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Forest Phytocoenoses of Floodplain Terraces in Eastern Zangezur (Azerbaijan)

Bahar Muradova
Institute of Ecology of the National Aerospace Agency

Iskender Elman
Ministry of Science and Education of Azerbaijan Republic

Huseynova Humira
Baku State University

Fidan Mammadova
Baku State University

Sabina Jafarzadeh
Karabakh University

Panah Muradov
Ministry of Science and Education of Azerbaijan Republic

Minara Hasanova
Ministry of Science and Education of Azerbaijan Republic

Shalala Gulmammadova
Ministry of Science and Education of Azerbaijan Republic

Vusala Badalova
Ministry of Science and Education of Azerbaijan Republic

Abstract: This study examined the forest phytocoenoses of floodplain terraces in the Eastern Zangazur region, with particular attention to tree species composition, the structural features of the understory, projective vegetation cover, and the distribution of tree trunk diameters across different forest stands. The analysis showed that floodplain terraces located at comparable elevations exhibited no substantial differences in the taxonomic composition of their forest communities. A similar group of dominant and accompanying species was consistently recorded in all surveyed plots, indicating stable ecological conditions and relatively uniform habitat characteristics throughout the study area. The proportion of secondary species reserves varied notably among sites, ranging from 5% to 25%, depending on microrelief, soil moisture, and past disturbance history. Mensurational measurements demonstrated that the majority of trees possessed medium-sized trunk diameters, corresponding mainly to quality classes III–IV. These trees were typically middle-aged, falling within the 30–50-year age range, which suggests a moderately developed forest structure with ongoing natural renewal processes. *Quercus iberica*, one of the key species of the region, was present in all sample plots. Its average trunk diameter ranged between 18–20 cm, with heights generally reaching 6–8 m. The mean forest stock of this species was calculated at 71.7 m^3/ha for individuals aged 40–110 years. Notably, the natural regeneration of Q. iberica was relatively high—approximately 72 young individuals per hectare—exceeding the regeneration rates of other associated tree species. Overall, structural disturbances observed within the studied forest stands were

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minimal. The data obtained serve as a valuable quantitative baseline for characterizing forest structure, species composition, and regeneration dynamics within the floodplain terraces of the Eastern Zangazur region, providing essential insights for long-term ecological monitoring and forest management planning.

Keywords: Phytocoenosis, Floodplain terraces, Site quality, Forest mensuration, *Quercus iberica*

Introduction

From the climatic perspective, the southwestern part of the Lesser Caucasus in Azerbaijan is almost identical to other regions of the Lesser Caucasus. Here, variations in climate conditions and vegetation cover are observed depending on altitude above sea level. Observations have shown that, in addition to elevation, the presence of water bodies in the area also plays a certain role in the distribution of vegetation cover. According to the literature, more than 260 thousand hectares of land in the liberated territories belonged to the state forest fund, of which more than 225 thousand hectares were forested areas. Analyses indicate that nearly 60 thousand hectares were destroyed during the Armenian occupation [8]. In recent years, during afforestation activities in the liberated territories, planning works were carried out first. The main reason for implementing planning was the diversity of relief forms, and thus afforestation works were organized in accordance with the relief. According to statistical data, tree species corresponding to the natural flora of the region have been planted on more than 70 hectares in the research area. Examples of these species include representatives of the genera *Carpinus* L., *Quercus* L., *Juniperus* L., *Fraxinus* L., *Pinus* L., and others. In the arid zones of the region, species such as *Quercus araxina* (Araz oak), *Quercus longipes* (long-stalked oak), *Zelkova carpinifolia* (Eastern zelkova), *Juniperus* spp., and others are more commonly found. At present, forest restoration activities are ongoing in the research area. It is expected that, as a result of forest recovery in Eastern Zangezur, the study area will soon return to its pre-occupation state.

