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Characteristics of Forest Phytocoenoses Established by the Biogroup Method in the Eastern Zangezur Region

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ABSTRACT
Forest stand density and spatial distribution are fundamental determinants of ecosystem structure and productivity; however, their dynamics in artificially established biogroup plantations in the South Caucasus remain insufficiently studied. This study investigates the structural characteristics of forest phytocoenoses established using the biogroup method in the Zangilan district of the Eastern Zangezur region during the 2024–2025 field research period. Three sample plots (each 1 ha) were established, and the forest phytocoenosis was examined based on biometric indicators of trees in central rows, trees in edge rows, and ground vegetation cover. The number of biogroups per hectare ranged from 210 to 240, with maximum stand density (up to 5,000 plants/ha) recorded in 13–15-year-old stands. In the central parts of the biogroups, 25-year-old trees had a mean stem diameter of 8.7 cm and a mean height of 7.9 m. Tree mortality was most intensive during the first decade of growth. Maximum standard deviation for diameter was recorded in 25-year-old stands (δ = 2.9 cm); minimum deviation was observed in 5-year-old biogroups (δ = 1.0 cm). Coefficients of variation for diameter (41–43%) exceeded those for height (30–33%), indicating greater variability in radial than in vertical growth. These findings confirm that intra-specific competition is most intense in younger biogroups and provide a scientific basis for optimising stand density in sustainable forest management of the Eastern Zangezur region.
Keywords: *Eastern Zangezur; forest phytocoenosis; biogroup method; stand density; biometric indicators; intra-specific competition; Azerbaijan*

1. INTRODUCTION

Existing forest plant communities are of particular importance as sources of genetic resources ensuring natural forest regeneration. Due to the relatively limited area occupied by forest phytocoenoses, they create additional ecological niches for populations and therefore possess high biocenotic significance (Kurbanov, 2024). In this context, the research materials have been evaluated not only from an economic perspective (as a source of timber), but also from an ecological standpoint, considering forest-protective functions, reforestation potential, food value, aesthetic importance, and other ecosystem services (Labokha, 2018; Ibrahimov, 2005).

Landscape is understood as a complex of relief elements, forest stands, shrubs, meadows, rivers, lakes, and other natural components that, in various spatial compositions and density gradients, create scenery with definite aesthetic value. It represents a complex system in which the physical and biological characteristics of a territory interact dynamically. Forest landscapes, as structural elements of broader ecosystems, reflect both ecological processes and anthropogenic influences (Dzhandzhugakova, 2017; Snytko, 2018).

Forest ecosystems have significant sanitary, hygienic, social, and ecological importance. One of the most essential hygienic properties of green areas is their capacity to create a favorable microclimate by regulating temperature, humidity, and solar radiation. Forest stands mitigate extreme thermal effects, reduce wind velocity, and stabilize local climatic conditions, which is particularly important under current climate change scenarios (Zheldak et al., 2023).

The protective role of forests against dust, gases, wind, and noise is well documented. Forest phytocoenoses serve as natural filters: when polluted air masses encounter forest stands, airflow velocity decreases, causing suspended particles to settle under gravitational force. Dust particles accumulate on the morphological organs of trees and shrubs, especially leaves, significantly reducing airborne particulate concentration. In general, the amount of dust within forested areas is 2–3 times lower than in adjacent open areas (Ibrahimov, 2005; Mammadov et al., 2017).

It should also be noted that the dust-retention capacity of forests depends on the characteristics of the understory layer. Researchers emphasize that the absence of a well-developed herbaceous cover significantly reduces dust deposition efficiency within forest stands (Ibrahimov, 2005). Thus, the structural complexity of forest ecosystems—including canopy, shrub, and herb layers—directly influences their ecological and sanitary effectiveness.

Beyond sanitary functions, forests play a crucial role in biodiversity conservation and the maintenance of native plant communities. Studies on vegetation structure and phytosociology highlight the importance of preserving natural forest remnants as reservoirs of floristic diversity and genetic variability (Theurillat et al., 2021; Lazzaro et al., 2020). Forest ecosystems also contribute to the stability of soils, prevention of erosion, and conservation of rare and endangered tree species (Mammadov, Iskender & Talıbov, 2016; Fedorkov, 2024).

Therefore, the comprehensive ecological assessment of forest phytocoenoses—considering sanitary-hygienic conditions, soil integrity, plant resistance, and landscape aesthetics—provides a scientific basis for sustainable forest management and long-term ecosystem resilience (Cheshko, 2024; Kovtunov, 1962).

2. MATERIALS AND METHODS

In carrying out the research, both classical and modern methods of forest ecological assessment were applied (Labokha, 2018; Cheshko, 2024). The methodological approach was based on forest inventory principles, phytocoenological analysis, and landscape-ecological evaluation (Kovtunov, 1962; Shevelina et al., 2016).

