; ES-M: Euro-Siberian-Mediterranean; Pl: Polyregional; Hyrc: Hyrcani.

### 3.2. The Classification of Plant Communities

The results of TWINSpan analyses were shown in Figure 3. that five distinct plant communities were identified along the altitudinal gradient, and also their accessory species in each elevation class were listed (Supplementary Table 1). At first level, 48 plots with eigenvalue 0.6059 were divided to two groups. Sixteen plots were located on left group (negative group). *Epipactis* sp. was an indicator herbaceous species in this group. In the right and positive group, there were 32 plots with *Geranium columbinum* as the indicator species. These groups did not have any indicator tree species. In the second level of classification, a group with 16 species, and eigenvalue 0.1826 was divided in 2 groups. In negative group, 8 plots were identified with *Alnus glutinosa* as indicator species without any herbaceous species. The positive group also involved 8 plots with *Euphorbia amygdaloides*. In the next step, two groups were obtained of a group with 32 plots (eigenvalue; 0.5092), 15 plots with *Dryopteris pallida* and 17 plots with *Phedimus stoloniferus* as indicator species were presented in negative and positive group, respectively. In the third level of classification

a group including 15 species and eigenvalue 0.2778 was divided to two groups. 8 plots with *Clinopodium umbrosum* were belonged to negative group and 7 plots with *Geranium* sp. were belonged to positive group. Indicator species for first level of groups has been achieved of plots that the presence of indicator species in those plots was a factor to separation. Classification process was stopped with five communities in third level. Overall, sampling plots were divided into five groups using TWINSpan. First group was belonged to first class of altitude (i.e., from 500 to 700 m a.s.l.) and included plots 1 to 8 (A). The second group had plots from 9 to 16 and was located in altitude from 700 to 900 m a.s.l. (B). The plots 17 to 24 were presented in third group that were located in altitude from 900 to 1100 m a.s.l. (C). The fourth group was belonged to 1100 to 1300 m a.s.l. (D) with 7 plots (from 25 to 31). Finally, the fifth group which was located in altitude range from 1300 to 1700 m a.s.l. (1300-1500= E<sub>1</sub>, 1500-1700= E<sub>2</sub>), with 17 plots. According to identification of plant ecological group using TWINSpan, each group was considered as a plant community (Abla et al., 2024) and was named by Species Important Value



**Figure 3.** Classification of sampling plots using TWINSpan.

### 3.3. Diversity, Evenness and Richness Values among Plant Communities

The results of ANOVA test indicated that there was a significant difference among plant communities in terms of Shannon-Wiener, Smith-Wilson and Margalef indices ( $P \leq 0.05$ ) (Table 1). The highest value of Shannon-Wiener was belonged to second community (4.20). While, the fourth

community had the lowest value (2.8) (Figure 4). The highest and lowest value of evenness was obtained for the first and third communities, respectively (Figure 5). Finally, the first community had the highest value of Margalef richness index (5.13) and the lowest was belonged to fifth community (2.39). There was a significant difference between the third community with others (Figure 6).

**Table 1.** Results of ANOVA test of diversity indices among plant communities.

Variables	DF	MS	Mean± SE	P	F
Shannon-Wiener	4	3.825	3.44±0.11	0.000*	15.54
Smith-Wilson	4	0.133	0.42± 0.02	0.000*	6.46
Margalef	4	14.824	3.46± 0.18	0.000*	52.30

MS: mean square, SE: standard error.

### 3.4. Diversity, Evenness and Richness Values in Altitude, Slope and Aspect Classes

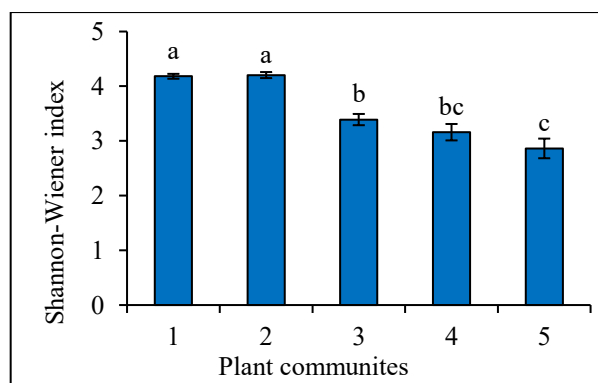
ANOVA test showed that altitude influenced all indices including Shannon-Wiener, Smith-Wilson and Margalef richness, and returned statistical significance ( $P$ -value  $\leq 0.05$ ) as indicated in Table 2. The data of this research demonstrated

that altitude influenced diversity ( $F = 13.47, P = 0.000$ ) as well as evenness ( $F = 4.23, P = 0.003$ ) and richness ( $F = 44.4, P = 0.000$ ). The values obtained for these indices showed no significant correlation to slope measurements since their corresponding  $P$ -values were 0.252 for diversity, 0.327 for evenness, and 0.121 for richness.

**Table 2.** Results of ANOVA test of diversity values in altitude, slope and aspect classes.

Variations source	Indices	DF	MS	P	F
Altitude	diversity	5	3.188	0.000*	13.47
	evenness	5	0.095	0.003*	4.23
	richness	5	12.28	0.000*	44.4
Slope	diversity	2	0.76	0.252 <sup>ns</sup>	1.42
	evenness	2	0.034	0.327 <sup>ns</sup>	1.14
	richness	2	3.20	0.121 <sup>ns</sup>	2.21
Aspect	diversity	46	0.036	0.682 <sup>ns</sup>	0.17
	evenness	46	0.042	0.221 <sup>ns</sup>	0.074
	richness	46	0.309	0.787 <sup>ns</sup>	4.54

The results of means comparison revealed that the highest value of Shannon-Wiener was belonged to altitudinal class B (2.4), however, the altitudinal range of E<sub>1</sub> had the lowest value (0.55) (Figure 7). In relation to evenness, the highest and lowest value was gained in altitudinal classes including A and C, respectively (Figure 8). Eventually, the altitudinal range of A had the highest value of Margalef richness index and the lowest was belonged to E<sub>2</sub> class (Figure 9).



**Figure 4.** Diversity indices among plant communities.

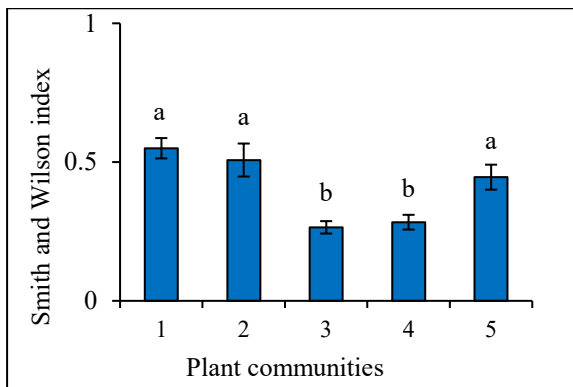


Figure 5. Evenness indices among plant communities.

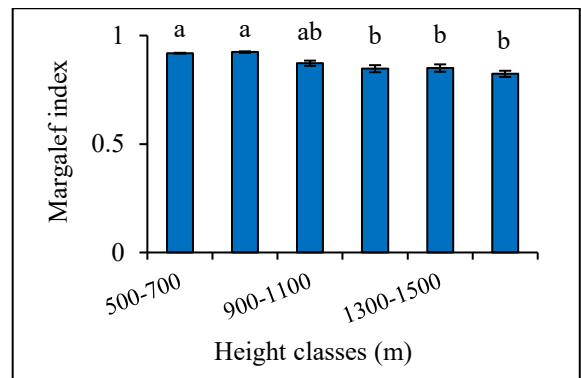


Figure 9. Richness indices of altitudinal classes.

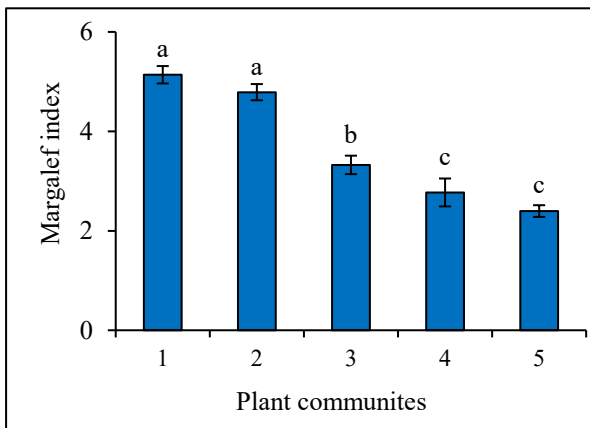


Figure 6. Richness indices among plant communities.

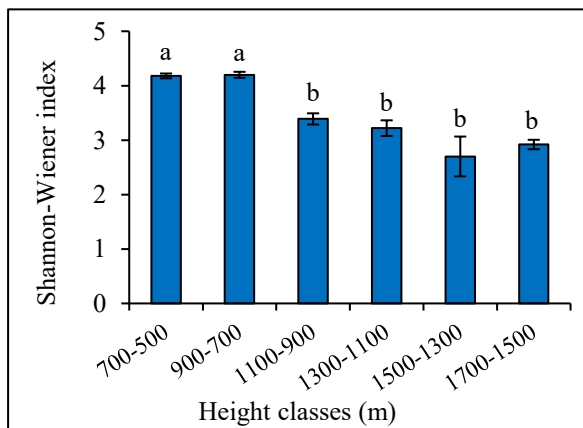


Figure 7. Diversity indices among altitudinal classes.

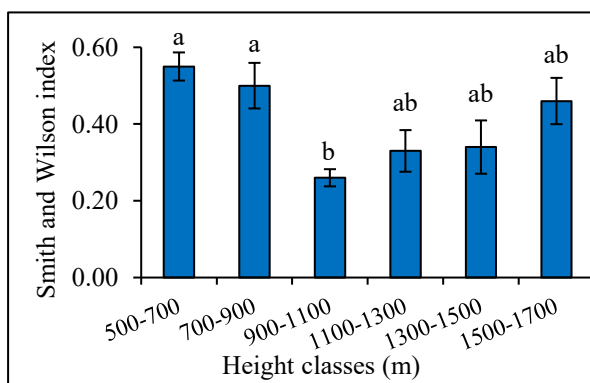


Figure 8. Evenness indices of altitudinal classes.

#### 4. Discussion

In an ecosystem, the study of floristic characteristics, and chorotype form of plant species are effective method for understanding the capacities, management, and conservation of genetic resources which can determine ecosystems position in the natural conservation global network (Haq & Badshah, 2021). According to the results, 60 species were identified in the studied area. The highest number of species was belonged to Rosaceae and Lamiaceae families. It may be related to geographical position as well as topographical heterogeneity in the studied area that possibly provided suitable edaphic conditions for species of these families (Naqinezhad et al., 2010). The results of life form classification showed that Hemicryptophytes and Cryptophytes were dominant. The highest frequency of Hemicryptophytes in an ecosystem can be a result of mountainous, and cold climates (Das et al., 2020; Ghafari et al., 2020; Wagner et al., 2021). Species belonged to this life form are tolerant to these kind of climate by keeping reviver buds in the soil (Naqinezhad et al., 2010).

Kourdkey region is a temperate area with mountainous and cold climate, and dominance of Hemicryptophytes confirm the adaptation of these life form to climatic condition (Midolo et al., 2024). Hemicryptophytes were associated with humid, and cold climate in higher geographical latitude. While, Therophytes and Chamaephytes were tolerant in dry, and unfavorable conditions (Alzamel, 2024; Di Biase et al., 2021). The geographical distribution of plant species in an area is affected by the surrounding vegetation regions (Liu et al., 2016). The temperate forests of Northern Iran belong to the Euxino-Hyrcanian province of the Pontic subregion within the Europe-Siberian region. Therefore, the presence of species belonging to these geographical ranges in the flora is reasonable (Ghorbanalizadeh et al., 2022).

The classification of plant communities indicated that there was a significant difference among diversity values. In addition, altitudinal ranges were significant among topographic factors. Therefore, it can be concluded that TWINSpan has more reasonable in the vegetation unites differentiation by various ecological characteristics than topographic classification.

Moreover, it indicates a favorable description of vegetation in compared to floristic methods (Witte, 2002).

According to TWINSpan, five plant communities were identified. The study of diversity indices among plant communities revealed that the first community had the highest richness, and evenness among groups that can be a result of higher temperature, lower percentage cover of tree species, and also increasing the entrance light in these slopes (Tuomisto et al., 2014). The second community with *Euphorbia amygdaloides* and without an indicator tree species had the highest species diversity. Excessive utilization of tree species and diminishing tree and canopy density are reasons to increase plant species diversity in forests floor (Kashian et al., 2003). On the other hand, the greater density of tree species in higher altitude is an effective factor to limited distribution of different plant species which lead to reduce species diversity (Karami et al., 2008). The third community with *Dryopteris pallida* had the lowest evenness. This species was mainly present in gaps resulting from human activities. In addition, the larger size of these species likely increased competition for light, which may have contributed to reduced richness and percent cover of many understory plants (Ebrahimi et al., 2014). Moreover, this species can diminish growth of other species by allelopathy, and chemical release (Pourbabaei & Ahani, 2004). On the other hand, the high frequency of this species in third group can be an indicative of high humidity in the environment (Chia & Lim, 2022). The presence of this group was demonstrated in the wettest slopes of the study area. The fourth and fifth groups had the lowest value of diversity indices. It may be associated with their establishment at a higher altitude (Rathore et al., 2018; Siles & Margesin, 2016). The highest value of species richness and diversity was found at intermediate altitude. Conversely It was decreased by increasing altitude, and decreasing temperature.

Results of ANOVA test for diversity indices among altitudinal classes indicated that the first, and, second classes had the highest value, and there were significant differences among classes. By increasing altitude, plant growing season will be decreased in climate condition including extreme cold, snow, hail and strong winds which can lead to diminish plant species diversity with absence sensitive species (Zhang et al., 2022; Zhu et al., 2019). Species composition is another factor which can be effective on plant diversity reduction. At lower altitudinal gradient, *Fagus orientalis* was mixed with other tree species. Whereas, the pure communities of *Fagus orientalis* were presented at altitudinal gradient from 1400 to 1700 m a.s.l. Overall, plant species diversity in pure beech communities is lower than mixed communities (Hrivnák et al., 2014; Williams et al., 2017; Benavides et al., 2019). Variation in tree species composition may be associated with differences in light availability in the studied area, possibly reflecting the shade-tolerant characteristics of beech (Chamagne et al., 2016; Zellweger et al., 2016; Driesen et al., 2020). The minimum

value of species richness was belonged to higher altitudinal gradient, which can be attributed to decrease temperature and liquid water availability in this altitude (Sharma et al., 2019). However, environmental variables such as soil properties, and microclimatic conditions were not directly measured in this study, and further research would be useful to better understand the underlying ecological factors.

## 5. Conclusion

This study identified five plant communities along the altitudinal gradient in the Hyrcanian forest using TWINSpan classification. The results indicated that altitudinal gradient had a significant effect on diversity, richness, and evenness values. Plant community distributions were affected by altitudinal factor which was the most important variability factor among the groups. An altitudinal class can be effective on plant species distribution by temperature, and humidity factors. As the result showed the higher elevation had lower species diversity. Selecting tree species that match the habitat is crucial for forest reconstruction with low diversity at high altitudes. Therefore, it is essential to adjust management strategies for effective care of forest ecosystems.

## Conflict of Interest

The authors declare that they have no competing interests.

## References

- Abla, S., Djebbouri, M., & Kefil, S. (2024). Diagnosis of the plant biodiversity of an anthropogenic zone in Algiers: Case of the Bouzaréah Forest Massif. *CRF*, 19(01), 520-536.
- Acwin Dwijendra, N. K., Sivaraman, R., Kaliyaperumal, K., & Romero-Parra, R. M. (2022). [Retracted] Balance harvest from the forest as a renewable resource using game theory. *Discrete Dynamics in Nature and Society*, 2022(1), 1377775. <https://doi.org/10.1155/2022/1377775>
- Ahmadi, K., Mahmoodi, S., Pal, S. C., Saha, A., Chowdhuri, I., Kolyaie, S., Linh, N. T. T., Thai, V. N., & Kumar, L. (2023). Modeling tree species richness patterns and their environmental drivers across Hyrcanian mountain forests. *Ecological Informatics*, 77, 102226. <https://doi.org/10.1016/j.ecoinf.2023.102226>
- Ali, A., Sanaei, A., Li, M., Nalivan, O. A., Ahmadaali, K., Pour, M. J., Valipour, A., Karami, J., Aminpour, M., Kaboli, H., & Askari, Y. (2020). Impacts of climatic and edaphic factors on the diversity, structure and biomass of species-poor and structurally-complex forests. *Science of the Total Environment*, 706, 135719. <https://doi.org/10.1016/j.scitotenv.2019.135719>
- Alzamel, N. (2024). Floristic composition, diversity, and vegetation structure in Wadi Al-Quwayiyah, Riyadh Region, Saudi Arabia. *Journal of Environmental*

