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BIOMASS AND ENZYMATIC ACTIVITY ASSESSMENT OF THE CONIFEROUS-DECIDUOUS FORESTS IN AZERBAIJAN

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SUMMARY

The presented research aimed to assess the contribution of various components, such as biomass and mortmass of the stand, young growth, undergrowth, living ground cover, and forest litter, to the total mass of organic matter used by the plant community. The study commenced in a coniferous-deciduous forest massif located in the Kish River valley, Markhal, Kish Village, Sheki Region, Azerbaijan, with five permanent sample plots allocated measuring 50 m × 50 m. The greatest contribution to the total mass of organic matter of the studied plant communities mostly consisted of perennial parts of the stand (87%) and mortmass of the stand (14%). However, the share of phytomass of deciduous species in the stand ranged from 32% to 98%, which indicates the incompleteness in the process of forest restoration succession. The forest litter contribution was no more than 3%, and the litter reserves were not high (0.18 to 1.21 kg m^{-2}), and the same was not typical for spruce forests, as in fact the litters belong to the destructive type. A higher catalase activity was evident in the mineral horizons of deciduous forest soils compared with the coniferous ones.

Key words: Forestry, conıferous-decıduous forest ecosystems, biomass, enzyme activity, litters, organic matter, catalase activity, plant communities

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Key findings: The study explored the ability of forest ecosystems to deposit carbon by biomass and mortmass and the contribution of phytomass of the aboveground and underground vegetation layers, as well as terrestrial detritus. In different plant communities, the study based on invertase and catalase enzymes has proven the importance of assessing biomass in conıferous-decıduous forest ecosystems.

INTRODUCTION

Reserves of phytomass

In the global carbon balance, vegetation plays a major role as a carbon reservoir, mainly through its felling and degradation. According to the National Oceanic and Atmospheric Administration (NOAA), it contributes a vital role in the global carbon cycle by absorbing carbon dioxide from the atmosphere through photosynthesis. The carbon found in vegetation is comparable to carbon structure in the atmosphere. Phytomass reserves assessment is crucial for solving the issues with sustainable development on a biosphere scale (Bunyatova *et al.,* 2025). Currently, phytomass reserves evaluation progressed based on remote methods that provide operational mapping of the territory, ground-based monitoring sites for validation of remote sensing data, as well as developing phytomass dependence models on various abiogenic factors (Diwan *et al.,* 2022).

The living ground cover, in terms of floristic composition and eco-cenotic structure, is typical for the coniferous-broad-leaved forests; however, its contribution to the overall productivity of the forest biogeocenoses is not considerable. The spatial intra-biogeocenotic structure of the litter reserves and biomass of the living ground cover bears disruption compared with typical spruce forests due to the highest proportion of deciduous species. The deciduous species in the tree layer, typical for the secondary coniferous forest formation during succession, causes some enhancement in the intensity of biological turnover, as an indicator of decrease in the litter stock and its structural simplification. Since the biomass and mortmass of the forest stand make the greatest contribution to carbon deposition, which requires characterization to assess the carbon stocks of terrestrial ecosystems.

In the Azerbaijan Republic, forests are the predominant plant communities, occupying more than 12% of the territory. An adequate assessment of carbon stocks in the forests is necessary to understand the atmospheric carbon deposition by forest ecosystems (Az-Stat, 2024). Four pools of forest carbon involved verifying, i.e., phytomass (aboveground and underground), perennial and green parts of plants, dead wood, and forest litter, along with the soil organic matter. The largest carbon reserves concentration in forest biogeocenoses was in the perennial parts of the forest stand—trunks, branches, and perennial roots. For the assessment of phytomass reserves, various conversion methods' development succeeded, including the reserves of individual fractions of the forest stand: roots, trunks, branches, needles, and leaves (Ghirardo *et al.,* 2023). The living ground cover does not contribute too much to the phytomass reserves; however, it plays a vital role in the biological cycle of the forest biogeocenoses and carbon deposition. Additionally, its floristic composition, ecological-cenotic structure, biomass, and spatial distribution have a considerable role in understanding the functioning of the forest biogeocenoses (Nazim *et al.,* 2025).

Under the forest canopy and vegetation, the nutrient content varies from 12% to 37% in the tree layer. However, the data on the groundcover productivity are currently insufficient (Makki *et. al.,* 2025). The forest litter is a special biogeohorizon, and determining its existence can succeed by the forest stand, which works as a carbon sink and also performs other important ecological functions. Studying litter and its spatial heterogeneity requires a fundamentally different approach compared with soils. Several methodological problems showed an association with the division into subhorizons, the selection method within the phytocenoses, and analysis of the physicochemical and chemical properties of litters (Hasanova, 2015; Baba-zade and Amiraslanova, 2024).

