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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

ECOLOGICAL ASSESSMENT AND RESTORATION PATHWAYS OF THE BASITCHAY STATE NATURE RESERVE

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Field of science:	Biology
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Baku – 2025

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INTRODUCTION

Relevance and degree of elaboration of the topic. In the modern era, ecosystem degradation, biodiversity loss, and the unsustainable use of natural resources are among the world's major environmental challenges. In this context, studying natural complexes in the liberated territories is of great importance both nationally and internationally, as these areas have suffered severe degradation of soil, water, and vegetation due to prolonged military activities.

The Basitchay State Nature Reserve is one of Azerbaijan's rarest natural sites, hosting unique Platanus orientalis forests. As these plane-tree forests are distributed over a very limited area in the Caucasus, their protection is crucial for global biodiversity conservation.

Floristic studies, which reveal how plants respond to variations in micro and macroenvironmental conditions, including climate change, form the basis of eco-geographical zoning of mountainous regions. Under global climate change, rising temperatures, water scarcity, soil degradation, and anthropogenic pressures threaten the reserve's ecological balance. Therefore, analyzing soil chemical properties, diagnosing heavy metal pollution, studying phytocenotic composition, and examining plant life forms and ecological groups are vital research priorities.

The conducted research allows for tracking the development dynamics of flora and vegetation, forming a scientific basis for ecosystem management and reducing anthropogenic impacts.Thus, a comprehensive study and evaluation of the ecological condition of the Reserve fills a scientific gap on the theoretical level while also providing a practical basis for protection and restoration measures.

The relevance of the topic is further reinforced by international legal commitments. The Republic of Azerbaijan is a party to several global environmental conventions, including the Convention on Biological Diversity, the Ramsar Convention on Wetlands, and the Paris Climate Agreement. These instruments oblige the country to ensure biodiversity conservation, prevent land degradation, and promote the sustainable management of ecosystems. Similarly, the UN Sustainable

Development Goals particularly (SDG 13 Climate Action[1] and SDG 15 Life on Land[2]) have been adopted as national policy priorities. Scientific research carried out in the Basitchay State Nature Reserve directly contributes to the implementation of these commitments.

At the national level, the "Green Energy Zone" concept, the development of ecotourism potential, and ecological restoration programs in the liberated territories occupy an important place within the state's strategic documents. Therefore, the ecological assessment of the soil, water, and vegetation resources of the Reserve serves not only the realization of state environmental programs but also the long-term goal of ensuring sustainable regional development.

The present dissertation fills an existing gap in ecological research and holds both theoretical and practical importance. It contributes to the country's environmental security, the sustainable management of its natural resources, and the fulfillment of the obligations undertaken by Azerbaijan within the framework of international conventions and the UN Sustainable Development Goals.

The object and subject of the study. The object of the research is the soil, water, and vegetation cover of the Basitchay State Nature Reserve, located in the liberated Zangilan district in the south-western part of the Republic of Azerbaijan. The Reserve is an ecologically significant natural area distinguished by its unique natural plane-tree (Platanus orientalis) forests, rich floristic diversity, and complex landscape structure.

The subject of the research comprises the parameters characterizing the ecological condition of the Reserve's soil, water, and vegetation components, including the morphogenetic properties, chemical and biogenic composition of soils, levels of contamination by heavy metals, life forms and ecological groups of plants, as well as the ecological consequences of anthropogenic impacts on these

[1] United Nations (2015). *Sustainable Development Goal 13: Take urgent action to combat climate change and its impacts.* Retrieved from https://sdgs.un.org/goals/goal13

[2] United Nations (2015). *Sustainable Development Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss.* Retrieved from https://sdgs.un.org/goals/goal15

components.

Purpose and objectives of the research. The main purpose of the research is to comprehensively study the ecological condition of the soil, water, and vegetation cover of the Basitchay State Nature Reserve, analyze their morphogenetic, chemical, and biological characteristics, assess the impacts of anthropogenic factors on ecosystem components, and develop a scientific basis for the reserve's restoration and conservation.

To achieve this purpose, the following objectives were set:

- To study the vegetation cover of the Basitchay State Nature Reserve, identify the dominant species, determine their taxonomic composition, carry out typological classification, and analyze their ecological groups;
- To collect water samples from various parts of the Reserve and soil samples from different depth layers in order to determine the degree of contamination with heavy metals;
- To determine the accumulation levels of heavy metals in the plant species distributed in the area and investigate soil–plant interactions;
- To assess environmental stress factors by analyzing symmetry deviations in plane-tree (Platanus orientalis) leaves using the fluctuating asymmetry method;
- To develop thematic maps reflecting the ecological condition of the Reserve based on collected field and laboratory data;
- To develop scientific foundations for organizing ecological monitoring and planning restoration measures within the territory of the Reserve.

Research Methods. Comprehensive research methods were employed in the dissertation. Analytical laboratory techniques were used to determine the concentrations of heavy metals in soil and plant components, and the samples were analyzed using the spectral analysis method (ICP – Inductively Coupled Plasma Spectroscopy). Soil samples were collected from different areas and depth layers of the Reserve in accordance with state standards for sampling procedures and a methodology adapted to the specific conditions of the study area.

The levels and distribution of heavy metals accumulated in plant

samples were determined, and these indicators were correlated with soil data to assess the level of bioaccumulation.

The fluctuating asymmetry (FA) method was used as a bioindicator of ecological stress, by measuring symmetry deviations in plane-tree (Platanus orientalis L.) leaves and analyzing the resulting morphological variations.

For the purpose of studying the flora of the Reserve, literature and information materials were collected and analyzed, route and stationary observations were carried out in the area, and based on the principles of geobotanical classification, the taxonomic composition, dominant species, and phytocoenotic structure of the vegetation cover were identified.

Laboratory analyses were carried out in the Scientific Research Laboratory of the "Soil Science" Department at the Azerbaijan State Agricultural University and in the "Functional Analyses" Laboratory of the Vegetable Research Institute under the Ministry of Agriculture of the Republic of Azerbaijan.

