

Biodiversity Conservation in the Mountain Forests of the Greater Caucasus

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Abstract

In this article, the theoretical foundations and significance of biodiversity and the natural-geographical features of the Greater Caucasus are examined, including the features of mountain forest ecosystems. At the same time, particular attention was paid to the current state of biodiversity; a spatial analysis of the biodiversity of the Greater Caucasus was conducted. In addition to this, the study also analyzed the main threats to biodiversity and ways to conserve it. The issues of international experience in biodiversity conservation and state policy and environmental legislation in this area are discussed. At the end of the article, the main directions for biodiversity conservation and practical recommendations for the conservation of the Greater Caucasus's biodiversity are outlined.

Keywords: biodiversity, flora, fauna, mountain forest ecosystems, biodiversity conservation, spatial analysis.

1. Introduction

The mountain forests of the Greater Caucasus constitute an important part of Azerbaijan's natural ecosystems and play a significant role in maintaining the ecological balance of the region. They perform water protection, soil protection, and climate-regulating functions, and also serve as a habitat for a large number of plant and animal species. Due to the peculiarities of the geographical location of Azerbaijan, the country's territory, situated at the junction of several biogeographic zones, is characterized by a high level of biodiversity.

The forests of the Greater Caucasus account for a significant share of the country's forest resources. They are considered one of the main centers for the conservation of flora and fauna. Both widespread and rare species are found here, including endemic and disappearing species, many of which are listed in the Red Book. The richness of species composition makes these ecosystems particularly important from a nature conservation perspective.

In recent decades, an intensification of anthropogenic activity has been observed to impact the region's natural ecosystems. Among the main factors are deforestation, expansion of agricultural land, construction of infrastructure, population growth, as well as the impact of climate change. These factors lead to a reduction in the numbers of many plant and animal species and the disruption of the natural equilibrium.

The decline in biodiversity in the mountain forests of the Greater Caucasus is a serious environmental problem as it disrupts the stability of ecosystems and reduces their capacity for self-recovery. This results in long-term changes in forest structure. Despite the existence of scientific research, the problem of

conserving biodiversity in the mountain forests of the Greater Caucasus remains relevant. A more detailed assessment of the state of individual ecosystems is required, as well as the identification of factors influencing their degradation, and the development of effective measures for the conservation of natural diversity. Thus, the study of the biodiversity of the mountain forests of the Greater Caucasus is an important area of environmental research aimed at preserving natural heritage and ensuring the sustainable development of the region.

2. The Concept of Biodiversity and Its Types

Biodiversity is the totality of all forms of life on Earth, including species diversity, genetic diversity within species, as well as the diversity of ecosystems and ecological processes that ensure the stability of the biosphere. The term "biodiversity" was introduced into scientific circulation at the end of the 20th century, but the very idea of the diversity of living beings has deep roots in ecology and biogeography. Three main levels of biodiversity are distinguished: genetic, species-level, and ecosystem-level. These levels are closely interconnected and support the functioning of natural systems.

Genetic diversity reflects the variation of hereditary traits within populations and between populations of the same species. It serves as the foundation of adaptive processes that ensure the resistance of organisms to environmental changes of the environment and the influence of anthropogenic factors. The higher the genetic variability, the higher the ability of a species to adapt to new conditions and survive environmental stresses.

Species diversity is the totality of all types of living organisms in a specific ecosystem or biosphere. This level of biodiversity is the most obvious, and usually it is used as a primary indicator of the richness of the natural world. The Greater Caucasus is characterized by an extremely high level of diversity, including many endemic and relict species. The region is part of one of the world's centers of biodiversity - the Caucasus bioregion. Over 6,000 species of vascular plants are found here, of which about 25% are endemic. Species diversity also plays a critical role in ecosystem resilience. Each type performs a specific functional role, and the loss of even a single component can lead to a disruption of the ecological balance.

Ecosystem diversity reflects the differences between natural systems. This level includes diversity of biogeocenoses, their structural and functional features, as well as the interrelationships between organisms and abiotic factors. Biodiversity in Azerbaijan is a combination of all living organisms, ecosystems, and genetic resources that are formed in various natural areas of the country. The territory of Azerbaijan, located at the junction of Europe and Asia, is characterized by high natural landscape diversity, which has given rise to a wealth of flora and fauna.

There are three main levels of biodiversity in the country: genetic, species, and ecosystem. Genetic diversity manifests itself in the presence of a multitude of endemic and relict species (for example, different forms of oak and beech in forests of Azerbaijan). Species diversity is particularly rich in mountainous regions. Greater Caucasus is where rare species of plants and animals are found. Ecosystem diversity encompasses forest, mountain, subalpine, and alpine ecosystems. Azerbaijan has more than:

- 4,500 species of higher plants
- hundreds of animal species
- a significant number of endemics of the Caucasus region.