The forests of the Caucasus are rich in biodiversity, with rare and endangered tree species playing a key role in maintaining ecosystem stability. Conservation and introduction of these species into new areas are essential for preserving ecological balance (Iskenderov, 1993). Studies documenting local flora, such as the flora of Sof Mountain, provide valuable information on species distribution and ecological requirements (Iskender, Özuslu, & Yayla, 2004). Pollen morphology and reproductive studies under in situ and ex situ conditions help evaluate species fertility and adaptability (Jafarzadeh & Iskender, 2024). Despite existing research, knowledge gaps remain regarding how rare tree species respond to varying environmental conditions, making such studies crucial for conservation and sustainable forest management in the Greater Caucasus. Floodplain ecosystems are among the most dynamic and ecologically significant components of terrestrial landscapes. They provide key ecosystem services, including biodiversity maintenance, nutrient cycling, and hydrological regulation (Affonso, Barbosa, & Novo, 2011). The periodic flooding and drying cycles characteristic of floodplain environments play a decisive role in shaping vegetation structure, soil development, and biogeochemical processes. Studies from the Amazon Basin have demonstrated that water-level fluctuations strongly influence water quality, soil fertility, and forest composition (Affonso et al., 2011; Pires et al., 2023). Climatic conditions further define the ecological boundaries and productivity of floodplain forests. According to the updated Köppen–Geiger climate classification (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006), Azerbaijan falls primarily within the dry steppe and temperate climatic zones, with local variations along river valleys and mountainous regions. These gradients create distinct hydrological and thermal regimes that influence the formation of floodplain terraces and the distribution of vegetation. The floodplains of Eastern Zangezur, situated along the Hakari and Okhchuchay river systems, thus represent transitional ecosystems where climatic and hydrological factors jointly determine forest composition and soil properties.

Soil fertility, texture, and hydromorphism are known to be fundamental determinants of phytocoenotic diversity in floodplain forests (Pires et al., 2023). According to the *World Reference Base for Soil Resources* (IUSS Working Group WRB, 2015), these areas typically contain a mosaic of alluvial, fluvisol, and hydromorphic soils, which vary in nutrient availability and drainage status. Such heterogeneity provides a foundation for understanding the spatial differentiation of forest communities across floodplain terraces.

Despite the ecological significance of these systems, the floodplain forests of Eastern Zangezur remain poorly studied, particularly in terms of their vegetation–soil–climate relationships. Understanding the structural and compositional characteristics of these forests is essential for biodiversity conservation and for guiding post-conflict ecological restoration efforts in Azerbaijan.The growing demand for sustainable and renewable energy sources has increased global interest in bioenergy crops, including perennial grasses and short-rotation woody plants, as potential solutions for climate change mitigation and energy security (Katelevskyi, 2020; Amichev et al., 2014). Among these, giant miscanthus and short-rotation willow have shown significant promise due to their high biomass yield and adaptability to various temperate environments (Katelevskyi, 2020; Doronin et al., 2018). Biomass productivity in these crops is highly influenced by cultivation practices, including the selection of high-quality planting material and optimized agronomic management (Doronin et al., 2018; Daniuk & Daniuk, 2022). Short-rotation willow cultivars, in particular, demonstrate rapid vegetative growth, which makes them suitable for both bioenergy applications and sustainable land-use strategies (Amichev et al., 2014; Daniuk & Daniuk, 2022). Integrating bioenergy crop production into marginal lands and floodplain ecosystems presents opportunities to enhance land-use efficiency while maintaining essential ecosystem services, such as soil and water regulation, habitat provision, and climate moderation (Funk et al., 2019; Smiraglia et al., 2016; Smith et al., 2013). Lessons from urban sustainability and resilience studies further suggest that multifunctional land use, including biomass cultivation, can contribute to broader environmental planning and resource management (Chelleri et al., 2015; Chelli et al., 2016). Moreover, floodplain restoration and water management strategies highlight the importance of considering hydrological interactions when implementing bioenergy plantations, ensuring that energy production does not compromise ecological functions (Souter et al., 2014; Sponseller et al., 2013; Stacke et al., 2014). Finally, advances in biomass-derived materials, including innovative applications in energy storage and industrial technologies, underscore the potential for these crops to serve multiple purposes beyond conventional bioenergy (Zhang et al., 2019). Collectively, these findings provide a strong rationale for studying optimal cultivation practices, ecological integration, and multifunctional uses of bioenergy crops such as miscanthus and willow.