The coordinate data and satellite images collected during the research were processed in AutoCAD software, and route-scheme, hydrographic, and topographic electronic maps of the Basitchay State Nature Reserve were prepared.

The main provisions submitted for defense:

- Study of the floristic composition of the Reserve, identification of dominant species and their phytocoenotic structure, typological classification of the vegetation cover, and analysis of ecological groups;
- Measurement of heavy metal contamination levels in the soil and water cover of the Basitchay State Nature Reserve and investigation of the distribution of heavy metals across soil layers;
- Determination of the degree of heavy metal accumulation in plant species distributed within the Reserve, analysis of their bioaccumulation potential, and assessment of ecological risk coefficients;
- Conducting fluctuating asymmetry analysis on the leaves of the Oriental plane tree (Platanus orientalis L.) and assessing environmental stress indicators and the degree of ecological stability through this method;

➢ Preparation of hydrographic, route-scheme, and topographic electronic maps of the Basitchay State Nature Reserve for the first time;

➢ Comprehensive assessment of the ecological condition of the area based on biodiversity indicators, bioindicator methods, and contamination levels, as well as identification of priority directions for conservation measures based on the obtained results.

Scientific novelty of the research

1. The vegetation cover of the Basitchay State Nature Reserve was comprehensively studied from an ecological perspective for the first time. Its taxonomic diversity, the ecological position of dominant species, phytocoenotic structure, and bioecological groups were identified, and the typological structure of the vegetation was evaluated in relation to environmental conditions.

2. The degree of heavy metal contamination in the soil and water cover of the Reserve was investigated, and patterns of correlation and distribution across soil layers were identified within the soil component.

3. The bioaccumulation properties of plant species in the natural flora of the Reserve with respect to heavy metals were studied, and scientific foundations were proposed for their use as bioindicators.

4. By applying the fluctuating asymmetry method to the leaves of the Oriental plane tree (Platanus orientalis L.), indicators of ecological stress and anthropogenic impact in the area were assessed. This represents the first approach in the region to characterizing ecological stability using biomorphometric indicators.

5. For the first time, hydrographic, route-scheme, and topographic electronic maps of the Basitchay State Nature Reserve were prepared, and these maps were presented as an applied basis for the visual analysis of the ecological and geographical condition of the area.

6. The ecological condition of the Reserve was assessed based on biodiversity indicators, bioindicator methods, and contamination levels, and the results made it possible to determine the priority directions for conservation measures.

Theoretical and practical significance of the study. The results of the research make it possible to accurately identify ecological risk zones and effectively plan reclamation activities in the Basitchay State Nature Reserve by determining the distribution dynamics and

bioaccumulation levels of heavy metals in soil layers and vegetation.The application of the fluctuating asymmetry method enables the monitoring of anthropogenic impacts based on biomorphometric indicators and demonstrates the potential for applying this approach in other nature reserves as well. Furthermore, the analysis of the floristic composition and typological features of the vegetation cover can be effectively used in the development of biodiversity conservation strategies and for ecological education purposes. The prepared hydrographic, route-scheme, and topographic electronic maps serve as an invaluable visual-analytical basis for land management, the design of tourism routes, natural resource monitoring, and the conduct of scientific research. Overall, methodological approaches such as bioaccumulation analysis, fluctuating asymmetry, and phytocoenotic classification applied in the research form a system of practical recommendations for assessing and sustainably monitoring the ecological condition of the region. These results can also be widely used by the Ministry of Ecology and Natural Resources, agencies responsible for the management of specially protected natural areas, local municipalities, and scientific institutions engaged in ecological research.

Publications, approval and application of work. Materials related to the dissertation have been presented at The 2nd International Scientific Conference on Reconstruction and Restoration in Post-Conflict Conditions (Baku, 2022), The International Scientific Conference on Modern Problems of Natural and Economic Sciences (Ganja, 2022), The III International Congress of Applied Sciences "Year of Shusha – 2022" (Baku, 2022), The International Scientific Conference Modern Problems of Theoretical and Experimental Chemistry Dedicated to the 90th Anniversary of Academician Rafiga Aliyeva (Baku, 2022), The International Scientific Conference Modern Problems of Natural and Economic Sciences Dedicated to the 100th Anniversary of National Leader Heydar Aliyev (Ganja, 2023), Materials of the International Scientific-Practical Conference "Modern Approaches in the Study of Plant Kingdom" Dedicated to the Year of Heydar Aliyev (Baku, 2023), Proceedings of the IX International Scientific and Practical Conference (Madrid, Spain, 2023), International Conference of Young Scientists Dedicated to the Year of Heydar Aliyev

(Baku, 2023), International Conference "National Environmental Priorities and Global Economic Challenges: New Opportunities and Perspectives" (Ganja, 2023), The International Conference Modern Problems of Natural and Economic Sciences Dedicated to the 101st Anniversary of National Leader Heydar Aliyev (Ganja, 2024), The Republican Scientific-Practical Conference Global Climate Variability as a Contemporary Environmental Challenge (Ganja, 2024), The International Conference COP-29 and the "Year of Solidarity for a Green World": The Impact of Global Climate Change on Living Nature and Ways of Mitigation (Ganja, 2024), The LXVI EurasiaScience International Scientific-Practical Conference (Moscow, Russia, 2024), International Multidisciplinary Ecology and Environmental Studies Congress (Paris, France, 2025), The 1st International Scientific-Practical Conference "Entrepreneurship Education: New Opportunities for Economic Growth" Dedicated to the 95th Anniversary of UNEC (Baku, 2025), The International Conference Modern Problems of Natural and Economic Sciences Dedicated to the 102nd Anniversary of National Leader Heydar Aliyev (Ganja, 2025).

A total of 6 scientific articles (including 3 published abroad) and 16 theses (including 3 published abroad) reflecting the main sections of the dissertation have been published.

Name of the organization where the dissertation work was performed. The dissertation work was performed at the Department of Ecology and nature protection of Ganja State University.