Thus, biodiversity constitutes a multi-level phenomenon based on the interaction of genetic, species, and ecosystem components. Conservation of all three levels of diversity is particularly relevant for the Caucasus as it is a region with unique natural history and a high level of endemism, where the violation of one level inevitably affects others.

3. The Importance of Biodiversity

The ecological significance of biodiversity lies primarily in ensuring the sustainable functioning of ecosystems and maintaining their self-regulation. Diversity of species forms complex food chains and networks that ensure the circulation of substances and the flow of energy in nature. The higher the level of biodiversity, the more resilient the ecosystem's response to external impacts, such as climatic fluctuations, natural disasters, and anthropogenic interference.

In the mountain forests of the Greater Caucasus, this aspect takes on a special significance, since these ecosystems are highly sensitive to changes in natural conditions. Forest communities perform important ecological functions, including the regulation of the water regime, the prevention of soil erosion, the maintenance of microclimate and the preservation of the genetic pool of rare species. Loss of individual species can lead to a disruption of the ecological balance and a decline in the resilience of the entire ecosystem.

In addition, biodiversity plays a key role in the natural process of self-healing. Different types perform specific functions in the ecosystem, and their disappearance leads to functional gaps that are difficult to compensate for. Thus, biodiversity conservation is a necessary condition for maintaining the environmental stability of the region.

The economic importance of biodiversity is reflected in its role as a source of natural resources and the basis for various types of economic activity. Biological resources are used in forestry, agriculture, pharmaceutical and food industry. For example, forest ecosystems provide wood, medicinal plants, mushrooms, and other natural products of economic value. In mountainous regions such as the Greater Caucasus, development of ecotourism is also gaining momentum. Unique landscapes and rich flora and fauna create conditions for sustainable tourist development that, if properly organized, could become an alternative to resource-intensive economic activity. However, the excessive exploitation of natural resources without regard for the principles of sustainable development leads to ecosystem degradation and long-term economic losses. For example, cutting down forests may be temporarily profitable, but subsequently leads to soil erosion, reduced land productivity, and deterioration of water resources. Therefore, the economic value of biodiversity should be considered from the perspective of long-term sustainability.

The social significance of biodiversity is expressed in its impact on an individual's quality of life, public health, and the cultural development of society. Natural ecosystems provide recreational services and contribute to psychological well-being. For the populations of mountain regions, biodiversity is also of cultural and traditional significance. Many species of plants and animals are used in folk medicine, economic activities, and cultural practices. Thus, biodiversity is part of the intangible cultural heritage of local communities. Furthermore, the preservation of biodiversity is directly linked to ensuring food and environmental security of the population. Sustainable ecosystems help maintain clean water, air, and soil, which have a positive effect on human health. In turn, degradation of the natural environment can lead to an increase in diseases and a decline in quality of life. Thus, biodiversity possesses not only a natural but also a profound socio-economic significance, making its preservation a priority task of modern environmental policy.

4. Theoretical Approaches to the Study of Biodiversity

The study of biodiversity in modern science is based on several theoretical approaches that allow us to examine the structure, functioning, and dynamics of natural ecosystems. Among the most significant are the ecosystem approach, the landscape approach, and the population approach. These approaches complement each other and provide a comprehensive analysis of natural systems, including the mountain forests of the Greater Caucasus.

The ecosystem approach examines the interaction of living organisms with the environment within natural complexes of the Greater Caucasus. It views biodiversity as an integral part of the functioning of an ecosystem where all living organisms interact with each other, with themselves and with the environment. The main focus is not only on the species composition, but also on the functional connections between ecosystem components, including energy flows, the cycle of matter, and trophic chains.

According to this approach, the sustainability of ecosystems directly depends on the level of biodiversity: the higher the diversity of species and functional groups, the more stable the system is against external impacts. In the context of mountain forests, an ecosystem approach to the Greater Caucasus makes it possible to assess the role of individual species in maintaining the ecological balance, as well as to identify the consequences of their loss for the entire system.

The landscape approach allows us to analyze the spatial distribution of natural resource complexes, including forests, mountain meadows, and subalpine zones. The landscape approach considers biodiversity in a spatial aspect, analyzing the structure and dynamics of natural complexes at the landscape level. In contrast to the ecosystem approach, here special attention is paid to the spatial mosaic nature of the natural environment, the interaction of various ecosystems, and the influence of relief, climate, and soils on species distribution.

For mountainous regions such as the Greater Caucasus, this approach has particular importance, since vertical zonation and complex relief create diverse natural zones within a relatively small area. This contributes to a high concentration of species and endemism. The landscape approach also makes it possible to identify zones of heightened vulnerability, which is important for conservation planning. The population approach focuses on studying the population dynamics of individual species, especially rare and endangered ones.