Floodplain lakes and river dynamics significantly influence water quality and ecosystem functioning (Affonso, et al., 2011). Short-rotation bioenergy plantations have been explored for their productivity and resource efficiency (Amichev et al., 2014). Urban resilience and sustainability in relation to ecosystem services have been analyzed in various socio-ecological contexts (Chelleri et al., 2015). Vegetative growth and varietal performance of willow for bioenergy production demonstrate the importance of species selection (Daniuk & Daniuk, 2022). The formation of Miscanthus planting material depends on cultivation technology and management practices (Doronin et al., 2018). Standards and definitions of navigability and ordinary conditions support environmental and legal assessments (Fuller, 2018). The multifunctional role of water in river networks has implications for floodplain ecology (Funk et al., 2019, 2020). Soil classification and international standards are key to understanding forest and floodplain soils (IUSS Working Group WRB, 2015). Statistical software facilitates accurate ecological and forestry analyses (Jamovi, 2021). New cultivation practices influence yield potential in energy crops such as giant miscanthus (Katelevskyi, 2020). Studies of plant cover in former reservoirs help track ecological succession and restoration potential (Kuzemko et al., 2024). Chemical and textural soil properties are important for floodplain forest productivity (Pires et al., 2023). Energy willow can provide a sustainable source of solid biofuel (Roik, Humentyk, & Mamaisur, 2013). Ecosystem management contributes to climate regulation and soil, water, and air quality (Smith et al., 2013). Raising river levels can improve floodplain forest conditions in semi-arid regions (Souter et al.,2014). Water's ecological roles include nutrient transport and habitat connectivity in rivers (Sponseller, Heffernan, & Fisher, 2013). Holocene evolution studies of floodplains inform long-term landscape changes (Stackeet al., 2014). Advanced carbon-based materials derived from biomass highlight potential applications in environmental engineering (Zhang et al., 2019). Land use change and degradation analyses link ecosystem services and sustainability assessments (Smiraglia et al., 2016).

Understanding how three-dimensional forest structure affects ecological processes is critical for sustainable forest management and conservation planning. Despite increasing recognition of the importance of vertical complexity, there is still limited knowledge on how environmental gradients shape canopy heterogeneity and, in turn, influence biodiversity and ecosystem functioning. Therefore, this study aims to fill this gap by investigating the structural characteristics and ecological roles of forest organization across different environmental conditions. The main aim of this study was to characterize the structure and composition of floodplain forests in the Gubadli and Zangilan districts of Azerbaijan. Specifically, we sought to quantify tree mensuration parameters, assess understory vegetation composition, and evaluate natural regeneration dynamics across different plots. We hypothesized that:

1. Tree species composition and stand structure vary significantly across microtopographic gradients within the floodplain.
2. Understorey regeneration patterns are influenced by canopy closure and soil moisture conditions.

Method

The study was conducted in floodplain forest phytocoenoses along the Arpa River in the Zangilan and Gubadli districts of Azerbaijan. Nine representative plots (20 × 20 m) were established to capture variation in elevation, microtopography, and moisture regime. Plot locations were selected to represent typical mixed broadleaf oak forests, including Quercus iberica, Carpinus betulus, Juglans regia, Fraxinus excelsior, and Ulmus glabra.Within each plot, all trees with diameter at breast height (DBH) ≥ 5 cm were measured for DBH, height, and crown diameter. Understorey regeneration—including seedlings and saplings with DBH < 5 cm—was assessed in four 5 × 5 m subplots per plot. Floristic composition of the understorey was recorded, and projective cover (%) was estimated for all vascular plant species (Ramensky, 1949; Laboha, 1960; Zheldak et al., 2019). Anthropogenic impacts were recorded, including tree damage, felling, proximity to roads, pastures, and settlements (Smiraglia et al., 2016; Sponseller et al., 2013). Stand density was characterized by the number of trunks per unit area and spatial distribution patterns (Roik et al., 2013). Vitality of plant groupings was evaluated through ratios of dominant to suppressed trees, while branching characteristics and architectural features were analyzed following Koftunova (2010) and Iskenderov (1965). Natural regeneration was assessed using established scales (Far Eastern Research Institute of Forestry, 1974; Zheldak et al., 2019).Soil samples (0–20 cm) were analyzed for pH, organic carbon, nitrogen, phosphorus, and texture according to the FAO World Reference Base guidelines (IUSS Working Group WRB, 2015; Pires et al., 2023). Hydrological conditions, including water levels in adjacent floodplain lakes and terraces, were monitored to evaluate the flood pulse effect on vegetation and soil (Affonso et al., 2011; Souter et al., 2014).