Structure and Scope of the Dissertation. The dissertation consists of an introduction, 5 chapters, conclusions, proposals and recommendations, a list of references, and appendices. It includes 25 figures, 31 tables, and additional materials. The introduction covers 8 pages and contains 13259 characters; the first chapter consists of 11 with 16040 characters; the second chapter includes 17 pages with 28915 characters; the third chapter comprises 38 pages with 57103 characters; the fourth chapter has 34 pages with 42107 characters; and the fifth chapter occupies 26 pages with 40395 characters. The section of conclusions covers 2 pages with 1844 characters, while the proposals and recommendations section includes one page with 971 characters. The list of references contains 207 cited sources, extends over 21 pages,

and comprises 31,222 characters. The total volume of the dissertation amounts to 169 pages of computer text, with a total of 239088 characters (excluding the list of references and appendices, the main text comprises 200634 characters).

CHAPTER I
PHYSİCAL–GEOGRAPHİCAL CONDİTİONS AND OROGRAPHY OF THE BASİTCHAY STATE NATURE RESERVE

In accordance with the main purpose of the dissertation, the first chapter analyzes literature sources and describes the geographical location, relief and geological features, hydrological conditions, and climate of the Reserve.

The Basitchay State Nature Reserve, one of the most valuable natural monuments of Azerbaijan, is geographically located in the south-western part of the country. The Reserve was established by Decision[3] No. 172 of the Council of Ministers of the Azerbaijan SSR dated June 4, 1974, within the administrative territory of the Zangilan district.

The Basitchay State Nature Reserve extends for about 15 km, starting from the border with Armenia and reaching the border with the Islamic Republic of Iran. Its total area is 107 hectares. The territory of the Reserve and its surrounding areas consist mainly of medium and low mountain landscapes.

The hydrography of the Reserve and its adjacent territories is primarily represented by the Basitchay River and its tributaries — Sobuchay, Topchay, and Shikhauzchay. The Basitchay River is 44 km long with a basin area of 354 km², originating from the Zangezur Range and flowing into the Araz River.

The territory of the Basitchay State Nature Reserve belongs to the mild-warm climatic type with dry winters, and is characterized by hot summers.

The main purpose of establishing the Reserve was the preservation of the Oriental plane-tree (Platanus orientalis L.) forests,

[3] CHARTER of the Basitchay State Nature Reserve of the Republic of Azerbaijan. https://e-qanun.az/framework/52836

which form a unique ecosystem. Approximately 93.5% (about 100 hectares) of the Reserve's territory is covered by plane-tree forests[4].

CHAPTER II
THEORETICAL AND METHODOLOGICAL FOUNDATIONS OF THE ECOLOGİCAL ASSESSMENT OF THE BASITCHAY STATE NATURE RESERVE

In accordance with the plan-program, this chapter addresses issues such as the degree of study of the problem and the research object, as well as the research methodology.

The flora of the Reserve was studied based on the collection and analysis of literature and information materials, as well as field observations and measurements conducted in the area. For this purpose, route and stationary observations were carried out, and according to the principles of geobotanical classification, the taxonomic composition, dominant species, and phytocoenotic structure of the vegetation cover were determined.

The life forms of species were analyzed according to the systems of Raunkiaer (1934) [5] and Serebryakov (1964) [6], while ecological groups were classified following the methodology of Shennikov (1964)[7]. The classification of wetland vegetation was conducted in accordance with the system of V. M. Katanskaya (1981) [8]. The flowering plant specimens collected for research and herbarium purposes were grouped by family and genus according to the APG IV system, and the family and species names were verified using E. M. Qurbanova and the multi-volume "Flora of Azerbaijan" (1951–1961).

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[4] Official website of the Ministry of Ecology and Natural Resources of the Republic of Azerbaijan. https://eco.gov.az/index.php?pg=102

[5] Raunkiaer C. (1934). The life forms of plants and statistical plant geography Oxford: 48-154

[6] Серебряков И. Г. (1964). Жизненная форма высших растений и их изучение. Полевая геоботаника. М. Наука. 3: 146-202.

[7] Шенников, А.П. Введение в геоботанику / А.П.Шенников. – Л.: ЛГУ, –1964. –447 с

[8] Катанская В.М. 1981. Высшая водная растительность континентальных водоемов СССР. Методы изучения. Л. 187 с.

Phytogeographical analysis was performed according to A. A. Grossheim's classification.

Soil profiles were established at different points of the study area, and physical and chemical analyses were conducted on the collected samples. Granulometric composition was determined by Kachinsky's method, humus and total nitrogen by Walkley and Black, pH by a pH meter, salt content by conductometry, total phosphorus by the Olsen method, and sodium and potassium by Maslov's method.

The naming and classification of soil types followed M. M. Salayev's system and the national soil map of Azerbaijan at a 1:200,000 scale (2022) prepared by A. I. Ismayilov, M. P. Babayev, V. H. Hasanov, and S. M. Huseynova, in accordance with international classification standards. The preparation and digitization of maps for the Reserve were conducted using AutoCAD software.

The fluctuating asymmetry (FA) of the Oriental plane-tree leaves (Platanus orientalis L.) was determined based on the methodology of V. A. Zakharov (2001) [9]. All obtained results were statistically processed and analyzed.

CHAPTER III
ANALYSİS OF SOİL AND VEGETATİON COVER IN THE BASITCHAY STATE NATURE RESERVE

3.1. Characteristics of the Soil Cover of the Basitchay State Nature Reserve

The soil cover of the Basitchay State Nature Reserve is formed under the combined influence of geomorphological, climatic, hydrological, and biotic factors. The diversity of soil types corresponds to the heterogeneity of relief forms and vegetation communities. Based on field research and laboratory analysis, the soil cover of the Reserve is represented mainly by alluvial meadow–forest soils, brown mountain–forest soils, and mountain gray–brown soils.

[9] Захаров В.М., Баранов А.С., Борисов В.И., Валецкий А.В, Кряжева Н.Г., Чистякова Е.К., ЧубинишвилиА.Т.. Здоровье среды: методика оценки. — М.: Центр экологической политики России, 2000. — 68 с.