Enzymatic activity

Enzymes are biological catalysts of a protein nature that play a vital role in metabolism and regulating biochemical processes in the soils. The enzymes can gain synthesis from microflora and higher plants and enter the soil with their vital secretions, as well as after the death and lysis of microbial and plant remains. The enzymes' functional role as catalysts of material and energy exchange in soil and its various processes is enormous (Ismayilova *et al.,* 2025; Liliane and Charles, 2020; Ismayilova, 2023). Enzyme systems found in soil are consistently functioning and carrying out biochemical reactions, performing component and energy exchanges based on the synthesis and transformation of the substances. Enzymes of soil microorganisms in the process of immobilization retain their activity and take part in the synthesis and decomposition of humus, hydrolysis of organic compounds, and remains of higher plants and microorganisms. Moreover, they considerably contribute to the transfer of nutrients into an accessible state (Makki *et al.,* 2025).

MATERIALS AND METHODS

Biomass research

The beneficial study on the biomass and mortmass of the vegetation occurred in a forest massif of coniferous-deciduous forest, with an area of more than 40 hectares in the Kish River Valley, south of Marhal, Kish Village, Sheki Region, Azerbaijan. In 2024, the authors surveyed five permanent sample plots (SP) measuring 50 m × 50 m, with the centers' location at a distance of 150–200 m from each other. The coordinates were 41°15′45.0″ N 47°12′57.6″ E, 41°15′54.8″ N 47°13′12.5″ E, 41°16′03.8″ N 47°13′14.2″ E, 41°16′03.3″ N 47°13′34.9″ E, and 41°16′29.6″ N 47°12′52.0″ E. Crown density in tier A varied from 35% to 80% and averaged about 60%. Stand height ranged from 9 to 35 m and averaged 23 m. The age determination was selective for 25 large spruce trees at the five sites—the average value was 72 years, ranging from 42 to 99 years. At most sites, the dominant tree species in tier A was the European spruce, *Picea abies* L. Furthermore, the undergrowth (layer B), from 1 to 10 m in height, had a crown density of 5% to 70%. It forms the groups represented by *Acer platanoides* L., *Tilia cordata* Mill., *Quercus robur* L., *Sorbus aucuparia* L., *Corylus avellana* L., *Lonicera xylosteum* L., and *Padus avium* Mill. (Macnunlu *et al.,* 2025).

The soil cover with medium loamy soils in different sites showed a representation of one horizon, L, with a thickness of 0.5 to 1 cm (Mondal *et al.,* 2023). The study collected 15 litter samples, which were taken to determine the root biomass in a monolith measuring 0.25 m × 0.25 m × 0.30 m, followed by washing the roots from mineral particles in water and drying to a dry state. At each SP, taxation measurements of the tree stand continued on an area of 50 m × 50 m, the undergrowth on five circular sites of 10 m^2 on each SP, as well as mortmass on a circular site of 300 m^2. Based on the initial data obtained on the tree height and its diameter at the level of 1.3 m from the ground, the reserves of the fractions of the phytomass (plant biomass) of the stands obtained recalculation (Mammadova *et al.,* 2024).

The mortmass reserves comprised deadwood of all tiers, fallen wood, large fallen dry branches (brushwood), and stumps. They received calculations based on the forest inventory data, i.e., the mass of trunks, branches, and roots of deadwood obtained, using the same allometric equations as for the living tree stand. The remaining fractions of the mortmass underwent formulations based on the primary data provided by the taxonomists for each fraction. The final indicators succeeded in compilation considering the known correction factors for the density of dead wood at different stages of decomposition

(Mirzezadeh *et al.,* 2025). The detection of hygroscopic moisture ensured in plant samples, accounting for the reserves of phytomass and mortmass (Nat. Encycl. Azerbaijan, 2018). All the calculations reached presenting for absolutely dry matter. Statistical indicator computations used the Statistics 6.4 package in the R software environment (Nazim *et al.,* Nasirova *et al.,* 2022).