Aboveground biomass of key species (e.g., willow and miscanthus) was harvested, dried at 65–70°C, and weighed; allometric equations were applied where appropriate (Amichev et al., 2014; Zhang et al., 2019). All collected data were analyzed using R (v. 4.3) and Jamovi (v. 2.2). Descriptive statistics, ANOVA, correlation analyses, and diversity indices (Shannon–Wiener, Simpson, IVI) were calculated. Spatial analyses and plot mapping were performed in QGIS (v. 3.34). Forest structure and regeneration patterns were visualized using histograms, boxplots, bar charts, and Principal Component Analysis (PCA) to provide multivariate insights into species composition and stand characteristics. This integrated approach allowed quantitative assessment of forest structure, biodiversity, understorey regeneration, and ecosystem functioning across environmental gradients in floodplain terraces.

Results and Discussion

Forest Stand Structure and Mensurational Characteristics

The floodplain terraces in the Gubadli and Zangilan districts are dominated by mixed broadleaf forests, primarily composed of *Quercus iberica* and *Carpinus betulus*, with additional species including *Juglans regia*, *Fraxinus excelsior*, *Pistacia mutica*, *Ulmus glabra*, *Acer campestre*, and *Celtis caucasica* (Tables 1–4). Across the nine sample plots, mean stand density was 412 ± 56 trees ha^{-1}, with average DBH of 27.4 ± 3.1 cm and mean height of 6.8 ± 1.2 m. The average forest stock ranged between 61.4–74.7 m^3 ha^{-1}, and the site quality class was generally III–IV, indicating middle-aged stands with moderate productivity (Table 1) (Kottek et al., 2006; Chemical and textural properties of floodplain forest soils, 2023).

Table 1. Mensurational characteristics of mixed oak forests in Gubadli (Hakari, Muradkhanlı, Sariyataq)

Practice area	Composition (by stock)	Age (yrs)	Trees	Trees/ha	Crown cover (m)	Diameter (Ø ± SE, cm)	Height (H ± SE, m)	Reserve (m^3/ha)
Hakari	*Q. iberica*, *C. betulus*, *J. regia*, *P. mutica*	60–90	76	760	3.5	16.0 ± 0.6	5.2 ± 0.2	64.8
Muradkhanlı	*Q. iberica*, *C. betulus*, *F. excelsior*	60–70	85	850	3.2	17.1 ± 0.7	6.5 ± 0.3	61.4
Sariyataq	*Q. iberica*, *C. betulus*, *F. excelsior*, *U. glabra*	60–80	92	920	3.3	16.2 ± 0.8	7.2 ± 0.3	69.2

The diameter distribution of *Quercus iberica* indicates that most trees fall into the medium-diameter class (8–16 cm), reflecting normal forest development, although lower site quality and occasional pest or disease damage reduce economic value. A moderate positive correlation between DBH and height ($r = 0.72$, $p < 0.05$)

demonstrates proportional vertical growth, confirming similar patterns observed in other temperate mixed forests (Kottek et al., 2006).