3.1.1. Alluvial meadow-forest soils

The alluvial meadow–forest soils, which constitute the main soil type of the Basitchay State Nature Reserve, were formed on alluvial deposits brought by river valleys. Alluvial and hydromorphic influences are clearly visible in their genetic profiles. These soils developed under plane-tree forests and rich vegetation cover, occupying the main part of the area and ensuring the high fertility of the ecosystem.

The thickness and organic matter content of the humus horizon in this soil type not only increase soil productivity but also provide a favorable environment for the activity of microorganisms (table 3.1.1.1).

Alluvial meadow–forest soils play a key role in maintaining ecosystem stability. These soils ensure the sustainability of plane-tree forests and are an important ecological factor contributing to water retention and the reduction of flood and erosion processes.

3.1.2. Brown Mountain–Forest Soils

The parent rocks of the areas where these soils are distributed are mainly represented by limestone, calcareous sandstones, carbonate clay shales, and their eluvial–deluvial weathering products consisting of calcareous clays. These soils, formed on carbonate weathering crusts, show a high degree of base saturation as a result of the accumulation of alkali elements.

Brown mountain–forest soils are non-carbonate or weakly carbonate, with carbonates occurring mainly in the deeper horizons. The upper horizons possess neutral or slightly alkaline reactions (table 3.1.2.1). A distinctive morphological feature of these soils is the thickness of the humus horizon and the clearly expressed illuvial–clay B horizon beneath it.

3.1.3. Mountain Gray–Brown Soils

These soils are divided into two main types based on thickness, stoniness, and skeletal content. Heavy clayey mountain brown soils have a high clay fraction (47–51%), leading to increased water retention

Table 3.1.1.1

Chemical indicators of alluvial meadow–forest soils

Horizon	Depth (cm)	pH	Humus (%)	Nitrogen (%)	Phosphorus (mg/kg)	Potassium (mg/kg)	Carbonate ($CaCO_3$, %)	Salinity (EC, µS/cm)
AU	0–30	7.3	4.7	0.23	15	350	11	500
AB	30–60	7.4	3.2	0.18	12	300	10	400
B	60–90	7.7	2.2	0.12	8	250	12	300
BC	90–120	7.8	1.5	0.08	5	200	11	200
C	120+	7.9	0.5	0.03	3	150	8	100

Table 3.1.2.1

Chemical indicators of brown mountain–forest soils

Depth (cm)	Hygroscopic moisture (%)	Humus (%)	Total N (%)	$CaCO_3$ (%)	pH (H_2O)	C/N
0–19	3.8	5.60	0.25	0.8	7.11	13.0
19–36	3.9	4.86	0.23	0.9	7.19	12.3
36–63	4.1	3.16	0.17	1.2	7.21	10.8
63–84	4.3	1.15	0.12	2.5	7.36	5.6
84–100	4.5	0.38	0.05	3.5	7.48	4.4

but poor infiltration and aeration. Medium clayey soils contain 39–44% clay, offering a more favorable water-air regime and easier tillage. Humus content decreases with depth, reaching 2.4–2.8% in the upper layer, indicating a moderate supply of organic matter (table 3.1.3.1).

Table 3.1.3.1

Some chemical indicators of mountain gray–brown soils

Depth (cm)	**Hygroscopic moisture (%)**	**Humus (%)**	**Total N (%)**	**$CaCO_3$ (%)**	**pH (H_2O)**
0–20	4.1	2.42–2.80	0.21	10.31	7.6
20–40	4.8	2.10	0.16	11.61	7.7
40–60	4.9	1.72	0.13	12.40	7.8
60–90	4.7	1.50	–	12.88	7.9
90–120	5.3	1.32	–	13.74	8.2

3.2. Analysis of the Flora of the Reserve

As a result of floristic studies conducted in 2022–2024, 124 species, 101 genera, and 46 families were identified within the territory of the Reserve. These indicators prove that, despite the relatively small area of Basitchay, it possesses high plant diversity. Among the families, Asteraceae (13 genera, 16 species), Rosaceae (10 genera, 16 species), Fabaceae, and Poaceae are predominant. The dominance of Asteraceae is associated with the adaptive ability of its species to ecological conditions, while the wide distribution of Rosaceae is related to its important function in the nitrogen cycle and food chain within natural phytocenoses (figure 3.2.1).

Along with the systematic classification of plants, the study of their life forms is an essential stage of floristic research. Analysis based on the Raunkiaer classification shows that the proportion of life forms in the reserve's flora varies, reflecting the natural conditions of the area (table 3.2.1).

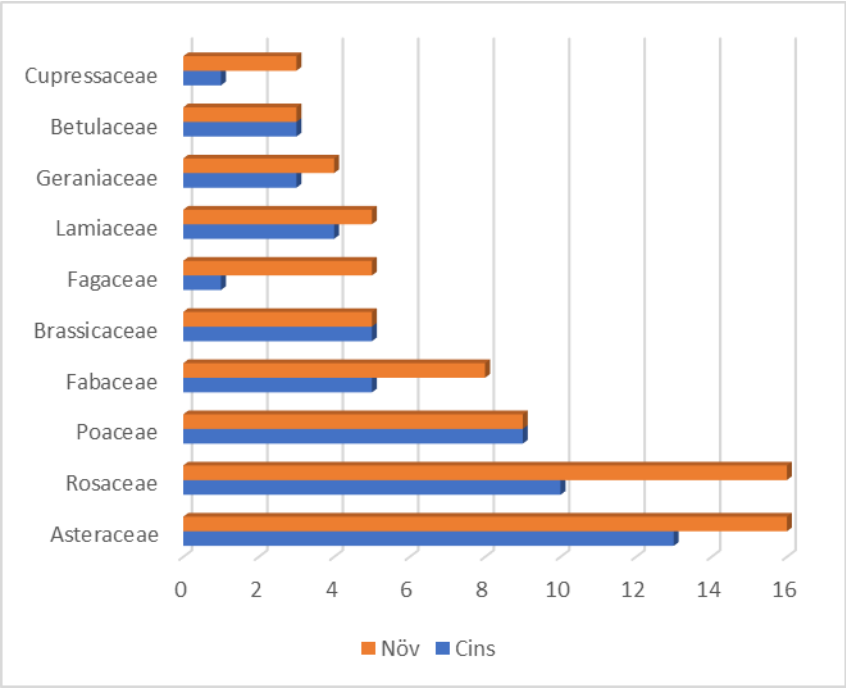

Figure 3.2.1. Taxonomic spectrum of leading families in the territory of the Reserve

According to the Raunkiaer classification, the most widespread group is the phanerophytes (41.9%). Trees, shrubs, and lianas belonging to this group form the foundation of the reserve's forest ecosystems. Large forest trees such as Platanus orientalis, Quercus iberica, Q. araxina, Ulmus glabra, Fraxinus excelsior, and Salix alba play a crucial role here.