Bioactivity research

In soils, the microbial biomass carbon (C_{mic}), when determined, employed the rehydration method according to T.P. Mirchink and N.S. Pannikov; the catalase activity by the Johnson and Temple method; the invertase activity according to T.A. Shcherbakov; and humus was according to the approach of I.V. Tyurin. The degree of soil enrichment with enzymes attained assessment according to the scales of D.G. Zvyagintsev. The material for the research was soil samples collected in May–June 2024 at the six survey sites. The sample sites layout accounted for the predominant tree species and their age groups. At each site, the collected soil samples came from humus horizons using the envelope method. The soil section laid out in the center of the site was where collection of samples occurred as per genetic horizons. Laboratory studies of the humus horizons were in five replicates, and mineral horizons were in two. The carbon stock of microbial biomass succeeded its calculation for the upper 30 cm soil layer, not including the forest litter in the calculations. Variation indices of the studied soil properties acquired computations only for humus horizons.

Assessing differences among the samples engaged the analysis of variance (ANOVA) with subsequent posteriori comparison of the group means using the Tukey criterion ($\alpha = 0.05$). Accounting for the relationship among the indices, the study used Spearman's correlation analysis ($\alpha = 0.05$) (Saha *et al.,* 2023).

RESULTS

Biomass of the forest stand

In the studied area, the total phytomass for the SP for the undergrowth and both tiers of the forest stand was, on average, 22.64 kg m^{-2} for five sites. It varied based on the SP, ranging from 17.04 to 28.80 kg m^{-2}, and the variation coefficient was 21%. However, the individual component's role significantly varies. The undergrowth phytomass for the SP with an average value of 0.50 kg m^{-2} for five sites on the SP with a predominance of spruce was 0.10–0.22 kg m^{-2}, and in the fourth and fifth sites, the proportion of deciduous species increased (0.84 and 1.15 kg m^{-2}, respectively). The contrary pattern was noticeable for the undergrowth. In the fourth and fifth sites, it was completely absent, while in the rest, the phytomass was, on average, 0.006 kg m^{-2}, varying from 0.001 to 0.022 kg m^{-2}. The tree layer makes the main contribution to the total phytomass, and its share was 93.8%–99.6%. The largest average phytomass reserves were the characteristics of *Picea abies* (11.27 kg m^{-2}), with a variation coefficient of 75%, followed by *Betula alba* (7.36 kg m^{-2}), with a variation coefficient of 23%. A significantly smaller contribution resulted from *Populus tremula* L., *Acer pseudoplatanus*, and other species, with average phytomass reserves of 1.62, 1.43, and 0.44 kg m^{-2} and variation coefficients of 144%, 106%, and 139%, respectively (Figure 1).

The different tree species contribution in each specific SP can vary significantly (Table 1). For example, spruce dominates in terms of phytomass reserves in the first three SPs and makes a substantial contribution to SP 5. Birch was noticeably prevalent in all SPs; however, its share was the highest in SP 4. The share of aspen in SP 5 was significant and comparable to the indicators observed for birch and spruce. Maple phytomass reserves also rose in SP 4 and SP 5. However, other tree species' contributions were small, except for SP 4,

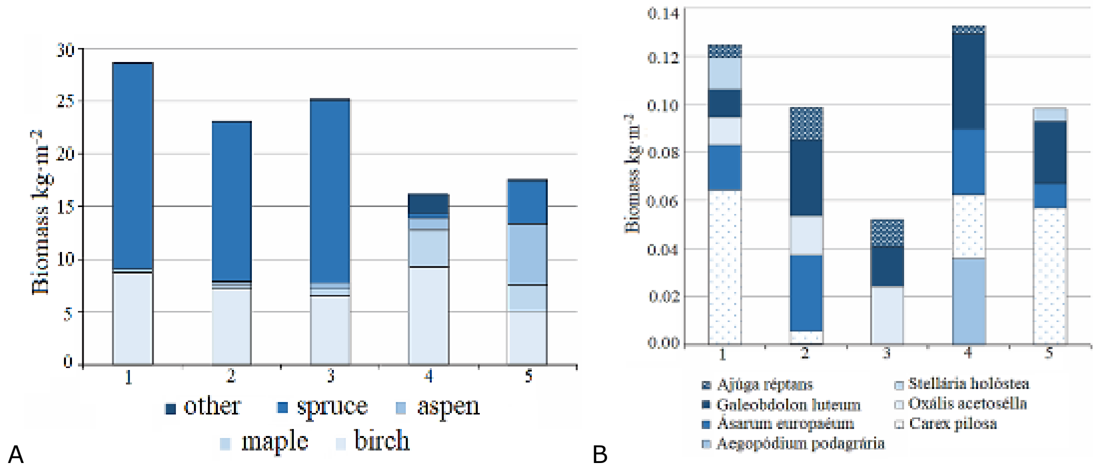

Figure 1. A) Reserves of phytomass of the tree layer considering the species composition and B) Aboveground biomass of the most common species of the herbaceous layer. Note: The numbers indicate the number of the permanent trial plot.