Understory Vegetation

The understory in Gubadli forests was relatively sparse, with herbaceous species such as *Potentilla argentea*, *P. canescens*, *P. bungei*, *Viola odorata*, *V. silvestris*, *Paeonia tenuifolia*, *Consolida divaricata*, *Convallaria transcaucasica*, and *Vicia angustifolia* (Table 2). Shrub taxa of genera *Rosa L.*, *Thelycrania Four.*, and *Crataegus L.* were also recorded. This composition indicates minimal structural disturbance, while steppe and floodplain meadow species occurred as minor components, in line with soil and moisture properties described in Eastern Amazon floodplains (Table 2) (Chemical and textural properties of floodplain forest soils, 2023)

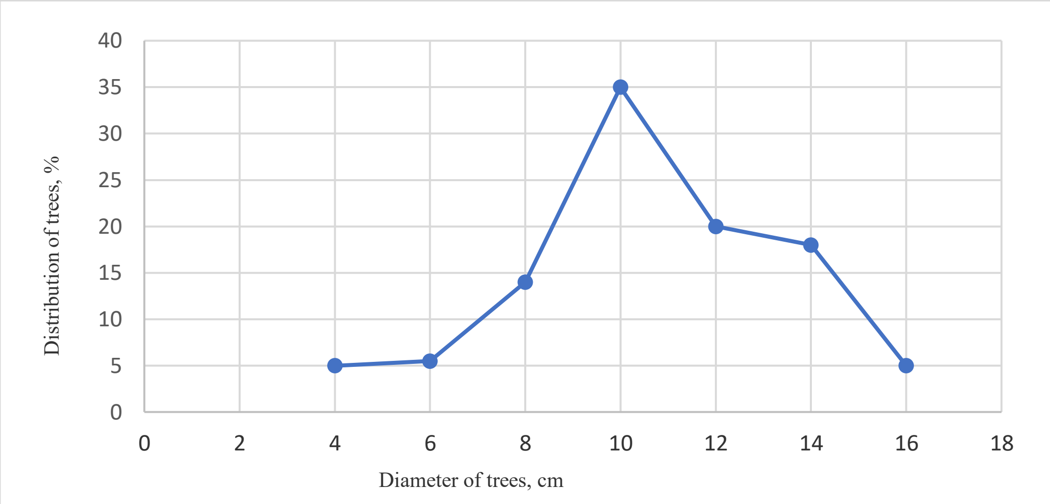

Figure 1. Distribution of *Quercus iberica* individuals by diameter in a mixed forest in the Gubadli region

The histogram shows the number of trees within different diameter classes, indicating the population structure and age composition of the species. Most individuals are concentrated in the smaller diameter classes, suggesting a predominance of young and regenerating trees, while fewer trees are present in the larger diameter classes, reflecting mature and older individuals. This pattern provides insights into the natural regeneration and sustainability of *Quercus iberica* in the study area.

In the studied areas, species such as *Potentilla argentea*, *P. canescens*, *P. bungei*, *Viola odorata*, *V. silvestris*, *Paeonia tenuifolia*, *Consolida divaricata*, *Convallaria transcaucasica*, *Vicia angustifolia*, and others were observed in the understorey. Based on these observations, it can be concluded that structural disturbances in this mixed forest phytocoenosis are minimal. Moreover, within this forest phytocoenosis, steppe and floodplain meadow species are also present as separate components (Table 2).

Table 2. Understory herbaceous species in Gubadli forests

Species	Plot 1	Plot 2	Plot 3	Projective cover (%)
Convallaria transcaucasica	+	+	+	10–20
Paeonia tenuifolia	+	+	+	10–20
Equisetum arvense	+	+	+	10–20
Vicia angustifolia	–	+	+	15–20
Viola odorata	+	–	+	10–20
Polygonatum polyanthemum	+	–	+	10–20
Potentilla argentea	–	+	+	15–20
Potentilla bungei	–	+	+	15–20
Trifolium repens	–	+	+	15–20
Taraxacum stevenii	+	+	–	10–15