The concept of sustainable development considers biodiversity in the context of a balance between economic development, social stability, and preservation of the natural environment. According to this concept, the satisfaction of the needs of the present generation must not jeopardize the ability of future generations to meet their own needs. Theoretical foundations of the biodiversity of the Greater Caucasus are based on the principle of vertical zonation. The main idea is that natural conditions and biodiversity change significantly depending on altitude above sea level. The lower sections of the mountain profile comprise foothill and low-mountain zones, characterized by a warmer climate and relatively high levels of human development. Agricultural areas, shrub vegetation, and isolated forest patches are found here. As elevation increases, broad-leaved forests – comprising species such as oak and beech – develop; these forests are characterized by high levels of species diversity and ecological resilience. Beyond lie subalpine and alpine meadows, where woody vegetation gradually disappears due to falling temperatures and changing climatic conditions. These territories are characterized by distinctive herbaceous communities and animal species adapted to harsh conditions. The highest elevation is occupied by the nival zone. Here, the biodiversity is limited due to perpetual snow and glaciers. Key natural factors influencing biodiversity and determining the spatial distribution of ecosystems:

- climatic conditions,
- geological structure,
- hydrological networks.

Thus, the image illustrates the complex structure of the mountain ecosystems of the Greater Caucasus and highlights that biodiversity in this region depends directly on altitudinal zonation and the interaction of natural factors.

5. Factors Affecting Biodiversity

Thus, the concept of sustainable development integrates environmental, economic, and social aspects, ensuring the long-term preservation of biodiversity and the stability of natural systems. Biodiversity is a dynamic system, the level and structure of which are shaped by a complex of interrelated factors. In scientific literature, it is customary to distinguish two main groups of factors determining the state and stability of biological systems: natural (abiotic and biotic) and anthropogenic.

Natural factors include climatic conditions, topography, geological structure, soil characteristics, the hydrological regime, and biotic interactions between species. Climate is one of the key determining factors, as temperature, precipitation, humidity, and seasonality directly influence the formation of species ranges and the structure of ecosystems. In mountainous regions, including the Greater Caucasus, vertical climatic zonation creates distinct vegetation belts and a highly mosaic pattern of biodiversity.

Azerbaijan's biodiversity is influenced by natural and anthropogenic factors. Among natural factors, the climate, relief, and vertical zonation of the Greater Caucasus play a key role. Anthropogenic factors include deforestation, livestock grazing, urbanization, and land-use change. In recent years, the impact of climate change has also intensified, leading to shifts in the ranges of many species.

Topography also has a significant impact on biota, creating a diversity of ecological niches. Changes in elevation, slope aspect, the degree of terrain dissection, and geomorphological features determine microclimatic conditions, the water regime, and soil formation. As a result, communities differing sharply in species composition can form even within relatively small areas.

The soil cover is a crucial factor determining ecosystem productivity and species richness. Differences in soil composition, acidity, and humus and mineral content influence the distribution of plant communities, which, in turn, affects the animal world. Hydrological conditions also play a significant role in shaping ecosystem structure, including the presence of rivers and groundwater, as well as moisture levels.

Biotic factors include competition, predation, symbiosis, parasitism, and other forms of interspecific interactions. These processes regulate population sizes, determine community structure, and contribute to maintaining ecological balance. For example, the presence of keystone species can have a disproportionately large impact on the stability of the entire ecosystem. In the modern era, anthropogenic factors are assuming a dominant role in changes to biodiversity. These include:

- climate change,
- deforestation,
- extensive agricultural development,
- urbanization, industrial pollution,
- the expansion of infrastructure, and
- the overexploitation of natural resources.

The outcomes include habitat fragmentation, a decline in population numbers, and a loss of genetic diversity. Of these, climate change poses a particular threat to biodiversity. Rising average annual temperatures, changes in precipitation patterns, and extreme weather events lead to shifts in the ranges of species and disruption of established ecosystems. This is especially important in mountain ecosystems, since many species there are usually adapted to a narrower range of environmental conditions and possess limited ability to migrate.

6. Natural and Geographical Features of the Greater Caucasus

The Greater Caucasus is a mountain system characterized by a complex tectonic structure, significant elevation gradients, and a pronounced mosaic of climates and landscapes. These factors collectively give

rise to the region's high biodiversity. The Greater Caucasus stretches between the Black and Caspian Seas, forming a massive barrier that separates the air masses of the temperate and the subtropical zones. The topography is characterized by significant complexity and contrast, featuring high mountain ranges, intermontane basins, deep river valleys, and glacial landforms. This terrain creates the vertical zonation of landscapes, which is a key factor in the formation of biodiversity. The climate in this region is characterized by significant variability, which is determined by both its geographic position and complex topography. On the northern slopes, a temperate continental climate prevails, whereas the southern slopes tend towards a subtropical climate, usually characterized by higher humidity and milder winter conditions.