- Studies*, 34(1), 1-9.  
<https://doi.org/10.21608/jesj.2024.289071.1075>
- Assadi, M. (1988-2003). Flora of Iran. Research Institute of Forests and Rangelands. Tehran, Iran.
- Ataei, A., Kazemnezhad, F., Nimvari, M. E., & Sheykholeslami, A. (2021). Ecotones and forest communities along an elevation gradient in Hyrcanian forests, north of Iran. *Caspian Journal of Environmental Sciences*, 19(2), 317-323.  
<https://doi.org/10.22124/CJES.2021.4605>
- Bayat, M., Bettinger, P., Heidari, S., Henareh Khalyani, A., Jourgholami, M., & Hamidi, S. K. (2020). Estimation of tree heights in an uneven-aged, mixed forest in northern Iran using artificial intelligence and empirical models. *Forests*, 11(3), 324.  
<https://doi.org/10.3390/fl1030324>
- Benavides, R., Scherer-Lorenzen, M., & Valladares, F. (2019). The functional trait space of tree species is influenced by the species richness of the canopy and the type of forest. *Oikos*, 128(10), 1435-1445.  
<https://doi.org/10.1111/oik.06348>
- Bjorkman, A. D., Myers-Smith, I. H., Elmendorf, S. C., Normand, S., Rüger, N., Beck, P. S., ... & Weiher, E. (2018). Plant functional trait change across a warming tundra biome. *Nature*, 562, 57-62.  
<https://doi.org/10.1038/s41586-018-0563-7>
- Brosfokske, K. D., Chen, J., & Crow, T. R. (2001). Understory vegetation and site factors: Implications for a managed Wisconsin landscape. *Forest Ecology and Management*, 146(1-3), 75-87.  
[https://doi.org/10.1016/S0378-1127\(00\)00447-3](https://doi.org/10.1016/S0378-1127(00)00447-3)
- Chamagne, J., Paine, C. T., Schoolmaster Jr, D. R., Stejskal, R., Volarřík, D., Šebesta, J., Trnka, F., Koutecký, T., Švarc, P., Svátek, M., Hector, A., & Matula, R. (2016). Do the rich get richer? Varying effects of tree species identity and diversity on the richness of understory taxa. *Ecology*, 97(9), 2364-2373.  
<https://doi.org/10.1002/ecy.1479>
- Chia, S. Y., & Lim, M. W. (2022). A critical review on the influence of humidity for plant growth forecasting. *IOP Conference Series: Materials Science and Engineering*, 1257, 012001. <https://doi.org/10.1088/1757-899X/1257/1/012001>
- Das, D. S., Rawat, D. S., Maity, D., Dash, S. S., & Sinha, B. K. (2020). Species richness patterns of different life-forms along altitudinal gradients in the Great Himalayan National Park, Western Himalaya, India. *Taiwania*, 65(2), 154-162.  
<https://doi.org/10.6165/tai.2020.65.154>
- Davis, P. H., (1965-1985). *Flora of Turkey and the East Aegean islands*. Edinburgh University Press.
- Department of Natural Resources and Watershed Management of Golestan Province. (2013). *Kourdkoy forestry plan*. Department of Natural Resources and Watershed Management of Golestan Province.
- Di Biase, L., Pace, L., Mantoni, C., & Fattorini, S. (2021). Variations in plant richness, biogeographical composition, and life forms along an elevational gradient in a Mediterranean mountain. *Plants*, 10(10), 2090. <https://doi.org/10.3390/plants10102090>
- Driesen, E., Van den Ende, W., De Proft, M., & Saeys, W. (2020). Influence of environmental factors light, CO<sub>2</sub>, temperature, and relative humidity on stomatal opening and development: A review. *Agronomy*, 10(12), 1975. <https://doi.org/10.3390/agronomy10121975>
- Ebrahimi, S. S., Pourbabaei, H., Potheir, D., Omid, A., & Torkaman, J. (2014). Effect of livestock grazing and human uses on herbaceous species diversity in oriental beech (*Fagus orientalis* Lipsky) forests, Guilan, Masal, northern Iran. *Journal of Forestry Research*, 25(2), 455-462. <https://doi.org/10.1007/s11676-014-0476-8>
- Gao, M., Wang, X., Hui, C., Yi, H., Zhang, C., Wu, X., Bi, X., Wang, Y., Xiao, L., & Wang, D. (2015). Assembly of plant communities in coastal wetlands—the role of saltcedar *Tamarix chinensis* during early succession. *Journal of Plant Ecology*, 8(5), 539-548. <https://doi.org/10.1093/jpe/rtu037>
- Ghafari, S., Ghorbani, A., Moameri, M., Mostafazadeh, R., Bidarlord, M., & Kakehmami, A. (2020). Floristic diversity and distribution patterns along an elevational gradient in the northern part of the Ardabil province rangelands, Iran. *Mountain Research and Development*, 40(1), R37. <https://doi.org/10.1659/MRD-JOURNAL-D-18-00089.1>
- Ghahreman, A. (1975-2000). Colored Flora of Iran. Vol. 1-20. Research Institute of forests and Rangelands, Tehran. (In Persian).
- Ghorbanalizadeh, A., & Akhiani, H. (2022). Plant diversity of Hyrcanian relict forests: An annotated checklist, chorology and threat categories of endemic and near endemic vascular plant species. *Plant Diversity*, 44(1), 39-69. <https://doi.org/10.1016/j.pld.2021.07.005>
- Gómez, J. A. A., Bellon, M. R., & Smale, M. (2000). A regional analysis of maize biological diversity in Southeastern Guanajuato, Mexico. *Economic Botany*, 54(1), 60-72. <https://doi.org/10.1007/BF02866600>
- Haq, A., & Badshah, L. (2021). Floristic description and ecological characteristics of the plants of Pashat Valley, Pak-Afghan border, district Bajaur, Pakistan. *Acta Ecologica Sinica*, 41(6), 524-536. <https://doi.org/10.1016/j.chnaes.2021.03.010>
- Hasanpori, R., Tavili, A., & Javadi, S. A. (2014). Classification and determination of indicator environmental properties in western Iran rangelands. *Asia Pacific Journal of Energy and Environment*, 1(1), 39-44. <https://doi.org/10.18034/apjee.v1i1.208>

- He, X., Arif, M., Zheng, J., Ni, X., Yuan, Z., Zhu, Q., Wang, J., Ding, D., & Li, C. (2023). Plant diversity patterns along an elevation gradient: The relative impact of environmental and spatial variation on plant diversity and assembly in arid and semi-arid regions. *Frontiers in Environmental Science*, 11, 1021157. <https://doi.org/10.3389/fenvs.2023.1021157>
- Hosseini, N., Ghorbanpour, M., & Mostafavi, H. (2024). The influence of climate change on the future distribution of two *Thymus* species in Iran: MaxEnt model-based prediction. *BMC Plant Biology*, 24(1), 269. <https://doi.org/10.1186/s12870-024-04965-1>
- Hosseinzadeh, R., Soosani, J., Alijani, V., Khosravi, S., & Karimikia, H. (2016). Diversity of woody plant species and their relationship to physiographic factors in central Zagros forests (Case study: Perc forest, Khorramabad, Iran). *Journal of Forestry Research*, 27(5), 1137-1141. <https://doi.org/10.1007/s11676-016-0243-0>
- Hrivnák, R., Gömöry, D., Slezák, M., Ujházy, K., Hédl, R., Jarčuška, B., & Ujházyová, M. (2014). Species richness pattern along altitudinal gradient in central European beech forests. *Folia Geobotanica*, 49(3), 425-441. <https://doi.org/10.1007/s12224-013-9174-0>
- Jafarian, Z., Kargar, M., Tamartash, R., & Alavi, S. J. (2019). Spatial distribution modelling of plant functional diversity in the mountain rangeland, north of Iran. *Ecological Indicators*, 97, 231-238. <https://doi.org/10.1016/j.ecolind.2018.10.019>
- Karami, P., Gorgin, K. M., Basiri, R., & Kargari, E. (2008). Analyzes of species diversity in ecological species group case study: The Kurdistana's Kouhsalan habitat. *Journal of Environmental Studies*, 34(46), 47-56.
- Kashian, D. M., Barnes, B. V., & Walker, W. S. (2003). Ecological species groups of landform-level ecosystems dominated by jack pine in northern Lower Michigan, USA. *Plant Ecology*, 166(1), 75-91. <https://doi.org/10.1023/A:1023265012964>
- Kent, M. (2011). Vegetation description and data analysis: A practical approach. *Oikos*, 76(1), 70-82. <https://doi.org/10.2307/3545749>
- Kessler, M., Toivonen, J. M., Sylvester, S. P., Kluge, J., & Hertel, D. (2014). Elevational patterns of *Polylepis* tree height (Rosaceae) in the high Andes of Peru: Role of human impact and climatic conditions. *Frontiers in Plant Science*, 5, 194. <https://doi.org/10.3389/fpls.2014.00194>
- Kooch, Y., Parsapour, M. K., & Wirth, S. (2023). Soil functional indicators in different development stages of an oak (*Quercus castaneifolia* CA Mey.) stand. *Applied Soil Ecology*, 189, 104922. <https://doi.org/10.1016/j.apsoil.2023.104922>
- Kraft, N. J., Adler, P. B., Godoy, O., James, E. C., Fuller, S., & Levine, J. M. (2015). Community assembly, coexistence and the environmental filtering metaphor. *Functional Ecology*, 29(5), 592-599. <https://doi.org/10.1111/1365-2435.12345>
- Krömer, T., Acebey, A., Kluge, J., & Kessler, M. (2013). Effects of altitude and climate in determining elevational plant species richness patterns: A case study from Los Tuxtlas, Mexico. *Flora-Morphology, Distribution, Functional Ecology of Plants*, 208(3), 197-210. <https://doi.org/10.1016/j.flora.2013.03.003>
- Kulakowski, D., Seidl, R., Holeska, J., Kuuluvainen, T., Nagel, T. A., Panayotov, M., Svoboda, M., Thorn, S., Vacchiano, G., Whitlock, C., Wohlgemuth, T., & Bebi, P. (2017). A walk on the wild side: Disturbance dynamics and the conservation and management of European mountain forest ecosystems. *Forest Ecology and Management*, 388, 120-131. <https://doi.org/10.1016/j.foreco.2016.07.037>
- Liu, X., Zhou, W., & Bai, Z. (2016). Vegetation coverage change and stability in large open-pit coal mine dumps in China during 1990–2015. *Ecological Engineering*, 95, 447-451. <https://doi.org/10.1016/j.ecoleng.2016.06.051>
- Lu, S., Zhang, D., Wang, L., Dong, L., Liu, C., Hou, D., Chen, G., Qiao, X., Wang, Y., & Guo, K. (2023). Comparison of plant diversity-carbon storage relationships along altitudinal gradients in temperate forests and shrublands. *Frontiers in Plant Science*, 14, 1120050. <https://doi.org/10.3389/fpls.2023.1120050>
- Manish, K., Pandit, M. K., Telwala, Y., Nautiyal, D. C., Koh, L. P., & Tiwari, S. (2017). Elevational plant species richness patterns and their drivers across non-endemics, endemics and growth forms in the Eastern Himalaya. *Journal of Plant Research*, 130(5), 829-844. <https://doi.org/10.1007/s10265-017-0946-0>
- Midolo, G., Axmanová, I., Divišek, J., Dřevojan, P., Lososová, Z., Večeřa, M., ... & Chytrý, M. (2024). Diversity and distribution of Raunkiaer's life forms in European vegetation. *Journal of Vegetation Science*, 35(1), e13229. <https://doi.org/10.1111/jvs.13229>
- Mouquet, N., Lagadeuc, Y., Devictor, V., Doyen, L., Duputié, A., Eveillard, D., ... & Loreau, M. (2015). Predictive ecology in a changing world. *Journal of Applied Ecology*, 52(5), 1293-1310. <https://doi.org/10.1111/1365-2664.12482>
- Mucina, L., Bültmann, H., Dierßen, K., Theurillat, J. P., Raus, T., Čarni, A., ... & Tichý, L. (2016). Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. *Applied Vegetation Science*, 19(S1), 3-264. <https://doi.org/10.1111/avsc.12257>
- Naqinezhad, A., Hosseini, S., Rajamand, M. A., & Saiedi Mehrvarz, S. (2010). A floristic study on Mazibon and Sibon protected forests, Ramsar, across the altitudinal gradient (300–2300 m). *Taxonomy and Biosystematics*, 2(5), 93-114.

- Noroozi, J., Moser, D., & Essl, F. (2016). Diversity, distribution, ecology and description rates of alpine endemic plant species from Iranian mountains. *Alpine Botany*, 126(1), 1-9. <https://doi.org/10.1007/s00035-015-0160-4>
- Pourbabaei, H., & Ahani, H. (2004). Biodiversity of woody species in *Acer platanoides* sites in the Shafaroud Forests, Gilan (Iran). *Rostaniha*, 5(2), 147-158.
- Pourbabaei, H., Ebrahimi, S. S., Torkaman, J., & Pothier, D. (2014). Comparison in woody species composition, diversity and community structure as affected by livestock grazing and human uses in beech forests of northern Iran. *Forestry*, 20(1), 1-11.
- Pourbabaei, H., & Haghgooy, T. (2013). Effect of physiographical factors on tree species diversity (case study: Kandelat Forest Park). *Iranian Journal of Forest and Poplar Research*, 21(2), 243-255.
- Pourbabaei, H., Salehi, A., & Ebrahimi, S. S. (2019). Modelling of plant species richness along altitudinal gradient: Asalem Watershed basin, temperate deciduous forests in northern Iran. *Acta Ecologica Sinica*, 39(5), 335-347. <https://doi.org/10.1016/j.chnaes.2018.09.013>
- Pourbabaei, H., Salehi, A., Ebrahimi, S. S., & Khodaparast, F. (2020). Variations of soil physicochemical properties and vegetation cover under different altitudinal gradient, western Hyrcanean forest, north of Iran. *Journal of Forest Science*, 66(4), 159-169. <https://doi.org/10.17221/136/2019-JFS>
- Pourghasemi, H. R. (2016). GIS-based forest fire susceptibility mapping in Iran: A comparison between evidential belief function and binary logistic regression models. *Scandinavian Journal of Forest Research*, 31(1), 80-98. <https://doi.org/10.1080/02827581.2015.1052750>
- Rahman, I. U., Hart, R. E., Ijaz, F., Afzal, A., Iqbal, Z., Calixto, E. S., Abd Allah, E. F., Alqarawi, A. A., Hashem, A., Al-Arjani, A.-B., F., Kausar, R., & Haq, S. M. (2022). Environmental variables drive plant species composition and distribution in the moist temperate forests of Northwestern Himalaya, Pakistan. *PLoS One*, 17(2), e0260687. <https://doi.org/10.1371/journal.pone.0260687>
- Rathore, N., Thakur, D., & Chawla, A. (2018). Seasonal variations coupled with elevation gradient drives significant changes in eco-physiological and biogeochemical traits of a high altitude evergreen broadleaf shrub, *Rhododendron anthopogon*. *Plant Physiology and Biochemistry*, 132, 708-719. <https://doi.org/10.1016/j.plaphy.2018.08.009>
- Rechinger, K. (1963-1998). *Flora Iranica*. Akademische Druck University, Graz.
- Rezende, V. L., de Miranda, P. L., Meyer, L., Moreira, C. V., Linhares, M. F., de Oliveira-Filho, A. T., & Eisenlohr, P. V. (2015). Tree species composition and richness along altitudinal gradients as a tool for conservation decisions: The case of Atlantic semideciduous forest. *Biodiversity and Conservation*, 24(9), 2149-2163. <https://doi.org/10.1007/s10531-015-0939-z>
- Scherrer, D., & Körner, C. (2011). Topographically controlled thermal-habitat differentiation buffers alpine plant diversity against climate warming. *Journal of Biogeography*, 38(2), 406-416. <https://doi.org/10.1111/j.1365-2699.2010.02407.x>
- Schroeder, L., Robles, V., Jara-Arancio, P., Lapadat, C., Hobbie, S. E., Arroyo, M. T., & Cavender-Bares, J. (2024). Drivers of plant diversity, community composition, functional traits, and soil processes along an alpine gradient in the central Chilean Andes. *Ecology and Evolution*, 14(2), e10888. <https://doi.org/10.1002/ecc3.10888>
- Sharma, N., Behera, M. D., Das, A. P., & Panda, R. M. (2019). Plant richness pattern in an elevation gradient in the Eastern Himalaya. *Biodiversity and Conservation*, 28(8), 2085-2104. <https://doi.org/10.1007/s10531-019-01699-7>
- Siles, J. A., & Margesin, R. (2016). Abundance and diversity of bacterial, archaeal, and fungal communities along an altitudinal gradient in alpine forest soils: What are the driving factors? *Microbial Ecology*, 72(1), 207-220. <https://doi.org/10.1007/s00248-016-0748-2>
- Sinha, S., Badola, H. K., Chhetri, B., Gaira, K. S., Lepcha, J., & Dhyani, P. P. (2018). Effect of altitude and climate in shaping the forest compositions of Singalila National Park in Khangchendzonga Landscape, Eastern Himalaya, India. *Journal of Asia-Pacific Biodiversity*, 11(2), 267-275. <https://doi.org/10.1016/j.japb.2018.01.012>
- Smith, B., & Wilson, J. B. (1996). A consumer's guide to evenness indices. *Oikos*, 78(1), 70-82. <https://doi.org/10.2307/3545749>
- Su, Y., Gan, X., Zhang, W., Wu, G., & Huang, F. (2024). Woody plant structural diversity changes across an inverse elevation-dependent warming gradient in a subtropical mountain forest. *Forests*, 15(6), 1051. <https://doi.org/10.3390/f15061051>
- Sun, W., Song, X., Mu, X., Gao, P., Wang, F., & Zhao, G. (2015). Spatiotemporal vegetation cover variations associated with climate change and ecological restoration in the Loess Plateau. *Agricultural and Forest Meteorology*, 209, 87-99. <https://doi.org/10.1016/j.agrformet.2015.05.002>
- Takhtajan, A. (1986). *Floristic region of the world*. University of California Press.
- Tuomisto, H., Zuquim, G., & Cárdenas, G. (2014). Species richness and diversity along edaphic and climatic gradients in Amazonia. *Ecography*, 37(11), 1034-1046. <https://doi.org/10.1111/ecog.00770>

- Wagner, J., Gruber, K., Ladinig, U., Buchner, O., & Neuner, G. (2021). Winter frosts reduce flower bud survival in high-mountain plants. *Plants*, 10(8), 1507. <https://doi.org/10.3390/plants10081507>
- Wani, Z. A., Negi, V. S., Bhat, J. A., Satish, K. V., Kumar, A., Khan, S., Dhyani, R., Siddiqui, S., Al-Qthanin, R. N., & Pant, S. (2023). Elevation, aspect, and habitat heterogeneity determine plant diversity and compositional patterns in the Kashmir Himalaya. *Frontiers in Forests and Global Change*, 6, 1019277. <https://doi.org/10.3389/ffgc.2023.1019277>
- Williams, L. J., Paquette, A., Cavender-Bares, J., Messier, C., & Reich, P. B. (2017). Spatial complementarity in tree crowns explains overyielding in species mixtures. *Nature Ecology & Evolution*, 1(4), 0063. <https://doi.org/10.1038/s41559-016-0063>
- Witte, J. -P. M. (2002). The descriptive capacity of ecological plant species groups. *Plant Ecology*, 162(2), 199-213. <https://doi.org/10.1023/A:1020370629402>
- Zellweger, F., Baltensweiler, A., Ginzler, C., Roth, T., Braunisch, V., Bugmann, H., & Bollmann, K. (2016). Environmental predictors of species richness in forest landscapes: Abiotic factors versus vegetation structure. *Journal of Biogeography*, 43(6), 1080-1090. <https://doi.org/10.1111/jbi.12696>
- Zhang, Q. -P., Wang, J., & Wang, Q. (2021). Effects of abiotic factors on plant diversity and species distribution of alpine meadow plants. *Ecological Informatics*, 61, 101210. <https://doi.org/10.1016/j.ecoinf.2021.101210>
- Zhang, W., Shi, H., Zhang, K., Shu, X., & Dang, H. (2024). Effects of abiotic and biotic factors on woody plant diversity across vertical strata in a temperate forest. *Plant Ecology*, 225(1), 1-11. <https://doi.org/10.1007/s11258-023-01370-w>
- Zhang, Z., Hautier, Y., Bao, T., Yang, J., Qing, H., Liu, Z., Wang, M., Li, T., Yan, M., & Zhang, G. (2022). Species richness and asynchrony maintain the stability of primary productivity against seasonal climatic variability. *Frontiers in Plant Science*, 13, 1014049. <https://doi.org/10.3389/fpls.2022.1014049>
- Zhou, Z., Ding, Y., Shi, H., Cai, H., Fu, Q., Liu, S., & Li, T. (2020). Analysis and prediction of vegetation dynamic changes in China: Past, present and future. *Ecological Indicators*, 117, 106642. <https://doi.org/10.1016/j.ecolind.2020.106642>
- Zhu, Z. -X., Nizamani, M. M., Sahu, S. K., Kunasingam, A., & Wang, H. -F. (2019). Tree abundance, richness, and phylogenetic diversity along an elevation gradient in the tropical forest of Diaoluo Mountain in Hainan, China. *Acta Oecologica*, 101, 103481. <https://doi.org/10.1016/j.actao.2019.103481>




## Supplementary Information

Supplementary Table 1. Characteristics of identified plant communities according to plant ecological group.