Our analysis based on I.Q. Serebryakov's classification shows that perennial herbs dominate the reserve's flora, accounting for 36.3% (Figure 3.2.2). Trees (24.2%) and shrubs (16.9%) together make up a significant proportion, while annual and biennial herbaceous plants constitute 17.7% and 2.4%, respectively.

The study revealed that mesophytic species (58.9%) prevail in the flora of the Reserve (figure 3.2.3), which indicates the soil–climatic conditions characteristic of moderately humid forest–

Table 3.2.1

Distribution of the flora of the Basitchay State Nature Reserve by life forms according to Raunkiaer's system

Life form	Number of species	Percentage (%)
Phanerophyte	52	41.9
Chamaephyte	2	1.6
Hemicryptophyte	40	32.3
Cryptophyte	5	4.0
Therophyte	25	20.2
Total	**124**	**100**

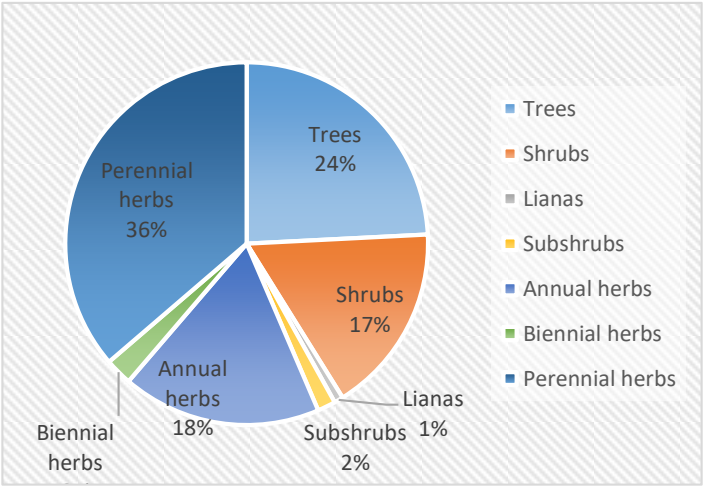

Figure 3.2.2. Distribution of the flora of the Reserve by life forms according to I. G. Serebryakov's system

meadow ecosystems. The 16.1% share of xerophytes is explained by the presence of dry slopes and sunny terraces in the relief. The existence of mesoxerophyte (8.9%) and mesohygrophyte (6.5%) species confirms the formation of moderately humid transitional zones within the Basitchay valley.

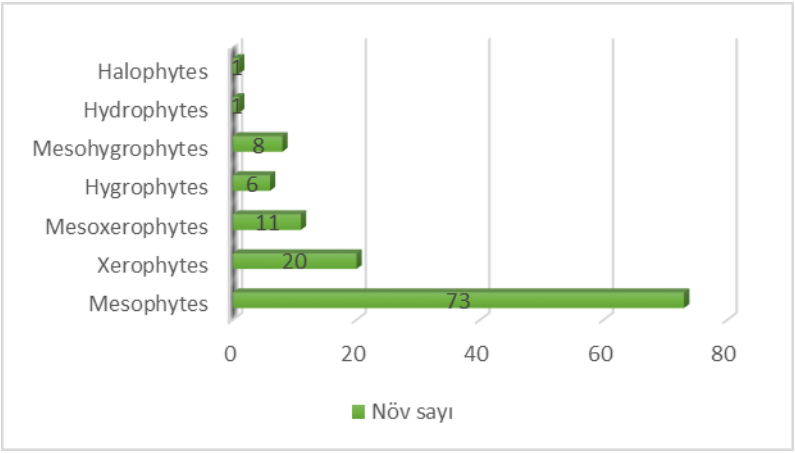

Figure 3.2.3. Distribution of the flora of the Basitchay State Nature Reserve by ecological groups

3.3. Ecological Characteristics of the Vegetation of the Basitchay State Nature Reserve

The natural conditions of the reserve are characterized not only by floristic richness but also by the organization of plants into various phytocoenoses. Ecological and geobotanical analysis of the area identified four main vegetation types: forest, shrub, meadow, and wetland.

The forest vegetation type is the dominant component of the reserve, mainly distributed in the Basitchay valley and at the foothills of slopes. The dominant species is the Oriental plane tree (Platanus orientalis L.), accompanied by oak (Quercus spp.), elm (Ulmus spp.), maple (Acer spp.), hazelnut (Corylus avellana), walnut (Juglans regia), cherry (Prunus avium), and juniper (Juniperus spp.).

The shrub vegetation type develops in zones where forests are sparse, with main representatives including Crataegus meyeri, Cotoneaster integerrimus, Rosa sachokiana, Pyracantha coccinea, and Ligustrum vulgare.

The meadow vegetation type forms on alluvial terraces and fertile soils, dominated by perennial grasses such as Trifolium pratense, Lolium giganteum, Dactylis glomerata, and Chrysopogon

gryllus. Annual and biennial grasses are less common and mainly complete their vegetation cycle during the spring–summer season.

Although the wetland vegetation type is less widespread, it plays an important role in maintaining ecosystem stability. The analysis of hydrophytic and hygrophytic groups was carried out following the methodology of V.M. Katanskaya (1981). Among hydrophytes, Phragmites australis and Nasturtium officinale are widespread, while Salix alba, Alnus glutinosa, Sambucus ebulus, and Tussilago farfara are the main hygrophytes occurring along riverbeds and moist habitats. The amphibious species Nasturtium officinale can grow both in water and in moist soils.