Vertical zonation plays a crucial role in the Greater Caucasus. As elevation increases, temperatures drop and precipitation patterns change. At higher elevations, snow cover deepens. A transition is observed here from a subtropical climate in the lower, more southern regions to colder conditions in the high-mountain areas. This leads to the formation of distinct climatic zones, ranging from steppe and forest-steppe areas at the foothills to alpine and nival landscapes in the high mountains. The distribution of precipitation is extremely uneven. Western regions receive significantly more moisture than eastern ones, a pattern driven by the influence of westerly air mass transport and the local relief. This leads to the dominance of xerophytic and drought-tolerant species in the Eastern regions.

The soil cover of the Greater Caucasus is characterized by high patchiness, resulting from the diversity of climatic conditions, topography, and vegetation. Chernozems and chestnut soils, which are highly fertile, are widespread in the foothill regions. Thus, the natural and geographical characteristics of the Greater Caucasus are shaped by the complex interaction of relief, climate, and soil cover. These components create unique conditions for the development of diverse ecosystems.

7. Characteristics of Mountain Forest Ecosystems

Mountain forest ecosystems perform important functions such as:

- water regime regulation,
- soil protection,
- climate regulation.

Mountain forest ecosystems are characterized by a high proportion of endemic and relict species in their flora and fauna. Many plant and animal species have limited distribution ranges and are closely associated with specific altitudes. This makes them particularly vulnerable to climate change. Recent research shows that even a small increase in average annual temperature causes forest zones to shift upslope and disrupt existing ecosystem relationships.

In Azerbaijan and in the Greater Caucasus region, the mountain forest ecosystems are characterized by high bioproductivity and species-level biodiversity. About 49% of the country's forests are located in the Greater Caucasus. Broad-leaved forests predominate here.

The forests of the Greater Caucasus are composed primarily of oak, beech, hornbeam, and other broad-leaved species. These species make up the bulk of the forest cover (over 80%). Vertical zonation influences forest ecosystem types:

- low mountains are characterized by oak forests;
- mid-Mountain Zone is composed of hornbeam, oak, and maple;
- highland communities are made of beech, mountain oak, and in some parts birch.

At the upper limit of the forest belt, open woodlands and subalpine shrub communities develop, transitioning into alpine meadows. One of the most important features of the mountain forest ecosystems of the Greater Caucasus is their high degree of fragmentation. This fragmentation is caused by both natural factors (complex topography, cut slopes, differences in size and heterogeneity of microclimate) and the

long-term impact of human activity. Fragmentation of forest areas limits the migration of species and reduces genetic exchange between populations, which in turn strengthens isolation processes and increases the risk of local extinction of individual species.

Analysis of data from 2000 to 2018 indicates slow changes in forest cover. Even though a slight increase in overall forest cover is observed, processes of both regeneration and degradation occur simultaneously. Land use changes lead to the expansion of agriculture, the growth of residential areas, and changes in land structure contributing to this complex dynamic.

The preservation of mountain forest ecosystems is a priority area of Azerbaijan's environmental policy. Thus, the mountain forest ecosystems of the Greater Caucasus constitute a dynamic natural system subject to the influence of a complex array of natural and anthropogenic factors. Their structure and functioning are determined by altitudinal zonation, climatic heterogeneity, and the region's geographical location. These factors collectively account for their high ecological significance and the need for their preservation in the face of intensifying anthropogenic impact.

8. Current State of Biodiversity in the Greater Caucasus

Floral diversity. The Greater Caucasus has exceptional floral diversity and high levels of endemism. Azerbaijan alone is home to more than 4,700 plant species. This is understood to be the result of natural-historical isolation and the high diversity of environmental conditions. Common tree species in the Greater Caucasus include oak, beech, hornbeam, maple, linden, and various coniferous species. The Oriental beech (*Fagus orientalis*) is widely distributed in the forests of the Greater Caucasus. Its primary growing areas are Zaqatala, Qakh, and Shaki. Beech forests help retain soil moisture, prevent erosion, and create a favorable microclimate.

Another one of the principal tree species in the region is oak. The chestnut-leaved oak (*Quercus castaneifolia*) is the most widespread variety. Oak forests play a role in soil conservation and serve as a habitat for a wide range of animals.

Hornbeam (*Carpinus betulus*) is found in mixed forests of the Greater Caucasus. It is characterized by durable wood and resistance to various climatic conditions. Hornbeam forests play an important role in maintaining biodiversity.

The Eldar pine (*Pinus eldarica*) is an example of a rare endemic species in Azerbaijan. Its primary distribution areas are in the Eldarian steppe, where it can be found in protected nature reserves. This species is highly drought-resistant and is used in reforestation.

The ironwood tree (*Parrotia persica*) is a relict species. It is mostly found in the Talysh forests, with many other relict species. Its wood is characterized by high density



Figure 1. Ironwood tree.

Figure 1 shows the ironwood tree, which is listed in the Red Book of Azerbaijan as a rare relict species. It is found only in the eastern part of the Greater Caucasus region, while its main populations are concentrated in the Hyrcanian forests of south-east Azerbaijan.