Plant communities	Height class (m.a.s.l.)	SIV of dominant species		Indicator species
		tree	herb	
Cyclameno-Fagetum community	500-700	<i>Fagus orientalis</i> 148.85	<i>Cyclamen coum</i> 109.52	<i>Carpinus betulus</i> L. <i>Ilex spinigera</i> Loes. <i>Myosotis anomala</i> Riedl, <i>Carex sylvatica</i> Huds, <i>Chelidonium majus</i> L. <i>Allium paradoxum</i> G.Don, <i>Hesperis hyrcana</i> Bornm.& Gauba, <i>Polystichum</i> sp. <i>Prunella vulgaris</i> L.
Carexeto-Fagetum community	700-900	<i>Fagus orientalis</i> 204.13	<i>Carex sylvatica</i> 104.66	<i>Carpinus betulus</i> L. <i>Pteris cretica</i> L. <i>Primula heterochroma</i> Stapf. <i>Chelidonium majus</i> L. <i>Epipactis</i> sp. <i>Geum urbanum</i> L. <i>Danae racemosa</i> Moench, <i>Allium paradoxum</i> G.Don, <i>Mentha aquatica</i> L.
Athyriumeto-Fagetum community	900-1100	<i>Fagus orientalis</i> 229.96	<i>Athyrium filix-femina</i> 108.09	<i>Carpinus betulus</i> L. <i>Trifolium</i> sp. <i>Prenanthes cacalifolia</i> Beauverd, <i>Sanicula europaea</i> L. <i>Geranium columbinum</i> L. <i>Geranium</i> sp. <i>Galium odoratum</i> (L.) Scop
Athyriumeto-Fagetum community	1100-1300	<i>Fagus orientalis</i> 236.89	<i>Athyrium filix-femina</i> 112.05	<i>Clinopodium umbrosum</i> (M.Bieb.) Kuntze, <i>Geranium columbinum</i> L. <i>Geranium</i> sp. <i>Dryopteris pallida</i> (Bory) Fomin, <i>Hedera pastuchovii</i> Woronow, <i>Galium odoratum</i> (L.) Scop.
Galiumo-Fagetum community	1300-1500 1500-1700	<i>Fagus orientalis</i> 241.65	<i>Galium odoratum</i> 123.50	<i>Athyrium filix-femina</i> (L.) Roth. <i>Acer cappadocicum</i> Gled. <i>Galium rotundifolium</i> L. <i>Solanum kiesseritzkii</i> C.A.Mey. <i>Lapsana communis</i> L.

## RESEARCH ARTICLE

# Design and Implementation of a Digital Herbarium Database: The Case of the Bilgehan Bilgili Herbarium

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## ABSTRACT

Herbaria are essential repositories for documenting plant biodiversity and provide irreplaceable data for taxonomic, ecological, and conservation-oriented research. However, the rapid growth of herbarium collections has increasingly challenged the efficient management, accessibility, and long-term sustainability of specimen data. In this study, the design and implementation of a digital herbarium database are presented through a case study of the Bilgehan Bilgili Herbarium at Kastamonu University (Türkiye). Approximately 2,000 vascular plant specimens, primarily collected from northern Türkiye, were revised, standardised, and digitised in accordance with international herbarium and data management standards. Specimens were identified using up-to-date taxonomic sources, relabeled where necessary, imaged using high-resolution digital photography, and integrated into a relational database developed with Microsoft SQL Server. A web-based virtual herbarium interface was subsequently created using ASP.NET technology to enable remote access to specimen data and images. As a result, 1,563 taxa belonging to 107 families, including 134 endemic taxa, were recorded and made digitally accessible. The most represented families were Asteraceae, Fabaceae, and Lamiaceae, while Euro-Siberian phytogeographical elements predominated. The developed digital infrastructure significantly enhances data accessibility, reduces risks associated with physical specimen handling, and supports regional floristic research, biodiversity analyses, and conservation planning. This study demonstrates that the digitisation of herbarium collections provides a sustainable and scalable model for improving the management and global accessibility of botanical data, and it offers a practical framework for similar initiatives in Türkiye and beyond.

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## 1. Introduction

Plants are fundamental components of biological diversity and constitute indispensable research material for numerous disciplines, including ecology, medicine, forestry, agriculture, pharmacy, and environmental sciences. In this context, plant specimens are collected for scientific purposes, dried, and preserved in herbaria for long-term storage (Borsch et al., 2020). Herbaria represent collections of critical importance at the global scale for documenting, monitoring, and conserving plant diversity. With the increasing scope of biological and

ecological research, both the number of herbaria and the volume of their collections continue to grow steadily.

Beyond their role in species identification, nomenclature, and classification, herbaria provide valuable information on historical vegetation patterns, past climatic conditions, species distributions, and traditional uses of plants. They also serve as primary data sources for developing conservation strategies for threatened plant species. In this regard, herbaria play an indispensable role in advancing plant science and biodiversity conservation.

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In parallel with scientific and technological advances, the scope of herbarium use has expanded considerably. Initially established primarily for the identification and classification of plants, herbaria are now widely used in diverse research fields, ranging from medicinal plant studies to the monitoring of climate change and phenological shifts, from assessing historical plant responses to atmospheric carbon dioxide fluctuations to tracing isotopic signatures of environmental change, and from investigating the spread of plant pathogens to the detection of invasive species. Indeed, herbaria have been shown to support more than 72 distinct scientific and applied uses (Harris & Marsico, 2017; Cantrill, 2018; Funk, 2018; Sass-Gyarmati & Táborská, 2020). According to Index Herbariorum data, as of 2025, a total of 406,426,591 specimens are preserved in 4,035 active herbaria worldwide. In Türkiye, 1,168,727 specimens including native flora and numerous foreign plant samples are housed in 72 herbaria (URL-1). These figures highlight the strategic importance of herbaria for documenting and conserving Türkiye's floristic richness.

As herbarium collections expand, the management of locality, morphological, phenological, and ecological data associated with plant specimens becomes increasingly complex. Accessing such information through physical collections alone has become time-consuming and restrictive, particularly as specimen numbers grow. Consequently, various database management systems have been developed to enable more efficient, reliable, and sustainable management of herbarium data (Akman et al., 1996; Geven et al., 2008). Advances in information technologies have rendered the digitisation of herbarium collections inevitable (Vaganov et al., 2021).

In recent years, virtual herbaria have rapidly proliferated due to developments in computer technologies, high-resolution digital imaging systems, GPS-based geolocation tools, and internet infrastructure. Digital herbaria are systems in which images of plant specimens, label information, and locality records can be stored in detail, queried, and accessed remotely. These systems not only facilitate collection management but also enhance data sharing among researchers, thereby strengthening scientific collaboration (Nelson et al., 2012; Soltis, 2017; Paton et al., 2025).

In traditional herbaria, researchers typically accessed specimens either through postal loans or on-site visits. However, these methods involve several challenges, including the risk of specimen damage, loss during shipment, and temporal constraints. Digitisation of herbarium data substantially reduces these risks while simultaneously enabling access for a much broader user community. Digital collections also allow large-scale analyses, particularly in fields such as climate change research, biogeography, and conservation biology (Bebber et al., 2010; Page et al., 2015).

In Türkiye, efforts to improve the management of plant data have accelerated over the past two decades, particularly through the establishment of digital plant databases. Physical collections that were previously accessible to a limited number of researchers are now being transformed into comprehensive data resources that support multidisciplinary research through digitisation initiatives. In parallel with these developments, virtual herbarium projects have also emerged, aiming to provide online access to high-resolution specimen images and associated metadata. Early examples of such initiatives in Türkiye include the study by Öztürk and Ege (2014), which highlighted the importance of digitising herbarium materials and establishing web-based access systems. More recently, Çiftçi et al. (2023) and Aslan et al. (2024) presented applied models and case studies focusing on the development, management, and research potential of virtual herbarium infrastructures in the country. These studies demonstrate that virtual herbaria not only enhance accessibility but also contribute to biodiversity monitoring, conservation planning, and interdisciplinary scientific collaboration. Nevertheless, digitisation efforts remain limited in many Turkish herbaria, highlighting the need for new projects in this field.

Within this framework, the present study aims to organise, revise, and update the label information of approximately 2,000 plant specimens primarily collected from the surrounding region housed in the Bilgehan Bilgili Herbarium of the Faculty of Forestry at Kastamonu University. In addition, the study seeks to establish a virtual herbarium infrastructure by transferring all specimen data into a digital environment. This initiative is intended to provide faster and more reliable access to plant data for researchers at the university and for all scientists working on the flora of northern Türkiye.

In conclusion, digitising herbaria in Türkiye will not only enable the effective management of data related to the country's rich plant biodiversity but also strengthen scientific collaboration at national and international levels. The virtualisation of the Bilgehan Bilgili Herbarium represents an important step toward ensuring the sustainability of regional floristic research.

## 2. Materials and Methods

### 2.1. Study Area and Plant Material

The material of this study consists of plant specimens collected by academic staff and students of the Faculty of Forestry at Kastamonu University as part of various regional flora and vegetation studies. The research was conducted within the Bilgehan Bilgili Herbarium of the Faculty of Forestry, which is currently in its establishment and development phase. The herbarium collection comprises approximately 2,000 vascular plant specimens collected primarily from Kastamonu and its surroundings, as well as from other parts of northern Türkiye.

Collected specimens were pressed, dried, and mounted on herbarium sheets in accordance with standard herbarium techniques (Smith & Chinnappa, 2015). Species identifications were carried out using relevant floristic sources and up-to-date taxonomic literature, and the current validity of species names was verified using international plant databases (e.g. POWO, IPNI).

## 2.2. Labelling and Collection Arrangement

Standard label information was prepared for each herbarium specimen, including family, genus, species, subspecies, variety, grid system, province, district, locality, habitat, altitude, collector name, collection date, and identifier name. Labels were prepared in accordance with herbarium standards and affixed to the specimen sheets.

Following labelling, specimens were arranged alphabetically by family and placed on herbarium shelves. This organisation aimed to improve physical accessibility and ensure data integrity during the digitisation process.

## 2.3. Digital Imaging Process

Specimens whose identification and labelling were completed were subjected to the digitisation process. Each herbarium sheet was photographed in a manner that ensured clear visibility of label information (Figure 1). High-resolution digital cameras were used to preserve morphological details of the specimens.



**Figure 1.** Prepared herbarium specimens.

The resulting digital images were processed using Adobe Photoshop software, with adjustments made to colour balance, sharpness, and readability. This stage is consistent with image enhancement practices commonly employed in international virtual herbarium projects.

## 2.4. Database Development and Management

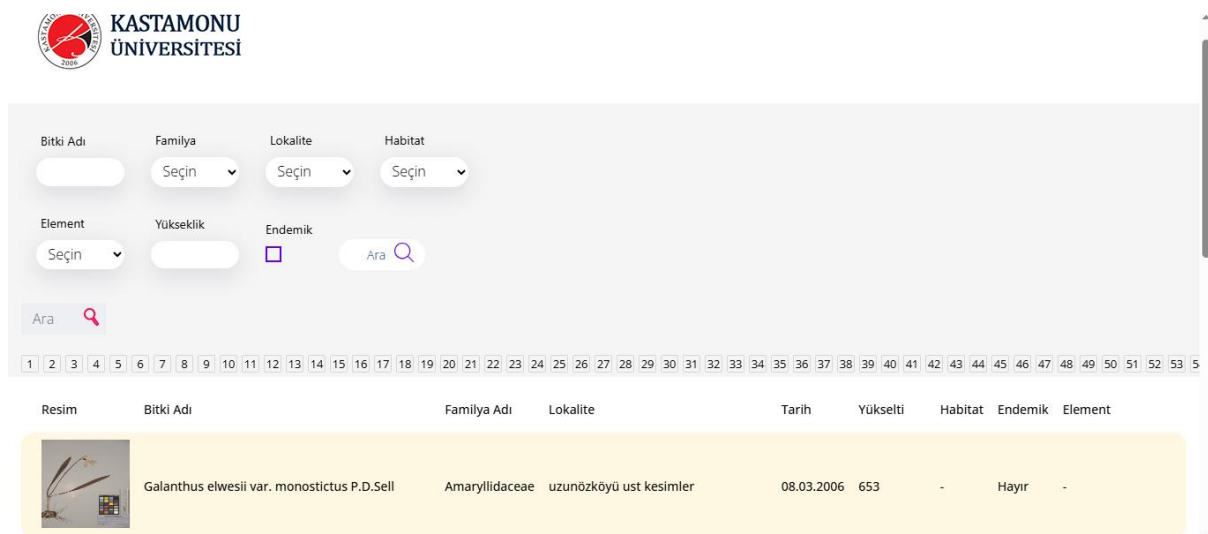
All label data and images associated with the digitised specimens were transferred to a dedicated database. Taxa were listed to create a comprehensive inventory of the herbarium collection. The database infrastructure was developed using Microsoft SQL Server, which was also employed for data management.

The database was structured to support taxonomic queries, locality-based filtering, altitude and habitat analyses, as well as user authorisation, data updating, and backup procedures. This architecture complies with international standards recommended for the digital management of biological collections (Page et al., 2015).

## 2.5. Development of the Web-Based Virtual Herbarium

To provide online access to the database, an ASP.NET-based web interface was developed on the Microsoft SQL Server infrastructure. Adobe Dreamweaver software was used in the design of the web pages. The virtual herbarium system

was integrated into the internet infrastructure of Kastamonu University and made accessible at: <http://herbarium.kastamonu.edu.tr> (Figure 2).



**Figure 2.** View of the virtual herbarium website.

The developed virtual herbarium enables researchers to remotely access plant specimens, conduct taxon-based searches, and view high-resolution images of specimens. This approach aligns with global digital biological collection initiatives aimed at increasing the accessibility of herbarium collections worldwide (Bebber et al., 2010; Nelson et al., 2012; Markiewicz et al., 2025).

### 3. Results and Discussion

Within the scope of this study, the plant collections of the Bilgehan Bilgili Herbarium at the Faculty of Forestry, Kastamonu University, were organised, revised, and recorded in accordance with herbarium standards. Throughout the organisation process, avoiding damage to specimens was adopted as a fundamental principle. Specimens previously incorporated into the herbarium but lacking complete or up-to-date label information were re-labelled accurately. Mounted specimens were arranged alphabetically by family and placed in cabinets, resulting in a systematic structure both physically and digitally.

A total of 1,563 taxa belonging to 107 families were entered into the database of the Bilgehan Bilgili Herbarium. Of these taxa, 134 are endemic. This result demonstrates the herbarium's considerable potential for documenting regional floristic diversity. With future flora and vegetation studies conducted at the university, the number of taxa in the collection is expected to increase.

An examination of families with the highest number of specimens revealed that Asteraceae ranked first with 169 specimens, followed by Fabaceae (149) and Lamiaceae (127).

This pattern likely reflects the wide distribution of these families in the flora of Türkiye and their adaptability to diverse habitats. At the genus level, the most represented genera in the collection were *Trifolium* (29 specimens), *Salvia* (22), and *Astragalus* (21). The high representation of *Astragalus* and *Salvia* is consistent with Anatolia being a major centre of diversification for these genera. This finding indicates that the herbarium may serve as an important reference source for taxonomic and phytogeographical studies.

Analysis of the phytogeographical distribution of plant taxa revealed a predominance of Euro-Siberian elements. This pattern is directly related to the geographical location and climatic characteristics of Kastamonu and its surroundings. Although the region exhibits transitional zone features, the data indicate a strong influence of the Euro-Siberian floristic region.

Through this study, all specimens were formalised as herbarium material, a current and standardised plant list was created, and all associated data were transferred to a digital environment. The resulting database provides rapid and reliable access to specimens, label information, and images, reducing the need for physical visits and offering significant advantages in terms of time and cost for scientific research.

In Türkiye, several virtual herbarium initiatives now provide publicly accessible specimen data and images, enabling comparative analyses with new research findings. For example, the Nezahat Gökyiğit Botanik Bahçesi Virtual Herbarium has transferred the data and images of its approximately 16,000 plant specimens online as part of its digitisation efforts, making them easily accessible through a web portal for researchers and the public (URL-2). Similarly, the IZEF Virtual Herbarium at Ege University has digitised and published around 6,000

herbarium specimens in its TürkiyeFlorası 1.0 database, representing the first large-scale virtual herbarium project in the country (URL-3). Another notable example is the Van Gölü Havzası (VHLV) Virtual Herbarium, where approximately 9,000 identified plant images and records have been made available online, contributing to regional biodiversity documentation and research (URL-4). More comprehensive digitisation models, such as the DUOF Virtual Herbarium at Düzce University, have also scanned and incorporated roughly 11,000 herbarium specimens into their searchable digital systems, highlighting the growing emphasis on digital infrastructure in Turkish herbaria (URL-5). These examples illustrate the expanding landscape of virtual herbaria in Türkiye and demonstrate their value as comparative data sources for contemporary floristic and biodiversity studies.

The database software developed for transforming the Bilgehan Bilgili Herbarium into a virtual herbarium was designed to accommodate the integration of new data and future updates, allowing the herbarium to evolve into a sustainable digital biological collection over the long term.

Digitisation of the herbarium collection has minimised risks associated with specimen loans and postal shipment of physical materials. Moreover, the digital data infrastructure has transformed the collection into a sustainable data source for floristic research, biodiversity analyses, and conservation biology studies (Soltis, 2017).

In conclusion, this study makes a significant contribution to the preservation of regional floristic knowledge and the support of scientific research by organising, documenting, and digitising the Bilgehan Bilgili Herbarium. Serving as a model for the digitisation of herbaria in Türkiye, this work offers an applicable framework for similar collections.

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## Conflict of Interest

The authors declare that they have no conflict of interest.

## References

- Akman, Y., Ketenoğlu, O., İlarıslan, R., Kurt, L., Bingöl, M. Ü., Kurt, F. & Geven, F. (1996). ANK. Herbariumu Revizyonu TÜBİTAK-DPT (No: TBAG-DPT/16). (In Turkish)
- Aslan, S., Aydıncal, R. M., Aksoy, N., & Özkan, N. G. (2024). Modern sayısal herbaryumlar için öne çıkan bir model: Düzce Üniversitesi Orman Fakültesi (DUOF) sanal herbaryumu. *Düzce Üniversitesi Orman Fakültesi*






*Ormancılık Dergisi*, 20(1), 78-105. <https://doi.org/10.58816/duzceod.1420896> (In Turkish)

- Bebber, D. P., Carine, M. A., Wood, J. R., Wortley, A. H., Harris, D. J., Prance, G. T., Davidse, G., Paige, J., Pennington, T. D., Robson, N. K. B., & Scotland, R. W. (2010). Herbaria are a major frontier for species discovery. *Proceedings of the National Academy of Sciences*, 107(51), 22169-22171. <https://doi.org/10.1073/pnas.1011841108>
- Borsch, T., Stevens, A. D., Häffner, E., Güntsch, A., Berendsohn, W. G., Appelhans, M., ... & Zizka, G. (2020). A complete digitization of German herbaria is possible, sensible and should be started now. *Research Ideas and Outcomes*, 6, e50675. <https://doi.org/10.3897/rio.6.e50675>
- Cantrill, D. J. (2018). The Australasian Virtual Herbarium: Tracking data usage and benefits for biological collections. *Applications in Plant Sciences*, 6(2), e1026. <https://doi.org/10.1002/aps3.1026>
- Çiftçi, A., Mollman, R., Kaleli, B. S., Çapar, A., & Erol, O. (2023). Teaching old collections new tricks: Initial findings of the ISTF herbarium digitization project. *Herbarium Turcicum*, (3), 26-33. <https://doi.org/10.26650/HT.2023.1246170>
- Funk, V. A. (2018). Collections-based science in the 21st century. *Journal of Systematics and Evolution*, 56(3), 175-193. <https://doi.org/10.1111/jse.12315>
- Geven, F., Bingöl, Ü., & Güney, K. (2008). ANK Herbarium'u Polygonaceae familyasının revizyonu ve veritabanının hazırlanması. *Kastamonu University Journal of Forestry Faculty*, 8(1), 67-85. (In Turkish)
- Harris, K. M., & Marsico, T. D. (2017). Digitizing specimens in a small herbarium: A viable workflow for collections working with limited resources. *Applications in Plant Sciences*, 5(4), 1600125. <https://doi.org/10.3732/apps.1600125>
- Markiewicz, J., Niedzielski, P., & Osadowski, Z. (2025). Herbarium digitisation as a platform for scientific knowledge accessibility: The case of Herbarium Pomeranicum. *European Research Studies Journal*, 28(3), 1315-1333.
- Nelson, G., Paul, D., Riccardi, G., & Mast, A. R. (2012). Five task clusters that enable efficient and effective digitization of biological collections. *ZooKeys*, (209), 19. <https://doi.org/10.3897/zookeys.209.3135>
- Öztürk, B., & Ege, M. (2014). Türkiye'nin ilk sanal herbaryumu IZEF örneği ve sanal herbaryumların bitkisel ilaç hammaddesi araştırmaları açısından önemi. *Marmara Pharmaceutical Journal*, 18(2), 79-84. <https://doi.org/10.12991/mpj.2014186124> (In Turkish)
- Page, L. M., MacFadden, B. J., Fortes, J. A., Soltis, P. S., & Riccardi, G. (2015). Digitization of biodiversity collections reveals biggest data on