Assessment of Recreational Digression of Forests

The stages of recreational digression of forests were determined according to established forestry and landscape assessment approaches (Kovtunov, 1962; Labokha, 2018):

Stage I – No observable changes in the forest environment (forest landscapes are intact, no trails or trampled areas). The understory vegetation and soil cover remain undisturbed. Tree trunks exhibit healthy growth and development indicators. No regulatory measures are required from a recreational perspective.

Stage II – Minor changes in the forest environment (slightly disturbed forest landscapes; trails and trampled areas occupy up to 5–7%). Understory vegetation and natural regeneration are relatively evenly distributed. Damaged or dried trees constitute 5–20% of the total tree number. Trees affected by diseases or pests do not exceed 20%. Certain management measures are required for recreational use.

Stage III – Moderate changes in the forest environment (moderately disturbed landscapes; trails and trampled areas account for 11–30%). Understory vegetation and shrubs are moderately dense and distributed in patches. Tree mortality ranges from 20–50%. Significant management interventions are required for recreational purposes.

Stage IV – Significant changes in the forest phytocoenosis (heavily disturbed landscapes; trails and trampled areas exceed 35%). Between 50–70% of trees are diseased or dead. Understory vegetation is sparse, patchy, or absent. Serious restoration measures are required for recreational suitability.

Stage V – Severe degradation of the forest phytocoenosis (extensive disturbance; trails and trampled areas exceed 51%). Understory vegetation and regeneration are absent. Forest stands are sparse, and more than 70% of trees are diseased or dead. The area is considered unsuitable for recreational use.

Aesthetic Evaluation of Tree and Shrub Species

A three-point scale was used for the aesthetic evaluation of trees and shrubs (Dzhandzhugakova, 2017):

-Class I – High decorative value;

-Class II – Moderate decorative value;

-Class III – No decorative value.

Selection and Description of Sample Plots

Further work consisted of selecting representative sites (sample plots) for detailed analysis of typical phytocoenoses. To assess variability in species characteristics, at least four plots were selected for each forest type. Field studies were conducted in different parts of the research region, including Zangilan, Gubadli, and Lachin districts. In each district, four sample plots were established.

The size of each experimental plot was 500 m². Whenever possible, plots were square-shaped; however, in some cases, rectangular plots were used depending on site conditions. During plot selection, attention was given to ensuring that the site was sufficiently representative of the target forest type and that the taxa present were systematically comparable (Labokha, 2018).

Field Survey and Inventory Methods

The description of each experimental plot was carried out using the route (transect) survey method, covering all vegetation layers—primarily trees and shrubs—as well as other components of the forest biogeocoenosis (Snytko, 2018). Natural regeneration (seedlings and saplings) in the understory was recorded in each plot.

Tree stem density was characterized by the number of stems per unit area. The following density classification scale was applied (Labokha, 2018):

-Very dense – more than 1000 stems/ha;

-Dense – 1000–400 stems/ha;

-Medium density – 400–150 stems/ha;

-Low density – 150–60 stems/ha;

-Sparse (open woodland) – 60–15 stems/ha.

Architectural and Landscape Characteristics

The architectural and landscape characteristics of tree stands were determined according to established forestry assessment criteria (Shevelina et al., 2016):

The landscape type was determined according to the Kovtunov method (Kovtunov, 1962), which integrates stand structure, spatial composition, and functional characteristics in forest landscape classification.

3. RESULTS AND DISCUSSION

During the 2024–2025 field research period, experimental plots were established within the forest area of the Zangilan district. The forest phytocoenosis of the selected sites was studied based on several structural indicators: trees located in the central rows of biogroups, trees located in the edge rows, and ground vegetation cover.

The age range of plants within the experimental forest phytocoenoses varied between 5 and 49 years. Three sample plots were established for 5-year and 25-year biogroups, as the period between these age limits plays a significant role in the further development and structural differentiation of forest phytocoenoses. A biogroup is defined as a group of plants of different ages forming a localized structural unit within a forest stand.

It is well known that one of the most important characteristics of forest vegetation is stand density and spatial distribution. The issue of density in forest plantations remains one of the fundamental and debated topics in silviculture and forest biology (Saxnov et al., 2023).

In the studied sample plots, the maximum number of biogroups per hectare reached 230 units. The maximum density of plants was determined as 5000 seedlings per hectare. The number of biogroups ranged from 210 to 240 per hectare. The highest density was observed in stands aged 13–15 years (5000 plants per hectare). The maximum size of each sample plot was 1 hectare.

Table 1. Characteristics of Sample Plots

Plot No.	Area (ha)	Number of Biogroups per ha	Density (plants/ha)	Bonitet Class	Age (years)
1	1	230	4500	III–IV	10–15
2	1	210	5000	III–IV	6–20
3	1	240	4200	III	10–49

Analysis of age-related changes (5–49 years) allows determination of the characteristics of biogroup formation and development dynamics.

Biometric Indicators of Trees in the Central Rows.

The average biometric indicators of trees located in the central rows of biogroups are presented in Table 2.