In Eastern parts of the South Caucasus, the Oriental plane (*Platanus orientalis*) forests have been preserved along the banks of the Basitchay River. Azerbaijan is particularly rich in giant plane trees. One of the world's largest plane trees grows near the settlement of Qirmizi Bazar (Khojavend district of Azerbaijan). It is approximately 1,500 years old, 50 m tall, and has a trunk circumference of 28 m; the area of its hollow is 50 m², and the area of its crown projection is 1,400 m².

The walnut (*Juglans regia*), like the Oriental plane tree, belongs to the wild flora of the Caucasus, a fact that is evidenced by its widespread distribution in characteristic relict refugia (Colchis, Talysh, Dagestan), as well as the regions situated between the Greater and Lesser Caucasus. The walnut tree often grows alongside broad-leaved species such as beech and oak. Its total distribution in Azerbaijan covers an area of 25,000 hectares. According to forest inventory data, the share of the Persian walnut in the composition of the plantings ranges from 10% to 70%. Several other rare and endangered species of plants are listed in the Red Book of Azerbaijan. These include:

- Colchic boxwood (*Buxus colchica*)
- European yew (*Taxus baccata*)
- Many rare orchid species (Orchidaceae)

The presence of endemic and relict plant species in isolated mountain ecosystems is of particular importance to regional and global biodiversity. These species help maintain the stability of natural-territorial complexes.

Faunal diversity. The fauna of the Greater Caucasus is also characterized by a rich diversity of mammals, birds, amphibians, and reptiles, as well as many relict and endemic species. The mammals of the Greater Caucasus could be divided into typical forest, mountain, and steppe species. The most characteristic among them are the Caucasian red deer (*Cervus elaphus maral*), the brown bear (*Ursus arctos*), the chamois (*Rupicapra rupicapra caucasica*), West Caucasian tur (*Capra caucasica*), lynx (*Lynx lynx*), and wolf (*Canis lupus*). Mountain ecosystems serve as important refugia for large mammals, many of which are under threat due to population declines and habitat fragmentation. A significant number of rare and endangered mammal species are listed in national and regional Red Books: Among mammals, these include:

- the West Caucasian tur (*Capra caucasica*),

- the Persian leopard (*Panthera pardus tulliana*),
- the Caucasian chamois (*Rupicapra rupicapra caucasica*), and
- the Caucasian brown bear.

These species are under strict protection and require continuous monitoring of their population numbers. The preservation of ungulate populations is of particular importance. In recent years, a partial recovery in the numbers of certain species has been observed thanks to the establishment of nature reserves, national parks and special protected areas.

The region's bird fauna includes eagles, vultures, falcons, and other birds of prey. High-altitude mountain areas serve as important nesting and migration sites for many regional and transregional bird species. Habitat loss, pressure from human activity, and climate change are negatively affecting the populations of certain predatory and rare bird species, necessitating enhanced monitoring and conservation measures. Caucasian bird species included in the Red Book are:

- the golden eagle (*Aquila chrysaetos*),
- bearded vulture (*Gypaetus barbatus*),
- Caucasian black grouse (*Lyrurus mlokosiewiczi*),
- and griffon vulture (*Gyps fulvus*).

Their populations are declining primarily due to the destruction of nesting sites and the disruption of migration routes. Diversity of natural conditions facilitates the high levels of resilience of the Caucasian fauna, yet it still faces severe pressure from anthropogenic factors.

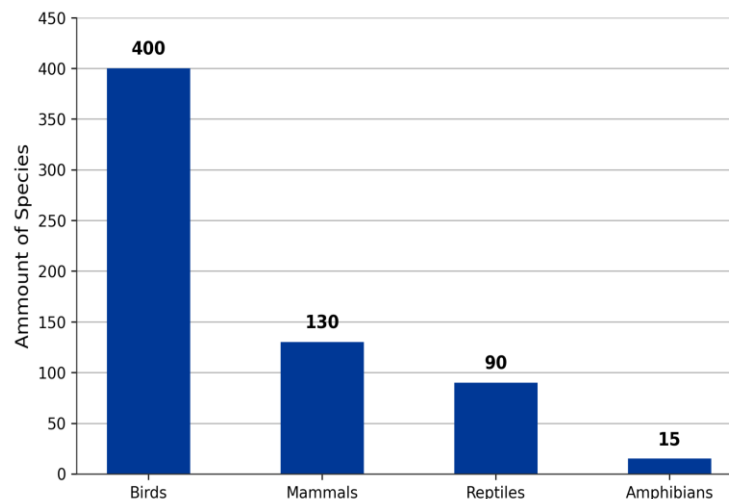


Figure 2. Number of animal species in the Greater Caucasus.