- biodiversity. *BioScience*, 65(9), 841-842. <https://doi.org/10.1093/biosci/biv104>
- Paton, A. J., Ameka, G. K., Antonelli, A., Asase, A., Barrett, R. L., Bogaerts, A., ... & Young, A. (2025). Life after herbarium digitisation: Physical and digital collections, curation and use. *Plants, People, Planet*, Early view. <https://doi.org/10.1002/ppp3.70078>
- Sass-Gyarmati, A., & Táborská, J. (2020). Plant collections: Possibilities of using herbaria, digital herbaria and plant databases in botany teaching at Eszterházy Károly University. *Sectio Biologiae*, 45, 83-91.
- Smith, B., & Chinnappa, C. C. (2015). Plant collection, identification, and herbarium procedures. In E. C. T. Yeung, C. Stasolla, M. J. Sumner & B. Q. Huang (Eds.), *Plant microtechniques and protocols* (pp. 541-572). Springer. [https://doi.org/10.1007/978-3-319-19944-3\\_30](https://doi.org/10.1007/978-3-319-19944-3_30)
- Soltis, P. S. (2017). Digitization of herbaria enables novel research. *American Journal of Botany*, 104(9), 1281-1284. <https://doi.org/10.3732/ajb.1700281>
- URL-1. *The World's Herbaria 2025: A summary report based on data from index herbariorum*. Retrieved Jan 27, 2026, from [https://sweetgum.nybg.org/science/wp-content/uploads/2026/01/The\\_Worlds\\_Herbaria\\_2025.pdf](https://sweetgum.nybg.org/science/wp-content/uploads/2026/01/The_Worlds_Herbaria_2025.pdf)
- URL-2. *Nezahat Gökyiğit botanik bahçesi herbariyumu (NGBB)*. Retrieved Mar 03, 2026, from <https://herbariyum.ngbb.org.tr/index-en.html>
- URL-3. *Ege Üniversitesi Eczacılık Fakültesi IZEF HERBARYUMU*. Retrieved Mar 03, 2026, from <http://izef.ege.edu.tr/> (In Turkish)
- URL-4. *Van Gölü Havzası sanal Herbariyumu*. Retrieved Mar 03, 2026, from <https://nadidem.net/flora/index.htm> (In Turkish)
- URL-5. *DUOF sanal Herbariyumu*. Retrieved Mar 03, 2026, from <https://duof.duzce.edu.tr/sayfa/e3b2/duof-sanal-herbariyumu> (In Turkish)
- Vaganov, A. V., Shmakov, A. I., Smirnov, S. V., Usik, N. A., Shibanova, A. A., Kechaykin, A. A., ... & Belkin, D. L. (2021). Virtual Herbarium ALTB: Collection of vascular plants of the Altai Mountain Country. *Biodiversity Data Journal*, 9, e67616. <https://doi.org/10.3897/BDJ.9.e67616>

## RESEARCH ARTICLE

# Systematic Search for Drought-Resilient Provenances in Bavaria, Germany

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## ABSTRACT

Repeated droughts have led to a decline in vitality and the death of entire populations of European beech (*Fagus sylvatica* L.), particularly in Lower Franconia, over the last decade. In order to identify suitable seed sources for future forest conversion measures, seed stands are being sought that remain resistant even under hot and dry conditions. This article presents a concept for a systematic method for identifying climate-resilient beech populations in Bavaria. Data from forest damage surveys, climate models, and site data have been merged for the first time in this context. The pilot study demonstrated a significant correlation between the modelled climatic marginality and the reported drought damage. The method of stratification using niche models and forest damage survey data thus proved to be a good starting point for identifying endangered forest sites and stands. The approach enables a targeted search for phenotypically healthy trees and forest stand that show little drought symptoms even under high site-related vulnerability (e.g., marginal sites, low plant available water capacity [AWC]). These stands, showing an apparently high phenotypic plasticity, are observational classified and hypothesised as particularly drought-resilient. Hence, carrying out these data analyses for the identification of more drought resilient beech in a first step effectively narrows the search area for field work and genetically analysis of potential seed stands.

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**Terminology**

**Resilience** is the capacity of a tree or forest system to recover its structure and function after a disturbance. It reflects the speed and degree of return to pre-disturbance growth, vitality, or population structure (DeRose & Long, 2014; Holling, 1973).

**Resistance** is the capacity of a tree (or population) to withstand a disturbance or stress event (e.g., drought, frost, pests) with little or no reduction in performance (e.g., growth, survival, physiological function) (DeRose & Long, 2014).

**Vitality** refers to the overall physiological vigor and functional performance of a tree, typically reflected in growth rate, crown condition, reproductive output, carbohydrate

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reserves, and ability to maintain metabolic processes under prevailing environmental conditions (Dobbertin, 2005; Roloff, 1991).

## 1. Introduction

Over the past decade, there have been repeated extreme drought events in northern Bavarian forests, especially in

Lower Franconia. These weather conditions have affected the water supply and thus the growth of trees. Second, they also reduced the forest's resistance to abiotic damages and pests. Tree species that were once considered robust and vital, such as the European beech (*Fagus sylvatica* L.), showed signs of severe drought stress at many forest sites, especially in Lower Franconia. These ranged from premature leaf fall and crown damage to increased mortality (Figure 1).

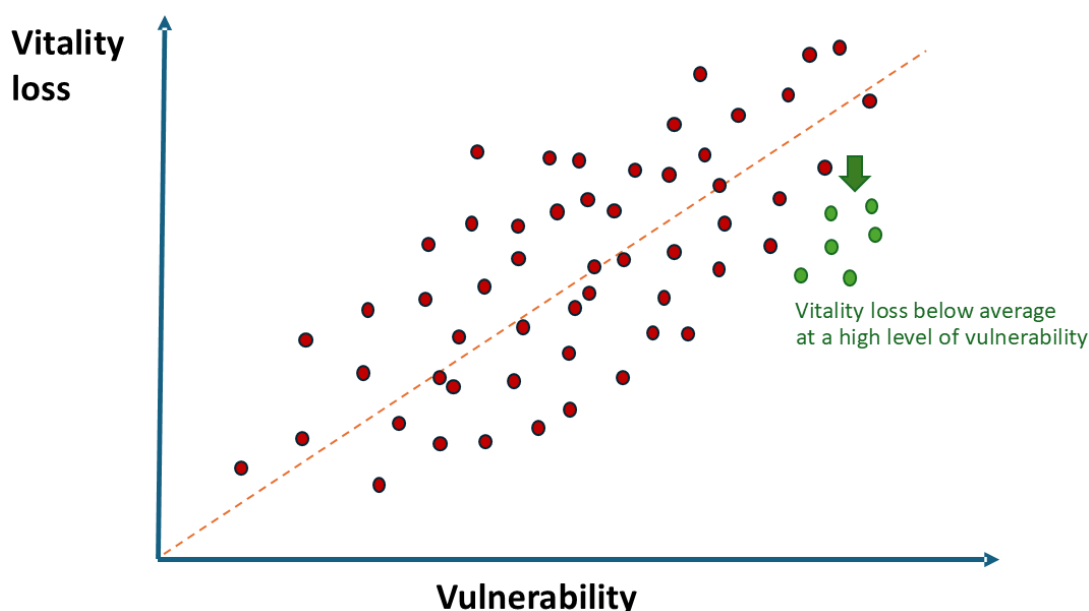


**Figure 1.** Vitality loss of beech trees in Lower Franconia. Photos: Yves-Daniel Hoffmann (Bavarian Office for Forest Genetics), Andreas Hahn (Bavarian State Institute of Forestry)

This abiotic damage underscores the urgency of adapting to climate change in order to strengthen the resilience of forest stands. The search for resilient populations and their use in “assisted migration” (Fady et al., 2016) would be an important measure to increase the resilience of forests. However, moving a species within or even outside its range may disrupt ecological relationships and expose species to novel stresses. There is also the risk that introduced populations could become invasive, hybridize with local genotypes, alter community structure, or reduce local biodiversity (Aitken et al., 2013). We show, using the example of European beech, how forest damage survey data and precise observations on viability, vitality and water and nutrient supply can enhance the identification of resilient populations. This work was carried out as part of the sensFORnative project.

Field observations show that – contrary to most individuals of a population – some individual trees and specific groups of trees can maintain their vitality even under adverse environmental conditions. The influence of site-related factors on tree vitality is frequently observed and is considered

ecophysiologicaly plausible. The search for suitable seed stocks base on visually and externally recognizable healthy tree populations, i.e. those that are apparently phenotypically resilient. It is obvious that observed resilience in populations could also be based on many factors other than genetic causes. Therefore, the search scheme focuses on genetically resilient populations by excluding other causes for the apparent resilience as far as possible, e.g. by taking site conditions into account (a high AWC is a key to bridge the water supply to trees during periods of drought; Marano et al., 2025). We demonstrate this here using a simple initial approach with a few parameters observed by us in this small preliminary study. This simple search scheme is based on comparing the intensity of vitality loss and their vulnerability, which is determined by climate at the large scale and local site conditions at the small scale. The relationship between vitality loss and vulnerability can be represented graphically (Figure 2). Those forest stands or individuals that show only minor damage even during a drought period despite high site-related damage susceptibility can be expected to be particularly suitable under climate change conditions (Figure 2, green dots).



**Figure 2.** Schematic representation of the relationship between vitality loss (observed damage) and potential site-related vulnerability/susceptibility to damage. The interaction of site characteristics such as water, nutrient supply and the local climate determine the potential susceptibility to damage of a site. Some forest stands may show below-average symptoms despite high susceptibility (green points below the red regression line).

## 2. Materials and Methods

### 2.1. Survey on Regional Level

Vitality loss and drought symptoms in beech are reported within the forest damage survey of the Bavarian Forest Administration (WSM reports). Data used for this study was noted every six months between 2018 and 2021 for the total forest area (Schißlbauer et al., 2022). The forest damage survey includes all stands in a forest district this means both damaged and non-damaged stands were considered. Beech stands had to show noticeable signs of dieback in the upper crown to be recorded – but the beech trees did not have to be completely dead.

The potential vulnerability of seed crop stands was determined in the sensFORclim project as climatic marginality (CMI) on the basis of niche models (Mellert et al., 2023). The tree species distribution data were taken from the Bayerische Landesanstalt für Wald und Forstwirtschaft (2020) dataset. In order to fully exploit the climatic potential of a tree species, beech was already considered present if it occurred within a 16 x 16 km grid. WorldClim (Fick & Hijmans, 2017) was used as climate data. The variables BIO6 (minimum temperatures in the coldest month), BIO10 (average summer temperatures), and BIO18 (summer precipitation) for the climate period from 1970 to 2000 were used as proxies for the limitation caused by chilliness and frost (BIO6) as well as for summer heat (BIO10) and drought (BIO18) (Mellert et al., 2015). For the large-scale representation of vulnerability, climate data for Bavaria was taken, assuming a climate warming of +2.5 °C. This incremental scenario was used because such elevated

temperatures have already been observed in Bavaria in recent years. The resulting forecast of marginality (CMI) was mapped and classified with the threshold values (CMI < 0.4 = marginal; CMI 0.4–0.7 = intermediate; CMI > 0.7 = optimal) for vulnerability (1-CMI). On this basis the CMI of European beech was mapped.

We checked whether the classes of climatic vulnerability provide a meaningful classification. Further, we examined whether there is a relationship between the CMI as a measure for potential vulnerability and the damage reports according to the concept described in Figure 2 by nonparametric correlation analysis with Kendall's tau.

### 2.2. Survey on Stand Level

The data for the local site conditions includes the defoliation rate of 332 trees situated in twelve European beech stands in northern Bavaria (Schmied et al., 2024). The data which was collected in the sensFORbeech project with a different objective (Schmied et al., 2024) are used here for an illustrative example how the search process at the stand level up to the plus tree could look like (for further details, Materials and Methods section and Schmied et al., 2024). Therefore, the identification of “drought-resilient” populations relies only on visual interpretation of deviations from the regression line. No statistical criteria were applied to identify significant outliers.

The potential vulnerability of stands was described by the available water capacity (AWC) as a main driver for the small-scale vulnerability (Marano et al., 2025; Mellert et al., 2018, 2023). This allows us to show the relationship according to the concept described in Figure 2 at the stand level, where AWC

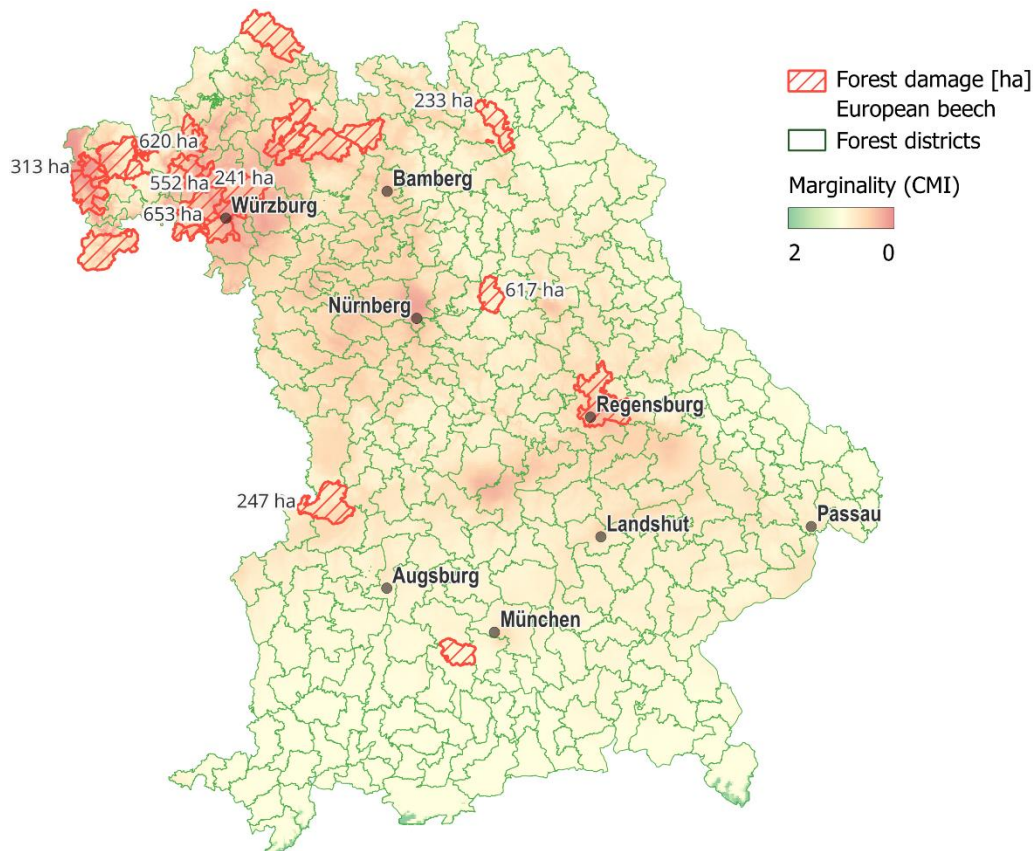
represents the potential vulnerability (x-axis) and the rate of defoliation represents vitality loss (y-axis).

### 3. Results and Discussion

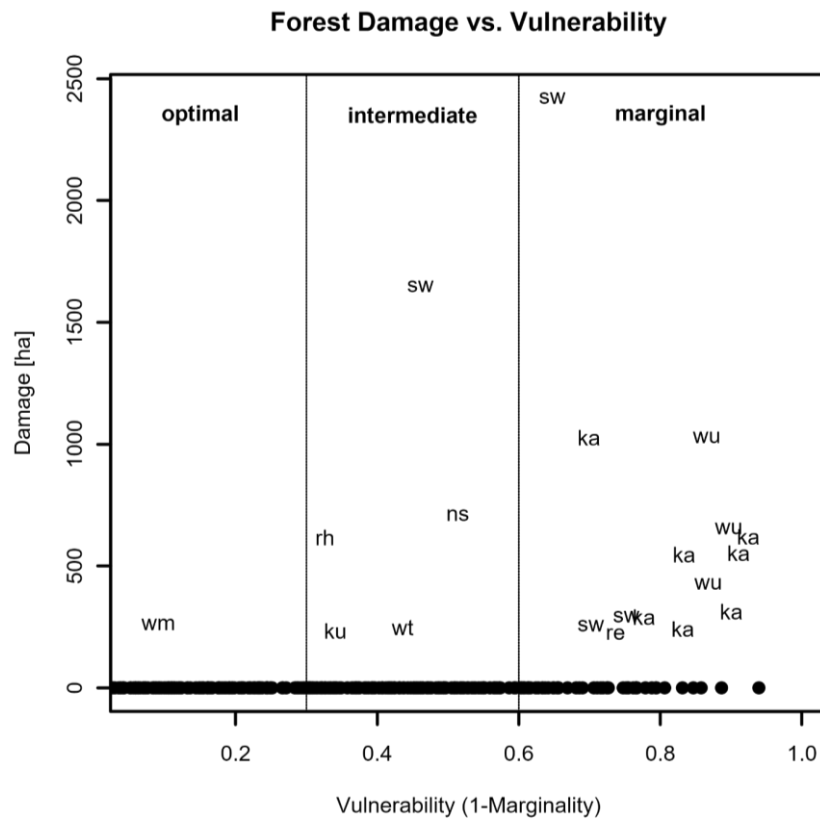
#### 3.1. Survey on Regional Level

The resulting area forecast of the CMI was divided into an optimal, intermediate, and marginal range in each case. A correlation between vulnerability and damage is plausible but cannot be expected with certainty. This is due to the fact that the niche models used are based on historical climate data (period 1970–2000) and a projected climate warming of +2.5 °C, while the WSM reports reflect the current annual damage. This analysis can therefore be seen as a proof of concept whether large-scale ecological parameters such as marginality or derived variables such as vulnerability are at all suitable as measures of potential susceptibility to damage.

As the map in Figure 3 shows, there is a correspondence between the CMI and the reported damage areas in the forest districts visible (Figure 4). Statistical analysis of the relationship between the two parameters provides more detailed information (Figure 4). The correlation between the two variables is significant (Kendall's tau = -0.2;  $p < 0.001$ ). The lower the CMI, i.e. the more marginal the stand, the greater the damage. The scatter plot in Figure 5 shows that the greatest damage occurs in forest districts in Lower Franconia – a climatically highly vulnerable area (marginal area: CMI < 0.4). In the optimal area, on the other hand, less damage occurs (see Figure 3). These results suggest that the stratification method based on niche models is fundamentally suitable for assessing the climatic vulnerability of populations.



**Figure 3.** Marginality of European beech in Bavaria (CMI) overlaid by the damaged areas reported for the forest districts of the Bavarian Forest Administration (regional offices for food, agriculture, and forestry) for the years 2018–2021 (hatched polygons).