CHAPTER IV
ECOLOGİCAL ASSESSMENT OF THE SOIL, WATER, AND PLANT COMPONENTS OF THE BASITCHAY STATE NATURE RESERVE

4.1. Impact of anthropogenic factors on soil, water, and plant components

During the long period of occupation, the soil cover of the Basitchay State Nature Reserve was subjected to erosion, compaction, and mechanical degradation due to the impact of military machinery and fortification activities. In some areas, contamination with heavy metals and fuel residues was observed. These factors reduced the biological productivity of the soil and weakened ecosystem functions. The vegetation cover was among the most severely affected components during the years of occupation. Field investigations recorded felled and burned tree specimens, particularly the destruction of Oriental plane trees (Platanus orientalis) and other forest species (figures 4.1.1 and 4.1.2).

Figure 4.1.1. Cut trees near Ordakli village

Figure 4.1.2. Registration of burned plane trees near Mashadiismayilli village

Field observations within the reserve also documented traces of trenches and defensive fortifications dug during the war (figure 4.1.3).

Figure 4.1.3. Trench excavated near Razdara village

Excavation and displacement of soil in trench and fortification areas intensified erosion and denudation processes, while the exposure of gravel layers slowed down vegetation recovery and facilitated the spread of weed species.

Field observations and satellite imagery analysis revealed that in several parts of the reserve, natural phytocoenoses, shrublands, and pasture areas were subjected to anthropogenic impacts, ploughed, and used for cultivation purposes. As a result of prolonged occupation and military activities, forested areas suffered significant damage, and inventory results indicate considerable losses in the forest fund of the reserve.

4.2. Ecological ımportance and determination methods of microelements

Microelements play both essential and potentially toxic roles in ecosystems. Elements such as iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn) are vital components of photosynthesis, enzymatic activity, and metabolic processes under normal conditions. However, their excessive accumulation leads to toxicity in soil and water, reduces biological diversity, and causes physiological stress in plants. At this stage of the research, the concentrations of heavy

metals in the soil, water, and plant components of the reserve were determined, and their ecological distribution characteristics were assessed.

Samples for laboratory analysis were collected from various points across the reserve. For ecological assessment, the territory was conditionally divided into 3 groups, and evaluations were carried out separately for each. The analyses were performed using an ICP–OES instrument.

4.3. Ecological assessment of the soil component

Analysis of Group A indicates that post-war heavy metal contamination was observed not only in roadside areas but also within interior zones, although the scale and persistence of the impact varied (table 4.3.1). These results confirm the presence of a

Table 4.3.1

Content of heavy metals in soil samples of Group A

(Method DTPA (1:2), Unit mg/kg)

Date	Sampling point	Depth (cm)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
June 2022	A1	0–10	26	2.2	7.5	3
		10–20	20	1.8	6	2.4
		20–30	18	1.6	5.5	2.1
June 2023	A1	0–10	24.2	2	7.1	2.9
		10–20	22	1.9	6.3	2.6
		20–30	19.5	1.7	5.8	2.3
June 2022	A3	0–10	24	2	6.8	2.6
		10–20	18.5	1.6	5.4	2.1
		20–30	17	1.4	5	1.9
June 2023	A3	0–10	19.2	1.7	5.8	2.2
		10–20	20	1.7	5.7	2.3
		20–30	18.7	1.5	5.3	2.1

post-war “double impact” effect in the soil environment, where essential microelements exceeded normal levels and transformed into hazardous heavy metals for the ecosystem.

For Group B, three sampling points were selected (table 4.3.2). These points are mainly located far from road influence and intensive anthropogenic activities. The purpose was to observe the indirect effects of war and transformations occurring in the soil environment under conditions of weaker anthropogenic pressure.

For Group C, three sampling points were selected (table 4.3.3). These points are located in areas of the Reserve close to the Armenian border and were subjected to more intensive impacts of

Table 4.3.2

Content of heavy metals in soil samples of Group B (Method DTPA (1:2), Unit mg/kg)

Date	Sampling point	Depth (cm)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
June 2022	B2	0–10	14	1	4,2	1,5
		10–20	12	0,9	3,6	1,2
		20–30	11	0,8	3,3	1
June 2023	B2	0–10	12,5	0,9	3,8	1,3
		10–20	12	0,85	3,5	1,2
		20–30	11,2	0,8	3,4	1,1
June 2022	B3	0–10	13,5	1	4	1,4
		10–20	11,5	0,9	3,4	1,1
		20–30	10,8	0,8	3,2	0,9
June 2023	B3	0–10	12	0,9	3,7	1,2
		10–20	11,2	0,85	3,3	1,1
		20–30	10,5	0,8	3,1	1
June 2022	B4	0–10	14,2	1,1	4,3	1,6
		10–20	12,2	0,9	3,7	1,2
		20–30	11,2	0,8	3,4	1
June 2023	B4	0–10	12,8	1	3,9	1,3
		10–20	12	0,9	3,6	1,2
		20–30	11	0,8	3,2	1

military activities and deliberate destruction. Therefore, it was expected that traces of anthropogenic influence would be more evident in the soils of Group C.

Table 4.3.3

Content of heavy metals in soil samples of Group B (Method DTPA (1:2), Unit mg/kg)

Date	Sampling point	Depth (cm)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
June 2022	C3	0–10	20,5	1,6	6,2	2,4
		10–20	17,5	1,3	5,2	2
		20–30	16	1,2	4,8	1,8
June 2023	C3	0–10	18,5	1,5	5,7	2,2
		10–20	17	1,3	5,3	2,1
		20–30	15,8	1,2	4,9	1,9
June 2022	C4	0–10	21	1,7	6,5	2,5
		10–20	18	1,4	5,5	2,1
		20–30	16,5	1,3	5	1,9
June 2023	C4	0–10	19	1,5	6	2,3
		10–20	17,5	1,4	5,4	2,2
		20–30	16,2	1,3	5,1	2
June 2022	C5	0–10	19,5	1,5	6	2,3
		10–20	17	1,3	5,1	1,9
		20–30	15,8	1,2	4,7	1,7
June 2023	C5	0–10	18	1,4	5,6	2,1
		10–20	16,8	1,3	5,2	2
		20–30	15,5	1,2	4,8	1,8

Comparative analysis of Groups A, B, and C shows that soils reflect the dual impact of war and long-term occupation. Essential microelements exceeded normal levels under anthropogenic pressure, becoming hazardous contaminants in Groups A and C. This highlights the need to consider both short- and long-term impacts in soil assessment. Group B remained relatively stable, though signs of past

occupation were still present.