Figure 2 shows a chart illustrating the number of animal species in the territory of Azerbaijan from 2025 to 2026. The chart shows that birds account for the largest number (over 400 species), while amphibians account for the smallest number (about 15 species).

9. The Conservation of Rare and Endemic Species

The main factors leading to the reduction in the populations of many species in the Greater Caucasus are anthropogenic impact and changes in natural conditions. Key causes include deforestation and expansion of agricultural areas, infrastructure construction, and poaching. These factors lead to the

destruction of natural habitats and the disruption of ecological balance. An additional negative factor is climate change, which causes a shift in altitudinal vegetation zones and a contraction of the ranges of cold-loving species. High mountain ecosystems are particularly vulnerable, where even minor climate change leads to significant environmental consequences. To preserve them, nature reserves and national parks are being established in Azerbaijan. Parks such as Shahdag National Park play a key role in conserving the biodiversity of the Greater Caucasus. Modern research shows that without strengthening security measures, there is a risk associated with expanding the network of specially protected natural areas, further decline in the numbers of rare species, and loss of the region's biodiversity.

10. Spatial Analysis of Biodiversity

The biodiversity of the Greater Caucasus is characterized by a high degree of patchiness, which is due to complex terrain, significant elevation changes, variations in climatic conditions, and heterogeneity of the landscape structure. These factors shape a clearly defined vertical and horizontal differentiation of ecosystems, which determines the uneven distribution of flora and fauna across the region's territory.

Several natural-biogeographic zones are distinguished within the Greater Caucasus, each characterized by a specific level of biodiversity. The western part of the region is characterized by a more humid climate and the presence of Colchian forests, which are distinguished by dense vegetation cover and a significant number of relict species. The eastern part, by contrast, is characterized by more continental conditions and a predominance of drought-resistant vegetation, which is reflected in the species composition.

The northern part of the Greater Caucasus is characterized by harsher climate and lower biodiversity, whereas the southern parts of the Greater Caucasus have more favorable conditions for the development of forest and meadow ecosystems. High-mountain areas are characterized by a high degree of endemism and are therefore important for preserving the region's biodiversity.

Modern remote sensing methods play an important role in the study and analysis of the biodiversity of the Greater Caucasus. The use of satellite data and spatial modeling makes it possible to identify patterns of species distribution, assess the state of ecosystems, and predict changes driven by anthropogenic and climatic factors.

Geographic Information Systems (GIS) enable the creation of biodiversity maps that display areas of high species concentration, ecological corridors, and territories with heightened vulnerability. Such maps are an important tool for nature conservation planning and developing strategies for the region's sustainable development. Thus, Azerbaijan is a crucial part of the Caucasus biogeographic region where the spatial structure of biodiversity is formed under the influence of natural factors and human activity, which makes its territory particularly significant for research and conservation efforts.

11. Threats to Biodiversity and Ways to Conserve It

The modern biodiversity of the Greater Caucasus is experiencing a complex impact of anthropogenic and natural-climatic factors that lead to a decline in species numbers, ecosystem degradation, and the disruption of ecological regional equilibrium. The scientific literature of recent years has emphasized that the greatest dangers are deforestation, climate change, and intensive anthropogenic activities that act in concert, as well as synergistically, amplifying the negative consequences. These processes lead to the fragmentation of natural ecosystems and a reduction of habitats of many species.

Forest ecosystems play a key role in maintaining the stability of natural complexes by serving as a habitat for many endemic and relict species. However, economic activities related to timber harvesting and the expansion of agricultural areas, land, and infrastructure construction lead to the fragmentation of forest arrays and loss of biotopes. According to research in recent years, the reduction of forest areas directly contributes to the decline of populations of rare flora and fauna species.

Table 1. Key threats to the biodiversity of the Greater Caucasus and their characteristics.

Threats	Brief description	Key consequences
Deforestation	Intensive logging, expansion of agricultural land and infrastructure	Forest fragmentation, habitat loss, decline in species numbers
Climate change	Rising temperatures, changes in precipitation patterns, and an increase in the frequency of extreme events.	Shifting of natural zones, disruption of phenological cycles, disappearance of mountain species.
Anthropogenic activity	Urbanization, industry, mining, recreational pressure	Environmental pollution, soil degradation, ecosystem destruction

Climate change also acts as a critical factor transforming natural ecosystems of the Greater Caucasus. An increase in average annual temperatures, changes in precipitation patterns and the increased frequency of extreme weather events lead to the shifting of natural zones and the disruption of the phenological cycles of plants and animals. Scientific papers note that climate change is particularly dangerous for high-mountain ecosystems, where many species possess a narrow ecological amplitude and limited migration capacity.

Anthropogenic activities such as urbanization, industrial development, mining operations, and increasing recreational pressure lead to the degradation of the natural environment. Increased tourism contributes to soil erosion and the destruction of vegetation cover. Industrial pollution degrades the quality of soil and water resources.