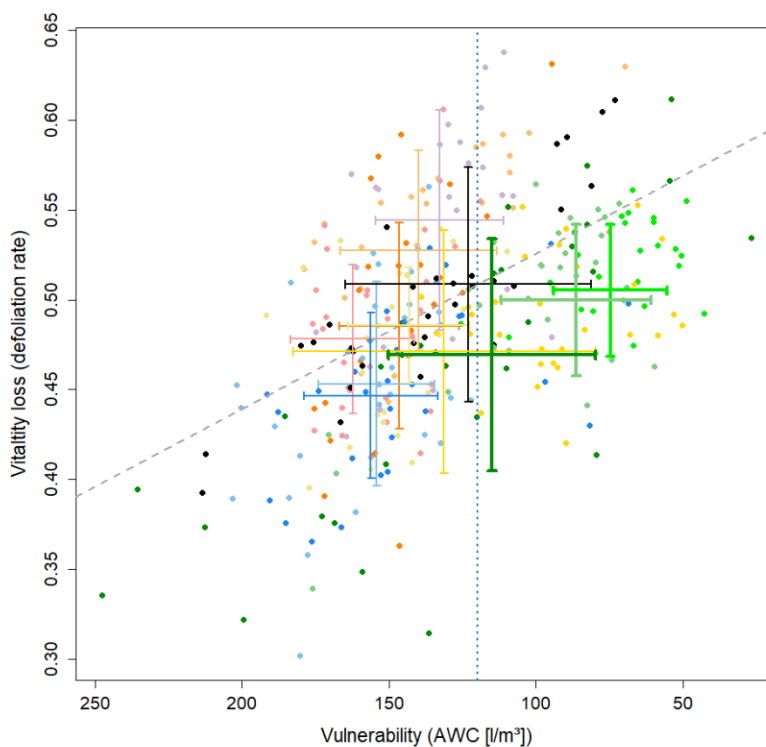
**Figure 4.** Reported forest area with drought damage to European beech in Bavaria stratified according to vulnerability classes (V). Forest districts of the regional offices of the Bavarian Forest Administration with reported damages are represented by abbreviations. Particularly noteworthy are the forest districts of regional offices in Lower Franconia with high levels of damage (ka=Karlstadt, sw=Schweinfurt, wu=Würzburg; see Figure 3).  $V < 0,3$  = optimal;  $V 0,3 - 0,6$  = intermediate;  $V > 0,6$  = marginal.

### 3.2. Survey on Stand Level

The scatter plot in Figure 5 represents the effect of AWC as a driver for the vulnerability at small scale on the vitality loss (defoliation rate). Error bars in Figure 5 visualize the variation of individual trees within a forest stand. Increased climate plasticity is assumed in cases of below-average damage (stands below the dashed grey regression line). Promising trees or stands are present when high vulnerability is accompanied by only minor damage (highlighted error bars in shades of green).

According to our assessment scheme, three of the twelve tree populations stand out from the average trend, symbolized

by the highlighted greenish error bars in Figure 5. These populations could therefore contain drought-resilient genotypes. We expressly formulate this conclusion as a hypothesis for further testing. It is obvious that an observed deviation from the expected damage does not in itself prove a genetic adaptation process. Therefore, the stocks identified in this way should be tested in further studies and practical cultivation trials. The propagation material from stocks tested in this way would be a valuable contribution to increasing the resilience and stability of forests.



**Figure 5.** Example for the identification of drought-resilient trees (N=332) within stands (N=12): Vitality loss (estimated degree of defoliation of individual European beeches in August 2022) vs. small-scale vulnerability represented by AWC in declining order versus increasing vulnerability (vertical dotted blue line: AWC = 120 l/m<sup>2</sup>).

### 3.3. Operational Procedure Despite Unresolved Issues

After the severe drought events in recent years, the resistance and resilience of European beech was doubted for large amounts of forest sites (Klemmt et al., 2023). It was questioned, how these symptoms should be interpreted: Can the vitality loss and the dieback of European beech be assessed as an individual adaptation to new environmental conditions? Or is a reassessment of the suitable site requirements for European beech needed?

However, recent research in Bavaria points to a complex response of trees to drought impacts on a variety of environmental conditions - varying with spatial scales such as climate (Mellert et al., 2018), soil chemistry (Schmied et al., 2023), soil water storage (Schmied et al., 2024), and tree neighbourhood composition and structure (Rieder et al., 2026).

As we could show, concluding data on potential vulnerability information (Mellert et al., 2023) and forest damages (Schleißbauer et al., 2022) are already available and can be used for a systematic search for climate-resilient provenances in Bavaria, although the underlying processes for forest damage are not fully understood.

Nevertheless, the searching procedure described here have to be further developed with more comprehensive data: Future application-oriented research should include, forest protection data (data from all types of forest ownerships, longer time

series), data from the forest condition survey, updated site data (Mette et al., 2025), but also high-resolution recording of damage symptoms using remote sensing data. Initial studies certainly give cause for optimism (Pfenninger et al., 2025).

## 4. Conclusion

Damage surveys at the forest district level provide a good overview on the dispersion of biotic and abiotic damages to forest stands; hot spot regions can be identified. The correlation between forest damage and climatic marginality, which serves as a criterion for the regional susceptibility of forests to damage, highlights the important role of macroclimatic drought risks. The climatic marginality can therefore be a starting point for a systematic search for drought-resilient populations. Stands with little or no vitality loss in such problem areas could indicate more resilient stands. Such phenotypically promising candidates derived from observational classification can be included in a systematic testing procedure. In particular, site-specific causes for (apparently) increased resistance of the populations should be excluded as far as possible. A tree population with increased resilience identified in this way could, after further intense testing in accordance with the German Forest Reproductive Material Act (BLE, 2003) – e.g., with regard to its quality and genetic adaptability – be designated as a seed stand for drought-resilient propagation material.

## Acknowledgment

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## Conflict of Interest

The authors declare that they have no conflict of interest.

## References

- Aitken, S. N., & Whitlock, M. C. (2013). Assisted gene flow to facilitate local adaptation to climate change. *Annual Review of Ecology, Evolution, and Systematics*, 44(1), 367-388. <https://doi.org/10.1146/annurev-ecolsys-110512-135747>
- Bayerische Landesanstalt für Wald und Forstwirtschaft. (2020). *Praxishilfe Klima-Boden-Baumartenwahl Band 2*. Freising. (In German)
- BLE. (2003). *Forstliches Vermehrungsgut*. [https://www.ble.de/DE/Themen/Wald-Holz/Forstliches-Vermehrungsgut/forstliches-vermehrungsgut\\_node.html](https://www.ble.de/DE/Themen/Wald-Holz/Forstliches-Vermehrungsgut/forstliches-vermehrungsgut_node.html) (In German)
- DeRose, R. J., & Long, J. N. (2014). Resistance and resilience: A conceptual framework for silviculture. *Forest Science*, 60(6), 1205-1212. <https://doi.org/10.5849/forsci.13-507>
- Dobbertin, M. (2005). Tree growth as indicator of tree vitality and of tree reaction to environmental stress: A review. *European Journal of Forest Research*, 124(4), 319-333. <https://doi.org/10.1007/s10342-005-0085-3>
- Fady, B., Aravanopoulos, F. A., Alizoti, P., Mátyás, C., von Wühlisch, G., Westergren, M., ... & Zlatanov, T. (2016). Evolution-based approach needed for the conservation and silviculture of peripheral forest tree populations. *Forest Ecology and Management*, 375, 66-75. <https://doi.org/10.1016/j.foreco.2016.05.015>
- Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*, 37(12), 4302-4315. <https://doi.org/10.1002/joc.5086>
- Holling, C. S. (1973). Resilience and stability of ecological systems. In: *Socio-Environmental Research in Ecology*. DOI: <https://doi.org/10.1017/9781009177856.038>
- Klemmt, H. J., Eusemann, P., Grüner, J., Hahn, A., Kätzel, R., Kühling, M., Langer, G., Mund, M., Niesar, M., Reiter, P., & Sanders, T. (2023). Die Zukunft der Rotbuche in Mitteleuropa. *AFZ, der Wald*, 78(15), 12-16. (In German)
- Marano, G., Hiltner, U., Knapp, N., & Bugmann, H. (2025). Simulating the recent drought-induced mortality of European beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* L.) in German forests. *EGUsphere*, 2025, 1-29. <https://doi.org/10.5194/egusphere-2025-1534>
- Mellert, K. H., Deffner, V., Küchenhoff, H., & Kölling, C. (2015). Modeling sensitivity to climate change and estimating the uncertainty of its impact: A probabilistic concept for risk assessment in forestry. *Ecological Modelling*, 316, 211-216. <https://doi.org/10.1016/j.ecolmodel.2015.08.014>
- Mellert, K. H., Lenoir, J., Winter, S., Kölling, C., Čarni, A., Dorado-Liñán, I., ... & Ewald, J. (2018). Soil water storage appears to compensate for climatic aridity at the xeric margin of European tree species distribution. *European Journal of Forest Research*, 137(1), 79-92. <https://doi.org/10.1007/s10342-017-1092-x>
- Mellert, K.-H., Schmied, G., Buness, V., Steckel, M., Uhl, E., Pretzsch, H. (2023). Small-scale variation in available water capacity of the soil influences height growth of single trees in Southern Germany. *Forest Systems*, 32(2), e013-e013.
- Mette, T., Falk, W., Hipler, S. M., & Wellhausen, K. (2025). BaSIS 2.0: Das neue (Baumarten-) Anbaurisiko. *LWF Aktuell*, 153, 4-9. (In German)
- Pfenninger, M., Langan, L., Feldmeyer, B., Eberhardt, L., Reuss, F., Hoffmann, J., Fussi, B., Šeho, M., Mellert, K. -H., & Hickler, T. (2025). Predicting forest tree leaf phenology under climate change using satellite monitoring and population-based genomic trait association. *Global Change Biology*, 31(9), e70484. <https://doi.org/10.1111/gcb.70484>
- Rieder, J. S., Žmegač, A., Link, R. M., Köthe, K., Ullmann, T., Seidel, D., Fäth, J., Zang, C., & Schuldt, B. (2026). Tree size, neighbourhood composition and structure affect individual tree vitality of European beech following extreme drought. *Forest Ecology and Management*, 599, 123293. <https://doi.org/10.1016/j.foreco.2025.123293>
- Roloff, A. (1991). Crown structure and tree vitality. In J. W. S. Longhurst (Ed.), *Acid deposition: Origins, impacts and abatement strategies* (pp. 193-213). Springer. [https://doi.org/10.1007/978-3-642-76473-8\\_13](https://doi.org/10.1007/978-3-642-76473-8_13)
- Schleißbauer, J., Bork, K., Muser, M., Klemmt, H.-J., & Hahn, A. (2022). Waldschutzfragen und aktuelles zur Vitalität der Buche in Bayern. *LWF-Wissen*, 86, 44-56. (In German)
- Schmied, G., Hilmers, T., Mellert, K. H., Uhl, E., Buness, V., Ambs, D., Steckel, M., Biber, P., Šeho, M., Hoffmann, Y. D., & Pretzsch, H. (2023). Nutrient regime modulates drought response patterns of three temperate tree species. *The Science of the Total Environment*, 868, 161601. <https://doi.org/10.1016/j.scitotenv.2023.161601>
- Schmied, G., Pretzsch, H., Ambs, D., Uhl, E., Schmucker, J., Fäth, J., Biber, P., Hoffmann, Y. -D., Šeho, M., Mellert, K. H., & Hilmers, T. (2024). Rapid beech decline under recurrent drought stress: Individual neighborhood structure and soil properties matter. *Forest Ecology and Management*, 545, 121305. <https://doi.org/10.1016/j.foreco.2023.121305>

## RESEARCH ARTICLE

## Genetic Resource Potential of Turkish Hazel (*Corylus colurna* L.) in Yukarı Çakırçay Village (Hanönü, Kastamonu)

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## ABSTRACT

The Turkish hazel (*Corylus colurna* L.) is one of the two hazelnut species naturally occurring in Türkiye and differs from other hazel species by its single-stemmed tree form. This study was conducted to identify naturally growing Turkish hazel individuals in Yukarı Çakırçay Village of Hanönü District, Kastamonu Province, and to evaluate the genetic resource potential of the area. In order to confirm the presence of the species in the specified area, species identification, geolocation recording of the individuals, determination of morphological traits, site characteristics, ethnobotanical features, and morphological characteristics of the nuts were investigated. A total of nine Turkish hazel individuals were recorded in the study area. The average diameter at breast height was 33.6 cm, the average tree height was 11.4 m, and the mean crown diameter was 7.7 m. The slope of the terrain ranged from 20% to 45%. All individuals were located on southern aspect, at elevations ranging from 1118 to 1277 meters above sea level. The limited number of individuals and the large distances between them suggest that the Turkish hazel in this area could be considered a potential genetic resource. To ensure their conservation, these individuals should be propagated under ex situ conditions and conserved through in situ strategies.

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## 1. Introduction

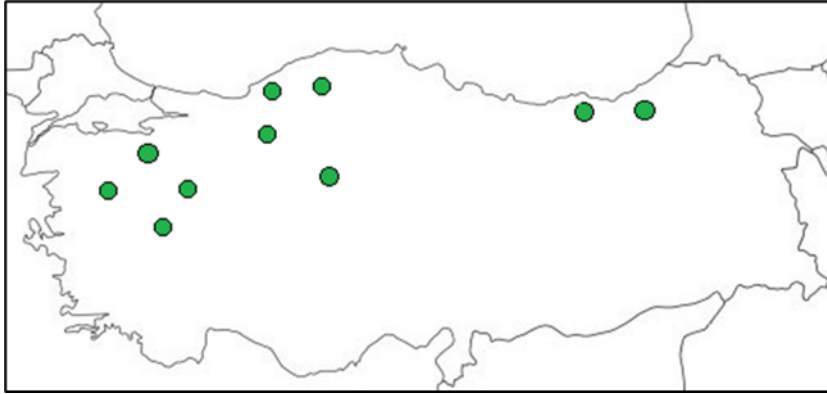
The hazelnut belongs to the Betulaceae family and grows naturally in the temperate regions of the Northern Hemisphere. There are more than 25 species within the genus *Corylus* worldwide, and among them, the common hazel (*Corylus avellana* L.) and the Turkish hazel (*Corylus colurna* L.) grow naturally in Türkiye (Polat, 2014). In the literature, this species is also referred to as Balkan hazel, bear hazel, Turkish hazel, tree hazel, and in the Kastamonu region, as rock hazel (Yaltırık, 1993; Ayan et al., 2016).

Turkish hazel is widely distributed in the Anatolian forests of Türkiye. Some of the provinces where these trees are found are Kastamonu, Bolu, Ankara, Zonguldak, Balıkesir, Rize, Trabzon, Bursa, Uşak, and Kütahya (Ayan et al., 2016; Kalkan & Yılmaz, 2024; Oguzkan et al., 2018; Temel et al., 2017) (Figure 1). The species generally appears either as solitary individuals or in small groups beneath broadleaf forests (such as Oriental beech, Caucasian linden in Bolu, maple, European hornbeam, Turkey oak, and Hungarian oak) as well as within stands containing juniper species, Anatolian black pine, trembling poplar, and mixed beech–fir forests. Its altitudinal

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distribution ranges between 800 and 1700 meters (Yaltırık, 1993; Yaltırık & Efe, 1994; Kalkan & Yılmaz, 2024).



**Figure 1.** Some of the areas in Türkiye where Turkish hazel is distributed (Created by: Cansu Günay).

Turkish hazel is a straight-stemmed tree that can reach up to 25 meters in height. In mature trees, the bark is thick, deeply fissured longitudinally, corky, and dark gray in color. Young shoots are pale rusty-brown and densely pubescent (Yaltırık, 1993). The margins of the involucre are torn into irregular thin strips, the tips are curved backward, and the surface is covered with sticky hairs. The nuts measure 15–20 × 10–18 mm, are slightly flattened at the top, and have a broadly ovoid shape. Compared to other hazelnut species, the fruit shell is notably thicker (Yaltırık, 1993). The matte area where the nut attaches to the stem covers approximately half of the nut's surface, a feature characteristic of Turkish hazel (Yaltırık & Efe, 1994).

Although Turkish hazel is not currently classified as an endangered species, it faces the risk of becoming one (Arslan, 2009). Owing to its wood and fruit characteristics, it is an important species in terms of its contributions to ecosystems, biodiversity, and fauna elements. With its high nutritional value, it is also considered a valuable food resource (Doğanay, 2012).

Plant genetic resources are important sources of genetic diversity and encompass the variability and richness of hereditary information contained within the genome of a plant species. Genetic diversity is essential for the adaptation of plant species to changing environmental conditions (Altındal & Akgün, 2015).

Forest genetic resources and genetic diversity have long been negatively affected by natural and especially human-induced (anthropogenic) impacts. The methods applied to conserve genetic resources in forests can be grouped into two main categories: *in-situ* conservation, which is based on preserving these genetic resources in their natural environment, and *ex-situ* conservation, which aims to protect them outside

their natural habitat. Within *in-situ* conservation, seed stands represent the most significant example. In *ex-situ* conservation, clonal seed orchards, clone banks, clone parks, arboreta, and pollen and seed banks are primarily utilized. Additionally, the cryopreservation of embryonic tissues under laboratory or artificial conditions is also an important component of this method (Dirik, 1994).

Ethnobotany fundamentally refers to the relationship between humans and plants. The term ethnobotany was first introduced in 1895 and has played an important role in understanding the use of plants in the treatment of many diseases. Ethnobotanical studies are generally based on long-term observations and the transmission of local knowledge (Kendir & Güvenç, 2010).

The identification of the morphological characteristics of Turkish hazel is a fundamental step in revealing its genetic resource potential and ethnobotanical significance. In this context, within the scope of the study, examinations conducted on naturally occurring Turkish hazel individuals in Yukarı Çakırçay Village aimed to obtain data on the species' current status, morphological features, and potential genetic resource value.

## 2. Materials and Methods

The Turkish hazel individuals examined in the study area are located within compartments 49 and 65 of the Çatalçam Forest Subdistrict, which is part of the Hanönü Forest District Directorate under the Kastamonu Regional Directorate of Forestry, and lie within the boundaries of Yukarı Çakırçay Village. The map of the areas where the species is distributed is presented in Figure 2.





**Figure 3.** Measurement of morphological characteristics of hazelnuts and kernels.

Additionally, ethnobotanical information on the species' recognition and its uses was gathered through interviews with local residents.

### 3. Results

Within the scope of the study carried out in 2023 in Yukarı Çakırçay Village and its surroundings in the Hanönü District of Kastamonu Province, potential areas where Turkish hazelnut could naturally distribution were evaluated based on the knowledge and guidance of local residents. The potential distribution areas were carefully examined, and based on field observations and morphological assessments, the presence of natural individuals was identified in the Çal and Sekü Hill localities. No individuals of the species were encountered in other investigated areas. All identified individuals were located

on south-facing slopes, at elevations between 1118 and 1277 meters, and on sites with varying slope gradients.

A total of nine individuals were recorded during the field studies (Figures 4–12). The dbh of these individuals ranged between 10–53 cm, while their heights varied between 5–16.5 m. Mean DBH and height were 33.6 cm and 11.4 m, respectively. The average crown diameter was of 7.9 m in the north–south direction, and 7.5 m in the east–west direction. The slope of the sites where the trees were located ranged between 20% and 45%, with an average slope of 34%. Due to the presence of cavities in the trunks, age determination could be performed on only one individual, which was measured to be 77 years old. For the remaining individuals, suitable increment cores could not be obtained (Table 1).