Table 1. The share of different tree species in the total phytomass of the tree layer**.**

Sample plots (SP)	Share of tree species (%)					
	Birch	Maple	Aspen	Spruce	Other	Total
1	30.5	0.1	1.0	67.9	0.5	100.0
2	31.2	1.9	1.2	65.6	0.1	100.0
3	26.0	2.3	2.7	68.6	0.4	100.0
4	57.5	21.8	7.1	2.5	11.1	100.0
5	28.6	14.7	32.6	23.0	1.1	100.0
Average diameter at the height of 1.3 m (cm)						
SP	35.6	11.8	32.7	22.0	18.4	-
Average height (m)						
For all SP	27.1	14.6	26.3	18.3	13.2	-
Quantity (#)						
For all SP	150	271	32	395	15	-

where a single but fairly large oak grew. The ratio of different fractions of the forest stand underwent calculation. The results further revealed the trunk fraction predominates in the structure of the forest stand, which makes up 65.5%–70.2% of the total phytomass depending on the SP, with a share of branches (10.9%–11.7%) and roots (16.3%–18.8%). In total phytomass, the smallest contribution came from assimilating organs (1.8%–4.6%).

Ground cover species composition

In the studied sample plots (SP), the grass layer was descriptive of high floristic similarity (Sadigov and Mustafayev, 2024). According to the biomass of aboveground organs, the following species predominate, i.e., *Carex pilosa* Scop., *Galeobdolon luteum* Huds., *Asarum europaeum* L., and the species typical of the broad-leaved forests. The species *Dryopteris filix-mas* (L.) Schott, typical of both boreal and nemoral forests, predominates in the grass layer at the SP 5. *Oxalis acetosella*, a boreal species, reaches 50% at the SP 3. However, not a single dominant species prevailed at all the studied sites; usually 2–3 species dominated with approximately the same proportions.

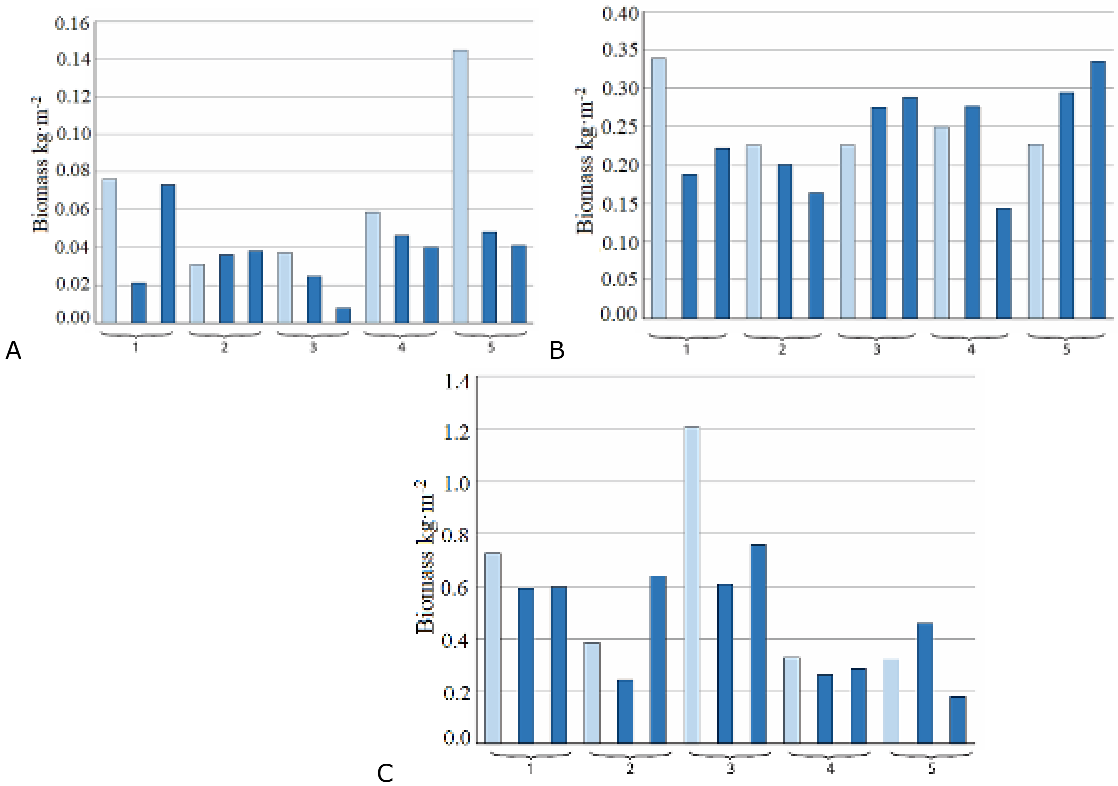

Figure 2. A) Total reserves of aboveground biomass of the grass layer, B) Underground (root) biomass of the grass layer, and C) Forest litter reserves. Note: The numbers indicate the number of the permanent sample plot. Light columns - intercrown space and dark - undercrown space.