As shown in Table 1, the biodiversity of the Greater Caucasus is affected by a complex of interrelated factors, among which three main groups of threats stand out: deforestation, climate change, and human activity. These factors act synergistically, amplifying the negative impact on the region's ecosystems. Thus, the primary threats to the biodiversity of the Greater Caucasus are multifaceted in nature and require a systemic approach to their study and mitigation. This highlights the need to integrate nature conservation measures, sustainable natural resource use, and climate adaptation to preserve the region's unique ecosystems.

12. Consequences of Biodiversity Degradation

The loss of species is a result of declines in population numbers, habitat destruction, climate change, and anthropogenic pressure. The decline in the population of certain species disrupts trophic networks and energy flow within ecosystems. If this leads to the dominance of certain species over others, it may cause a decrease in the overall stability of natural-territorial complexes. As a result, ecosystems become more vulnerable to external impacts such as droughts, fires, and climatic fluctuations. Even a slight reduction in key species can trigger cascading changes in the ecosystem's structure.

Furthermore, the degradation of biodiversity leads to a decline in the quality of ecosystem services, including water-regulating, soil-protecting, and climate-regulating functions. The decline in forest cover, especially in the mountainous regions of Azerbaijan, further increases soil erosion, landslides, and flood activity. The deterioration of ecosystems also has a negative impact on the quality of life and health of the local population.

Table 2. Consequences of biodiversity degradation in the Greater Caucasus.

Consequences	Content	Environmental effects	Examples of manifestation
Loss of species	Decline in population numbers and the extinction of individual species	Disruption of ecosystem stability, loss of genetic diversity	Disappearance of endemic and rare flora and fauna species of the Caucasus
Disruption of ecosystem connections	Disruption of food chains and trophic interactions	Destabilization of ecosystems, reduction of their resilience to external factors	Changes in the structure of forests and mountain ecosystems
Decline in ecosystem services	Degradation of natural ecosystem functions	Reduction in water regulation, soil protection, and climate regulation	Increased soil erosion, disruption of the water regime

As shown in Table 2, the degradation of biodiversity in the Greater Caucasus region leads to several consequences, notably the loss of species, the disruption of ecosystem linkages, and a decline in ecosystem services. Thus, an analysis of the table shows that the degradation of biodiversity has a complex negative impact on the ecosystems of the Greater Caucasus, reducing their resilience and functional significance.

13. International Biodiversity Conservation

Biodiversity conservation is a major priority in global environmental policy today. To that end, countries have created a mix of legal, financial, and organizational tools to preserve ecosystems. Worldwide, conservation usually relies on setting up protected natural areas, international treaties, and sustainable natural resources management. The 1992 Convention on Biological Diversity (CBD) and work under the auspices of UNEP laid the foundation for these initiatives. CBD encourages nations to design their own environmental strategies, focusing on sustainable resource use.

The adoption of the path of sustainable development as the global approach to conservation means that many countries, particularly in the developing world, are trying to balance nature protection with economic growth. UNESCO biosphere reserves, World Heritage sites, and other types of protected areas help to preserve ecosystems and give endangered species a chance for recovery.

Transboundary cooperation is essential. Initiatives like the Pan-European Biological and Landscape Diversity Strategy and WWF projects help neighboring states share scientific data and facilitate joint conservation programs.

Economic mechanisms also play a big part. Carbon markets, compensation systems, environmental taxation, and fines encourage businesses and governments to act more responsibly and reduce their impact on the biosphere. A multi-level strategy for environmental conservation requires integrating legal, scientific, and economic methods. Adapting these strategies to the Greater Caucasus will help protect the region's unique ecosystems in the long run.

Table 3. International biodiversity conservation.

Area	Contents	Key instruments	Impact
International conventions	Global agreements on biodiversity conservation	Convention on Biological Diversity (CBD, 1992)	Formulation of national nature conservation strategies
Specially protected areas	Conservation of unique ecosystems and species	UNESCO biosphere reserves, World Heritage sites	Population stabilization, ecosystem restoration
Regional cooperation	Coordination of nature conservation policy among countries	WWF programs, Pan-European Strategy	Strengthening of transboundary nature conservation
Economic mechanisms	Financial incentives for nature conservation	Environmental payments, carbon markets	Reduction of human-induced pressure

As shown in Table 3, international biodiversity conservation is based on a combination of legal, organizational, economic, and scientific coordination mechanisms aimed at preserving natural ecosystems and ensuring the sustainable use of natural resources.

Thus, an analysis of the table demonstrates that international experience in biodiversity conservation is characterized by a comprehensive and multi-level approach, integrating legal norms, protected areas, international cooperation, and economic instruments, which makes it an effective model for adaptation in various regions of the world.