**Table 1.** Morphological and site characteristics of the identified Turkish hazelnut individuals.

Tree No	DBH (cm)	Height (m)	Age	Crown diam. (N–S / E–W, m)	Elevation (m)	Coordinates	Aspect	Slope (%)	Hill
1	49.0	16.5	77	11.3 / 10.8	1236	41.67406 34.56604	South	40	Çal
2	40.0	14	-	7.0 / 10.0	1250	41.67446 34.56615	South	38	Çal
3	53.0	14	-	10.3 / 9.7	1260	41.67464 34.56594	South	41	Çal
4	50.0	11	-	8.5 / 8.5	1277	41.67529 34.56629	South	35	Çal
5	45.0	10.5	-	9.4 / 9.2	1250	41.67446 34.56638	South	45	Çal
6	11.0	5	-	5.1 / 4.5	1250	41.67446 34.56638	South	45	Çal
7	10.0	6	-	5.3 / 4.5	1118	41.66585 34.56316	South	20	Sekü
8	17.0	10	-	6.4 / 4.2	1118	41.66584 34.56278	South	23	Sekü
9	27.0	16	-	7.9 / 5.7	1119	41.66582 34.56282	South	22	Sekü
<b>Mean ± SD</b>	<b>33.6 ± 17.5</b>	<b>11.4 ± 4.1</b>	<b>-</b>	<b>7.9 ± 2.2</b>	<b>1208 ± 68.6</b>	<b>-</b>	<b>South</b>	<b>34 ± 10</b>	<b>Çal, Sekü</b>



**Figure 4.** Turkish hazelnut individual No. 1.



**Figure 5.** Turkish hazelnut individual No. 2.



**Figure 6.** Turkish hazelnut individual No. 3.



**Figure 7.** Turkish hazelnut individual No. 4.



**Figure 8.** Turkish hazelnut individual No. 5.



**Figure 9.** Turkish hazelnut individual No. 6.



**Figure 10.** Turkish hazelnut individual No. 7.



**Figure 11.** Turkish hazelnut individual No. 8.



**Figure 12.** Turkish hazelnut individual No. 9.

A total of 150 hazelnut samples were collected on 8 October 2023 from the fruits present on the identified Turkish hazelnut individuals in the study area. The available fruits on the trees were sampled, and a total of 150 nuts could be obtained from the population. The morphological measurements of these samples were conducted in the laboratory. Based on these measurements, the fill rate of the nuts was determined 28%,

while the empty rate was 72%. The average length, width, thickness, and weight of the hazelnut fruits were determined 15.74 mm, 17.05 mm, 13.85 mm, and 1.5599 g, respectively. For the kernels of the same samples, the average length, width, thickness, and weight were determined 11.29 mm, 10.92 mm, 7.03 mm, and 0.4413 g, respectively (Table 2).

**Table 2.** Morphological measurements of hazelnuts and kernels.

		<b>Length (mm)</b>	<b>Width (mm)</b>	<b>Thickness (mm)</b>	<b>Weight (g)</b>
<b>Hazelnut</b>	Min–Max	13.61–17.72	9.94–20.17	8.64–16.35	0.3959–2.7054
	Mean ± SD	15.75 ± 0.81	17.05 ± 1.74	13.85 ± 1.63	1.5599 ± 0.4268
<b>Kernel</b>	Min–Max	8.09–13.20	6.38–14.13	5.20–9.17	0.1798–0.7632
	Mean ± SD	11.29 ± 1.13	11.15 ± 1.62	7.20 ± 0.99	0.4413 ± 0.1377

Ethnobotanical investigations revealed that Turkish hazelnut is well recognized by local residents, whose nuts are commonly consumed as a snack and occasionally collected for economic purposes. The wood of the species is also traditionally used in the manufacture of household items and agricultural tools due to its high durability. However, individuals are sparsely distributed, occur at considerable distances from one another, and are confined to a limited number of natural sites. These findings indicate a restricted local distribution of the species and provide baseline information for future genetic and conservation-oriented studies.

#### 4. Discussion and Conclusion

This study identified a natural distribution area of Turkish hazelnut in and around Yukarı Çakırçay Village, Hanönü District, Kastamonu Province. The presence of this population is consistent with existing knowledge that the species exhibits a fragmented and scattered natural distribution in Türkiye.

The presence of individuals in the study area on slopes with a mean inclination of 34% and at elevations between 1118 and 1277 m aligns well with the topographic conditions reported from other regions where the species naturally occurs. Turkish hazelnut, which is distributed between 100–1300 m in the

Balkans and 800–1700 m in Türkiye, typically occupies similar elevation ranges and sloping terrains, indicating that the species prefers similar ecological conditions (Kalkan et al., 2023; Šeho et al., 2019).

The morphological characteristics of the individuals, including diameter, height, and crown width, are largely consistent with the ranges reported in previous studies from different regions of Türkiye. The mean diameter (33.6 cm) and height (11.4 m) observed in this study closely correspond to values reported from Bulkaz Mountain (Uşak), where stem diameters range from 30 to 100 cm and tree heights from 10 to 20 m (Polat & Güney, 2015). Similarly, studies conducted in the Dağakça and Çakallar regions of Bursa documented dbh values between 20 and 70 cm and heights ranging from 6 to 15 m, suggesting that individuals from Yukarı Çakırçay display comparable morphological characteristics (Kalkan & Yılmaz, 2024). In contrast, populations reported from Mount Şaphane include individuals reaching heights of up to 18 m (Kabak et al., 2020), indicating that the Yukarı Çakırçay population is relatively shorter. Such variation in growth form may be attributed to differences in environmental conditions, including site conditions, elevation, soil characteristics, and levels of intra-population competition.

The morphological measurements of *Corylus colurna* fruits obtained in this study show general agreement with values reported in the literature, although some minor differences are observed. For instance, Kalkan (2023) reported mean fruit dimensions of  $15.91 \times 15.34 \times 12.02$  mm and a fruit weight of 1.45 g, along with mean kernel dimensions of  $12.93 \times 11.07 \times 7.62$  mm and a kernel weight of 0.50 g across ten different populations. In the present study, the mean fruit length (15.74 mm) was comparable to those values, while fruit width (17.05 mm), thickness (13.85 mm), and mean fruit weight (1.56 g) were slightly higher. Kernel dimensions ( $11.29 \times 11.15 \times 7.20$  mm) and kernel weight (0.4413 g) obtained in this study were slightly lower but generally within the range reported by Kalkan (2023). These differences may be related to local ecological conditions, site characteristics, sampling differences, or the limited number of fruit-bearing individuals available in the population. Nevertheless, the values obtained in the present study generally fall within the range reported for *Corylus colurna* in previous studies.

Ünalın (2016) and Ayan et al. (2018) reported that the mean fruit dimensions across four different populations were  $15.45 \times 15.53 \times 12.04$  mm, with an average fruit weight of 1.48 g, while the kernel dimensions were  $12.46 \times 11.37 \times 7.56$  mm with a kernel weight of 0.5 g. Similarly, Balık and Kayalak Balık (2016) reported higher average values, with a mean fruit weight of 2.6 g and a mean kernel weight of 0.8 g. When compared with these results, individuals from Yukarı Çakırçay generally fall within the overall morphological range reported for the species but display moderate differences in certain traits,

particularly kernel size and weight. Such variation may reflect natural intraspecific variability and suggests that the Yukarı Çakırçay population may represent a locally important component of the species in terms of morphological diversity and its potential relevance for future genetic and conservation-oriented studies.

Popović et al. (2022) demonstrated that *Corylus colurna* populations in Serbia exhibit high morphological variation, while some populations are genetically weak. Therefore, the individuals identified in Yukarı Çakırçay should be considered for seed production using methods that preserve genetic diversity.

It is well documented that *Corylus colurna* forms mixed stands with various forest tree species within its natural distribution range. In this study, individuals were observed either as solitary trees or in small clusters, occurring alongside broadleaved species such as wild pear (*Pyrus elaeagnifolia*) and oak (*Quercus* spp.). The literature indicates that the species frequently coexists with Oriental beech (*Fagus orientalis*), Turkey oak (*Quercus cerris*), Hungarian oak (*Quercus frainetto*), and European hornbeam (*Carpinus betulus*) (Ayan et al., 2016; Kalkan & Yılmaz, 2024; Yaltırık, 1993).

Ethnobotanical observations in the Yukarı Çakırçay region indicate that local communities consume the fruits of Turkish hazelnut primarily as a snack and occasionally harvest them for economic purposes. The wood of the species has also been traditionally utilized in the manufacture of household items and agricultural tools, reflecting its high durability. These practices are consistent with reports from the Dağakça and Çakallar villages in Bursa, where the fruits are used in the preparation of bread, cakes, and desserts, and the shells serve as a fuel source, as well as with similar uses reported for Kastamonu and other regions (Ayan et al., 2016; Kalkan & Yılmaz, 2024). Likewise, Polat (2014) reported that local populations collected and consumed the fruits of *Corylus colurna* as a food resource. Taken together, these findings suggest that Turkish hazelnut has a broadly consistent pattern of traditional use across its natural distribution range.

Turkish hazelnut exhibits a characteristically fragmented distribution across its range, typically occurring in small and spatially isolated populations. Recent studies from the Balkans (particularly in Serbia and Bosnia-Herzegovina) have documented numerous small and isolated populations (Šeho et al., 2019, 2023), a pattern that is likewise evident in Türkiye (Kalkan, 2023; Kalkan & Yılmaz, 2024; Polat, 2014). Although the species is listed as “Least Concern” on the IUCN Red List, factors such as habitat loss, population isolation, and low fruit productivity indicate that it may be locally threatened. The fact that the individuals identified in Yukarı Çakırçay are relatively small in diameter, old, and dispersed, combined with habitat fragmentation and limited seed dispersal, suggests that maintaining genetic diversity in the long term could be

challenging. Consequently, treating this population as a candidate genetic reserve and securing its protection through integrated *in-situ* and *ex-situ* conservation measures should be considered a priority.

In conclusion, the individuals identified in Yukarı Çakırçay significantly enhance our understanding of the natural distribution of Turkish hazelnut in Türkiye and contribute original evidence on the species' morphological and ecological variability. Continued, systematic monitoring of this and comparable local populations is therefore imperative to support effective conservation and to inform their integration into sustainable forest management frameworks.

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## Conflict of Interest

The authors declare that they have no conflict of interest.

## References

- Akgün, B., Okumuş, A., & Yazar, E. (2018). Gaziantep yöresinde bulunan ve anıt ağaç niteliği taşıyan doğu çınarı (*Platanus orientalis* L.)'nın fiziksel özelliklerinin belirlenmesi. *Kahramanmaraş Sütçü İmam Üniversitesi Mühendislik Bilimleri Dergisi*, 21(4), 305-311. (In Turkish)
- Altındal, D., & Akgün, İ. (2015). Bitki genetik kaynakları ve tahıllardaki durumu. *Adnan Menderes Üniversitesi Ziraat Fakültesi Dergisi*, 12(1), 147-153. (In Turkish)
- Arslan, M. (2009). Kabukları çıkartılmış Türk fındığı tohumlarına uygulanan ön işlemlerin çimlenmeye etkisi. *Düzce Üniversitesi, Ormancılık Dergisi*, 5, 170-178. (In Turkish)
- Ayan, S., Aydınöz, D., Yer, E. N., & Ünal, E. (2016). Türk fındığı (*Corylus colurna* L.)'nın Kuzeybatı Anadolu ormanlarındaki yeni bir yayılış alanı: Kastamonu-Ağlı Müsellimler, Tunuslar Mevkii. *Biological Diversity and Conservation*, 9(1), 128-135. (In Turkish)
- Ayan, S., Ünal, E., Sakici, O. E., Yer, E. N., Ducci, F., Isajev, V. V., & Ozel, H. B. (2018). Preliminary results of Turkish hazelnut (*Corylus colurna* L.) populations for testing the nut characteristics. *Genetika*, 50(2), 669-686. <https://doi.org/10.2298/GENSR1802669A>
- Balık, H. İ., & Kayalak Balık, S. (2016). Türk fındığı (*Corylus colurna* L.)'nın tanımlanması. *Bahçe*, 45(Özel Sayı 1), 442-446. (In Turkish)
- Dirik, H. (1994). Genetik çeşitlilik ve orman gen kaynaklarının korunması. *Journal of the Faculty of Forestry Istanbul University*, 44(3-4), 113-122. (In Turkish)
- Doğanay, H. (2012). Türkiye fındık meyvacılığındaki yeni gelişmeler. *Eastern Geographical Review*, 17(27), 1-22. (In Turkish)
- Kabak, B., Polat, S., & Aydınöz, D. (2020). A new distribution area of Turkish Hazel (*Corylus colurna* L.): Mount Şaphane (Kütahya). *Journal of Academic Social Research*, 8(109), 376-396.
- Kabak, B., Polat, S., & Aydınöz, S. P. D. (2020). Türk Fındığı'nın (*Corylus colurna*) yeni bir yayılış alanı: Şaphane Dağı (Kütahya). *The Journal of Academic Social Science*, 8(109), 376-396. <https://doi.org/10.29228/ASOS.45520> (In Turkish)
- Kalkan, M. (2023). *Türk fındığı (Corylus colurna L.) tohumlarının fizyolojisi üzerine araştırmalar* (Doctoral dissertation, Bursa Technical University). (In Turkish)
- Kalkan, M., & Yılmaz, M. (2024). Türk fındığı (*Corylus colurna*)'nın doğal yayılışında yeni alanlar: Dağakça ve Çakallar (Bursa). *Turkish Journal of Forestry*, 25(2), 205-212. <https://doi.org/10.18182/tjf.1456983> (In Turkish)
- Kalkan, M., Yılmaz, M., & Oral, R. A. (2023). The morphological and chemical variability of Turkish hazel (*Corylus colurna* L.) fruits in Turkey. *Journal of Forestry Society of Croatia/Sumarski List Hrvatskoga Sumarskoga Društva*, 147(1-2), 65-74. <https://doi.org/10.31298/sl.147.1-2.5>
- Kendir, G., & Güvenç, A. (2010). Etnobotanik ve Türkiye'de yapılmış etnobotanik çalışmalara genel bir bakış. *Hacettepe University Journal of the Faculty of Pharmacy*, (1), 49-80. (In Turkish)
- Oguzkan, S., Karagul, B., Aksoy, E., Uzun, A., Can, M., Yılmaz, H., Ugras, H. I., Binici, B., & Goren, A. C. (2018). Determination of taxanes by validated LC-MS/MS method in hazelnut collected from different regions and altitudes in Turkey. *Journal of Chemical Metrology*, 12(1), 26-33. <http://doi.org/10.25135/jcm.16.18.03.082>
- Özçelik, R. (2006). Mersin-Aydıncık ilçesi anıt dallı servileri (*Cupressus sempervirens* L. var. *horizontalis* (Mill.) Gord.). *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 10(2), 197-201. (In Turkish)
- Polat, S. (2014). Türk fındığı (*Corylus colurna*) 'nın Türkiye'deki yeni bir yayılış alanı. *Marmara Coğrafya Dergisi*, (29), 136-149. <https://doi.org/10.14781/mcd.51065> (In Turkish)
- Polat, S., & Güney, Y. (2015). Türk Fındığı'nın (*Corylus colurna*) Türkiye'deki yeni bir yayılış alanı. *Journal of Academic Social Research*, 3(18), 449-460. <https://doi.org/10.16992/ASOS.858> (In Turkish)
- Popović, V., Lučić, A., Jovanović, S., Mladenović, K., & Rakonjac, L. (2022). Variability of Turkish Hazel

- (*Corylus colurna* L.) populations in Serbia according to morphological nut traits. *Forestist*, 72(1), 41-47. <https://doi.org/10.5152/forestist.2021.21009>
- Šeho, M., Ayan, S., Huber, G., & Kahveci, G. (2019). A review on Turkish Hazel (*Corylus colurna* L.): A promising tree species for future assisted migration attempts. *South-East European Forestry*, 10(1), 53-63. <https://doi.org/10.15177/seeфор.19-04>
- Šeho, M., Kavaliauskas, D., Ayan, S., Čokeša, V., Petkova, K., & Fussi, B. (2023). First insights into genetic structure and diversity of the threatened tree species *Corylus colurna* L. for conservation of its genetic resources and possible assisted migration. *Forest Ecology and Management*, 549, 121480. <https://doi.org/10.1016/j.foreco.2023.121480>
- Temel, F., Arslan, M., & Çakar, D. (2017). Türkiye'deki doğal Türk fıncığı (*Corylus colurna* L.) popülasyonlarının durumu. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi*, 18(1), 1-9. <https://doi.org/10.17474/artvinofd.270346> (In Turkish)
- Ünalın, E. (2016). *Kastamonu yöresi Türk fıncığı (Corylus colurna L.) popülasyonları ve morfolojik polimorfizm* (Master's thesis, Kastamonu University). (In Turkish)
- Yaltrık, F. (1993). *Dendroloji ders kitabı 2 - Angiospermae (kapalı tohumlular) bölüm 1*. İstanbul Üniversitesi Orman Fakültesi Yayınları. (In Turkish)
- Yaltrık, F., & Efe, A. (1994). *Dendroloji: Ders kitabı: Gymnospermae-Angiospermae*. İstanbul Üniversitesi. (In Turkish)

## REVIEW ARTICLE

## Effects of *Acer negundo* Invasion in Europe

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### ABSTRACT

Aim of this review is to explain why the tree *Acer negundo*, a North American native species, is not considered at the European level as a priority invasive alien species. The analyzed information refers both to American country of origin and to other countries such as China, the majority focusing on the European continent. The study refers to a single taxon, *Acer negundo*-Box elder, but other taxa are also mentioned with which it competes or have represents pests. The desk study is based on the analysis of literature for the period 1960-2022; and was focused on species description (morphological characters, biological and ecological requests, pests); invasive particularities of specie; effect on biodiversity; mitigation effects of species invasion; eradication, containment and control mechanisms. Box elder is a non-native species for Europe that has a low degree of invasibility. It penetrates only in habitats disturbed by human activities, it is more competitive compared to willow and poplar, but it can be eliminated by *Alnus incana* and *Fraxinus excelsior*. Among the three main categories of control (chemical, mechanical and biological), the most effective and selective is the one with glyphosate, but mixed options (mechanical and chemical) are also recommended. Taking into account the negative effects on the ecosystems it entered, but also the low degree of invasion and the fact that are effective methods of combating it, we concluded that this invasive foreign species is not a priority for combating, only monitoring being necessary.

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## 1. Introduction

The spread of some species from the continent of origin to other continents is a process that has its roots in human expeditions with a role in the discovery and expansion of new territories (Igamberdiev, 2025).

As a result of a pragmatic behavior, at first, they were brought as sources of food (corn, coffee, cocoa etc.), as natural fibers (cotton) or as spices, later they were brought as decorative plants or as pets. The introduction of these species was initially done with good intentions, and had the role of diversifying food sources for the human population, for fishing, forestry, hunting or ornamental.

In the 20<sup>th</sup> century, with the diversification of means of locomotion, with the increase in travel speed and the number of people moving, the process of dissemination became uncontrollable. During this period, human society in full development uses more and more natural resources, exerting increased pressure on biodiversity (FiBL & IFOAM, 2010). Numerous studies have revealed the fact that there is a decrease in biodiversity at the global level, which led the academic community to identify the causes of this decline. An important factor leading to the reduction of biodiversity is the introduction of non-native species, whose invasive behavior can have devastating effects on native species (Kleespies & Dierkes,

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2020). The current study is limited to a single invasive species, *Acer negundo* Box elder that was introduced approximately 335 years ago from the North America to Europe as an ornamental species (Porté et al., 2011). The synthesis of the information regarding the behavior of this species alien to the European continent made in this review is useful in supporting the European Commission update the lists of invasive species of EU importance in order to combat and eradicate them (Regulation (EU) 1143/2014).