Ground cover biomass reserves

The total reserves of aboveground biomass of the grass layer varied from 0.008 to 0.140 kg m^{-2}, with an average of 0.048 kg m^{-2} and a variation coefficient at 67%. In intraribiogeocenotic variation, no stable trend was distinct. In the studied sample plots, SP 3, SP 4, and SP 5, in the intercrown space, the aboveground biomass exceeds the corresponding indicator under the crowns, which may refer to the lighting conditions. Particularly high biomass was evident for the intercrown space due to ferns at the site SP 5. The root biomass of the herbaceous layer nonsignificantly varies in all sample plots, ranging from 0.14 to 0.34 kg m^{-2}, with an average of 0.24 kg m^{-2} and a variation coefficient of 24%. Inconsistent differences emerged between the intercrown and undercrown spaces. No relationship occurred between the values of aboveground and underground biomass (Figure 2).

Litter reserves

In the studied areas, the collected forest litters were of the destructive type and comprised a single weakly decomposed horizon, L (O1). The said litter came from previous years (needles, branches, and leaves), which can be easily set apart from the upper mineral horizon (Steven, 2017). Therefore, the litter reserves have rather low values and vary from 0.18 to 1.21 kg m^{-2}, with an average of 0.50 kg m^{-2} and a variation coefficient at 53%. The lowest litter reserves were noteworthy for SP 4 and SP 5, corresponding to the greatest participation of deciduous species in the stand, while the highest litter reserve (1.2 kg m^{-2}) appeared for SP 3, where spruce obviously dominates in the stand (Mirzezadeh *et al.,* 2025).

Mortmass

In this type of forest, the mortmass reserves were moderate, varying from 1.34 to 3.77 kg m^{-2}, with an average of 2.36 kg m^{-2}. The main mass consisted of the deadwood of the forest stand (50.4%–81.2%), with a significant contribution from the fallen trees (17.5%–48.6%). Deadwood of undergrowth and young growth, stumps, and brushwood played nonsignificant roles. The contribution of individual tree species to the total mortmass reserves significantly varies across all the sample plots. Birch (12.5%–88.0%) and aspen (4.5%–82.5%) play a vital role. Spruce mortmass makes a remarkable contribution in SP 1 and SP 3 (42.7% and 20%, respectively). The ratio of mortmass and biomass of individual tree species in all the SPs revealed aspen was evidently with an enhanced share in the forest stand, leading to an increased share of mortmass in the SPs. However, no dependence was notable for the other species (Table 2).

Total organic matter and phytomass reserves

Total organic matter reserves of the plant community averaged 29.1 kg m^{-2} for the sites with a predominance of spruce in the stand, while for sites with a predominance of deciduous species, the said average was 21.1 kg m^{-2}. The results revealed an increase in the accumulation of organic matter by forest ecosystems as forest restoration succession occurs, during which spruce-small-leaved forests get replaced by complex spruce forests.

By analyzing the ratio of the studied components of the ecosystem, which accumulate carbon to one degree or another, one can conclude the most considerable carbon accumulators of these forest areas were the perennial parts of the tree stand (trunks, branches, and roots). For mortmass, these were stumps, fallen trees, and dead wood (Tabassum and Singh, 2025). In the plant community, in the reserves of organic matter, the share of total biomass and mortmass was

Table 2. Distribution of mortmass fractions.

Sample plots	Mortmass fractions (kg m^{-2})				
	Deadwood	Windfall	Stumps	Brushwood	General
1	1.51	0.32	0.0	0.01	1.84
2	2.71	0.84	0.20	0.01	3.76
3	0.89	0.61	0.08	0.06	1.64
4	1.06	0.28	0.0	0.01	1.35
5	1.61	1.55	0.03	0.0	3.19

Table 3. Ratio of stocks of different components of the studied biogeocenoses.