14. State Policy and Environmental Legislation

State policy and environmental legislation form the framework for biodiversity conservation, combining legal, managerial, and economic tools to prevent ecosystem degradation. In Azerbaijan, this framework is based on the Law "On Environmental Protection", the Law "On Specially Protected Natural Areas", and other legal documents. Especially important is the expansion of special protected natural areas. Reserves and national parks, such as Shahdag National Park in the Greater Caucasus, lower anthropogenic pressure and preserve biodiversity; alongside land protection, state-led initiatives focus on active restoration and reforestation, as well as continuous monitoring.

Practical recommendations for the conservation of biodiversity in the Greater Caucasus. Preserving the biodiversity of the Greater Caucasus requires not only a theoretical understanding but also the implementation of concrete practical measures that are comprehensive and long-term in nature. For example, it is necessary to expand the network of special protected natural areas. Currently, many of the ecosystems in the Greater Caucasus remain insufficiently protected. Expanding the area of nature reserves and national parks and establishing ecological corridors between them helps preserve animal migration routes and maintain genetic-level biodiversity.

Monitoring natural resources will greatly benefit from the integration of modern GIS technologies, remote sensing, and UAVs. Not only is this likely to improve the accuracy of assessments, but it will also speed up the decision-making process. According to UNEP, the digitalization of environmental monitoring significantly enhances the effectiveness of environmental management.

Another key area is the implementation of sustainable natural resource management in forest management and agriculture. Managing mountainous forest ecosystems requires a shift from intensive and often illegal exploitation to selective and certified logging. In agriculture, the adoption of agroecological practices such as crop rotation, minimal tillage, sustainable use of water resources, and reduced use of chemical fertilizers is recommended. Restoration of mountain forests and alpine meadows, which are undergoing degradation due to livestock grazing and climate change, is particularly relevant for the Greater

Caucasus and Azerbaijan. Involving local communities in nature conservation programs, developing community-based tourism and ecotourism, and conducting educational campaigns among the populace will increase the level of public responsibility for the state of the environment.

Fostering transboundary and regional cooperation is important, although not without its own challenges in the South Caucasus. Joint monitoring programs, the exchange of scientific data, and the implementation of international projects are the only ways to comprehensively address the environmental issues and challenges. Overall, the practical recommendations for conserving the biodiversity of the Greater Caucasus are based on a comprehensive approach that includes:

- area-based nature protection,
- sustainable natural resource use,
- ecosystem restoration,
- environmental monitoring,
- education, and
- international cooperation.

Implementing these measures will significantly enhance the resilience of the region's ecosystems and preserve its unique natural heritage for future generations.

15. Conclusion

Based on materials concerning the conservation of biodiversity in the mountain forests of the Greater Caucasus, several general conclusions can be drawn regarding the current state of the issue, the primary threats, and the prospects for addressing them.

The mountain forests of the Greater Caucasus in Azerbaijan constitute one of the country's most valuable natural ecosystems and play a vital role in preserving the biodiversity of the Caucasus region. An analysis of scientific materials and ecological studies has shown that these forest ecosystems are characterized by a high level of biodiversity, a complex spatial structure, and significant ecological resilience.

The study established that the mountain forests of the Greater Caucasus are characterized by distinct altitudinal zonation, a diversity of natural conditions, and a predominance of broad-leaved forests. The primary forest-forming species are beech, oak, and hornbeam, which constitute the basis of the region's forest cover. These forests support the conservation of a wide range of plant and animal species, including rare and endemic ones listed in the Red Book of Azerbaijan.

Forest ecosystems are of particular importance for maintaining ecological balance. They regulate climatic processes, play a role in shaping the water regime, prevent soil erosion, reduce the risk of landslides and mudflows, and ensure the stability of mountain natural complexes.

The materials studied and analyses conducted have shown that the highest concentration of forest resources and biological species is found precisely in the mountainous regions of the Greater Caucasus. At the same time, studies have revealed an uneven distribution of forests, as well as processes of fragmentation and local degradation of natural ecosystems.

The main threats to biodiversity are deforestation, the expansion of agricultural areas, livestock grazing, climate change, and human impact. These factors lead to the disruption of ecosystem structures, the loss of animal habitats, soil degradation, and a decline in the populations of certain species. Studies have also shown that measures to conserve biodiversity are being implemented in Azerbaijan, including the establishment of protected natural areas, reforestation efforts, environmental monitoring, and the use of modern technologies to monitor forest conditions. Thus, preserving the biodiversity of the mountain forests

of the Greater Caucasus is an important environmental task for Azerbaijan. Effective protection of natural ecosystems requires a comprehensive approach that includes state oversight, scientific research, rational use of natural resources, and the fostering of environmental awareness among the public. Preserving forest ecosystems will ensure the region's environmental sustainability and safeguard Azerbaijan's unique natural heritage for future generations

Author's contribution

The sole author is responsible for conceptualizing, collecting, and analyzing data, and writing and editing the manuscript.

Conflict of Interest

The authors declare no conflicts of interest.

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