## 2. Materials and Methods

The methodology consisted in the analysis of the scientific literature from the period 1960-2026. The review is a synthesis of the information related to the description of the species necessary for its correct identification and its behavior (morphological characteristics, biological and ecological demands, pests); invasive particularities of the species (the assets that give it an advantage in the competitive system with native species); effect on biodiversity (e.g. reducing the effectiveness of population of native species until their disappearance); mitigation effects of species invasion; prevent and control mechanisms. This paper is a review, based on a number of 245 papers consulted, of which 53 provided information that was relevant to the topic of the paper. Printed books consulted in the library represented approximately 10%, and the rest were bibliographic sources consulted on the internet. The main source of information was the Internet, scientific articles and older books printed on paper were consulted at the library. In the case of Internet sources, the websites of the scientific journals of forestry, biodiversity conservation, mycology, entomology and urbanism were accessed, and the search was carried out using keywords. For an effective control and eliminating the species, it is mandatory to know the behavior of the species both in the respective area of origin, North America, and in the area where it was introduced, for this reason; the literature was focused on these two geographical areas.

## 3. Results

### 3.1. Species Description and Their Range

*Acer negundo* is a species of tree in the family *Sapindaceae*, it has a self-supporting growth form, have compound, broad leaves and white flowers. The stem is crooked, bifurcated, often rotted in the middle, the bark is smooth, gray-green, which forms a slightly wrinkled rhytidome. Crown wide, irregular, interrupted, with vigorous, glabrous, shiny, reddish-green or purple stems, covered with a white hoar-frost that wipes off easily (Clinovschi, 2005). The buds are ovoid, green or brown-violet, slightly bruised, and attached to the shoot; the leaf scars join directly, at a very sharp angle. The leaves are odd-pinnate-compound with 3-7 leaflets variable in shape, ovate to ovate – separated, 5-10 cm long, acuminate, coarsely serrate, the

terminal one often trilobed. The flowers are dioecious, yellow-green, apetalous, appear before leafing, the male ones in fascicles, the female ones in pendent racemes. Immature bisamaras are light green, while mature ones are whitish gray; their wings are arranged at a sharp angle or almost parallel, and they are 2.5–3 cm long (Sofletea & Curtu, 2007). Box Elder is dioecious with imperfect flowers, although perfect flowers that appeared to be functional have been reported (Hall, 1954). The staminate flowers are fascicled; the pistillate flowers are drooping racemes and are wind pollinated (Plowman, 1915; Sargent, 1965). Flowers appear with or before the leaves from March to May, depending on the geographic location (Harlow et al., 1979). In its native range, flowers are pollinated by *Hesperiphona vespertina* (Evening Grosbeak) and *Andrena imitatrix* (The imitator miner bee) (Vines, 1960). The fruit ripening dates is August – October and the seeds dispersal period is September – March (Schopmeyer, 1974). Box Elder usually develops a shallow, fibrous root system. On deep soils it may form a short taproot with strong laterals (Green, 1934). Individuals can grow to 22.6 m height at maturity (Clinovschi, 2005). The species is short-lived, attaining an average age of 60 years but rarely 100 years. Growth during the first 15 to 20 years is very rapid and may be as much as 2.5 cm a year in Diameter at Breast Height (DBH). Poor sites in water and nutrients bring in a corresponding reduction in growth (Green, 1934). Native to North America, where it has grown extensively and vegetated as a native plant, it is considered "a weed species," especially in certain areas, such as parts of the northeastern United States ((Arno, 2020) [1977]). In 1928, Joseph Illick, chief forester for the state of Pennsylvania, wrote in *Pennsylvania Trees*, that "Box Elder" was "*rare and localized*" in this state (Illick, 2015). Lang remark also that it is originally from the Eastern and Central lands of North America. According to Overton cited by Schütt and Lang (2004), the American maple appears insular and in the west of the continent, being represented by two varieties of *arizonicum* Sarg. and *californicum* (Torr & A. Gray, 1891) Sarg. (Schütt & Lang, 2004; Sofletea & Curtu, 2007). It has a double reproductive strategy by seeds and vegetative: it produces a large number of seeds, starting at a young age, and seed germination does not require special requirements. Box Elder is capable of establishing itself on a variety of seedbeds, on flood lands, it is among the most abundant species, seeding in under willow and other soft wood species stands and invading old fields. On these sites, over story density is apparently not a factor in early germination and survival, but seedlings begin to die off after 1 or 2 years unless openings are provided. The 1- and 2-year-old Box Elder seedlings are also abundant in areas of ground vegetation ranging from light to heavy and in hardwood litter as much as 5 cm deep (Hosner & Minckler, 1960). Concerning the vegetative reproduction, it is by stump and root sprouts, being common in Box Elder from young, vigorous trees (Maeglin & Ohmann, 1973; Eyre, 1980). The propagation by cuttings indicate that best results are obtained

from cuttings taken during the period of transition from softwood to greenwood and treated with an 8,000 ppm Indole-3 Butyric Acid (IBA) -talcum mixture. European nurserymen propagate some ornamental cultivars of Box Elder using side grafting, whip and tongue grafting, or chip budding (Dirr & Heuser Jr, 1987).

### 3.2. Invasive Particularities of Species

After World War II, Box Elder's rapid growth made it a popular landscaping tree in suburban housing developments despite its poor form, vulnerability to storm damage, and tendency to attract large numbers of Box Elder bugs. Intentional cultivation has thus made the tree far more abundant than it once was. It can quickly colonize both cultivated and uncultivated areas and the range is therefore expanding both in North America and elsewhere (Uva et al., 1997). In Europe, where it was introduced in 1688 (the year of its first cultivation) as an ornamental park tree, it has spread rapidly and is now considered an invasive species in parts of Central and Eastern Europe, including Germany, the Czech Republic, Hungary, Slovenia, Romania, and Poland. In these regions, it can form dense stands in lowlands, disturbed areas, and riparian habitats on calcareous soils (Schopmeyer, 1974; Uva et al., 1997; Schütt & Lang, 2004). In Latvia and Lithuania, it was first introduced at the beginning of the 19<sup>th</sup> century. It is the most widely distributed alien maple species to be found in the parks and greeneries of Riga and Kaunas. In recent decades, the spread and invasion of this species has been observed (Straigyte et al., 2015). It has also become naturalized in eastern China (Gelderer & Gelderen, 1999). During plant species invasions, the role of adaptive processes is particularly of interest in later stages of range expansion when populations start invading habitats that initially have not been disposed to invasions (Erfmeier et al., 2011). Contrary to the resource trade-off of succession theory, *Acer* shows both high survival in shade and high growth in full light (Saccone et al., 2010a). This particular suite of traits shared with other invasive and native *Acer* species is an example of adaptive plasticity that is certainly an advantage to give it a competitive advantage over native species (Saccone et al., 2013). Box elder is invasive and is able to spread rapidly into new riparian areas (Straigyte et al., 2015). Box Elder currently invades riparian and disturbed areas in Europe, affecting both bank stability and ecosystems biodiversity. The European experts aimed at finding an eco-friendly method which would locally remove this species and help habitat restoration (Merceron et al., 2016). The invasive character of this species is the result of three characteristics of this species:

a) A species that is not demanding in terms of climate and soil, resistant to frost and negative temperatures, with eurytopic skills, it tolerates drought well, which made it also to be present in wood crops on sandy soils. But it also behaves well on moist soils in the meadow resorts. Tolerates the compact soils being

an euribiont species that adapt and grow in inappropriate conditions. Active growth and excellent vegetation condition are achieved on deep, humic acids rich soils with sufficient moisture, such as alluvial meadows. It is a species not resistant but tolerant to drought; but very resistant to frost. Prefer humid resorts, sandy-muddy, loose, fertile soils (Clinovschi, 2005). Litter decomposition and mineralization rate is increase by Box Elder leaf leachates that are characterized by higher total bacterial numbers and higher number of heterotrophic cellulose-decomposing bacteria colonies. The toxicity of *A. negundo* aqueous extracts and leachates on fungi cell are manifested at mortality and membrane depolarization levels, remove the fungus and stimulate the bacterial activities and nutrients release (Krevš et al., 2013). These mechanisms favor the processes of pedogenesis and allow the modification of some hostile environments in favorable environments for vegetation. The higher level of plasticity of the invasive species in foliage allocation in response to light and nutrient availability induced a better growth in non-limiting resource environments. Such behavior could explain the ability of *A. negundo* to outperform native tree species contributing to its spread in European resource-rich riparian forests and impedes its establishment under closed-canopy hardwood forests (Porté et al., 2011).

b) It has a double reproductive strategy by seeds and vegetative, the risk of seeds not maturing being compensated by vegetative multiplication. The individuals reach sexual maturity early in 8-11 years, longevity reaching almost 100 years. They are extremely prolific, the number of seeds being 8,200 - 20,400 cleaned seeds per pound. The seeds dormancy, in cold period, requires a mean temperature 17.7 °C and the interval is between 60-90 days (Schopmeyer, 1974; Sofletea & Curtu, 2007).

c) The trees once cultivated outside the natural range are free of natural pests, the size of the population is no longer kept under control, exploding and eliminating the native species in a competitive system. Individuals of the *A. negundo* species arriving in ecosystems different from those where the species grows natively produce a series of negative effects on the structure and functions of the ecosystem. An abundance of *A. negundo* individuals was accompanied by increased canopy cover. It is a negative relationship between canopy cover and the number of understory herbaceous species. Thus, the interception of light and the restriction of its amount for other species is a main factor supporting the negative influence of *A. negundo* on native plant communities (Veselkin et al., 2021).

### 3.3. Pests of the Species

In native range *A. negundo* is kept under control by 47 pests. It is attacked by a wide variety of insects, including the Box Elder bug, *Leptocoris trivittatus*, which is found across most of the host's range. Others include the boxelder aphid (*Periphyllus negundinis*), and the boxelder gall midge (*Contarinia*

*negundifolia*). A number of scale insects also attack *A. negundo*. Fungi are, however, much more damaging than insects to *A. negundo*, with species of *Fomitopsis*, *Perenniporia*, *Fomes*, *Inonotus* and *Ustulina* causing significant rotting, and *Eutypella parasitica* causing a stem canker. The only pathogen which kills significant numbers of *A. negundo* trees, however, is *Verticillium albo-atrum*, which causes verticillium wilt.

**Major host of:** *Anoplophora glabripennis* (Asian longhorned beetle); *Prociophilus mexicanus*; *Pseudomonas syringae* pv. *aceris* (leaf spot); *Sawadaea bicornis* (powdery mildew on *Acer* spp.); *Thyridopteryx ephemeraeformis* (evergreen bagworm); *Tremex fuscicornis* (Tremex wasp).

**Minor host of:** *Anoplophora chinensis* (black and white citrus longhorn); *Aphelenchoides eximius*; *Candidatus Phytoplasma asteris* (yellow disease phytoplasmas); *Chaetocnema confinis* (flea beetle); *Chilecomadia valdiviana* (Chilean carpenter worm); *Chinavia hilaris* (green stink bug); *Chionaspis acer*; *Diplodia seriata* (grapevine trunk disease); *Eulecanium tiliae* (nut scale); *Euwallacea fornicatus* (polyphagous shot-hole borer); *Fomitiporia mediterranea* (esca disease); *Ganoderma lucidum* (basal stem rot: *Hevea* spp.); *Halyomorpha halys* (brown marmorated stink bug); *Lymantria dispar* (gypsy moth); *Melolontha melolontha* (white grub cockchafer); *Orgyia leucostigma* (white-marked tussock moth); *Xylella fastidiosa* (Pierce's disease of grapevines).

**Wild host of:** *Archips xylosteanus* (variegated golden tortrix); *Fomitopsis pinicola* (brown crumbly rot); *Hyphantria cunea* (fall webworm); Longidorus (longidorids); *Lymantria dispar asiatica* (Asian gypsy moth); *Peridroma saucia* (pearly underwing moth); *Pratylenchus penetrans* (nematode, northern root lesion).

**Host of (source-data mining):** *Aspidiotus hedericola*; *Boisea trivittata* (boxelder bug); *Ceroplastes japonicus* (tortoise wax scale); *Corthylus punctatissimus* (pitted ambrosia beetle); *Drepanosiphum platanoidis* (sycamore aphid); *Eutypella parasitica* (stem canker of maple); *Leptocoris trivittatus* (boxelder bug); *Longidorus attenuatus* (needle nematode); *Longidorus elongatus* (needle nematode); *Metcalfeella monogramma*; *Parthenolecanium corni* (European fruit lecanium); *Parthenolecanium persicae* (peach scale); *Periphyllus aceris*; *Phomopsis theicola*; *Pulvinaria regalis*; *Taeniothrips inconsequens* (pear thrips) (CABI, 2019).

*Exserohilum rostratum* is a fungus of the ascomycete genus *Exserohilum* has a cosmopolitan distribution, including species naturally occurring in warm, tropical, and subtropical regions.

It has emerged as a pathogen of Box Elder nursery sites in Tai'an, Shandong Province, China, and that the pathogen may cause serious economic losses if appropriate mitigation measures are not undertaken, this is the first report of *E. rostratum* infecting a species of *Acer*. This fungus produces

fungus disease affecting Box Elders. Diseased trees exhibit partial blackening and wilting of infected branches, and, above the necrotic area, the leaves show symptoms of leaf blight and leaf spots. The disease produced by *Exserohilum rostratum* leads to the early death of *A. negundo* individuals (Liu et al., 2021).

This fungus has not yet arrived in Europe and can be used to combat of the *A. negundo* species that is a vegetal invader of forests with native species.

### 3.4. Effect on Biodiversity

Invasive plants significantly decrease native species diversity and modify ecosystem processes within invaded communities (Vilà et al., 2011) resulting in large investments to manage and restore these ecosystems (Pimentel et al., 2005). Riparian ecosystems are highly subjected to invasions given that (i) rivers are efficient dispersal corridors for propagules over long distances (Säumel & Kowarik, 2010), and (ii) frequent disturbances increase nutrient and light availability (Hood & Naiman, 2000; Merceron et al., 2016).

Many studies demonstrated that in communities dominated by *A. negundo*, the diversity of native plants decreases (Czortek et al., 2025). Was observed a decreased taxonomic richness among vascular herbaceous plant species by 40% (inter-habitat) and 20% (intra-habitat) in areas dominated by *A. negundo*; compared to areas dominated by native tree and shrub species. An abundance of *A. negundo* was accompanied by increased of cover degree of canopy. Also, was found a negative relationship between canopy cover and the number of herbaceous species. Thus, the interception of light and the restriction of its amount for other species is a main factor supporting the negative influence of *A. negundo* on native plant communities (Veselkin et al., 2021). Active substances contained in *A. negundo* leaf litter, have a selective inhibitory effect on the germination of seeds and the growth of seedlings of monocotyledonous and dicotyledonous plants. Allelopathic substances have an inhibitory effect on seed germination and seedling growth of only dicotyledonous plants. The allelopathic effect of the fall was not a limiting factor for the germination of seeds of herbaceous plants of the above-ground cover of the studied plantation (Nikolaeva et al., 2021). Vegetating well in meadow conditions, Box Elder, mainly invades riparian areas typical of poplar and willow forests. Despite their high ecological value, the poplar and willow forests have been increasingly taken over by the invasive tree species *A. negundo*. The studies found the willow forest to be more susceptible to invasion by *A. negundo* than the poplar forest; which was revealed in significantly higher share of the maple individuals and their greater volume per unit area. Ash-leaved maples also prevailed in numbers in younger stands (<10 years) than in older ones. The presence of *A. negundo* affected biodiversity, resulting in decreased undergrowth density and biodiversity expressed in number of species (Sikorska et al., 2019). A part of the studies stressed the

importance of positive interactions for the invasion of *A. negundo* in the floodplain riparian forest, with a shift from direct to indirect facilitation through succession. The direct facilitation by the tree canopy of the native pioneer *Salix* is the main biotic process allowing the colonization of the invasive *Acer* in the floodplain. Later in the invasion process, indirect facilitation by adult con-specifics is certainly the other biotic driver of invasion allowing the establishment of a population. These positive responses and effects were for the invasive but not for the natives, likely because this species had a particular combination of traits that natives do not have. In contrast with other invasive species, the persistence through time of *Acer* cannot be explained by higher direct competitive effects than native late-successional species (Saccone et al., 2010b). In meadow forests dominated by genus *Alnus* and *Fraxinus*, without biotic interactions *A. negundo* performed similarly to native species, suggesting that the flood zones of the rivers are not protected from *Acer* invasion by a simple abiotic barrier. In contrast, this species is performing less well than *Fraxinus excelsior* and *Alnus incana* in environments with intact tree and/or herb layers. *Alnus* show the best growth rate in these conditions, indicating biotic resistance of the native plant community (Saccone et al., 2013). In context of climate changes, although other ecological and socioeconomic factors are affecting the vegetation in urban areas, many of the nonnative invasive species like *A. negundo*, found colonizing cities (or naturalizing within them) originate in warmer areas and are benefiting from the more favorable climate, in European countries where they spread (Sukopp & Wurzel, 2003).

### 3.5. Mitigation Effects of Species Invasion

Since the species was introduced in Europe in 1688, it can no longer be a question of prevention, the only solution being control and eradication.

The negative effects on biodiversity, especially on habitats of European interest such as 92A0 *Salix alba* and *Populus alba* galleries, 91E0 \* Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*) led to European level that the European Commission, to intervene with measures. The first step was the creation of a legislative framework that would support and create the premises for control and combating invasive species.

In 22 October 2014 the European Parliament and of the Council adopt the Regulation (EU) No 1143/2014 on the prevention and management of the introduction and spread of invasive alien species. This European normative act was amended and supplemented by numerous other regulations such as: Implementing Regulation (EU) 2016/145, 2016/1141, 2017/1454, 2018/968.

At the European level, there is no normative act regulating the control and combating of the *A. negundo* species. Although

it is present in the floodplain of the main rivers, it is not even on the list of priority invasive alien species of European Union concern pursuant to Regulation (EU) No. 1143/2014 of the European Parliament and of the Council; but it is present on the European red list of invasive alien species drawn up by the IUCN (IUCN, 2022). The European Union is a signatory and has ratified a series of international conventions and treaties including the Biodiversity Convention (CBD) and the Berne Convention; international normative acts that regulate the prevention, control and combating of foreign invasive species. In accordance with Article 8 letter (h) of (CBD) the signatory states, have the following obligations: prevent the introduction of invasive alien species that threaten ecosystems, habitats or species with special conservation status; achieve their control or eradication as far as possible, using means appropriate to each state.

In the 2002 Conference of the Parties (COP), the CBD adopted a decision and 11 specific guiding principles to help parties implement these requirements. Through their governments, the decision calls on parties, that the various institutions/organizations, to prioritize the development concerning invasive species chapters in national and regional strategies and action plans/to promote and implement the guiding principles of the CBD. The Bern Convention, adopted in 1979, aims to promote cooperation between signatory countries to conserve flora and fauna wildlife and their natural habitats and to protect endangered migratory species. According to Article 11.2.b of the Berne Convention (CB), to which the European Community and 38 European states are parties, it requires parties "to strictly control the introduction of non-indigenous species". The EU Biodiversity Strategy 2020-2030 contains a commitment to manage invasive alien species on the European Red List and to reduce their numbers which pose a threat to biodiversity, by 50% by 2030. The European Red List is a review of status European species according to the guidelines of the IUCN Regional Red List. It identifies those species that are threatened with extinction at European level (Pan-Europe and European Union) so that appropriate conservation measures can be taken to improve their condition. Every six years, the member states of the European Union have the obligation to report to the European Commission which are the foreign invasive species that have entered the European continent, their dispersion, the hot spots, the effects on biodiversity, and the measures to prevent, control and combat of them. Although it is not on the list of priority invasive alien species, some countries such as Romania, Poland, and Sweden have also reported the situation of the *A. negundo* species on their national territory.

### 3.6. Stopping and Control Mechanisms

Knowledge of the biological and ecological characteristics of the *A. negundo* species is the basis of strategies and mechanisms to control and combat this species, this are focused

on two aspects: eliminating mature individuals and preventing the reproduction and dispersion. The areas with the greatest dispersion are the wetlands along the rivers, respectively the meadow forests. Because they act as critical buffer zones along water courses (Correll, 1996) traditional practices of invasive plant removal, inducing soil disturbance or chemical pollution, should be avoided. One challenge is therefore to develop efficient and eco-friendly methods to constrain plant invasions and restore invaded habitats (Merceron et al., 2016) Chemical, biological, and mechanical methods largely used by managers to control invasive herbaceous plants have also been tested on invasive woody species (Holt, 2009).