4.4. Ecological assessment of the vegetation cover

At At this stage of the research, the degree of heavy metal contamination in Oriental plane trees was examined. Results showed relatively higher concentrations of these elements in areas affected by anthropogenic impacts, with copper and zinc levels exceeding the norm particularly around burned and felled trees.

Similar to the soil, heavy metal levels in plants exceeded normal ranges in Groups A and C but remained within permissible limits in Group B (table 4.4.1).

Table 4.4.1

Average amount of heavy metals in plane-tree leaves (by dry weight, 2022)

Group	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
A	129	8.1	42	88
B	78	4.2	23	51
C	101	6.1	32	69

4.5. Ecological assessment of water resources

Based on field studies and laboratory analyses conducted in June 2023 in the section of the Reserve passing near Ördəkli village, the seasonal dynamics of water quality in the Basitchay River and the direction of biochemical processes occurring in the ecosystem were determined.

The analysis of bottom sediments initially showed that the concentrations of elements such as Fe (32,700 mg/kg), Mn (461 mg/kg), Cu (60.7 mg/kg), Zn (97.4 mg/kg), Pb (52.0 mg/kg), Cd (0.714 mg/kg), and Co (32.3 mg/kg) in the riverbed were mainly of geogenic origin; however, a slight anthropogenic increase was observed in Pb and Cd.

As a result of increased discharge, the concentrations of dissolved metals in water were considerably lower than in sediments, recorded within the ranges of Fe 0.10 mg/L, Mn 0.020 mg/L, Cu

0.006 mg/L, Zn 0.035 mg/L, Pb 0.0025 mg/L, and Cd 0.00025 mg/L. These indicators are within the safe limits when compared with the World Health Organization (WHO) recommended standards for drinking water (Pb < 0.01, Cd < 0.003, Cu < 2.0, Fe < 0.3 mg/L).

The analyses indicate that past military activities, fires, and soil disturbances in the area have caused certain localized anthropogenic impacts. However, these effects were mainly observed in the soil and vegetation cover, i.e., they were surface-level and temporary in nature.

CHAPTER V

CONDITION OF THE BASITCHAY STATE NATURE RESERVE BY FLUCTUATİNG ASYMMETRY OF ORIENTAL PLANE TREE LEAVES

5.1. Theoretical basis and ecological significance of the Fluctuating asymmetry method

Fluctuating asymmetry (FA) is an indicator that expresses small morphological deviations between the right and left sides of symmetric organs of plants. It reflects the degree of disruption in developmental stability and is considered an important tool for assessing the biomorphological consequences of environmental stress.

Developmental stability is the ability of an organism to form a morphological structure in accordance with its genetic program; when this stability is disturbed, FA increases. The excessive accumulation of heavy metals (Fe, Cu, Zn, and Mn) in soil and plants causes oxidative stress, weakens the functioning of enzymatic systems, and consequently leads to asymmetry in morphogenesis. Studies have established a correlation between FA indicators and the concentrations of these elements. The excess of copper and zinc slows down DNA synthesis, while iron and manganese reduce photosynthetic activity, thereby disrupting morphological balance.

Therefore, the FA index is evaluated not only as an indicator of morphological stability but also as a biomonitoring parameter of

environmental quality.

The research results show that changes in FA values correspond to the distribution of heavy metals in soil layers, allowing the identification of ecological stress zones. This method is considered a reliable bioindicator for assessing ecosystem adaptive stability and restoration dynamics under stress.

5.2. Ecological characteristics and bioindication potential of the oriental plane tree

The Oriental plane tree is the main edificator species of the reserve's forests. It has a pyramidal crown in its youth and develops into a large, broad-crowned tree with a monumental trunk as it matures. Its average height is 25–30 m, reaching up to 50 m under favorable conditions, with a trunk diameter of 2.5–3 m (average 75 cm). With a lifespan of several centuries, it is considered a long-lived and ecologically stable species. According to modern approaches, the leaves of Platanus orientalis exhibit both endogenous (metameric morphological) and ecological (environment-related during ontogeny) variability.

5.3. Selection of samples and applied methods

In accordance with the purpose of the research, the selection of sampling sites and methods was carried out considering the natural–geographical characteristics, landscape structure, and zones of anthropogenic impact of the Reserve. 13 points were grouped into three zones based on the level of ecological stress: A – areas close to the border and the main road, B – the central part of the Reserve, and C – areas near the Armenian border. Samples were collected during the same phenological phase of the vegetation period (May–June) from trees of the same age and healthy individuals, taken from parts of the crown equally exposed to sunlight. From each tree, 20–30 leaves were collected, and in total, hundreds of leaf samples from 35–40 individuals provided a reliable basis for morphometric analysis. In the laboratory, the samples were coded, digitized, and the

morphometric parameters of the leaf lamina (length, width, vein angle, number of teeth, and symmetry indices) were measured. Fluctuating asymmetry (FA) indicators were calculated based on the methodology for assessing developmental stability in natural populations. The results, analyzed according to Zakharov's scale, made it possible to conduct a comparative analysis of ecological stress zones.

5.4. Calculation and evaluation of fluctuating asymmetry ındicators (based on V.M. Zakharov's scale)

FA calculation was based on comparing the morphometric measurements of paired symmetrical elements of the leaf blade. Parameters such as the length of main veins, interveinal angles, and depth of lateral sinuses were measured on both sides of each leaf. The mean FA value was determined by calculating the standard deviation of differences between paired traits and dividing it by the number of samples. 8 morphological parameters were considered for each leaf (figure 5.4.1).