Components	SP1	SP2	SP3	SP4	SP5
Total reserves of phytomass and mortmass (kg m^{-2})	30.9	27.5	28.9	19.5	22.9
Share (%)					
Perennial parts of a tree stand	87.5	81.1	87.1	84.8	76.4
Assimilation organs of the forest stand	2.9	2.6	2.8	2.6	2.2
Undergrowth and young growth	< 1	<1	< 1	2.8	4.3
Aboveground part of the herbaceous layer	<1	<1	<1	<1	<1
Root mass of the grass layer	1.0	0.7	0.9	1.3	1.3
Mortmass	6.0	13.7	6.9	6.9	13.9
Forest litter	2.1	1.4	3.1	1.4	1.5

Source: by authors in the year 2024.

76%–87% and 6%–14%, respectively (Table 3). The share of forest litter reserves was even smaller (1%–3%), while the contribution of undergrowth with young growth and, especially, the biomass of the living ground cover was also minimal. In humus horizons of soils, a relationship (r = 0.53) existed between microbial biomass and the organic carbon. Within one soil profile, the relationship between these properties was even more prominent, and the correlation coefficient for the studied variables ranged from 0.89 to 0.98.

Down the profile, the content of humus and microbial biomass consistently decreases. The share of microbial biomass carbon in the total organic carbon of the soil increases to 14%–70% in the illuvial horizons. By assessing the enzyme activity indices, it was evident that invertase activity in humus horizons of the studied soils exhibited a considerable correlation with the microbial carbon (r=0.87) compared with humus (r=0.48). Within the soil profile, the relationship between humus content and invertase activity was more pronounced (r=0.98 to 0.99). Invertase is a catalyst for the hydrolysis of poly- and di-saccharides and takes an active part in the decomposition of labile humus.

According to the assessment scales of D.G. Zvyagintsev, in all the tested sample plots, the invertase activity received an average classification. In soils of the Sheki solution, the invertase activity under pine forests was lower than under deciduous forests. The results of a two-way analysis of variance with subsequent pairwise comparison of values revealed that, in contrast to middle-aged forests, differences in invertase activity in soils of overmature forests were considerably significant. Between forests of the same species composition with different ages, in invertase activity, a notable difference appeared only in birch forests (The State of the World's Forests, 2019). Catalase participated in the breakdown of hydrogen peroxide that appears in soils as a result of the respiration process. Its activity in humus horizons of soils of forest biocenoses of the Sheki region emerged closely associated with the activity of invertase (r=0.79), as well as the content of total (r=0.73) and microbial carbon (r=0.60).

In deciduous forest soils, catalase activity proved approximately two times higher than in pine forest soils. For overmature forests, the lowest activity indices resulted in pine forest soils, and their differences with birch and linden forests were significant. The latter showed nonsignificant differences in catalase activity. In humus horizons of soils, the proportion of microbial carbon varies, ranging from 2.5% to 4.4%; in the illuvial horizons, it increases to 13.8%–69.6%. This may be due to the accumulation of labile humus in the middle part of the profile, which was easily decomposed by microbes. The invertase activity showed a considerable correlation with the microbial biomass of soils versus the humus content (r = 0.87 and 0.48, respectively), which indicates its predominantly microbial origin. Contrastingly, catalase activity correlates more with the humus content than with the carbon of microbial biomass (0.73 and 0.60, respectively). The average, rather than high, correlation with the carbon of microbial biomass was probably because the significant proportion of catalase was plant root secretions in soil (Figure 3).

DISCUSSION

The presented results generally correspond to the characteristics of the coniferous-broadleaf forest subzone. The total phytomass of spruce forests was 26.4 kg m^{-2}, while in this study for sites SP 1 to SP 3 with spruce dominance in the forest stand, the obtained values were 23.3–28.4 kg m^{-2}. As for sites SP 4 and SP 5, where small-leaved species predominate, the total phytomass ranged from 17.8 to 19.3 kg m^{-2}, and for the primary and secondary coniferous-small-leaved forests, these were 19.1–21.3 kg m^{-2}. This may indicate some incompleteness of the process of forest restoration succession. The fact that the share of deciduous phytomass in the forest stand ranged from 32% to 98% also indicates the studied forests were not climax forests (Figure 4). The species and ecological-coenocytic structure of the grass layer, including nemoral species with boreal elements, correspond to typical forests of the coniferous-broadleaf