To date, broad-spectrum herbicide applications such as triclopyr and glyphosate are the most efficient methods to kill invasive perturbing tree species. However, these practices can have substantial ecological consequences on non-target species if sprayed or by contaminating soil and water. Infections by pathogen fungi such as *Chondrostereum purpureum* and *Fusarium* were also used with success but no homologation of these pathogens exist in Europe. Moreover, these generalist pathogens present a risk regarding native species and testing introduced ones would risk introducing a new virulent invasive species in weed management, allelopathic compounds have also been used but to our knowledge, allelopathic substances produced by native species were never tested to control invasive plants. Finally, mechanical methods (mowing, mulching, cutting, burning, uprooting, or girdling) are also largely used to eliminate invasive trees. Although it is often time consuming, methods such as girdling or cutting can be applied on targeted individuals thus avoiding environmental impacts. Girdling is a common practice in forestry (and is advised to locally eliminate invasive woody species in natural areas (Merceron et al., 2016). At present, *A. negundo* is regarded as a fast-growing species, the use of which is limited to a certain period of time and should be removed from the main plantations. However, no effective methods have been proposed for the removal of this species from the plantations. Cutting (trunk cutting) of plants is a necessary but not sufficient measure, as a large number of shoots are formed on the stump from the sleeping buds. Mechanical methods of struggle against vegetative renewal are labor-intensive and ineffective. Chemical method of treatment (application of arboricides) of shoots reduces labor costs in 5 times and the cost of work in 2.2 times. The first experiments with *A. negundo* young growth using arboricides (herbicide Tornado preparation 50%) showed the decrease of shoots growth in a month after treatment. Another herbicide used was glyphosate because it is a safety concerning other species. It was found that treatment of freshly cut stumps of *A. negundo* with glyphosate in concentration of 7.2 g/l causes death of 65% of plants. In the rest of the specimens of *A. negundo* from this option the amount of growing epicormic sprouts decreased by 5.2 times in comparison with the usual cutting (control). Besides, the

method demonstrated high ecological safety (herbicide does not get on the living ground cover, which excludes poisoning of animals); the preparation destructs quickly (2-4 weeks); low environmental impact; safe for humans; easy to use; independent from weather conditions. The results of the conducted experience allow recommending glyphosate for treatment of freshly cut stumps of *A. negundo* in specially protected areas as one of the most effective and ecologically safe ways to control this invasive species. (Nikolaeva et al., 2020).

#### 4. Discussion

*A. negundo* tree species was introduced to Europe in the 17<sup>th</sup> century, as an ornamental plant. It was introduced deliberately; at the time of introduction the population and scientists did not perceive this species as a threat to biodiversity. Although the biological peculiarities of the species allow it to invade new territories, it has not dispersed in all types of habitats, it has spread only in the flooded areas of rivers and along the access roads that cross areas with higher humidity. The negative effects of the presence of individuals of the species were observed only in the meadow forests where the *Salix* and *Populus* genera dominate, where through the competition for water, nutrients and light these genera were disadvantaged. The individuals of *A. negundo* participated in their elimination the herbaceous plants in the poplar and willow forests, both by shading, absorption of water and nutrients, and by inhibiting the germination of dicotyledonous seeds due to allelopathic substances in the litter. In the flooded meadow forests dominated by the *Alnus incana* and *Fraxinus excelsior* species, the species is kept under control, the first two that dominate showing the best growth rate in these conditions. This may be one of the explanations why *A. negundo* does not represent a major danger of invasion for natural habitats in a good state of conservation, only tree plantations and human-impacted habitats being vulnerable. In the vulnerable habitats where it has penetrated and manifests its effects, it can be combated with the help of effective selective methods that do not affect the other elements of biodiversity. Taking into account the negative effects it has on the ecosystems it entered, but also the not very high degree of invasion (it did not create hot spots in Europe), the period of over 300 years since it has been present in Europe and the fact that are effective methods of combating it, this invasive foreign species is not a priority for combating, only monitoring being necessary.

#### Conflict of Interest

The author has no conflict of interest to declare.

## References

- Arno, S. F. (2020). *Northwest trees: Identifying and understanding the region's native trees*. Mountaineers Books.
- CABI. (2019). *Acer negundo* (box elder). CABI Compendium. <https://doi.org/10.1079/cabicompendium.2862>
- Clinovschi, F. (2005). *Dendrologie*. SUCEAVA: Editura Universitatii din Suceava.
- Correll, D. L. (1996). Buffer Zones and water quality protection: General principles. In N. Haycock, T. Burt, K. Goulding & G. Pinay (Eds.), *Buffer zones: Their processes and potential in water protection* (pp. 7-20). Quest Environmental.
- Czortek, P., Depczyński, M., & Puchałka, R. (2025). How does *Acer negundo* invasion shape plant species diversity in the understory of early oak-hornbeam forests in proximity to a primeval ecosystem? *Forest Ecology and Management*, 597, 123164. <https://doi.org/10.1016/j.foreco.2025.123164>
- Dirr, M. A., & Heuser Jr., C. W. (1987). *The reference manual of woody plant propagation: From seed to tissue culture*. Varsity Press, Inc.
- Erfmeier, A., Böhnke, M., & Bruelheide, H. (2011). Secondary invasion of *Acer negundo*: The role of phenotypic responses versus local adaptation. *Biological Invasions*, 13(7), 1599-1614. <https://doi.org/10.1007/s10530-010-9917-2>
- Eyre, F. H. (1980). *Forest cover types of the United States and Canada*. Society of American Foresters.
- FiBL and IFOAM. (2010). *The World of organic agriculture: Statistics and emerging trends*. <https://orgprints.org/id/eprint/17126/1/world-of-organic-agriculture-2010.pdf>
- Gelderen, C. V., & Gelderen, D. V. (1999). *Maples for gardens: A color encyclopedia*. Timber Press.
- Green, G. H. (1934). *Trees of North America*. Edwards Brothers.
- Hall, B. A. (1954). Variability in the floral anatomy of *Acer negundo*. *American Journal of Botany*, 41(6), 529-532. <https://doi.org/10.2307/2438865>
- Harlow, W. M., Harrar, E. C., & White, F. M. (1979). *Textbook of dendrology: Covering the important forest trees of the United States and Canada*. McGraw-Hill.
- Holt, J. (2009). Management of invasive terrestrial plants. In M. N. Clout & P. A. Williams (Eds.), *Invasive species management: A handbook of principles and techniques* (pp. 126-140). Oxford University Press. <https://doi.org/10.1093/oso/9780199216321.003.0009>
- Hood, W. G., & Naiman, R. J. (2000). Vulnerability of riparian zones to invasion by exotic vascular plants. *Plant Ecology*, 148(1), 105-114. <https://doi.org/10.1023/A:1009800327334>
- Hosner, J. F., & Minckler, L. S. (1960). Hardwood reproduction in the river bottoms of southern Illinois. *Forest Science*, 6(1), 67-77. <https://doi.org/10.1093/forestscience/6.1.67>
- Igamberdiev, A. U. (2025). Human-driven evolution of cultivated plants and the origin of early civilizations: The concept of Neolithic revolution in the works of Nikolai Vavilov. *BioSystems*, 247, 105359. <https://doi.org/10.1016/j.biosystems.2024.105359>
- Illick., J. S. (2015). *Pennsylvania trees*. Pennsylvania Department of Forests and Waters.
- IUCN. (2022). *Acer negundo*. <https://www.iucnredlist.org/search?query=Acer%20negundo&searchType=species>
- Kleespies, M. W., & Dierkes, P. W. (2020). Personal assessment of reasons for the loss of global biodiversity—an empirical analysis. *Sustainability*, 12(10), 4277. <https://doi.org/10.3390/su12104277>
- Krevš, A., Darginavičienė, J., Gylytė, B., Grigutytė, R., Jurkonienė, S., Karitonas, R., Kučinskienė, A., Pakalnis, R., Sadauskas, K., Vitkus, R., & Manusadžianas, L. (2013). Ecotoxicological effects evoked in hydrophytes by leachates of invasive *Acer negundo* and autochthonous *Alnus glutinosa* fallen off leaves during their microbial decomposition. *Environmental Pollution*, 173, 75-84. <https://doi.org/10.1016/j.envpol.2012.09.016>
- Liu, C. L., Zheng, X. R., & Chen, F. M. (2021). Dieback and leaf spot in box elder (*Acer negundo*) caused by *Exserohilum rostratum*. *Plant Disease*, 105(10), 2955-2963. <https://doi.org/10.1094/PDIS-07-20-1424-RE>
- Maeglin, R. R., & Ohmann, L. F. (1973). Boxelder (*Acer negundo*): A review and commentary. *Bulletin of the Torrey Botanical Club*, 100(6), 357-363. <https://doi.org/10.2307/2484104>
- Merceron, N. R., Lamarque, L. J., Delzon, S., & Porté, A. J. (2016). Killing it softly: Girdling as an efficient eco-friendly method to locally remove invasive *Acer negundo*. *Ecological Restoration*, 34(4), 297-305. <https://doi.org/10.3368/er.34.4.297>
- Nikolaeva, A. A., Golosova, E. V., & Shelepova, O. V. (2020). Methods of combating *Acer negundo* L. in specially protected natural areas. *BIO Web of Conferences*, 24, 00063. <https://doi.org/10.1051/bioconf/20202400063>
- Nikolaeva, A. A., Golosova, E. V., & Shelepova, O. V. (2021). Allelopathic activity of *Acer negundo* L. leaf litter as a vector of invasion species into plant communities. *BIO Web of Conferences*, 38, 00088. <https://doi.org/10.1051/bioconf/20213800088>
- Pimentel, D., Zuniga, R., & Morrison, D. (2005). Update on the environmental and economic costs associated with

- alien-invasive species in the United States. *Ecological Economics*, 52(3), 273-288. <https://doi.org/10.1016/j.ecolecon.2004.10.002>
- Plowman, A. B. (1915). Is the box elder a maple? A study of the comparative anatomy of *negundo*. *Botanical Gazette*, 60(3), 169-192.
- Porté, A. J., Lamarque, L. J., Lortie, C. J., Michalet, R., & Delzon, S. (2011). Invasive *Acer negundo* outperforms native species in non-limiting resource environments due to its higher phenotypic plasticity. *BMC Ecology*, 11(1), 28. <https://doi.org/10.1186/1472-6785-11-28>
- Regulation (EU) 1143/2014. *Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species*. <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1483614313362&uri=CELEX:32014R1143>
- Saccone, P., Brun, J. J., & Michalet, R. (2010a). Challenging growth-survival trade-off: A key for *Acer negundo* invasion in European floodplains? *Canadian Journal of Forest Research*, 40(10), 1879-1886. <https://doi.org/10.1139/X10-134>
- Saccone, P., Pagès, J. P., Girel, J., Brun, J. J., & Michalet, R. (2010b). *Acer negundo* invasion along a successional gradient: Early direct facilitation by native pioneers and late indirect facilitation by conspecifics. *New Phytologist*, 187(3), 831-842. <https://doi.org/10.1111/j.1469-8137.2010.03289.x>
- Saccone, P., Girel, J., Pages, J. P., Brun, J. J., & Michalet, R. (2013). Ecological resistance to *Acer negundo* invasion in a European riparian forest: Relative importance of environmental and biotic drivers. *Applied Vegetation Science*, 16(2), 184-192. <https://doi.org/10.1111/j.1654-109X.2012.01227.x>
- Sargent, C. S. (1965). *Manual of the trees of North America (exclusive of Mexico)*. Dover Publications.
- Säumel, I., & Kowarik, I. (2010). Urban rivers as dispersal corridors for primarily wind-dispersed invasive tree species. *Landscape and Urban Planning*, 94(3-4), 244-249. <https://doi.org/10.1016/j.landurbplan.2009.10.009>
- Schopmeyer, C. S. (1974). *Seeds of woody plants in the United States*. U.S. Department of Agriculture, Forest Service.
- Schütt, P., & Lang, U. M. (2004). *Acer negundo*. in P. Schütt, H. Schuck, G. Aas & U. M. Lang (Eds.), *Handbuch und atlas der dendrology* (pp. 1-10). Ecomed Verlagsgesellschaft Landsberg.
- Sikorska, D., Sikorski, P., Archiciński, P., Chormański, J., & Hopkins, R. J. (2019). You can't see the woods for the trees: Invasive *Acer negundo* L. in urban riparian forests harms biodiversity and limits recreation activity. *Sustainability*, 11(20), 5838. <https://doi.org/10.3390/su11205838>
- Sofletea, N., & Curtu, L. (2007). *Dendrologie*. Editura Universitatii Transilvania din Brasov.
- Straigyte, L., Cekstere, G., Laivins, M., & Marozas, V. (2015). The spread, intensity and invasiveness of the *Acer negundo* in Riga and Kaunas. *Dendrobiology*, 74, 157-168. <https://doi.org/10.12657/denbio.074.016>
- Sukopp, H., & Wurzel, A. (2003). The effects of climate change on the vegetation of central European cities. *Urban Habitats*, 1(1), 66-86.
- The Bern Convention. (1979). *The convention on the conservation of european wildlife and natural habitats*. Retrieved Mar 03, 2026, from <https://www.coe.int/en/web/bern-convention>
- Torr & A. Gray. (1891). *Acer negundo* var. *californicum*. *Garden & Forest*, 4, 148.
- Uva, R. H., Neal, J. C. & DiTomaso, J. M. (1997). *Weeds of the Northeast*. Cornell University Press.
- Veselkin, D. V., Dubrovin, D. I., & Pustovalova, L. A. (2021). High canopy cover of invasive *Acer negundo* L. affects ground vegetation taxonomic richness. *Scientific Reports*, 11(1), 20758. <https://doi.org/10.1038/s41598-021-00258-x>
- Vilá, M., Espinar, J. L., Hejda, M., Hulme, P. E., Jarošík, V., Maron, J. L., Pergl, J., Schaffner, U., Sun, Y., & Pyšek, P. (2011). Ecological impacts of invasive alien plants: A meta-analysis of their effects on species, communities and ecosystems. *Ecology Letters*, 14(7), 702-708.
- Vines, R. A. (1960). *Trees, shrubs, and woody vines of the Southwest*. University of Texas Press.

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- Use only SI (international system) units.
- Use “dot” for decimal points.
- Use italics for species name.

### References

*SilvaWorld* uses APA style (7<sup>th</sup> edition). Accordingly, authors must format their references as per the guidelines below. Please ensure that each reference cited in the text is also presented in the reference list. Authors should always supply DOI or URL of the work cited if available.

#### In-text citation (Narrative):

...The results of Ayan (2022) support...  
...Ayan and Yer (2020) indicated that...  
...According to the method of Ayan et al. (2021)...

#### In-text citation (In parenthesis):

...It was found to be isometric (Ayan, 2018)...  
...is highly susceptible to diseases (Ayan & Kara, 2019)...  
...have been studied (Yer et al., 2020)...

## **Two or more works in the same parenthesis:**

...extremely toxic for the environment (Ayan & Turgut, 2021; Ayan, 2018, 2019; Sönmez et al., 2020a)...

## **Citation in the reference list:**

References should be listed first alphabetically and then further sorted chronologically at the end of the article. The citation of all references should conform to the following examples:

### **Article:**

Lastname, N., Lastname, M., & Lastname, O. (Year). Title of the work. *Title of the Journal*, Volume(Issue), Page numbers. DOI

Ayan, S. (1998). Tüplü sarıçam *Pinus silvestris* L. fidanı üretiminde yavaş yarıyışlı gübrelerin etkileri. *Developmental & Comparative Immunology*, 35(12), 1366-1375. <https://doi.org/10.1016/j.dci.2011.07.002>

Öztürk, S., & Ayan, S. (2015). Management alternatives in national park areas: The case of Ilgaz Mountain National Park. *Eco Mont-Journal on Protected Mountain Areas Research*, 4(4), 37-44. <https://doi.org/10.1046/j.1467-2979.2003.00121.x>

Yer Çelik, E. N., Baloğlu, M. C., & Ayan, S. (2021). Gene expression profiles of Hsp family members in different poplar taxa under cadmium stress. *Turkish Journal of Agriculture and Forestry*, 45(10), 102-110. <https://doi.org/10.1111/jfd.13229>

### **Article by DOI (early access):**

Ayan, S., Çalışkan, E., Özel, H. B., Yer Çelik, E. N., Yılmaz, E., Gülseven, O., & Akın, S. S. (2022). The influence of effective microorganisms on physiological characteristics of containerized Taurus Cedar (*Cedrus libani* A. Rich.) seedlings. *Cerne*. <https://doi.org/10.1590/01047760202228013018>

### **Book:**

Lastname, N., Lastname, M., & Lastname, O. (Year). Title of the work. Publisher.

Oidtmann, K., Xao, Q., & Lloyd, A. S. (2018). *The food need by the year 2050*. Elsevier.

### **Book Chapter:**

Lastname, N., Lastname, M., & Lastname, O. (Year). Title of the chapter. In N. N. Lastname, A. Lastname & B. Lastname (Eds.), *Title of the book* (pp. Page numbers). Publisher.

Barbati, A., Mugnozza, G. S., Ayan, S., Blasi, E., Calama, R., Cicatiello, C., Canaveira, P., Collalti, A., Corona, P., Rio, M. del R., Ducci, F., & Perugini, L. (2018). Adaptation and mitigation. In G. A. E. Gall & H. Chen (Eds.), *State of Mediterranean forests* (pp. 51-63). Elsevier. <https://doi.org/10.1016/b978-0-444-81527-9.50010-5>

## **Dissertation or Thesis:**

Lastname, N. (Year). Title of dissertation/thesis (Doctoral dissertation/Master's thesis, Name of Institution).

Ayan, S. (1990). *Determination of the characteristics of growing media and production technique for containerized oriental spruce (Picea orientalis (L.) link.) seedlings* (Doctoral dissertation, Karadeniz Technical University).

Ayan, S. (1988). *Appreciation on height growth of ten years of age of norway spruce (Picea abies (L.) karst.) origins in Eastern Black Sea region* (Master's thesis, Karadeniz Technical University).

## **Conference Proceedings:**

Lastname, N., Lastname, M., & Lastname, O. (Year). Title of the work. Title of the Conference. City.

Ayan, S., Ayan, Ö., Altunel, T., & Yer, E. N. (2014). *Honey forests as an example agroforestry practices in Turkey*. World Congress of Agroforestry. New Delhi.

## **Institution Publication:**

Institution name. (Year). Title of the work. URL

FAO. (2020). *Forestry statistics 2018*. <http://www.fao.org/3/cb1213t/CB1213T.pdf>

## **Internet Source:**

Lastname, N. (Year). Title of the work. Retrieved May 15, 2020, from URL

Ayan, S. (2019). *Utilization of Zeolite as plant growing media*. Retrieved Jan 12, 2021, from <https://earsiv.kastamonu.edu.tr/>

## **Table(s)**

Tables, numbered in Arabic, should be in separate pages with a short descriptive title at the top. Place footnotes to tables below the table body and indicate them with superscript lowercase letters (or asterisks for significance values and other statistical data).

## **Figure(s)**

All illustrations should be labelled as 'Figure' and numbered in consecutive Arabic numbers, Figure 1, Figure 2 etc. in the text. If panels of a figure are labelled (a, b, etc.) use the same case when referring to these panels in the text. Figures are recommended to be in electronic formats such as PNG, JPEG, TIFF (min. 300 dpi). All figures or tables should be presented in the body of the text.

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