All measurement results were processed using Microsoft Excel software, and the calculations were performed in consecutive stages. To assess developmental stability, the parameters of the right (R) and left (L) sides of leaves were compared, and the asymmetry values were determined. The summarized results are presented in table 5.4.1.

Figure 5.4.1. Scheme for determining morphometric parameters for FA measurement in the Oriental plane tree leaf

Table 5.4.1

Results of fluctuating asymmetry by reference points and groups

Group	Reference Point	Number of trees	Avg. FA (2022)	Avg. FA (2023)	Avg. FA (2024)
A	N1	2	0,058	0,056	0,053
	N2	3	0,06	0,057	0,056
	N3	3	0,053	0,052	0,048
B	N4	3	0,046	0,045	0,044
	N5	4	0,047	0,046	0,043
	N6	4	0,045	0,043	0,041
	N7	4	0,045	0,044	0,044
	N8	4	0,041	0,041	0,036
C	N9	4	0,049	0,049	0,047
	N10	4	0,05	0,049	0,049
	N11	4	0,05	0,048	0,048
	N12	3	0,048	0,048	0,047
	N13	2	0,052	0,052	0,05

5.5. Ecological ınterpretation of the results and assessment of the reserve's condition

The differences in climatic conditions and anthropogenic impacts during the research years directly influenced the variability of fluctuating asymmetry (FA) indicators in the Basitchay State Nature Reserve. The FA values obtained in different years confirmed the interdependence of this indicator with morphological and ecological factors. In the leaves of the Oriental plane tree, reductions in linear dimensions were observed under conditions of pollution, water deficiency, and thermal stress, accompanied by a decline in photosynthesis and a shift in metabolism toward the synthesis of phenolic compounds. Analyses conducted for the years 2022–2024 established a stable positive correlation ($r \approx 0.98–1.00$) between FA and the leaf vitality index (IV), demonstrating that FA is a reliable bioindicator under ecologically stable conditions. According to zonal

analysis, the FA value for Group A (roadside areas) was 0.055 – "polluted zones," for Group B (central part) 0.043 – "conditional norm," and for Group C (border areas) 0.049 – "slightly affected zones." Thus, the central part of the Reserve was assessed as the most ecologically stable area, while roadside zones represented the most environmentally stressed regions.

The summarized results show that FA, petiole length, and lateral vein arrangement in Oriental plane tree leaves are the most informative morphological traits for assessing environmental quality. The FA index demonstrates high reliability under ecologically stable conditions, while in extreme years it should be interpreted together with other ecological and chemical analyses.

RESULTS

1. The floristic composition of the Basitchay State Nature Reserve was comprehensively studied for the first time, and 124 species belonging to 101 genera and 46 families were recorded. This demonstrates that, despite its small area, the reserve possesses a high level of bioecological diversity[12].
2. Four main vegetation types were identified within the area: forest, shrub, meadow, and wetland vegetation[5, 16].
3. Valuable tree species cut down, burned areas, ploughed lands, and traces of trenches were identified in the Reserve. Such disturbances altered the structure of the soil profile, slowed the restoration of natural vegetation, and negatively affected the stability of the ecosystem[10, 19, 20].
4. It was determined that the concentrations of Fe, Mn, Cu, and Zn in soil and plant components were within normal limits in the central zones, but exceeded sanitary thresholds in border areas. This indicates that anthropogenic and transboundary impacts act as ecological risk factors within the ecosystem[2].
5. The water of the Basitchay River was found to be slightly mineralized, neutral in reaction, and sufficiently oxygenated. However, during spring, the increase in surface runoff and sediment washout leads to higher turbidity, causing variations

in some physico-chemical indicators. The concentrations of heavy metals (Fe, Cu, Zn, Mn) generally remain within sanitary norms, though local increases are observed in zones under anthropogenic influence[17].

6. The fluctuating asymmetry (FA) indicators in Platanus orientalis leaves were applied for the first time. The high FA values recorded in Zones A and C indicate the disruption of structural stability within the ecosystem, whereas Group B (central part) was assessed as the most ecologically stable zone[3, 6].
7. Thematic maps of the Reserve were compiled, anthropogenic impact zones and restoration priorities were identified. The results provide a scientific basis for use in ecological monitoring and reclamation planning of the Reserve[18].

RECOMMENDATIONS

1. **Inventory of anthropogenic disturbances:**
   Loss of trees, burned areas, and landscape degradation within the Reserve should be inventoried using remote sensing and field observations. Types of damage should be mapped via GIS, and ecosystem service losses should be evaluated in economic terms.
2. **Passportization of rare Oriental plane trees:**
   Platanus orientalis individuals older than 100 years should be registered with individual codes, with annual monitoring based on morphometric and phytosanitary indicators. Bioindicators such as FA and the vitality index should be included in a long-term observation system.
3. **Ecological restoration of soil and landscape:**
   Risk assessments should be conducted for trench and explosion sites, followed by phytomelioration and reclamation measures. The success of restoration should be evaluated through 3–5-year monitoring programs.
4. **Awareness and participatory management:**
   Community groups, schools, and NGOs should be engaged in biomonitoring, ecological education, and public

accountability programs. Local residents and students should be involved in conservation efforts using simple observation protocols.

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The dissertation defense will be held on 19 november 2025 at 11-00 at the meeting of the BFD 1.07 One-time Dissertation Council operating under the Institute of Microbiology of the Ministry of Science and Education of the Republic of Azerbaijan.

Address: Az1004, Baku c., A.Abbaszade street, 115.

Dissertation is accessible at the library of the Institute of Microbiology, the Ministry of Science and Education of the Republic of Azerbaijan.

Electronic versions of the dissertation and its abstract are available on the official website of the Institute of Microbiology, the Ministry of Science and Education of the Republic of Azerbaijan (https://azmbi.az/index.php/az/).

Abstract was sent to the required addresses on 17 october 2025.

Signed for print: 10.10.2025

Paper format: A5

Volume: 39343

Number of hard copies: 20