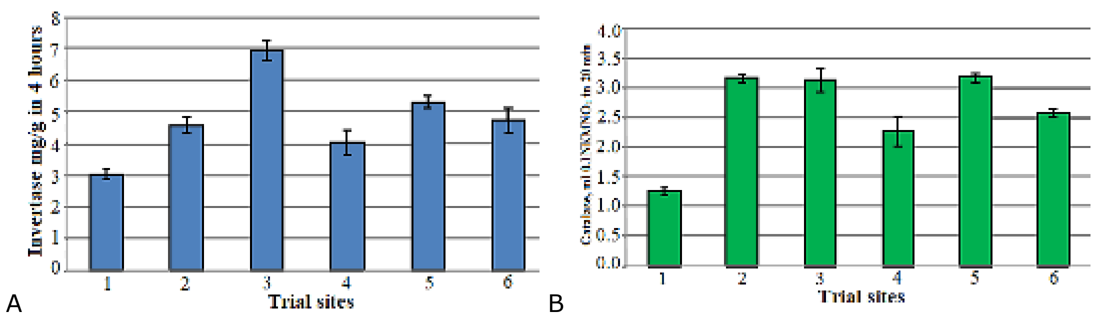

Figure 3. A) Invertase enzyme activity in the upper soil horizons (M±m) and B) Catalase activity in the upper soil horizons (M±m). Note: 1 – overmature pine, 2 – overmature linden, 3 – overmature birch, 4 – middle-aged pine, 5 – middle-aged linden, and 6 – middle-aged birch.

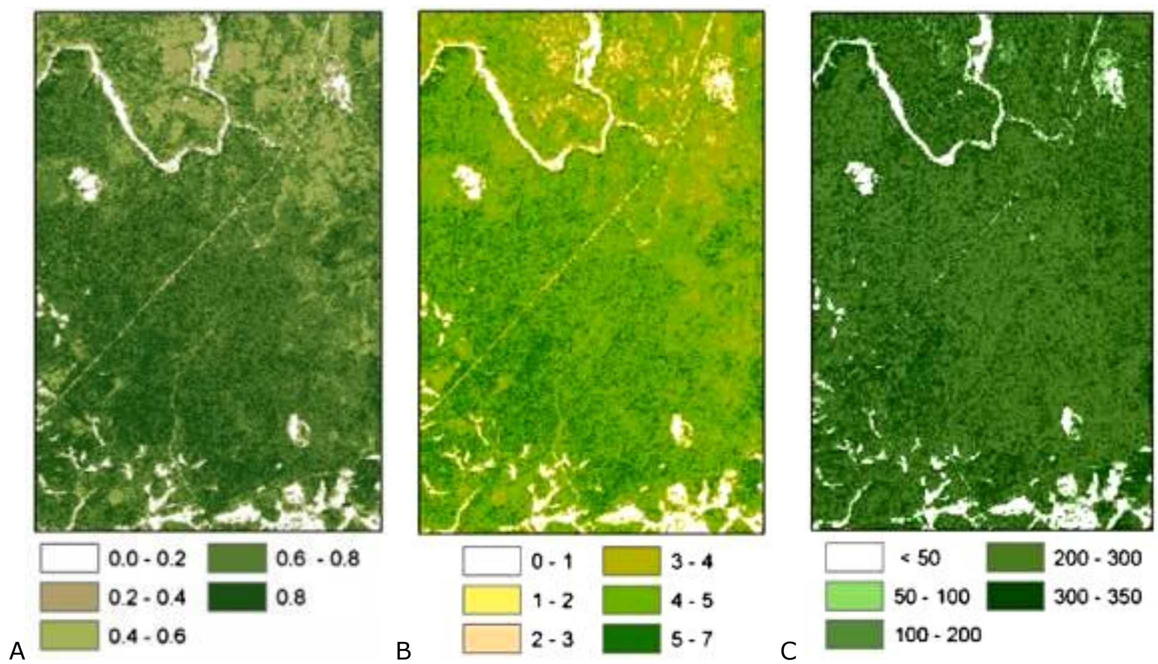

Figure 4. A) Normalized differential vegetation index, B) leaf area index, and C) above-ground biomass layers of coniferous-deciduous forest area in southern slopes of Greater Caucasus, Azerbaijan territory.

forest subzone; the absence of weed-ruderal components revealed the absence of anthropogenic contamination (Hasanova and Abasova, 2024). The biomass of the grass layer was relatively low, showing an association with the shading of predominantly dark coniferous forest stands in the undergrowth. However, the number and biomass of nemoral species significantly exceed the corresponding indicators for boreal species. One should note that shade-loving species, such as common wood sorrel, produce little mass, while relatively light-loving *Aegopodium podagraria* L. and ferns were outstanding by increased biomass (Mirzezadeh *et al.,* 2025).