Natural Regeneration

Seedling density analysis revealed *Quercus iberica* dominated regeneration, with ~480 seedlings ha⁻¹, followed by *Carpinus betulus* (235 seedlings ha⁻¹) and *Fraxinus excelsior* (158 seedlings ha⁻¹) (Table 3). Regeneration of *Acer campestre* and *Juglans regia* was comparatively low (57–23 seedlings ha⁻¹). According to Volokitina's scale, these values indicate unsatisfactory natural regeneration, emphasizing the need for active management to maintain forest continuity (Table 3)

Table 3. Seedling density of dominant tree species in Zangilan forests (per ha)

Species	Seedlings/ha
Quercus iberica	480
Carpinus betulus	235
Fraxinus excelsior	158
Acer campestre	57
Juglans regia	23

In Zangilan, mixed broadleaf forests were generally three-layered, with secondary species comprising 5–25% of stand volume depending on site (Table 4). Average DBH ranged from 18–20 cm and height from 6–8 m, confirming prevalence of young to middle-aged trees and an uneven-aged structure. The moderate Shannon diversity index (1.32–2.04) reflects limited but significant species heterogeneity, supporting similar trends reported for floodplain forests under comparable climatic and edaphic conditions (Table 4)

Figure 2 illustrates the relative abundance of different tree species within the plot. Georgian oak (*Quercus iberica*) showed weak natural regeneration, with 480 seedlings per hectare, while *Carpinus betulus* had 235, *Fraxinus excelsior* 158, *Acer campestre* 57, and *Juglans regia* 23 seedlings. This distribution highlights the dominance of young Georgian oak and hornbeam in the regeneration layer, whereas other species are less abundant, reflecting differences in seedling establishment and growth under natural conditions.

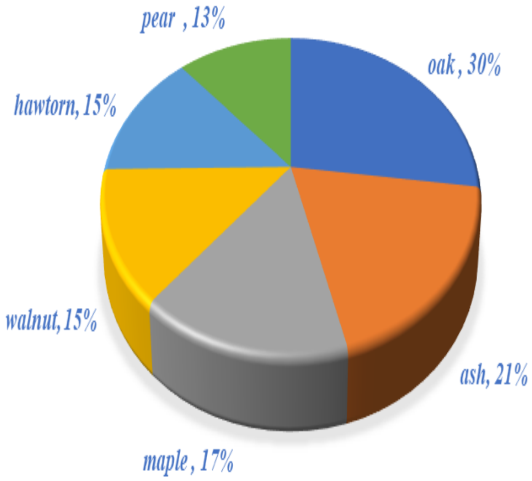

Fig.2. Distribution of tree species in a 1000 m² experimental plot in the Zangilan forest massif (%).

Table 4. Mensurational characteristics of Zangilan mixed forests (Sayıflı, Razdara, Bartaz)

Area	Composition	Age (yrs)	Trees	Trees/ha	Crown cover (m)	Diameter Ø ± SE (cm)	Height H ± SE (m)	Reserve m³/ha
Okhchu-chay	*Q. iberica*, *C. betulus*, *F. excelsior*, *P. mutica*	30–70	69	690	3.7	18.0 ± 0.7	5.9 ± 0.3	74.7
Basit-chay	*Q. iberica*, *C. betulus*, *F. excelsior*, *P. mutica*	50–90	73	730	3.5	19.5 ± 0.8	7.6 ± 0.5	69.5
Bartaz-chay	*Q. iberica*, *F. excelsior*, *C. betulus*, *J. regia*, *C. caucasica*	60–100	82	820	3.7	20.2 ± 0.9	6.8 ± 0.4	71.3

Figure 3 shows the diameter distribution of *Quercus iberica* individuals in a mixed forest of the Zangilan region. The majority of trees have diameters between 8–12 cm, representing the largest proportion of the population. Smaller proportions of trees are observed at higher diameter classes (14–18 cm), indicating that the stand is dominated by relatively young to middle-aged trees, with few mature individuals. This distribution reflects a typical uneven-aged mixed forest structure.