Table 2. Main Indicators of Trees in the Central Rows of Biogroups

Plot No.	Average Diameter (cm)	Average Height (m)	Number of Trees	Forest Site Type (C3)	Age (years)
1	2.3	1.7	43	C3	5
2	6.4	6.3	31	C3	15
3	8.7	7.9	33	C3	25

In the central parts of the biogroups, 25-year-old trees had an average stem diameter of 8.7 cm and an average height of 7.9 m. Tree mortality was more intensively observed during the first decade of growth.

The statistical indicators of trees in the central rows are shown in Table 3.

Table 3. Mean Statistical Indicators of Trees in the Central Rows

Plot No.	Average Diameter (cm) ± SE	Standard Deviation (δ)	Average Height (m) ± SE	Standard Deviation (δ)
1	2.3 ± 0.2	1.0	1.7 ± 0.1	0.4
2	6.4 ± 0.7	2.1	6.3 ± 0.5	2.0
3	8.7 ± 0.5	2.9	7.9 ± 0.4	2.3

From Table 3, it is evident that the maximum standard deviation for diameter was recorded in 25-year-old plants. The minimum deviation in diameter was observed in 5-year-old biogroups (Plot 1). For height, the greatest deviation was also recorded in 25-year-old plants, while the smallest was observed in 5-year-old trees.

To evaluate competition mechanisms and measurement reliability, the coefficient of variation (CV) was calculated (Table 4).

Table 4. Coefficient of Variation of Average Biometric Indicators (Central Rows)

Plot No.	Diameter CV (%)	Precision Coefficient (%)	Height CV (%)	Precision Coefficient (%)
1	41	5	32	5
2	43	6	31	6.5
3	42	4.5	30	5.0

According to statistical standards, a coefficient of variation above 20% is considered significant. In the studied plots, CV values indicate considerable variability within biogroups. However, precision coefficients did not exceed 6.5%, confirming the reliability of the experimental data.

The highest CV for diameter was recorded in 15-year-old Georgian oak stands, while the minimum was observed in 25-year-old stands. Variation in height was generally lower than variation in diameter, indicating that height growth is more stable compared to radial growth.

Biometric Indicators of Trees in the Edge Rows

The main parameters of trees located in the edge rows of biogroups are presented in Table 5.

Table 5. Main Parameters of Trees in the Edge Rows

Plot No.	Average Diameter (cm)	Average Height (m)	Number of Trees	Forest Site Type (C3)	Age (years)
1	2.1	1.8	57	C3	5
2	6.7	7.2	33	C3	15
3	8.1	8.6	31	C3	25

In the edge rows, 25-year-old trees had an average diameter of 8.1 cm and an average height of 8.6 m. The highest number of trees was recorded in the youngest plot (Plot 1), confirming that natural thinning processes reduce tree number over time.

The statistical indicators of edge-row trees are shown in Table 6.

Table 6. Mean Statistical Indicators of Trees in the Edge Rows

Plot No.	Diameter (cm) ± SE	Standard Deviation (δ)	Height (m) ± SE	Standard Deviation (δ)
1	2.1 ± 0.06	0.8	1.8 ± 0.06	0.5
2	7.2 ± 0.5	2.3	6.2 ± 0.52	2.3
3	8.6 ± 0.7	3.1	7.5 ± 0.6	3.2

Maximum standard deviation values for both diameter and height were recorded in 25-year-old stands, while minimum values were observed in 5-year-old trees.

The coefficients of variation for edge rows are presented in Table 7.

Table 7. Coefficient of Variation of Average Biometric Indicators (Edge Rows)

Plot No.	Diameter CV (%)	Precision Coefficient (%)	Height CV (%)	Precision Coefficient (%)
1	40	5.5	33	5.0
2	43	6.0	32	6.0
3	42	4.6	31	4.5

Comparison of Tables 4 and 7 shows that variation coefficients for diameter and height in central and edge rows are within similar ranges. In stands younger than 15 years, variation in diameter was greater than variation in height. With increasing age, variability decreases and remains within acceptable forestry standards.

The results demonstrate that intra-specific competition is more intensive in younger biogroups. As stands mature, structural differentiation stabilizes and competition intensity decreases. Central rows showed slightly more stable variation coefficients compared to edge rows.

4. CONCLUSION

The 2024–2025 field studies conducted in the forests of the Zangilan district revealed clear age-related patterns in the structure and development of forest phytocoenoses. The number of biogroups ranged from 210 to 240 per hectare, with maximum density (up to 5000 plants/ha) observed in 13–15-year-old stands, indicating intensive growth and competition at early stages.

Biometric analysis showed that both diameter and height increase with age; however, diameter exhibited greater variability than height. The highest coefficients of variation were recorded in younger (up to 15 years) biogroups, confirming stronger intra-specific competition during early development. With increasing age, variability decreases and stand structure becomes more stable.Comparison of central and edge rows demonstrated similar patterns of variation, although central rows showed slightly more stable indicators. Overall, younger stands are characterized by higher competition intensity and structural differentiation, while older stands display greater growth stability.These findings provide a scientific basis for optimizing stand density and improving sustainable forest management practices in the region.

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