In the tree stand, the variety of small-leaved and broad-leaved species disrupts the gradient of reduction in the aboveground biomass of the grass layer from under-crown spaces to inter-crown spaces. It was typical for spruce forests due to increased diversity of local ecological niches. Usually, the litter of spruce forests has, more or less, a distinct trend toward a decrease in reserves and simplification of the structure from the near-trunk spaces to the under-crown spaces. Likewise, it occurs from the under-crown spaces to the inter-crown spaces, since spruce was one of the most space-differentiating edificators species. In this case, no such patterns were evident, possibly due to the 'dilution' of the spruce stand with deciduous species. A small reserve of mortmass and a high proportion of dead wood, mainly small-leaved species in all the sample plots, as well as the secondary role of deadwood, correspond to the ongoing restoration succession.

A large reserve of phytomass of small-leaved species also indicates the studied forest area has not yet reached the climax state. A special problem (especially on rocky foundations) is the restoration of grass cover, shrubs, and trees in the event of soil layer demolition and severe erosion. In such cases, the use of artificial soil-turf carpets is applicable spread over any base. The roots of the grown grass penetrate below into the natural soil and get fixed. Lattice mats serve to fix the soil-vegetation layer (Hasanova, 2015).

Considering the obtained results of studying the structure of the phytocenoses, carrying out a detailed assessment of the living forest reserves, woody mortmass, and forest litter is essential. Likewise, such evaluation should include carbon reserves in the mineral part of the soil profile to understand the carbon accumulation by forest ecosystems of the coniferous-broadleaf forest subzone. The biomass of the living ground cover practically does not contribute to the long-term accumulation of the carbon by forest biogeocenoses. However, it works as an active link in the cycle, providing some share of the organic matter and ash elements into the soil as part of the aboveground and root litter.

In spruce forests with intensive accumulation of litter, nemoral species predominate; the trophicity score is 9.2, which is somewhat higher than for ordinary spruce forests. This connects with a more intensive decomposition of organic matter-in the trunk zones, enzymatic, with no humified litters developed, and in all other components of tesserae-predominantly destructive.

Bioactivity

In soils developing with middle-aged forests, the maximum catalase activity succeeded in recording under linden forests; the differences with the catalase activity indices of soils of middle-aged birch and pine forests were significant. As for the catalase activity in soils of the forests with different age groups and species composition, the differences appeared only for soils with pine forests (Hasanova and Abasova, 2024). It is necessary to adequately assess the contribution of phytomass from the aboveground and underground layers of vegetation, as well as terrestrial detritus, to assess the capacity of forest ecosystems to sequester carbon by biomass and mortmass. Secondary spruce forests with residual participation of small-leaved species were of the typical subclimax phytocenoses for this region, since there were apparently no real native forests left in the Sheki Region (Figure 3).

The incompleteness of the successional development of the forest ecosystem resulted in the dominance of spruce and small-leaved species in the forest stand. It was also because of the high proportion of birch and aspen in the deadwood with a relatively low stock of fallen trees (Steven 2017). Given the complex composition of the tree layer due to the inclusion of broad-leaved and small-leaved species and the presence of highly productive undergrowth, an enhanced diversity of local environmental conditions reached their development in the studied ecosystem. It determines the highest variability in reserves of the aboveground and underground biomass of the living ground cover. Estimating aboveground biomass from remote sensing is a complex procedure in which atmospheric conditions, complex biophysical environment, data saturation, mixed pixels, undersampling, extracted remote sensing variables, and selected algorithms can interactively influence the aboveground biomass estimate (Ismayil *et* *al.,* 2025). The reserves of forest litter entailed characterization with relatively low values compared with zonal coniferous forests, which may refer to the influence of numerous deciduous species in the forest stand.

Succession processes in forest ecosystems are difficult to observe directly, sometimes taking several years or decades to note. The attempt demonstrated a strong possibility of using spectral response-based models for biomass estimation. Their presence can succeed in establishment by indirect signs. During forest succession, biomass reserves and ecosystem productivity changed (Figure 4). The dynamics of these changes depend on the type of disturbance, the type of ecosystem, and other conditions. Knowledge of such patterns is important for developing forestry planning methods (Saha *et al.,* 2023; Madnee *et al.,* 2025).

CONCLUSIONS

The analysis revealed the total reserves of the organic matter of the secondary spruce forest ranged from 19.5 to 30.9 kg m^{-2}. As small-leaved forests transition to coniferous forests, the total biomass increases, which contributes to the accumulation of organic matter. In the accumulation of organic matter, the greater contribution came from perennial parts of the forest stand (87%) and mortmass of the forest stand (14%). In soil humus horizons, the carbon content of microbial biomass ranges from 0.48 to 1.27 mgC/g. Its reserves in the 0–30 cm layer varied from 1.36 to 2.65 tC/ha, which proved significant for this type of soil.

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