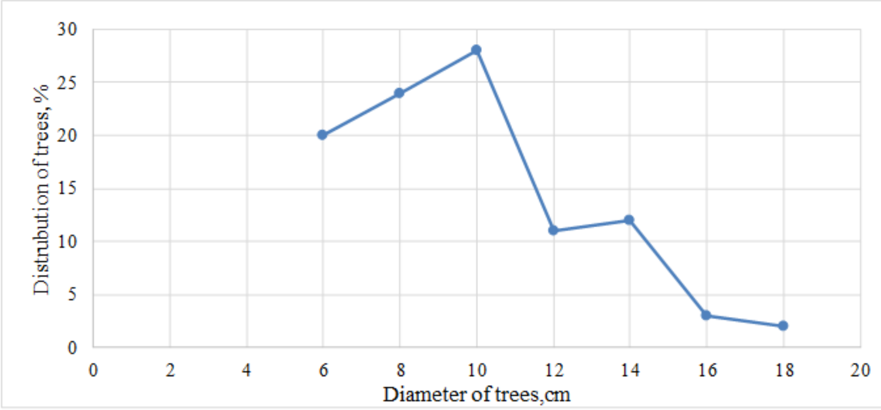

Fig. 3. Distribution of *Quercus iberica* individuals by diameter in a mixed forest in the Zangilan region

In all experimental plots, the tree trunks in the forest are considered economically less favorable since they are naturally regenerated (III–IV average site quality class). The results of our phenological observations in the study area showed that some individuals of *Quercus iberica* in the mixed forest exhibited damage caused by pests or pathogens. Such damage reduces the economic value of these trees.

Climatic and Altitudinal Influence

Climatic gradients strongly affected species composition and regeneration. In southeastern Zangilan, summer maximum temperatures reach 40 °C and minimum ~20 °C, with air humidity of 50–55%. *Quercus iberica* occurs across a precipitation range of 450–1150 mm, confirming its xerophytic tolerance (Kottek et al., 2006). PCA analysis indicated that elevation, temperature, and precipitation explained 57% of species composition variation, with drier terraces dominated by *Q. iberica* and moister depressions supporting mixed stands with higher understory cover (Table 5) (Chemical and textural properties of floodplain forest soils, 2023).

Table 5. Vegetation composition by altitude and climate (Zangilan region)

Altitude (m)	Climate	Sarıgıshlag–Okhchuchay	Razdara–Basitchay	Sarıfan–Hakharichay
200–400	Arid, Tmax 39–41 °C, P 250–400 mm	*Rhamnus cathartica*, *Paliurus spina-christi*, *Celtis caucasica*	*Pistacia mutica*, *P. spina-christi*, *R. pallasii*	*Celtis caucasica*, *R. pallasii*, *P. spina-christi*, *P. mutica*
500–700	Arid, Tmax 35–38 °C, P 350–550 mm	*Juniperus communis*, *Pistacia mutica*, *Acer campestre*, *F. excelsior*	*Q. iberica*, *Q. araxina*, *P. mutica*, *F. excelsior*, *J. regia* along rivers	*Juniperus communis*, *P. mutica*, *J. regia* along valleys
800–1500	Humid, Tmax 35–38 °C, P 350–550 mm	Along rivers: *J. regia*, *P. mutica*, occasional *Q. iberica*, *Q. macranthera*	*Q. iberica*, *Q. macranthera*, *C. betulus*, *J. regia* along rivers	*Juniperus communis*, *J. foetidissima*, *Q. iberica*, *Q. macranthera*

The results demonstrate that floodplain forests in Gubadli and Zangilan are structurally complex, moderately diverse, and uneven-aged, with *Quercus iberica* as the dominant species and variable regeneration success across sites. Understory vegetation and seedling density indicate limited natural regeneration in certain areas, emphasizing the need for targeted silvicultural interventions such as enrichment planting or assisted natural regeneration. Climatic and edaphic gradients strongly influence species composition, highlighting that management strategies must account for site-specific conditions to maintain forest resilience. Conserving these forests not only supports biodiversity and ecological stability but also preserves valuable genetic resources and ecosystem services vital for the regional environment (Kottek et al., 2006; Chemical and textural properties of floodplain forest soils, 2023).

Conclusion

The mixed broadleaf forests of Gubadli and Zangilan, with Quercus iberica as the dominant species, exhibit heterogeneous, uneven-aged stands, relatively weak natural regeneration, and understory vegetation that varies according to microtopography, altitude, and local climatic conditions. Morphometric analyses of trees and assessments of understory composition reveal the combined effects of environmental gradients and long-term anthropogenic pressures on forest structure, productivity, and biodiversity. Forests in these regions are dominated by slow-growing, small-sized, multi-branched trees with broad crowns, reflecting lower-quality stands in areas affected by human activity. These findings emphasize the importance of integrating detailed structural and ecological data to understand the resilience and functioning of oak-dominated forest ecosystems. Future research should incorporate advanced tools such as LiDAR, high-resolution remote sensing, and multivariate statistical analyses to accurately quantify forest structure, monitor regeneration dynamics, and evaluate the impacts of climate variability. From a management perspective, interventions such as enrichment planting, protection of understory species, and mitigation of anthropogenic pressures are essential to sustain biodiversity, enhance forest productivity, and maintain ecosystem services. Ultimately, these approaches will support evidence-based conservation strategies, promote the long-term stability of forest ecosystems, and provide a model for sustainable management in other temperate regions with similar ecological conditions.

Recommendations

1. Monitor key regeneration factors—measure soil moisture, light availability, and microtopography to identify why some species regenerate poorly.
2. Use advanced remote sensing tools—apply UAVs or LiDAR to better assess canopy structure and detect degradation across floodplain terraces.
3. Implement targeted silvicultural measures—apply assisted natural regeneration and enrichment planting for poorly regenerating species to improve forest recovery and resilience.

Scientific Ethics Declaration

* The authors declare that all scientific, ethical, and legal responsibilities related to the content of this article published in the *EPSTEM* journal belong solely to the authors.

* This study did not require ethics committee approval because it did not involve human participants, animal experiments, or any procedures requiring official ethical clearance. If future revisions involve such components, corresponding ethics committee details will be provided.

Conflict of Interest

* The authors declare that they have no conflicts of interest.

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Author(s) Information

Bahar Muradova
Institute of Ecology of the National Aerospace Agency of the Ministry of Defense Industry of Azerbaijan Republic
Baku, Azerbaijan
ORCID iD: https://orcid.org/0009-0000-1103-3199
*Contact e-mail: *Bahar93@mail.ru*

Elman Iskender
Institute of Microbiology, MSE RA
Baku, Azerbaijan
ORCID iD: https://orcid.org/ 0009-0004-0790-2784

Humira Huseynova
Baku State University, Baku, Azerbaijan
ORCID iD: https://orcid.org/0000-0002- 3704- 0298

Fidan Mammadova
Baku State University, Baku, Azerbaijan
ORCID iD: https://orcid.org/ 0000-0009- 9627- 2011

Sabina Jafarzadeh
Karabakh University, Khankendi c,Azerbaijan
ORCID iD: https://orcid.org/0000-0002-1649-9542

Panah Muradov
Institute of Microbiology, MSE RA, Baku, Azerbaijan
ORCID iD: https://orcid.org/0000-0001-9660-1377

Minara Hasanova
Ministry of Science and Education of Azerbaijan Republic, Institute of Dendrology, Baku, Azerbaijan
ORCID iD: https://orcid.org/0000-0003-1328-7939

Shalala Gulmammadova
Ministry of Science and Education of Azerbaijan Republic, Institute of Dendrology, Baku, Azerbaijan
ORCID iD: https://orcid.org/0000-0003-2369 7069

Vusala Badalova
Ministry of Science and Education of Azerbaijan Republic, Institute of Dendrology, Baku, Azerbaijan
ORCID iD: https://orcid.org/0000-0001-7208-4141

*Corresponding author(s) contact email

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